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Flint Hills Resources Alaska, LLC

Revised Draft Final
Human Health Risk Assessment

Flint Hills North Pole Refinery
North Pole, Alaska

May 2012

ARCADIS

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Revised Draft Final Human Health Risk Assessment

Flint Hills North Pole Refinery
North Pole, Alaska

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B0081981.0008.00005

Date:
May 23, 2012

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ABS_d	dermal absorption factor
ABSGI	percent oral absorption efficiency
ACL	alternative cleanup level
ADD	average daily dose
Addendum	Draft Site Characterization Work Plan Addendum
ADEC	Alaska Department of Environmental Conservation
ADHSS	Alaska Department of Health and Social Services
AEC	average exposure concentration
AF	soil-to-skin adherence factor
ALM	Adult Lead Model
ARCADIS	ARCADIS U.S., Inc.
AST	aboveground storage tank
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
B	permeability ratio
Barr	Barr Engineering Company
BCF	bioconcentration factor
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene and total xylenes
BW	body weight
CalEPA	California Environmental Protection Agency
CDC	Centers for Disease Control and Prevention
CF	conversion factor
city	North Pole, Alaska
cm^2	square centimeter
COI	constituent of interest

COPC	constituent of potential concern
CSF	cancer slope factor
CSFi	cancer slope factor for the ***i*** th constituent
CSM	conceptual site model
DA_{event}	dose per event
Dose	average daily dose or lifetime average daily dose
DRO	diesel range organic
ED	exposure duration
EF	exposure frequency
EFH	Exposure Factors Handbook
ELCR	excess lifetime cancer risk
EPC	exposure point concentration
EPC_a	exposure point concentration in outdoor or indoor air
EPC_{gw}	exposure point concentration in groundwater
EPC_p	exposure point concentration in produce
EPC_s	exposure point concentration in soil
EPC_w	exposure point concentration in groundwater or surface water
ET	exposure time
EU	exposure unit
EU-1	Exposure Unit 1
EU-2	Exposure Unit 2
EU-3	Exposure Unit 3
EV_s	event frequency (soil)
EV_w	event frequency (groundwater or surface water)
FA	fraction absorbed
FC	fraction in contact with soil

FHRA	Flint Hills Resources Alaska, LLC
FI	fraction ingested
GAC	granular activated carbon
GRO	gasoline range organic
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IR_s	ingestion rate (soil)
IR_w	ingestion rate (groundwater or surface water)
IRIS	Integrated Risk Information System
IRP_{fr}	fruit ingestion rate
IRP_{vg}	vegetable ingestion rate
ITRC	Interstate Technology Regulatory Council
IUR	inhalation unit risk
J&E	Johnson and Ettinger
kg	kilogram
kg/mg	kilograms per milligram
K_p	permeability coefficient
L/day	liters per day
LADD	lifetime average daily dose
$LADD_i$	lifetime average daily dose for the ***i*** th constituent
LAEC	lifetime average exposure concentration
LNAPL	light nonaqueous phase liquid
LOQ	limit of quantitation
m^3/kg	cubic meter per kilogram

mg/cm^2	milligrams per square centimeter
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilogram per day
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
MRL	minimal risk level
NOAEL	no adverse effect level
OEHHA	California Office of Health Hazard Environmental Assessment
offsite	area located off the property in the downgradient north-northwest direction
onsite	area that is located within the property boundary of the Flint Hills North Pole Refinery
PAH	polynuclear aromatic hydrocarbons
PbB	blood lead concentration
PEF	particulate emission factor
power plant	electrical generating facility
PPRTV	provisional peer reviewed toxicity value
PQL	practical quantitation limit
RAF	relative absorption factor
RAGS	Risk Assessment Guidance for Superfund
RAWP	Work Plan to Conduct a Human Health Risk Assessment
Revised Draft Final HHRA	Revised Draft Final Human Health Risk Assessment
RfD	reference dose
RME	reasonable maximum exposure
RRO	residual range organic
RSL	regional screening level
site	Flint Hills Refinery, North Pole, Alaska

SSA	skin surface area
SSA_s	skin surface area available for contact
SSA_w	skin surface area available for contact with water
sulfolane	tetrahydrothiophene-1,1-dioxide
SVOC	semivolatile organic compound
SWI	Shannon and Wilson, Inc.
t	time
t_{event}	event duration
T_{event}	lag time per event (hours/event)
TEF	toxicity equivalence factor
UCL	upper confidence limit
USEPA	United States Environmental Protection Agency
VF	volatilization factor
VF_{gw}	volatilization factor (groundwater)
VF_{soil}	volatilization factor (soil)
VOC	volatile organic compound
WWTP	wastewater treatment plant
$\mu g/cm^3$	micrograms per cubic centimeter
µg/dL	micrograms per deciliter
µg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
°C	degrees Celsius
>	greater than

1. Introduction

On behalf of Flint Hills Resources Alaska, LLC (FHRA), ARCADIS U.S., Inc. (ARCADIS) prepared this Revised Draft Final Human Health Risk Assessment (Revised Draft Final HHRA) for the Flint Hills North Pole Refinery located in North Pole, Alaska (site). This HHRA follows the approaches described in the Second Revision Work Plan to Conduct a Human Health Risk Assessment at the Flint Hills North Pole Refinery (RAWP; ARCADIS 2011a). As described in the RAWP (ARCADIS 2011a), FHRA proposed submittal of a RAWP for the site in a project schedule submitted to the Alaska Department of Environmental Conservation (ADEC) on August 2, 2011. FHRA purchased the site from Williams Alaska Petroleum, Inc. in 2004. The HHRA was conducted to answer the question: “Could concentrations of site-related constituents in soil and groundwater pose adverse health effects to current and future site users and potential receptors located offsite, downgradient of the site?” An HHRA uses a conservative (health-protective) approach to answer that question.

No HHRAs or ecological risk assessments have been previously conducted at the site. ARCADIS submitted an ecological conceptual site model (CSM) to the ADEC on June 10, 2011. The purpose of the ecological CSM was to establish whether environmental constituents related to site operations that are present at the site, or that have migrated offsite, will come in contact with ecological receptors. The CSM stated that tetrahydrothiophene-1,1-dioxide (sulfolane) is degraded in surface water in the presence of nutrients and oxygen and does not biomagnify in aquatic food chains. Furthermore, the CSM did not identify any complete exposure pathways for ecological receptors and concluded that no further evaluation is warranted. Therefore, evaluation of potential ecological receptors at the site is beyond the scope of this Revised Draft Final HHRA.

Pore-water samples were collected during the 2012 field season following the approach described in the Draft Site Characterization Work Plan Addendum (Addendum; ARCADIS 2011b) to address a risk assessment data gap identified by the ADEC. The methods for installation of some of the pore-water piezometers needed to be revised because the surface-water body was frozen and true pore-water samples could not be collected. The frozen surface-water body suggests that groundwater/surface water interaction was limited. Therefore, the piezometer samples were likely more representative of groundwater. Because sulfolane degrades more rapidly in the presence of nutrients and oxygen that would be present in the surface water (Alaska Department of Health and Social Services [ADHSS] 2010), and given the limited groundwater-surface water interchange adjacent to a frozen surface-water body, the groundwater collected adjacent to two of the three surface-water bodies in 2012 likely overestimates the surface water concentrations at those locations. The results from the pore-water evaluation do not change the conclusions from the ecological CSM.

This Revised Draft Final HHRA follows protocols presented in the Risk Assessment Procedures Manual (ADEC 2000) that are adopted into regulation in 18 Alaska Administrative Code (AAC) 75. The primary

ADEC references for this Revised Draft Final HHRA include the Draft Risk Assessment Procedures Manual (ADEC 2010a and ADEC 2011c), Cleanup Levels Guidance (ADEC 2008a), Cumulative Risk Guidance (ADEC 2008b) and 18 AAC 75 Oil and Other Hazardous Substances Pollution Control Guidance (ADEC 2008c). Other references used include Risk Assessment Guidance for Superfund (RAGS) (United States Environmental Protection Agency [USEPA] 1989, 1991, 2001, 2004a and 2009a), Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (USEPA 2002a), Vapor Intrusion Pathway: A Practical Guide (Interstate Technology Regulatory Council [ITRC] 2007a), and Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios (ITRC 2007b).

This Revised Draft Final HHRA follows the methodologies, approaches and assumptions of the RAWP (ARCADIS 2011a) and the ADEC approval of the RAWP (ADEC 2011d) to assess risks and hazards to receptors that are potentially exposed to constituents detected in environmental media at the site. In addition, this Revised Draft Final HHRA was developed based on information discussed during a comment resolution meeting held on January 20, 2012 and attended by the ADEC, Oasis/SPB Consulting, FHRA and ARCADIS regarding the Draft HHRA (ARCADIS 2011d) and subsequent follow-up conversations held on January 18 (Technical Project Team meeting), March 9, March 16, May 8, May 10, and May 16, 2012.

For this Revised Draft Final HHRA, potential exposures to constituents detected in two distinct geographical areas were evaluated, both on and offsite. The onsite evaluation identified potential exposures to petroleum hydrocarbon constituents and other constituents associated with refinery operations, including metals and tetrahydrothiophene-1,1-dioxide (sulfolane). The offsite evaluation was conducted for the area north-northwest and downgradient of the site, where only dissolved sulfolane in groundwater is currently identified as a constituent of potential concern (COPC).

It is acknowledged that in 18 AAC 75.990(115), the ADEC defines the term “site” as an “area that is contaminated, including areas contaminated by the migration of hazardous substances from a source area, regardless of property ownership.” For this Revised Draft Final HHRA, the term “onsite” is the area that is located within the property boundary of the Flint Hills North Pole Refinery, and the term “offsite” is the area located off the property in the downgradient north-northwest direction and is based on the approximate extent of the dissolved-phase sulfolane plume detected at concentrations above laboratory reporting limits (approximately 10 micrograms per liter [µg/L]). Figure 2-1 shows the extent of the onsite area and the approximate extent of the offsite area.

This Revised Draft Final HHRA also presents potential site-specific alternative cleanup levels (ACLs) for COPCs that contribute to the majority of the risk or hazard (also referred to as risk/hazard driving COPCs), as appropriate, including benzene, naphthalene, 1,3,5-trimethylbenzene and xylenes in onsite groundwater. A representative range of potential ACLs for the primary risk/hazard driving COPC, sulfolane, was developed based on a range of toxicity criteria and exposure assumptions. ACLs will likely be used to support a feasibility study evaluation of remediation alternatives for the site.

Both current and historical data were evaluated for applicability and usability in the HHRA. Risk assessment data gaps were identified during preparation of the Site Characterization and First Quarter 2011 Groundwater Monitoring Report (Barr Engineering Company [Barr] 2011). These data gaps were filled during the 2011 and 2012 field seasons following the approaches described in the Addendum (ARCADIS 2011b). The data collected during the 2011 and 2012 field seasons were assessed for inclusion into this Revised Draft Final HHRA. Shannon and Wilson, Inc. (SWI) completed the primary historical data collection events in 2000, 2002, 2009 and 2010 (SWI 2002 and 2010).

Estimated hazards and risks are presented based on two primary scenarios:

1. "Provisional peer reviewed toxicity value (PPRTV) Scenario," using toxicity criteria for sulfolane based on the January 2012 USEPA report, along with exposure assumptions approved by ADEC (Section 3).

2. "ARCADIS Comparative Scenario," using the toxicity criteria for sulfolane selected by ARCADIS after its literature review and data evaluations, with the ADEC-approved exposure assumptions (Section 4). In the Uncertainty Assessment of Section 4, also presented is an evaluation of risk using the ARCADIS toxicity criteria for sulfolane, with the exposure assumptions selected by ARCADIS based on its literature review and data evaluations (the "ARCADIS Scenario").

Except as explained above, the same site data, exposure assumptions, methodologies and approaches were used to estimate risk and hazards for all scenarios.

The remaining sections of this Revised Draft Final HHRA are organized as follows:

- Section 2 describes site features and summarizes environmental investigations performed at the site.

- Section 3 presents a risk characterization for the PPRTV scenario including subsections on exposure assessment, CSMs, data evaluation, quantification of exposure, toxicity assessment, risk estimates and uncertainties associated with the risk characterization.

- Section 4 presents a risk characterization for the ARCADIS Comparative Scenario including subsections on exposure assessment, CSMs, data evaluation, quantification of exposure, toxicity assessment, risk estimates and uncertainties associated with the risk characterization.

- ACLs are discussed in Section 5.

- Section 6 presents a complete list of the references cited in this Revised Draft Final HHRA.

2. Site Properties

This section presents an overview of site features and summarizes environmental investigations performed at the site. The site description is based on a review of historical records, maps and publicly available information; observations made during site visits; and data obtained during historical site investigations.

2.1 Site Location

The site is located on 240 acres just outside the city limits of North Pole, Alaska (the city). The city is located approximately 13 miles southeast of Fairbanks, Alaska, within Fairbanks North Star Borough (Figure 1-1).

2.2 Site Description

Three crude oil processing units and one sulfolane extraction unit are located in the southern portion of the site, making up the process area. Tank farms are located in the central portion of the site. Truck-loading racks are located immediately north of the tank farms and a railcar-loading rack is located west of the tank farms. Previously, a truck-loading rack was located between the railcar-loading rack and the tank farms, near the intersection of Distribution Street and West Diesel. Wastewater treatment lagoons, storage areas and two flooded gravel pits (the north and south gravel pits) are located in the western portion of the site. Rail lines and access roads are located in the northernmost portion of the site. An electrical generating facility (power plant) operated by Golden Valley Electric Association is located along the southern site boundary and is partially surrounded by the site. The power plant burns heavy aromatic gas oil (diesel 4) produced at the site. The property south of the site and the power plant is occupied by the Petro Star, Inc. Refinery. The Site Layout is presented on Figure 2-1.

North of the site are residential properties and the city's wastewater treatment plant (WWTP). The North Pole High School is located immediately north and west of the WWTP and residential properties. An undeveloped parcel, owned by the Alaska Department of Natural Resources, lies between the site and the WWTP. The Tanana River is located to the west, flowing in a northwesterly direction toward Fairbanks. East of the site is property that is residential or undeveloped, the Old Richardson Highway, the Alaska Railroad right-of-way and Chena Slough (known locally as Badger Slough).

2.3 Geology and Hydrogeology

This section summarizes geology and hydrogeology of the site based on information presented in previous site investigations and in the Site Characterization and First Quarter 2011 Groundwater Monitoring Report (Barr 2011).

2.3.1 Geology

The site and the area surrounding North Pole is located on the Tanana River Floodplain. The Beaver Springs Creek (also known as Thirtymile Slough) is located east of the site, with the shortest distance away at approximately 300 feet from the northeast corner of the site. The geology of the area is dominated by a thick sequence of unconsolidated alluvial deposits up to 600 feet thick. Discontinuous layers of silt, fine sandy silt and silty fine sand with occasional peat lenses have been encountered in the upper 10 feet of the unconsolidated sequence. Alluvial sand and gravel characterized as sandy gravels and gravelly sands, with occasional discontinuous lenses of sand, silt and organic deposits, are present below the silty layers. A ground-penetrating radar survey indicated the presence of silty layers in the shallow subsurface in onsite areas that were not identified through traditional drilling means. Onsite, these layers would likely influence the migration of constituents in the vadose and shallow saturated zones and may also influence onsite cleanup efforts. Data gathered during the planned soil investigation (described in the Site Characterization and First Quarter 2011 Groundwater Monitoring Report [Barr 2011]) were expected to provide additional information concerning the presence and potential influence of these layers. The results of the 2011 site characterization activities were reported in the Revised Site Characterization Report (Barr 2012). Soil borings installed in 2011 confirmed silty deposits in the vadose zone that were consistent with observations from previous investigations, including the 2010 ground penetrating radar study.

Permafrost has generally been identified using data from monitoring wells and private well installation logs. Top-of-permafrost depths ranged from 6 to greater than 150 feet below ground surface (bgs) in the study area. Residential well logs indicate that the bottom of the permafrost ranges from 14 to 245 feet bgs and that the thickness of the permafrost layer ranges from 5 to 232 feet. Moving northwest from the site, it appears that the top of the permafrost layer becomes shallower. The upper surface of the permafrost layer appears to be deepest near the site and also near Chena Slough. A “valley” in the upper surface of the permafrost layer appears to extend northwest from the site along Old Richardson Highway and the Alaska Railroad. Permafrost depth is likely to influence migration of sulfolane offsite. Additional data collection to further refine the understanding of the depth to and the location of permafrost is ongoing.

2.3.2 Hydrogeology

The site and the surrounding North Pole area are located on a relatively flat-lying alluvial plain that is situated between the Tanana River and Chena Slough. The site is located on the Tanana River Floodplain. Reference values of hydraulic conductivities of the aquifer materials range from 8 to 2,400 feet per day. Hydraulic conductivity estimates based on grain size range from 1 to 1,600 feet per day. Aquifer testing at the site in 2009 indicated a hydraulic conductivity of approximately 130 feet per day for wells screened in the upper 15 feet of the aquifer. This value was considered to be biased low because it was calculated with an aquifer thickness that did not account for the presence of permafrost. The geometric mean of results from single-well pump testing conducted in 2011 indicated a hydraulic conductivity of 200 feet per day. Aquifer testing of the city's new water supply wells (installed in 2010) indicated a hydraulic conductivity ranging from approximately 700 to 1,100 feet per day based on pumping of wells screened from approximately 120 to 150 feet below the water table. The water table in the area is approximately 15 feet bgs and is usually present within the alluvial sand and gravel, and occasionally in the silty deposits. The water table decreases in elevation from southeast to northwest, mimicking the gradually decreasing elevation of the ground surface. Based on limited data, the water table has fluctuated vertically up to 4 feet since 2007. Seasonal lows typically occur any time from late March through May, with seasonal highs occurring in July or August.

Groundwater flow directions are primarily controlled by discharge from the Tanana River to the aquifer and from the aquifer to the Chena River and the Chena Slough. Variations in river stage are believed to be the primary cause of variations in flow direction. The flow direction trends to the north-northwest in the winter and spring and more northerly in the summer and fall.

2.4 Land Use and Beneficial Water Use

An active petroleum refinery is located onsite. Specifically, three crude oil processing units and associated utility and effluent buildings, maintenance and administrative buildings, warehouse, laboratory, chemical injection room and sulfolane extraction unit, three lagoons, north and south gravel pits, hazardous waste storage area, and multiple aboveground storage tanks (ASTs) occupy the site. The site is located within a fenced, guarded facility. The primary historical and current use of the site is commercial/industrial, which is not expected to change in the foreseeable future. FHRA does not have plans to redevelop the site.

Currently, no potable wells are present onsite and groundwater would only be used for onsite fire suppression purposes. The city supplies potable water to the site.

Offsite, downgradient to the north of the site is a mixed residential and commercial area. Currently, offsite residents and commercial workers located immediately north of the site obtain drinking water from the city's new water supply wells. Residents and commercial workers located outside the city water service area but within or near the dissolved sulfolane plume have been provided alternative water supplies (including treatment systems, bulk water tanks or continued supplies of bottled water) to eliminate potential ingestion of groundwater impacted with sulfolane. Bulk water tanks have also been provided to residents for irrigation of home gardens.

2.5 Current Site Remediation

FHRA is implementing the interim corrective actions described in the Interim Removal Action Plan (Barr 2010a) to optimize the existing groundwater pump and treat remediation system to aggressively address light nonaqueous phase liquid (LNAPL) and impacted groundwater onsite. Operation of the remediation system currently involves groundwater recovery from five recovery wells.

Installation and startup of the sand filters and a granular activated carbon (GAC) treatment system was completed during the second quarter 2011 and active operation was initiated on June 9, 2011. The sand filters and GAC filters were installed to treat dissolved-phase sulfolane concentrations in extracted groundwater.

FHRA continues to remove LNAPL from recovery and monitoring wells through active LNAPL pumping systems, passive LNAPL recovery measures and periodic manual removal. The recovered LNAPL is recycled within a refinery process unit.

2.6 Data from Previous Investigations

This section describes sources of analytical data that were used in the HHRA. Historical on- and offsite soil, groundwater and surface-water data are available. Additional soil and groundwater data were collected during the 2011 field season. Some surface-water (i.e., pore space) data were collected offsite during the 2012 field season. Installation methods for two of the three offsite locations needed to be revised because the adjacent surface water was frozen. As noted in Section 1, the groundwater collected adjacent to two of the three surface-water bodies in 2012 was likely not representative of the interface between groundwater and surface water and may overestimate the actual pore-water concentrations at those locations.

This Revised Draft Final HHRA evaluates data with complete Level II data packages received from the analytical laboratory through February 2012. SWI maintains the site database, which is built on a Microsoft® Access platform, and performs data validation consistent with ADEC requirements.

2.6.1 Soil Data

Historical soil data are summarized in the Site Characterization and First Quarter 2011 Groundwater Monitoring Report (Barr 2011). Historically, soil analytical data have been collected primarily at depths exceeding 2 feet bgs and include analyses for: gasoline range organics (GRO); diesel range organics (DRO); residual range organics (RRO); benzene, toluene, ethylbenzene and total xylenes (BTEX); polynuclear aromatic hydrocarbons (PAHs); volatile organic compounds (VOCs); semivolatile organic compounds (SVOCs); metals; and sulfolane (Barr 2011).

During the 2011 field season, surface soil samples were collected onsite and analyzed for historically detected constituents and additional COPCs. As discussed in Section 3.1.2.4 identified soil data gaps were filled during the 2011 field season following the approaches described in the Addendum (ARCADIS 2011b). The soil data collected during this sampling event were assessed for inclusion into this Revised Draft Final HHRA. Due to an inadvertent error, samples collected from the 2011 COPC soil borings were not submitted for analysis to determine concentrations of propylene glycol and isopropanol; instead, they were analyzed for the other COPCs identified in the RAWP.

Soil samples collected in 2010 for sulfolane analysis were validated by a third party, and final sulfolane concentrations identified by the validators were incorporated into the data set used for the HHRA. Based on the Level IV validation, it was determined that soil sample O-2 (7.5-9) should be considered unusable due to the very low internal standard area count and the high levels of petroleum hydrocarbon interference with all four sulfolane mass ions in the sample. This sample was not included in the Exposure Point Concentration (EPC) calculations. Validated data used in this Revised Draft Final HHRA were described in the Revised Site Characterization Report (Barr 2012) that was submitted to ADEC in March 2012.

2.6.2 Groundwater Data

Groundwater data have been collected onsite from 1987 to present and offsite from 2009 to present. Groundwater monitoring data collected during the most recent reporting period (fourth quarter 2011) are generally consistent with data collected during previous reporting periods (ARCADIS 2011c) and are summarized below:

- Dissolved-phase benzene concentrations up to 7,470 µg/L were detected during the fourth quarter 2011 in the sample collected from monitoring well MW-116.
- Dissolved-phase toluene concentrations up to 6,080 µg/L were detected during the fourth quarter 2011 in the sample collected from monitoring well MW-135.
- Dissolved-phase ethylbenzene concentrations up to 586 µg/L were detected during the fourth quarter 2011 in the sample collected from monitoring well MW-135.
- Dissolved-phase total xylenes concentrations up to 4,334 µg/L were detected during the fourth quarter 2011 in the sample collected from monitoring well MW-116.
- Sulfolane concentrations continue to be detected in both samples collected from onsite groundwater monitoring wells at concentrations up to 10,400 µg/L and in samples collected from offsite groundwater monitoring wells and residential wells at concentrations up to 443 µg/L.

Groundwater samples were collected for COPC analyses during the third and fourth quarter 2011 groundwater monitoring events. The full list of COPCs was not analyzed in third quarter 2011 samples because the complete COPC list (Table 3-2a) was not yet finalized. The complete COPC analytical suite was analyzed during fourth quarter 2011, with the exception of isopropanol and propylene glycol. These two COPCs will be analyzed during the first quarter 2012 groundwater monitoring event.

2.6.3 Surface-Water Data

As reported in the Site Characterization and First Quarter 2011 Groundwater Monitoring Report (Barr 2011), on August 11, 2010, surface-water samples were collected from the onsite north and south gravel pits and on October 10, 2010 from offsite Chena Slough, which runs parallel to Badger Road. The samples were analyzed for sulfolane. The laboratory reported that sulfolane was not detected above its limit of quantitation (LOQ) of 10 µg/L in either of the gravel pit samples or above the LOQ of 10.2 µg/L in the surface-water sample collected from Chena Slough.

FHRA conducted a pore-water investigation in 2012 to better characterize sulfolane concentrations in the groundwater/surface-water interface and the potential for surface-water sulfolane impacts. The planned approaches are described in the Addendum (ARCADIS 2011b). Some of the samples were collected when the adjacent surface-water body was frozen; therefore, the degree of connectivity with surface water, if any, could not be established. Because two of the collected samples likely reflect higher sulfolane concentrations than would be expected in true pore-water samples (because of limited surface-water to groundwater interchange), and because pore-water samples will generally reflect higher sulfolane concentrations than would be encountered by actual recreational users of the surface-water bodies due to degradation of sulfolane in surface water, the collected data are included in this Revised Draft Final HHRA.

The three offsite samples collected in March 2012 to assess surface-water risks were analyzed for sulfolane. The results are as follows: Pore-5 at <6.2 µg/L, Pore-4 at 28.7 µg/L and Pore-3 at 156 µg/L. Pore-5 was a true pore-water sample, but Pore-3 and Pore-4 were piezometer samples of groundwater that may not be representative of true pore water, because the adjacent surface-water body was frozen. The maximum detected concentration of sulfolane from these samples was used to assess potential recreational user exposures to sulfolane in surface water.

3. Provisional Peer Reviewed Toxicity Value Scenario

3.1 Exposure Assessment

ARCADIS conducted an HHRA to evaluate the potential for human health risk from exposure to site-related constituents, following protocols presented in the June 8, 2000 ADEC Risk Assessment Procedures Manual that are adopted into regulation in 18 AAC 75. The primary ADEC references for this Revised Draft Final HHRA include the Draft Risk Assessment Procedures Manual (ADEC 2010a and 2011d), Cleanup Levels Guidance (ADEC 2008a), Cumulative Risk Guidance (ADEC 2008b), and 18 AAC 75 Oil and Other Hazardous Substances Pollution Control guidance (ADEC 2008c). Other references used include RAGS (USEPA 1989, 1991, 2001, 2004a and 2009a), Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (USEPA 2002a), Vapor Intrusion Pathway: A Practical Guide (ITRC 2007a) and Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios (ITRC 2007b).

3.1.1 Human Health Conceptual Site Models

Two preliminary human health CSMs (one onsite CSM and one offsite CSM) were prepared and submitted to the ADEC with the Site Characterization Work Plan (Barr 2010b). After this submittal, a substantial amount of additional site assessment data was collected and in April 2011 the updated CSMs were submitted to the ADEC to reflect the enhanced understanding of site conditions. In the RAWP submitted to ADEC in December 2011 (ARCADIS 2011a), the CSMs were further refined to better reflect existing site conditions. The updated CSMs were developed following the Human Health Conceptual Site Model Graphic and Scoping Forms and the Policy Guidance on Developing Conceptual Site Models (ADEC 2010b and 2010c, respectively). Due to the significant difference in COPC occurrence onsite (petroleum hydrocarbon constituents and sulfolane) versus offsite (sulfolane only), two human health CSM graphic forms (Figures 3-1 and 3-2) were prepared and updated to more clearly portray and distinguish potential exposure pathways for possible on- and offsite receptors.

This section describes the CSMs submitted to the ADEC in December 2011 and revisions to the offsite CSM based on ADEC comments discussed during the meeting held on January 24, 2012. Human health CSMs for on- and offsite locations are presented on Figures 3-1 and 3-2, respectively, and are discussed in the following subsections.

3.1.1.1 Potential Sources

During site operations, various materials associated with the crude oil refining process have been released in operating areas of the site, including the crude oil processing units, extraction unit, loading racks, wastewater lagoons, sumps and drain systems. In addition, spills and/or leaks to surface soil from ASTs, pumps and associated piping during routine operations constitute potential sources of petroleum constituents at the site. Petroleum hydrocarbons have also been detected in historical groundwater samples collected from onsite monitoring wells.

Onsite impacted environmental media may include surface (0 to 2 feet bgs) and subsurface (to a depth of 15 feet bgs, the maximum depth at which human exposure is likely to occur) soil, groundwater, indoor and outdoor air, surface water, sediment and biota. Offsite impacted media may include groundwater, surface water, sediment, wild food (such as fish) and homegrown produce.

3.1.1.2 Potential Fate and Transport Mechanisms

As described in Section 3.1.1, the primary sources of COPCs are spills and releases to soil and groundwater during facility operations. COPCs may be retained in site soils or subject to constituent fate and transport mechanisms at the site. Fate and transport mechanisms may include soil sorption; biodegradation; wind erosion and transport; migration to groundwater; advective/dispersive transport in groundwater, on or offsite; and volatilization into soil gas, outdoor air or indoor air.

Potential current and future onsite receptors may be directly exposed to COPCs in surface and subsurface soil via incidental ingestion, dermal contact and inhalation of dust particles in air. In addition, COPCs adhered onto dust particles may migrate from exposed surface or subsurface soil to outdoor air and be breathed by potential offsite receptors. When bound to surface soils, compounds sorbed to soil particles may be subject to wind erosion and windblown transport in outdoor air. Due to the nature of the site, the majority of operational areas are covered with asphalt pavement or gravel. However, exposed and unpaved areas do exist at the site. Therefore, although limited, windborne particulate transport is possible at the site, and this potential pathway was evaluated during the HHRA.

COPCs may leach from soil to groundwater by percolation or may have been directly released to groundwater. Based on groundwater samples collected from onsite wells, sulfolane is the only COPC that is known to have migrated offsite. Potential direct-contact exposures to COPCs in groundwater (e.g., tapwater ingestion and inhalation of volatiles in water) are not expected to occur for current and future onsite commercial/industrial workers because onsite groundwater is only used for industrial purposes (e.g., fire suppression). However, current and future onsite outdoor commercial/industrial receptors may be exposed to COPCs in groundwater by dermal contact while extinguishing fires, if they occur. In addition, due to the relatively shallow average depth to groundwater onsite (historically from 8 to 10 feet bgs), current and future onsite construction/trench workers may be exposed by incidental ingestion of and dermal contact with COPCs in groundwater that has pooled in excavated trenches.

The city provides municipal water for drinking and other potable uses at the site. Current onsite receptors consume drinking water from a municipal source and are expected to consume drinking water from this source in the future. Current and future offsite receptors may be exposed to sulfolane in groundwater that has migrated from the site to wells used for tapwater. In addition, groundwater may be used offsite to irrigate homegrown produce. Sulfolane in groundwater may be taken up by homegrown produce and consumed by offsite residents.

Onsite surface water consists of water that is stored in two lagoons and two gravel pits. Runoff and erosion from soil to surface water may be transport mechanisms. Groundwater from the site flows offsite in a north-northwesterly direction and groundwater is recharged by surface water from the Tanana River. COPCs in groundwater may eventually flow to offsite surface-water bodies and to sediment, which may be contacted by offsite recreational users. Pore-water data were collected to evaluate the potential for exposure at the groundwater/surface-water interface. Some of the samples used for this HHRA were collected when the adjacent surface-water body was frozen; therefore, the degree of connectivity with the surface water, if any, could not be established.

For this HHRA, potential ingestion of sulfolane in surface water by adult and child recreational users while swimming is considered a potentially complete exposure pathway offsite. The collected pore-water samples likely reflect higher sulfolane concentrations than would be expected in true pore-water samples because of limited surface water to groundwater interchange during frozen conditions. Pore-water samples will generally reflect higher sulfolane concentrations than would be encountered by actual recreational users of the surface water bodies because sulfolane degrades more rapidly in the presence of nutrients and oxygen that would be present in the surface water (ADHSS 2010). Accordingly, the data used in the surface-water evaluation in this Revised Draft Final HHRA provide a health-protective assessment of risk to swimmers.

Volatilization is another fate and transport mechanism at the site for lighter petroleum hydrocarbon compounds and other VOCs. VOCs may volatilize from subsurface soil into soil gas, with eventual diffusion and/or advection into outdoor air and/or indoor air in onsite buildings. VOCs may also leach from soil to groundwater, where dissolved-phase VOCs may be transported downgradient both on and offsite. VOCs may volatilize from shallow exposed groundwater in excavations directly into outdoor air. VOCs may volatilize from groundwater into soil gas, with eventual diffusion and/or advection into outdoor air and/or indoor air of on- and/or offsite buildings. VOCs may also be subject to degradation by microorganisms in subsurface soils and groundwater. Heavier petroleum hydrocarbon compounds, such as PAHs, adsorb to solids and do not tend to volatilize. As such, these compounds generally tend to remain in place, where they are subject to aerobic biodegradation by microorganisms. Sulfolane is not expected to volatilize under the conditions observed at the site, as discussed in Section 3.1.1.4.

3.1.1.3 Potential Receptors

Potential human receptors were identified based on current and reasonably foreseeable future land use at the site. A review of current and future land use identified the following potential human receptors at the site.

- **Current and future onsite indoor commercial/industrial workers** were considered to be individuals from 18 to 65 years old. It was assumed that these receptors perform commercial and/or industrial work activities (e.g., office work, laboratory analyses, shipping or warehouse inventory management) indoors onsite, under current or future (redeveloped) land use scenarios. Potential exposures to COPCs in soil are considered to be insignificant for onsite indoor commercial/industrial workers. These potential receptors may be exposed to COPCs in indoor air during a standard 40-hour work week for 25 years, for 250 days per year. Potential inhalation of outdoor air is insignificant. Inhalation of VOCs in indoor air was evaluated following USEPA (2009a) RAGS Part F.

- **Current and future onsite outdoor commercial/industrial workers** were considered to be individuals from 18 to 65 years old. These receptors were assumed to perform commercial and/or industrial work activities (e.g., maintenance work for ASTs or associated piping) outdoors at the site under current or future (redeveloped) land use scenarios. These individuals may occasionally use site groundwater for industrial purposes (e.g., fire suppression). Direct-contact exposures with groundwater are considered insignificant because fires are rare onsite and the exposure period is expected to be short. This exposure pathway was not quantitatively evaluated. These potential receptors may be exposed to COPCs in site media during a standard 40-hour work week for 25 years, for 250 days per year. Following ADEC (2010a) guidance, it was assumed that onsite outdoor workers with an average body weight (BW) of 70 kilograms (kg) are exposed to 100 milligrams per day (mg/day) COPCs in surface soil and that 100 percent of the fraction ingested (FI) is from onsite surface soil.

  FHRA requires all onsite workers to wear long-sleeved shirts, long pants and shoes. Thus, the adult commercial/industrial worker outdoor receptor was assumed to wear a long-sleeved shirt, long pants and shoes, which limits the exposed skin surface to the head and hands. The recommended USEPA (2011a) skin surface area (SSA) exposed to impacted soil for the adult commercial/industrial worker outdoor receptor is 2,230 square centimeters (cm^2), which is the average of the adult male and adult female mean values for head and hands. The USEPA (2004a) recommended weighted soil-to-skin adherence factor (AF) for a commercial/industrial adult worker of 0.2 milligram per square centimeter (mg/cm^2) based on the 50^{th} percentile weighted AF for utility workers (i.e., the activity determined to represent a high-end contact activity) was used. Potential inhalation of indoor air was considered insignificant for the outdoor commercial/industrial worker. Inhalation of volatile COPCs and dust in outdoor air was evaluated following USEPA (2009a) RAGS Part F.

- **Current and future onsite construction/trench workers** were considered to be individuals from 18 to 65 years old. These receptors were assumed to perform short-term maintenance and emergency repair activities on underground utilities or facility piping at the site. These receptors may be exposed to COPCs in surface and/or subsurface soil during the work day while performing the maintenance and/or repair task. Because the depth to groundwater at the site generally ranges from 8 to 10 feet bgs, construction/trench workers may be exposed to COPCs in groundwater that has pooled in a trench during performance of the maintenance and/or repair task. It was assumed that the same worker will provide maintenance and/or repair tasks.

  Potential construction/trench worker receptors were assumed to be exposed to COPCs in onsite soil (down to a depth of 15 feet bgs) and groundwater for 1 hour each day of a standard 5-day work week, for 125 days, for 1 year. This exposure frequency (EF) is a modification from that proposed in the RAWP (250 days per year). This deviation is justified because most of the utilities at the site are located aboveground and trenching activities typically do not occur during 6 months of each year, when the ground is frozen. It is assumed that soil may be accessible for trenching activities (i.e., not frozen) for 6 months per year.

  Construction/trench workers with an average BW of 70 kg are assumed to be exposed to 330 mg/day (USEPA 2002b) of COPCs in surface and subsurface soil, and 100 percent of the FI is assumed to be from surface and subsurface soil. It was assumed that onsite construction/trench workers incidentally ingest 0.0037 liter per day (L/day) of groundwater pooled in a trench. This rate is based on the mean ingestion rate for wading/splashing presented in the USEPA (2011a) Exposure Factors Handbook (EFH) Table 3-93 (3.7 milliliters per hour * 1 hour per day). This consumption rate is likely to overestimate actual exposure, because dewatering usually occurs at excavation sites where water has pooled in trenches.

  FHRA requires all onsite workers to wear long-sleeved shirts, long pants and shoes. Therefore, the onsite adult construction worker receptor was assumed to wear a long-sleeved shirt, long pants and shoes, and the exposed SSA was limited to the head and hands. The USEPA (2011a) recommended SSA exposed to impacted soil for the adult construction worker receptor is 2,230 cm^2. The USEPA (2002b) recommended weighted soil-to-skin AF for a construction worker of 0.3 mg/cm^2-day was used. Inhalation of volatile COPCs and dust in outdoor air were evaluated following USEPA (2009a) RAGS Part F.

- **Current and future onsite visitors and trespassers.** Occasional visitors or trespassers may also be present onsite. However, the site does not and is not expected to attract trespassers because of the character and location of the site (i.e., an industrial setting with controlled access). Moreover, it is anticipated that a trespasser's exposure at the site would be very infrequent. Onsite visitors are typically adults with limited access across the site. Children rarely visit the site. Thus, potential direct-contact exposures to COPCs in soil and groundwater by current and future onsite trespassers and visitors are insignificant. Potential inhalation of outdoor air is also insignificant. However, assuming the adult visitor is located in an onsite building, inhalation of volatile COPCs in indoor air by this potential receptor was evaluated following USEPA (2009a) RAGS Part F. Current and future onsite adult visitors (18 to 65 years of age) are assumed to be exposed to COPCs in indoor air for 2 hours per day, 12 days per year for 30 years.

- **Current and future offsite residents** were evaluated as infants (0 to 1 year of age), children (0 to 6 years of age) and adults (18 to 65 years of age). HHRAs do not typically focus on infant exposures as a separate receptor group, but infants are included here because the Agency for Toxic Substances and Disease Registry (ATSDR 2011) and the State of Alaska Department of Health and Social Services (ADHSS 2012) have addressed infants as a separate receptor group in their Health Consultations. There is evidence that sulfolane does not present a significant risk for developmental effects and it is not mutagenic, mitigating infant-specific exposure concerns. Resident receptors were assumed to be located downgradient of the site and may be exposed to sulfolane in groundwater that has migrated from the site. No other COPCs associated with site operations are known to be present in offsite groundwater. These potential offsite receptors may ingest sulfolane in groundwater as tapwater. In addition, it was assumed that these potential receptors consume homegrown produce, which may have taken up sulfolane from groundwater. It was assumed that potential resident receptors may be exposed to sulfolane in tapwater for a 1-, 6- and 30-year duration for infants, children and adults, respectively, for 350 days per year.

  Current and future offsite adult, child and infant residents may also inhale dust from the site. Inhalation of dust in outdoor air by these potential receptors was evaluated following USEPA (2009a) RAGS Part F.

  Following ADEC (2010a) guidance, it was assumed that 70 kg adult residents consume 2 L/day of tapwater. Following USEPA (1989) guidance, it was assumed that 15 kg child residents consume 1 L/day of tapwater. Infants were assumed to weigh an average of 6.75 kg (the average of the age-group specific mean values from 0 to 1 year) and to consume 1.05 L/day (the time-weighted average of the *per capita* age-group-specific 95th percentile values from 0 to 1 year) of tapwater based on USEPA (2011a) guidance. The groundwater ingestion exposure parameters for infants likely overestimate potential exposure, because it was assumed that they do not breastfeed and do not consume formula made with distilled water (a typical pediatric guideline for the first several months of life).

  Fractions of homegrown fruit and vegetables ingested, water-to-produce bioconcentration factors and ingestion rates for offsite adult and child residents for the PPRTV scenario are discussed in Section 3.1.3.1.6.

- **Current and future offsite indoor and outdoor commercial/industrial workers** were considered to be individuals from 18 to 65 years old. It was assumed that these potential receptors perform commercial and/or industrial work activities indoors or outdoors at offsite locations under current or future land use scenarios during a standard 40-hour work week for 25 years, for 250 days per year. These receptors may ingest sulfolane in groundwater as tapwater. Following ADEC (2010a) guidance, it was assumed that 70 kg offsite adult commercial/industrial workers consume 2 L/day of tapwater. In addition, they may inhale dust that may have been released onsite via wind erosion. Potential exposures to COPCs in dust were considered to be insignificant for offsite indoor commercial/industrial workers. Inhalation of dust in outdoor air by outdoor commercial/industrial workers was evaluated following USEPA (2009a) RAGS Part F.

- **Current and future offsite recreational users.** Sulfolane may potentially migrate offsite via groundwater to surface water and to sediment in downgradient surface-water bodies. Access to downgradient, offsite surface-water bodies is minimal due to surrounding industrial land use and hazardous physical conditions, and direct contact with surface water and sediment by human receptors is limited. Regardless, for this HHRA, ingestion of surface water by offsite adult and child recreational users while swimming is considered a potentially complete exposure pathway. Recreational user exposure assumptions for the PPRTV scenario are discussed in Section 3.1.3.3.

- **Current and future offsite construction/trench workers** were considered to be individuals from 18 to 65 years old. These receptors were assumed to perform short-term maintenance and emergency repair activities on underground utilities at offsite properties. These potential receptors may be exposed to sulfolane in groundwater that has pooled in a trench during performance of the maintenance and/or repair task. It was assumed that offsite construction/trench workers incidentally ingest 0.0037 L/day of groundwater pooled in a trench. This rate is based on the mean ingestion rate for wading/splashing presented in the USEPA (2011a) EFH Table 3-93 (3.7 milliliters per hour * 1 hour per day). This consumption rate overestimates actual consumption, because dewatering usually occurs at excavation sites where water has pooled in trenches. It was conservatively assumed that the same worker performs multiple maintenance and/or repair tasks. These potential receptors (70 kg for adults) may be exposed to sulfolane in groundwater for 1 hour each day of a standard 5-day work week, for 125 days per year, for 1 year.

3.1.1.4 Exposure Pathway Evaluation

Potential exposure pathways selected for quantitative evaluation are shown in the on- and offsite human health CSMs. An exposure pathway was retained for further evaluation if it was considered potentially complete. Each of the following components must be present in order for an exposure pathway to be considered complete (USEPA 1989):

- Source and/or constituent release mechanism
- Retention or transport medium
- Receptor at a point of potential exposure
- Exposure route at the exposure point.

Complete exposure pathways were evaluated for identified COPCs. Only potential ingestion exposures were quantitatively assessed for sulfolane. Dermal contact and inhalation exposure routes are not significant for sulfolane. The ATSDR (2010 and 2011) Health Consultations support these conclusions. Animal studies have shown that sulfolane is not readily absorbed through human skin because of its low permeability (Brown et al. 1966) and is not expected to pose a significant risk via an inhalation exposure route due to its low volatility (Andersen et al. 1977). Brown et al. (1966) studied the skin and eye irritant and skin sensitizing properties of acute exposures to sulfolane on two animal species. This study concluded that sulfolane did not irritate or sensitize the skins of guinea pigs or rabbits and, undiluted, was only very mildly irritating on the eyes of rabbits.

Andersen et al. (1977) conducted acute and subacute investigations of the inhalation toxicity of sulfolane on four animal species including monkey, dog, guinea pig and rat. A no-observed-effect level for sulfolane of 20 mg/m^3 was reported, and the authors concluded that airborne concentrations of sulfolane as high as those investigated are unlikely to be encountered on any but an emergency basis. Andersen et al. (1977) reported that sulfolane has a relatively low vapor pressure (approximately 0.13 millimeter of mercury at 32 degrees Celsius [°C]) and only unusual conditions would produce an extensive release of aerosolized sulfolane. Andersen et al. (1977) further noted that if sulfolane is handled at room temperature in an area with proper ventilation, it should not be regarded as posing an unusual hazard.

Potentially complete and significant exposure pathways were identified for the following receptors, with the exception that dermal and inhalation exposures to sulfolane are incomplete (as noted above):

- Onsite indoor commercial/industrial worker (current and future):
  - Inhalation of volatile COPC vapors in indoor air from groundwater.
- Onsite outdoor commercial/industrial worker (current and future):
  - Ingestion of, dermal contact with and inhalation (particulates) of COPCs in surface soil.
  - Dermal contact with COPCs in groundwater while extinguishing fires was qualitatively evaluated.
  - Inhalation of volatile COPC vapors in outdoor air volatilized from surface and subsurface soil and groundwater.

- Onsite construction/trench worker (current and future):
  - Ingestion of, dermal contact with and inhalation (particulates) of COPCs in surface and subsurface soil.
  - Inhalation of volatile COPC vapors in trench air from surface and subsurface soil and groundwater.
  - Ingestion of and dermal contact with COPCs in groundwater in excavation trenches.
- Onsite adult visitor (current and future):
  - Inhalation of volatile COPC vapors in indoor air from groundwater.
- Offsite adult, child and infant residents (current and future):
  - Ingestion of sulfolane in groundwater (i.e., tapwater).
  - Ingestion of homegrown produce irrigated with sulfolane-impacted groundwater.
  - Inhalation of fugitive windborne dust from onsite COPCs in surface soil.
- Offsite indoor and outdoor commercial/industrial worker (current and future):
  - Ingestion of sulfolane in groundwater (i.e., tapwater).
  - Inhalation of fugitive windborne dust from onsite COPCs in surface soil (outdoor worker only).
- Offsite construction/trench worker (current and future):
  - Ingestion of sulfolane in groundwater (i.e., in excavation trenches).
- Offsite adult and child recreational users (current and future):
  - Ingestion of sulfolane in surface water (i.e., pore water).

3.1.2 Data Evaluation, Constituent of Potential Concern Selection and Identification of Data Gaps

The proposed methods for data evaluation, identification of data gaps, selection of COPCs and proposed sampling to address data gaps are discussed below. Both maximum and 95% upper confidence limit (95% UCL) on the mean constituent concentrations for groundwater were evaluated.

3.1.2.1 Data Evaluation

The available data that were used include analytical results from soil investigations conducted at the site since 2001. Data from four sets of soil samples were evaluated, including samples collected in March and May 2001, July 2004, October 2010 and October 2011. One soil sample collected in 2010 (O-2 [7.5-9]) was determined to be unusable in a Level four data validation, so this sample was not included in EPC calculations.

Groundwater and surface-water data collected during the last 2 years were also included. SWI provided the soil and groundwater analytical data used in the HHRA in an electronic format. Initially, the data were separated into individual datasets by environmental media, including: onsite groundwater, offsite (downgradient) groundwater, onsite surface soil (0 to 2 feet bgs) and onsite subsurface soil (2 to 15 feet bgs).

The quality of the data is acceptable for risk assessment use. Parameters evaluated in the data quality assessment include spatial and vertical coverage and representativeness of sampling locations, analytical methods and reporting limits used by the laboratories, and data qualifiers applied during data validation. The HHRA relies on validated data supplied by SWI as presented in the Revised Site Characterization Report (Barr 2012). Data collected for this evaluation were collected per ADEC-approved sampling and analysis plans. Consideration was given to the recently developed standard procedure for analyzing sulfolane in groundwater (isotope dilution) and the historical variability between analytical results. The data relied upon in this risk assessment met the following criteria for data usability for risk assessment as recommended in ADEC (2010a) guidance:

- Analytical data sufficient for adequate site characterization were available.
- Data were collected consistent with ADEC and USEPA guidance.
- Sampling and analytical procedures gave accurate constituent-specific concentrations.
- Level two data validation was performed on analytical laboratory data used for this evaluation. Validation reports for the 2011 soil and groundwater data, and for the 2012 pore-water data prepared

by SWI, were included in the Revised Site Characterization Report (Barr 2012). Level four data validation was performed on the 2010 sulfolane in soil analyses.

- Method detection limits and sample quantitation limits were below screening criteria.
- Qualified data were used in the risk assessment; potential bias from qualified data and how it might result in an over or under estimation of risk is discussed in Section 3.5.
- Rejected data were not used for risk assessment purposes.
- For a given well, if all samples were reported as non-detects, then the lowest detection limit associated with any sampling event at that well was used to represent the well.
- If a well had both detected concentrations and reported non-detects for a given COPC, then the non-detect was represented by a value equal to one-half the detection limit associated with that COPC in that sampling event.

Offsite groundwater has been sampled at monitoring wells and private residential wells. At the request of ADEC, the off-site area was delineated into smaller exposure units (EUs) for the purposes of the 95% UCL evaluation. Accordingly, ARCADIS developed three separate exposure units (e.g., Exposure Unit 1 [EU-1], Exposure Unit 2 [EU-2] and Exposure Unit 3 [EU-3]) for statistical evaluation. These EUs were based on estimated sulfolane isocontour lines developed from fourth quarter 2011 groundwater sampling data, and generally reflect spatially contiguous areas that represent certain ranges of concentration and portions of the sulfolane plume in groundwater. Some data points outside of the concentration range are present within each of the defined EUs and are the result of data collected from well screens of varying depths. These data points were included in the analysis, because it is reasonable to assume that any hypothetical exposures to water from drinking water wells within any given unit may also include exposures to groundwater generated at varying depths. The EUs are bounded by the concentration contours of greater than (>) 100 µg/L, >25 µg/L and detectable sulfolane (Figure 3-3). These contour intervals were selected and drawn using the combined offsite well data set and are based on best professional judgment. Guidance presented in the Data Quality Assessment: Statistical Methods for Practitioners (USEPA 2006a) was considered during selection of the off-site groundwater dataset(s). The data from wells within a given EU were used to estimate the 95% UCL on the mean concentration as a health-protective and representative EPC. ProUCL version 4.1 (USEPA 2011b) was used to derive the 95% UCL on the mean of the constituent concentrations.

The utility of the soil and groundwater analytical data identified in the SWI (2000 and 2001) contaminant characterization studies conducted for the site was evaluated for the HHRA. The characterization study conducted at the site in 2001 was performed to collect additional soil and groundwater data to address data gaps from the site investigation conducted in 2000. In general, for both media, the analytical methods used included those for GRO, DRO, RRO, BTEX, selected metals, VOCs, SVOCs and sulfolane (for groundwater only).

3.1.2.2 Constituents of Potential Concern

COPCs have been identified from a list of potential constituents of interest (COIs), such as those that were likely used or spilled at the site. COPCs for each dataset were carried through the HHRA process.

Preliminary lists of COIs and COPCs in soil and groundwater at the site were presented in the Site Characterization and First Quarter 2011 Groundwater Monitoring Report (Barr 2011). The lists were revised in the Addendum (ARCADIS 2011b) based on the ADEC (2011a) Comment Matrix on the site characterization report. The lists of preliminary COIs and COPCs were also presented in the RAWP (ARCADIS 2011a).

As noted in the RAWP (ARCADIS 2011a), the list of COIs was developed according to the following process:

1. FHRA compiled a list of spills based on staff interviews, refinery records and a review of spill records retained by the ADEC.

2. The list of spills was refined by eliminating:

    a. Spills less than 10 gallons.
    b. Spills that were reportedly contained.
    c. Spills that were remediated and had confirmation sampling.

For many spills on the list, the material spilled was specific to one ingredient (e.g., propylene glycol) or was a material with obvious and limited ingredients (e.g., kerosene). However, the individual ingredients (e.g., oily water) of the other materials reportedly spilled were not provided. Refinery specialists such as chemists, wastewater experts and production leads were consulted to apply operational knowledge of the refinery to determine the ingredients that made up this set of materials. By this process, the list of spills was then distilled down to the “ingredients” or the primary constituents that make up the material spilled. This ingredient list was also compared to constituents that had been included in laboratory analyses of facility wastewater. The resulting ingredient list was then used to make up a list of COIs for the site. The COI list also included constituents that were analyzed during previous site characterization studies, regardless of whether they were detected above the practical quantitation limit (PQL). The list of COIs for the site is shown in Table 3-1. Constituents in the ingredient list that were analyzed for but not detected were not removed from this list. If a constituent was previously detected at the site and/or was included in the ingredient list, it was considered a COI.

Table 3-1 indicates if a constituent was previously analyzed in soil or groundwater samples collected at the site. Table 3-1 also indicates if a constituent was included in the ingredient list; the last four columns of the table summarize whether toxicity data are available from the USEPA's Integrated Risk Information System ([IRIS]; USEPA 2012a).

For this Revised Draft Final HHRA, maximum detected concentrations and/or the laboratory reporting limits of COIs in soil and groundwater are compared with ADEC screening levels corresponding to a 1×10^{-6} target excess lifetime cancer risk (ELCR) and 0.1 target hazard quotient (HQ), as shown in Table 3-2a. COI soil concentrations were compared with ADEC screening levels protective of potential migration to groundwater based on a zone with less than 40 inches of annual precipitation, direct-contact exposures and outdoor inhalation (ADEC 2008a [Table B-1 of 18 AAC 75, Method Two]). If ADEC soil screening levels were unavailable, then COI concentrations in soil were compared with USEPA Regional Screening Levels ([RSLs]; USEPA 2011c), adjusted to a target ELCR of 1×10^{-6} (if necessary) and a HQ equal to 0.1, for the applicable exposure pathway. Soil screening levels for GRO, DRO and RRO were from ADEC (2008a) Table B-2 Method Two. COI groundwater concentrations were compared with ADEC groundwater screening levels (ADEC 2008a; Table C). If ADEC groundwater screening levels were unavailable, then COI concentrations were compared with USEPA RSLs (USEPA 2011c) based on tapwater ingestion.

The higher of either the maximum COI concentration detected above the laboratory reporting limit or maximum detection limit was compared with the selected ADEC screening levels. The selected soil screening levels were based on the lesser of the migration to groundwater, $^{1}/_{10}$ the direct contact or $^{1}/_{10}$ the outdoor air screening levels. COIs with concentrations exceeding the selected soil screening level were identified as COPCs. Table 3-2a lists the COPCs identified in soil and groundwater based on ADEC (2010a) COPC selection guidance applied to the COIs identified in Table 3-1.

The preliminary COPCs identified at the site, as presented in Table 3-2a, are COIs that were detected in site media and exceeded ADEC screening levels. COIs not detected in site media but that had practical quantitation limits exceeding ADEC screening levels and COIs identified by the refinery as ingredients that could have been released are also considered COPCs. Arsenic was eliminated as a COPC in groundwater based on published background concentrations for the area of the site (U.S. Geological Survey 2001). However, it was retained as a COPC in soil in the RAWP (ARCADIS 2011a). An evaluation of the 2011 arsenic in soil data was presented in the Revised Site Characterization Report (Barr 2012). Based on this evaluation, it is likely that the presence of detectable arsenic in soil samples collected at the site is attributable to background concentrations. No other metal COIs were eliminated from the list of COPCs based on background concentrations. In accordance with ADEC (2010a) guidance, Table 3-2a has been provided to the ADEC in Microsoft® Excel format.

Table 3-2b summarizes COPCs by environmental media.

3.1.2.3 Data Gaps

Based on a review of the preliminary human health CSMs and available analytical data for environmental samples collected at the site, and discussions held during the June 24, 2011 Risk Assessment Scoping Meeting, four potential risk assessment data gaps were indicated:

- Limited surface soil data were available for the evaluation of potential risks and hazards to onsite human receptors.
- Onsite containment of COPCs other than sulfolane must be supported.
- Possible connection between groundwater at the site and surface water must be determined.
- No soil gas data were available to evaluate onsite vapor intrusion concerns.

3.1.2.4 Sampling Plans to Address Data Gaps

Sampling plans for additional data collection are described in the Addendum (ARCADIS 2011b). With respect to risk assessment data gaps identified in Section 3.1.2.3, the following field activities have been conducted:

- Onsite soil assessment activities, to characterize soil impacts and provide data for risk assessment activities. The soil data collected in 2011 adequately characterized the nature and extent of surface and subsurface impacts for the purposes of this HHRA evaluation. Additional sampling is planned for 2012 to complete characterization for the purposes of a remediation feasibility study. The 2011 soil data were validated and included in this evaluation.
- Additional groundwater sampling, during the third and fourth quarters 2011, confirmed that no other COPCs (except sulfolane) have migrated offsite.

A pore-water investigation was conducted to better characterize sulfolane concentrations in the groundwater/surface-water interface and the potential for surface-water sulfolane impacts. The March 2012 samples were collected when the adjacent surface-water body was frozen; therefore, the degree of connectivity with surface water, if any, could not be established. Therefore, the piezometer samples were likely more representative of groundwater. Because sulfolane degrades more rapidly in the presence of nutrients and oxygen that would be present in the surface water (ADHSS 2010), the groundwater collected adjacent to two of the three surface-water bodies in 2012 likely overestimates surface water concentrations at those locations. The data presented in this Revised Draft Final HHRA provide a health-protective estimate of risk to swimmers.

Soil gas data were not collected to evaluate potential vapor intrusion concerns. Instead, onsite groundwater data were used to evaluate the vapor intrusion exposure pathway. All onsite groundwater analytical data collected during the last 2 years (2009 through 2011) were used to predict indoor air concentrations of volatile COPCs and to estimate risks and hazards to current and future onsite indoor commercial workers. The maximum detected groundwater concentration for each COPC was used as the source term for Johnson & Ettinger (J&E) groundwater-to-indoor air modeling (USEPA 2004b) in the maximum exposure scenario. The 95% UCL concentration calculated from the average concentration in each onsite well was used as the source term in the 95% UCL scenario.

3.1.3 Quantification of Exposure

The objective of the exposure assessment was to estimate the type and magnitude of potential receptor exposure to COPCs. Results of the exposure assessment were then combined with constituent-specific toxicity values in the toxicity assessment (see Section 3.2) to characterize potential risks (USEPA 1989).

3.1.3.1 Dose/Intake Equations

Exposures were quantified using standard exposure equations consistent with RAGS (USEPA 1989, 1991, 2004a and 2009a) for the potentially complete exposure pathways identified in Section 3.1.1.4.

The general algorithms presented below were used to estimate the lifetime average daily dose (LADD) for carcinogenic compounds and the average daily dose (ADD) for noncarcinogenic COPCs for direct-contact pathways (i.e., ingestion and dermal contact) by combining environmental media concentrations with the receptor-specific exposure parameters that constitute “intake factors.” Both the ADD and the LADD are in units of milligrams per kilogram per day (mg/kg-day) (USEPA 1989). For inhalation exposure pathways, exposure was estimated as an average exposure concentration (AEC) for noncarcinogenic COPCs or lifetime average exposure concentration (LAEC) for carcinogenic COPCs. Both the AEC and the LAEC are in units of milligrams per cubic meter (mg/m^3) (USEPA 2009a).

The dose equations and parameter descriptions used are provided in the following subsections.

3.1.3.1.1 Incidental Ingestion of Soil

The doses of COPCs associated with incidental ingestion of soil were calculated as follows:

$$\text{Dose} = \frac{EPC_s * IR_s * FI * EF * ED * CF}{BW * AT} * RAF$$

Where:

Dose = ADD or LADD (mg/kg-day)

EPC_s = EPC in soil (milligrams per kilogram [mg/kg])

IR_s = soil ingestion rate (milligrams soil per day)

FI = fraction ingested (unitless)

EF = exposure frequency (days per year)

ED = exposure duration (years)

CF = conversion factor ($1x10^{-6}$ kilograms per milligram [kg/mg])

BW = body weight (kg)

AT = averaging time (days), for carcinogens is equal to 70 years * 365 days per year, and for noncarcinogens is equal to ED * 365 days per year

RAF = relative absorption factor (unitless), assumed to equal 1

The USEPA (1989) defines FI as a "pathway-specific" value that should be applied to consider constituent location and population activity patterns. FI accounts for the fraction of the site covered with asphalt or vegetation, which reduces potential exposure. Following the ADEC's (2010a) guidance, an FI of 1 was assumed for the current and future onsite outdoor commercial/industrial worker and future onsite construction/trench worker, despite the fact that much of the site is covered with asphalt and buildings.

3.1.3.1.2 Dermal Contact with Soil

Absorbed doses of constituents associated with dermal contact with soil were calculated as follows:

$$\text{Dose} = \frac{EPC_s * SSA_s * AF * FC * ABS_d * EV_s * EF * ED * CF}{BW * AT}$$

Where:

Dose = ADD or LADD (mg/kg-day)

EPC_s = EPC in soil (mg/kg)

SSA_s = SSA available for contact (cm^2/event)

AF = soil-to-skin adherence factor (mg/cm^2-event)

FC = fraction in contact with soil (unitless)

ABS_d = dermal absorption factor (unitless)

EV_s = event frequency (soil) (events/day), assumed to be 1 per day unless otherwise noted

EF = exposure frequency (days/year)

ED = exposure duration (years)

CF = conversion factor ($1x10^{-6}$ kg/mg)

BW = body weight (kg)

AT = averaging time (days), for carcinogens is equal to 70 years * 365 days per year, and for noncarcinogens is equal to ED * 365 days per year

Constituent-specific dermal parameters, such as SSA_s, AF and ABS_d were provided from USEPA (2004a) RAGS Part E. ABS_d are presented in Table 3-13.

Similar to FI for the soil ingestion pathway, FC was added to the dermal contact equation to account for the fraction of the site covered with asphalt or vegetation, which reduces potential exposure. Following the ADEC's (2010a) guidance, an FC of 1 was assumed for the current and future onsite commercial/industrial worker and future onsite construction/trench worker.

3.1.3.1.3 Ingestion of Groundwater

The doses of COPCs associated with ingestion of groundwater were calculated as follows:

$$\text{Dose} = \frac{EPC_w * IR_w * EF * ED}{}$$

BW * AT

Where:

Dose = ADD or LADD (mg/kg-day)

EPC_w = EPC in water (milligrams per liter [mg/L])

IR_w = water ingestion rate (liters water/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days), for carcinogens is equal to 70 years * 365 days per year, and for noncarcinogens is equal to ED * 365 days per year

3.1.3.1.4 Dermal Contact with Groundwater

Absorbed doses of constituents associated with dermal contact with groundwater were calculated as follows:

$$Dose = \frac{DA_{event} * SSA_w * EV_w * EF * ED}{BW * AT}$$

Where for organics ($t_{event} \leq t^*$):

$$DA_{event} = 2 * FA * K_p * EPC_w * CF * \sqrt{\frac{6 * \tau_{event} * t_{event}}{\pi}}$$

Where for organics ($t_{event} > t^*$):

$$DA_{event} = FA * K_p * EPC_w * CF * \left[\left(\frac{t_{event}}{(1+B)}\right) + \left(2\tau_{event}\left[\frac{1+3B+3B^2}{(1+B)^2}\right]\right)\right]$$

Where for inorganics:

$$DA_{event} = K_p * EPC_w * CF * t_{event}$$

Dose = ADD or LADD (mg/kg-day)

DA_{event} = dose per event (mg/cm^2-event)

SSA_w = SSA available for contact with water (cm^2/event)

EV_w = event frequency (water) (events/day), assumed to be 1 per day unless otherwise noted

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

t* = time to reach steady state (hours), equivalent to 2.4 x τ_{event}

AT = averaging time (days), for carcinogens is equal to 70 years * 365 days per year, and for noncarcinogens is equal to ED * 365 days per year

FA = fraction absorbed (unitless)

K_p = permeability coefficient (centimeter/hour)

EPC_w = EPC in water (mg/L)

CF = conversion factor ($1x10^{-3}$ liters per cubic centimeter)

τ_{event} = lag time per event (hours/event)

B = permeability ratio (unitless)

t_{event} = event duration (hours/event)

3.1.3.1.5 Inhalation of Outdoor or Indoor Air

Exposure concentrations associated with the inhalation of vapors or particulates in outdoor or indoor air are calculated using USEPA (2009a) RAGS Part F methodology as follows:

$$\text{AEC or LAEC} = \frac{EPC_a * EF * ED * ET}{AT}$$

Where:

AEC or LAEC = average or lifetime exposure concentration in air (micrograms per cubic meter [$\mu g/m^3$])

EPC_a = EPC in outdoor or indoor air ($\mu g/m^3$)

EF = exposure frequency (days/year)

ED = exposure duration (years)

ET = exposure time (hours/day)

AT = averaging time (hours), for carcinogens is equal to 70 years * 365 days per year * 24 hours per day, and for noncarcinogens AT is equal to ED (in years) * 365 days per year * 24 hours per day

3.1.3.1.6 Ingestion of Homegrown Produce

Groundwater from the site may be used to irrigate locally grown crops, creating the potential for sulfolane to be taken up into plants that are then consumed by humans. In the few studies that have been conducted on the topic of uptake in plants, sulfolane has been demonstrated to be taken up into plants as the result of the constituent's high miscibility with water. Sulfolane is carried, along with water, through the roots, into the xylem and ultimately into the leaves of the plants. When water is lost through the leaves due to evapotranspiration, the sulfolane, due to its low volatility, tends to remain in the leaves where it may accumulate. Based on this information, it is assumed that if sulfolane is taken up by plants, it would predominantly be present in the leaves rather than in the roots or fruit.

This assumption is corroborated by the Final Results of the North Pole Garden Sampling Project (ADEC 2011b), which demonstrated that concentrations in roots were substantially lower than those in the stems and leaves. In the ADEC (2011b) study, which was led by ADHSS, 27 types of plant parts from multiple gardens irrigated with sulfolane-containing groundwater were collected from July to September 2010. Approximately one-half of the plant samples were reported as not detected, but 14 of the plant types tested were confirmed to contain sulfolane, primarily in the leaves and stems. Using data from the Final Results of the North Pole Garden Sampling Project (ADEC 2011b), the ADHSS evaluated the potential for risk to consumers of vegetables irrigated with sulfolane-containing water and concluded that sulfolane levels in the plants were low and not likely to cause any adverse health effects. However, because of the limited number of gardens sampled and the fact that the data were collected during only one growing season, the results of the investigation were considered preliminary and the exposure pathway was further evaluated in this assessment.

Following USEPA (2005) guidance, bioaccumulation of sulfolane in locally grown crops was evaluated using a biotransfer factor to estimate concentrations in plant tissues based on groundwater concentrations. There are no accepted values developed for sulfolane, but there is evidence to suggest that the uptake of sulfolane does not follow standard models based on partitioning coefficients (e.g., K_{ow}); therefore, an appropriate surrogate was not identified. Given the lack of constituent-specific information available in the literature, the ADEC has requested the use of a factor of 1. Use of this value assumes that the concentration of sulfolane in the edible portions of the plant tissues is equivalent to the concentration of sulfolane in groundwater.

After estimating the EPC, the doses of sulfolane associated with resident ingestion of homegrown fruits and vegetables were calculated using the following equation:

$$\text{Dose} = \frac{EPC_p * (IRP_{fr} + IRP_{vg}) * FI * EF * ED * CF}{BW * AT}$$

Where:

Dose = ADD (mg/kg-day)

EPC_p = EPC in produce (mg/kg) = EPC_w * BCF

Where:

EPC_w = EPC in water (mg/L)

BCF = water-to-produce bioconcentration factor (unitless)

IRP_{fr} = fruit ingestion rate (mg/day)

IRP_{vg} = vegetable ingestion rate (mg/day)

FI = fraction ingested (unitless)

EF = exposure frequency (days/year)

ED = exposure duration (years)

CF = conversion factor (1×10^{-6} kg/mg)

BW = body weight (kg)

AT = for the noncarcinogen sulfolane is equal to ED * 365 days per year

The ADEC requested use of adult resident fruit and vegetable ingestion rates of 259,000 and 413,000 mg/day, respectively; child resident fruit and vegetable ingestion rates of 223,500 and 201,000 mg/day, respectively; and infant resident fruit and vegetable ingestion rates of 155,250 and 109,350 mg/day, respectively, based on 95th percentile *per capita* intakes presented in the USEPA (2011a) EFH Table 9-3. The intakes rates presented in the EFH were multiplied by receptor-specific BW (for example, adult fruit ingestion rate was calculated by 3.7 grams per kilogram per day * 70 kg * 1,000 milligrams per gram = 259,000 mg/day). These calculations translate into the assumption that infants will consume approximately 6 ounces of fruits and 4 ounces of vegetables a day; children will consume approximately 8 ounces of fruits and 7 ounces of vegetables a day; and adults will consume approximately 9 ounces of fruits and 15 ounces of vegetables a day. The risk assessment assumes that during their first year of life, infants will ingest approximately 228 pounds of homegrown fruits and vegetables. For children and adults, the assumption is approximately 342 and 548 pounds per year, respectively.

A fraction of 25 percent (i.e., an FI equal to 0.25) consumption of homegrown fruits and vegetables, for offsite residents is used in the exposure assessment. This represents a 3-month growing season.

3.1.3.1.7 Ingestion of Surface Water

The doses of sulfolane associated with ingestion of surface water while swimming were calculated as follows:

$$\text{Dose} = \frac{EPC_w * ET * EF * ED * CR_w}{BW * AT}$$

Where:

Dose = ADD (mg/kg-day)

EPC_w = EPC in water (mg/L)

ET = exposure time (hours per day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

CR_w = contact rate of surface water (liters/hour)

BW = body weight (kg)

AT = for the noncarcinogen sulfolane is equal to ED * 365 days per year

For the PPRTV Scenario, as shown in Table 3-12, the offsite adult and child recreational user surface-water ingestion rates of 0.071 and 0.12 liter/hour, respectively, were based on recommended upper percentile values for swimmers presented in the USEPA (2011a) EFH Table 3-5 representing the maximum ingestion rate for adults and the 97th percentile ingestion rate for children age 18 and under. Adult and child (1 to 6 years of age) recreational users were assumed to swim for 30 and 6 years, respectively, for 60 days per year for 1 hour per day.

3.1.3.2 Exposure Point Concentrations

Per ADEC (2010a) guidance, “the exposure point concentration is used to assess risk and should be estimated using a 95% UCL on the mean of the contaminant concentrations.” The EPC represents the average concentration of a COPC in an environmental medium that is potentially contacted by a receptor during the exposure period (USEPA 1989). The USEPA (1989) also recommends the use of the 95% UCL as a conservative estimate of the EPC, because it represents the average concentration for which we have 95 percent confidence that the true mean concentration has not been exceeded. Unless there is site-specific evidence to the contrary, an individual receptor is assumed to be equally exposed to media within all portions of the EU during the time of the risk assessment (USEPA 2002c). For this HHRA ADEC has also requested evaluation of maximum COPC concentrations in groundwater as EPCs in the PPRTV Scenario. Note that the ADEC Draft Risk Assessment Procedures Manual was updated during preparation of this HHRA (ADEC 2011c). The updated manual includes guidance on the use of maximum groundwater concentrations for EPCs.

EPCs are estimated separately for each medium. Consistent with USEPA (2006b, 2007) guidance, surface soil, subsurface soil and groundwater EPCs were estimated using the 95% UCL of the mean for datasets with at least eight samples and at least five detected values. For this HHRA, a "dataset" was considered the aggregate of samples for one COPC, for one pathway, within a particular EU (onsite or offsite). Calculation of a 95% UCL depends on the distribution of the dataset and variability in the data. To assess statistical validity, data evaluation, distribution testing and 95% UCL calculations were performed using the USEPA's ProUCL version 4.1 (http://www.epa.gov/osp/hstl/tsc/software.htm) and according to the recommendations provided in the associated technical documentation (USEPA 2006, 2007, 2011b). Analytical data used for the HHRA are provided in Appendix A and ProUCL output files are included in Appendix B. For datasets with fewer than eight samples or fewer than five detected values, the EPC was the maximum detected concentration. Soil and groundwater datasets for most COPCs have more than eight samples each.

To combine data collected from monitoring wells and private residential wells, individual well means were calculated. The following methods were used to normalize the groundwater data in a manner that provides equal representation between wells with different numbers of observations:

- For a given well, if all samples were reported as non-detects, then the lowest detection limit associated with any sampling event at that well was used to represent the well.

- If a well had both detected concentrations and reported non-detects for a given COPC, then any non-detect was represented as one-half the detection limit associated with that sampling event for that COPC.

With the individual well means calculated as described above, ProUCL was used to estimate the 95% UCL of the mean of sulfolane across all wells in an EU (Figure 3-3). EU-1 represents approximate sulfolane concentrations in groundwater of $\geq$100 µg/L, EU-2 where detected sulfolane concentrations range from $\geq$25 to 99.9 µg/L, and EU-3 where sulfolane concentrations ranged from not detected above the laboratory reporting limit to 24.9 µg/L. Given the sizable area of each EU, some results included in the data analyses are different from others in each EU. For example, some non-detect results occur in EU-1 and EU-3. These values are primarily attributable to groundwater samples collected from variable screen depths. It is reasonable to assume that groundwater extracted from a variety of screen lengths may be ingested by potential receptors that might use groundwater as drinking water. Therefore, these data points were included in the EPC calculations for each EU. Non-detect observations for the COPCs in soil and groundwater were addressed using the methods described above.

In addition, per ADEC (2010a) guidance for duplicate samples, the highest detected value from the primary and duplicate samples was used to represent that sample result. For any COPC, if the 95% UCL COPC of the mean concentration exceeded the maximum detected concentration, then the maximum detected concentration was the EPC. Summary statistics for the COPCs are presented in the risk characterization, including detection frequency, number of samples, minimum and maximum detected concentrations, and calculated 95% UCL concentrations.

EPCs were estimated separately for each medium. Tables 3-3 through 3-10 present area-wide summary statistics and EPCs for COPCs as follows:

- Surface soil (0 to 2 feet bgs; see Table 3-3 for 95% UCL COPC concentrations)
- Subsurface soil (0 to 15 feet bgs; see Table 3-4a for maximum COPC concentrations and Table 3-4b for 95% UCL COPC concentrations)
- Onsite groundwater (see Table 3-5a for maximum COPC concentrations and Table 3-5b for 95% UCL COPC concentrations)
- Offsite groundwater in all wells (see Table 3-6 for maximum sulfolane concentration)
- Offsite groundwater in EU-1 (see Table 3-7 for 95% UCL sulfolane concentration)
- Offsite groundwater in EU-2 (see Table 3-8a for maximum sulfolane concentration and Table 3-8b for 95% UCL sulfolane concentration)
- Offsite groundwater in EU-3 (see Table 3-9a for maximum sulfolane concentration and Table 3-9b for 95% UCL sulfolane concentration)
- Offsite surface water (see Table 3-10 for maximum sulfolane concentration estimated from pore water).

Soil, groundwater, outdoor air, indoor air, homegrown produce and surface-water EPCs are further discussed below.

3.1.3.2.1 Soil Exposure Point Concentrations

Onsite receptors may potentially contact surface soil or a combination of surface and subsurface soil. According to ADEC guidance 18 AAC 75.340(j)(2), “human exposure from ingestion, direct contact or inhalation of a volatile substance must be attained in the surface soil and the subsurface soil to a depth of at least 15 feet, unless an institutional control or site conditions prevent human exposure to the subsurface” (ADEC 2008c). Currently and in the future, FHRA will have institutional controls in place (i.e., permits) that provide worker protection (i.e., appropriate personal protective equipment) in the event of planned excavation of onsite soil. For this HHRA, two soil EPCs are calculated for each COPC. Surface soil is considered to occur from 0 to 2 feet bgs (Table 3-3) and subsurface soil is considered to occur from 0 to 15 feet bgs (Tables 3-4a and 3-4b). EPCs for soil were calculated using the 95% UCL on the mean of the dataset for surface soil exposures, or the maximum detected COPC concentrations for surface and subsurface soil exposures (relevant to potential onsite construction/trench workers).

3.1.3.2.2 Surface Soil Exposure Point Concentrations

For this HHRA, it is presumed that onsite commercial/industrial workers may potentially contact surface soil onsite that is not covered with pavement or vegetation. Therefore, surface soil EPCs were calculated and used to evaluate potential exposure by onsite commercial/industrial workers, using analytical data from the surface soil dataset in uncovered portions of the site (i.e., soil samples collected from ground surface to 2 feet bgs). The 95% UCL of the mean concentrations of COPCs in surface soil collected from 0 to 2 feet bgs were used to evaluate:

- Direct-contact exposure pathways to onsite outdoor commercial/industrial workers
- Potential inhalation of fugitive windborne dust from onsite surface soil by onsite outdoor commercial/ industrial workers, offsite residents and offsite outdoor commercial/industrial workers.

3.1.3.2.3 Surface and Subsurface Soil Exposure Point Concentrations

The 95% UCL of the mean concentrations of surface soil collected from 0 to 2 feet bgs were used to evaluate direct-contact exposure pathways to onsite outdoor commercial/industrial workers, and potential inhalation of fugitive windborne dust from onsite soil by onsite and offsite outdoor commercial/industrial workers. The onsite construction/trench worker may be directly exposed to surface and subsurface soil during excavation activities. Therefore, EPCs for evaluating exposure by the onsite construction/trench worker were generated using analytical data from the combined surface and subsurface soil dataset (i.e., soil samples collected from ground surface to as deep as 15 feet bgs). The maximum detected concentrations in the combined surface and subsurface soil sample dataset were used to estimate surface and subsurface soil EPCs for direct-contact pathways for the onsite construction/trench worker because that exposure may be localized rather than averaged over the entire site. In addition, in accordance with ADEC guidance (2010a), surface and subsurface soil EPCs based on the 95% UCLs were also used to evaluate potential exposures by the construction/trench worker.

3.1.3.2.4 Groundwater Exposure Point Concentrations

For COPCs in groundwater, COPC EPCs were distinguished for both on- and offsite potential exposures as described in the following sections.

3.1.3.2.4.1 Onsite Groundwater Exposure Point Concentrations

Groundwater EPCs were used to estimate direct-contact exposure (i.e., dermal contact) by the onsite outdoor worker and incidental ingestion and dermal contact by onsite construction/trench workers during excavation activities. Groundwater COPC EPCs were estimated using the last 2 years of data (i.e., 2009 to 2011) collected from onsite groundwater monitoring wells. In addition to evaluating the potential exposures to COPCs in groundwater over an EU using 95% UCL concentrations, the ADEC also requested that groundwater EPCs be calculated using the maximum detected concentration during the last 2 years of groundwater monitoring (see Tables 3-5a and 3-5b).

3.1.3.2.4.2 Offsite Groundwater Exposure Point Concentrations

Offsite sulfolane groundwater EPCs were used to estimate direct-contact exposure (i.e., incidental ingestion) by offsite construction/trench workers during excavation activities and to estimate direct-contact exposure (i.e., ingestion) by offsite residents and commercial/industrial receptors. In addition to evaluating the potential exposures to sulfolane in groundwater using a 95% UCL concentration for each of the EUs depicted on Figure 3-3, the ADEC also requested risk calculations using the maximum detected sulfolane concentration during the last 2 years of groundwater monitoring (i.e., 2009 to 2011), applied to the entire offsite area. EPCs were derived for each offsite EU identified on Figure 3-3 including:

- All offsite wells (Table 3-6), evaluated using the maximum offsite concentration as the EPC
- EU-1 (Table 3-7), evaluated using the 95% UCL concentration in offsite wells in EU-1 (the maximum concentration located in EU-1 is the same as the off-site maximum concentration, as shown in Table 3-6)
- EU-2 (Table 3-8a for maximum concentrations and Table 3-8b for 95% UCL concentrations)
- EU-3 (Table 3-9a for maximum concentrations and Table 3-9b for 95% UCL concentrations).

In summary, the maximum detected concentrations of sulfolane in offsite groundwater from EU-1, EU-2 and EU-3 were used to estimate risks and hazards for relevant receptors for the PPRTV Scenario. In addition, for each EU, EPCs based on the 95% UCL were also used to estimate risks and hazards for relevant receptors at each of the offsite groundwater offsite EUs (EU-1, EU-2 and EU-3), per USEPA (1989) guidance, professional judgment, and the RAWP (ARCADIS 2011).

3.1.3.2.5 Outdoor Air Exposure Point Concentrations

In accordance with the USEPA (1989), exposure to constituents in outdoor air was evaluated as exposure to fugitive dust emissions (for non-VOCs, from soil only) or volatile emissions (for VOCs, from soil or groundwater). The USEPA (2002b) recommendations for media transfer factors to evaluate these exposures are described below.

3.1.3.2.5.1 Estimating Outdoor Air Exposure Point Concentrations from Soil Concentrations

A particulate emission factor (PEF) for non-volatile COPCs was used to estimate EPCs in outdoor air from soil. The industrial PEF (1.36×10^9 cubic meters per kilogram [m^3/kg]) obtained from the Supplemental Guidance for Developing Soil Screening Levels for Contaminated Sites (USEPA 2002b) was used to estimate outdoor air EPCs of non-volatile COPCs for onsite outdoor commercial/industrial workers and construction/trench workers potentially exposed to particulate emissions from soil.

A volatilization factor (VF) for VOCs was used to estimate EPCs of volatile COPCs in outdoor air from soil (VF_{soil}). Outdoor air EPCs were estimated for the onsite outdoor commercial/industrial worker and onsite construction/trench worker using the EPC for the combined surface and subsurface soil dataset. Constituent-specific VFs_{soil} were obtained from the USEPA (2011c) RSL spreadsheets, where they exist, to estimate outdoor air EPCs of volatile COPCs for onsite outdoor commercial/industrial workers and construction/trench workers potentially exposed to volatile COPCs emanating from surface and subsurface soil. For volatile COPCs not listed in the USEPA's RSL table, VFs were derived according to USEPA guidance (USEPA 2002b). Table 3-11 presents the VFs_{soil} that were used to calculate VFs_{soil} if they were not available on the RSL spreadsheets.

The following equation was used to calculate outdoor air EPCs from soil EPCs using either a PEF or VF_{soil}:

$$EPC_a = \frac{EPC_s}{PEF \text{ or } VF_{soil}}$$

Where:

EPC_a = EPC in air (mg/m^3)

EPC_s = EPC in soil (mg/kg)

PEF = particulate emission factor (m^3/kg)

VF_{soil} = volatilization factor (soil) (m^3/kg)

3.1.3.2.5.2 Estimating Outdoor Air Exposure Point Concentrations from Groundwater Concentrations

Construction workers (i.e., trench workers) may also be exposed to VOCs released from shallow groundwater that may pool in a trench and volatilize to trench air. Groundwater occurs as shallow as 8 feet bgs in portions of the site. To estimate the potential concentrations of COPCs that could volatilize from groundwater to trench air, volatilization factors (VF_{gw}) obtained from the Virginia Department of Environmental Quality (2012) were used to estimate trench air EPCs from groundwater. The trench air EPCs were used to evaluate potential exposures by on and offsite construction/trench workers potentially exposed to volatile COPCs emanating directly from shallow groundwater in an excavation trench. The equation for using VF_{gw} to calculate trench air EPCs from groundwater EPCs is as follows:

$$EPC_a = EPC_{gw} * VF_{gw}$$

Where:

EPC_a = EPC in trench air (mg/m^3)

EPC_{gw} = EPC in groundwater (mg/L) (as 95% UCL and as maximum EPC; see Section 3.1.3.2.4 for discussion about on and offsite groundwater EPCs)

VF_{gw} = volatilization factor (groundwater) (liter per cubic meter)

For onsite exposures, the trench air EPCs are presented in Table 3-5a (maximum EPC) and Table 3-5b (95% UCL EPC).

As discussed in Section 3.1.1, onsite construction/trench workers may potentially be exposed to vapors emanating from soil during trench excavation. Therefore, potential exposures to volatile EPCs in trench air from both soil and shallow groundwater sources, as well as COPCs as fugitive dust from soil were estimated for onsite construction/trench workers. For offsite construction/trench workers, sulfolane in trench air from offsite groundwater is the only potential exposure onsite.

3.1.3.2.6 Indoor Air Exposure Point Concentrations

The Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (USEPA 2002a), Vapor Intrusion Pathway: A Practical Guide (ITRC 2007a) and Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios (ITRC 2007b) were used to assess vapor intrusion. The J&E model was used to estimate indoor air concentrations resulting from intrusion of vapors from sub-slab soil gas into onsite buildings. The J&E model is a one-dimensional, screening-level model used to evaluate subsurface vapor intrusion into buildings. It incorporates both convective and diffusive mechanisms to estimate the transport of constituent vapors emanating from soil gas into indoor spaces located directly above the source (J&E 1991, USEPA 2004b). When estimating the concentration of COPC vapors in indoor air, the J&E model assumes the following:

- Constant, infinite source of constituents (e.g., in groundwater or soil gas)
- Steady-state diffusion through the unsaturated zone
- Convective and diffusive transport through the basement floor or slab
- Complete mixing within the building, estimated using an air exchange rate.

Due to the uncertainties associated with partitioning from soil to soil gas, ITRC (2007b) does not recommend using soil data as a source of COPCs to evaluate potential vapor intrusion. Therefore, source concentrations were estimated using the groundwater data as discussed in Section 2.6.2. Source concentrations for the model consisted of the groundwater EPCs based on maximum detected COPC concentrations in groundwater as well as the 95% UCL of the mean groundwater concentrations (see Section 3.1.3.2.4). Site-specific parameters, such as soil type and average soil temperature, were used in the J&E model where available. The top 3 to 5 feet of soil was assumed to be sand. Geotechnical data show that this depth interval is silty sand. An average soil temperature of 5 °C was used. The remaining parameter values, including constituent-specific parameter values, were estimated using the default values provided by the USEPA (2004b) in the User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings and the associated model spreadsheets. Appendix C presents the results of the USEPA's J&E-based model to predict indoor air COPC concentrations from COPC concentrations in onsite groundwater. For onsite exposures, the indoor air EPCs are presented in Table 3-5a (maximum EPC) and Table 3-5b (95% UCL EPC).

3.1.3.2.7 Homegrown Produce Exposure Point Concentrations

Residents who consume homegrown produce that has been irrigated with offsite groundwater were evaluated. Homegrown produce EPCs were calculated using bioconcentration factors (BCFs) applied to offsite groundwater EPCs (Tables 3-6 through 3-9b). The Final Results of the North Pole Garden Sampling Project (ADEC 2011b) showed that sulfolane was taken up into garden plants at concentrations below adult risk-based screening criterion developed by the ADHSS. However, a BCF equal to 1 was used to predict uptake of sulfolane into both aboveground and belowground vegetables (as described in Section 3.1.3.1.6).

3.1.3.2.8 Surface-Water Exposure Point Concentrations

Recreational users who ingest surface water that has migrated from groundwater beneath the site were evaluated. The maximum detected concentration of sulfolane collected during the 2012 field season from adjacent to a frozen surface-water body was assumed to represent groundwater that has migrated offsite to downgradient water bodies. Summary statistics and the surface-water EPC are presented in Table 3-10.

3.1.3.3 Exposure Parameters

Exposure parameter values that were identified for each receptor at the site for the PPRTV scenario are provided in Table 3-12. The exposure parameters were based primarily on those provided in ADEC (2010a) and USEPA (1989, 1991, 1997a and 2004a) as well as other sources, as noted. These exposure parameters meet or exceed the USEPA (1989) approach for estimating reasonable maximum exposure (RME), which is the maximum exposure that is reasonably expected to occur in a population. Its intent is to estimate a health-protective exposure case (i.e., well above the average case) that is still within the range of possible exposures (USEPA 1989). Mathematically, the RME estimate for each exposure pathway combines upper percentile values and assumptions with selected average values and assumptions. The upper percentile assumptions tend to maximize estimates of exposure, such as choosing a value near the high end of the concentration or intake range. Therefore, the RME estimates tend to be at the high end of the exposure range, generally greater than the 90th percentile of the population.

3.1.3.4 Assessment of Potential Lead Exposures

The potential hazard associated with lead exposure was evaluated by comparing the predicted blood-lead concentrations to the Centers for Disease Control and Prevention (CDC) blood-lead threshold concentration. The threshold lead concentration is 10 micrograms per deciliter (µg/dL) of whole blood based on potentially adverse neurological effects in children (CDC 2011). A blood-lead concentration of less than 10 µg/dL was deemed acceptable. The USEPA's (2009b) Adult Lead Model (ALM) model, which estimates the blood-lead levels of workers and the fetus of a pregnant worker, was used to evaluate the potential onsite exposure to lead in groundwater for the receptors evaluated.

3.2 Toxicity Assessment

The toxicity assessment identified toxicity values that relate exposure (dose) to potential risk or hazard for each COPC. Toxicity values derived from dose-response data were combined with estimates of exposure to characterize potential noncarcinogenic hazard and carcinogenic risk (see Section 3.3.2). Toxicity profiles were provided for risk/hazard drivers and sulfolane. Selection of toxicity values followed the hierarchies described below.

3.2.1 Noncarcinogenic Toxicity Values

Chronic and subchronic reference doses (RfDs) were used to evaluate potential adverse effects from ingestion, dermal and inhalation (dust) exposures to noncarcinogenic COPCs. Chronic RfDs, which correspond to 7 or more years of exposure, are specifically developed to be protective of long-term exposures to a constituent with a considerable health-protective margin of safety, which is usually over 1000-fold. The USEPA (1989) defines the chronic RfD as “a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime.”

The following sources were used to identify chronic toxicological reference values:

- USEPA (2012a) IRIS.
- USEPA PPRTVs, derived by the USEPA's Superfund Health Risk Technical Support Center for the USEPA Superfund program. Current values were obtained directly from the USEPA.
- California Environmental Protection Agency (CalEPA) reference exposure levels from the California Office of Health Hazard Environmental Assessment (OEHHA).
- ATSDR Minimal Risk Levels (MRLs) (ATSDR 2012) Chronic MRLs were used to evaluate chronic exposure.
- USEPA (1997b) Health Effects Assessment Summary Tables (HEAST).

The USEPA (1989) defines exposures lasting between 2 weeks and 7 years as subchronic exposures. As a result, the short-duration and intermittent nature of construction/trench worker and infant exposures required consideration of subchronic toxicity values (subchronic RfDs) to estimate the potential for effects. Subchronic RfDs are developed to be protective of subchronic exposures to constituents with a conservative measure of safety (USEPA 1989). Subchronic RfDs for ingestion (oral) and inhalation (dust and vapor) exposure were identified from the following sources, in the following order of priority:

- USEPA PPRTVs. Current values were obtained directly from the USEPA.
- ATSDR MRLs (ATSDR 2012). Intermediate MRLs were used to evaluate subchronic exposure.
- USEPA (1997b) HEAST.

For the PPRTV Scenario, in addition to chronic RfDs, subchronic RfDs, if available, were used to evaluate potential exposures to onsite construction/trench workers and offsite infants. If subchronic RfDs were unavailable, then only chronic RfDs were used. For the PPRTV Scenario, chronic RfDs were used for offsite children.

Current USEPA guidance recommends calculating a dermal RfD by multiplying the oral RfD by the percent oral absorption efficiency (ABSGI). This recommendation requires one of the following:

- A critical study upon which the toxicity value is based employed an administered dose (e.g., delivery in diet or by gavage) in its design.

- A scientifically defensible database exists that demonstrates that the gastrointestinal absorption of the constituent in question from a medium (e.g., water, feed) similar to the one employed in the critical study is significantly less than 100 percent (e.g., less than 50 percent).

Values for ABSGI were obtained from RAGS (USEPA 2004a). Chronic and subchronic RfDs are presented in Table 3-13.

3.2.2 Carcinogenic Toxicity Values

Oral cancer slope factors (CSFs) and inhalation unit risk (IUR) factors were used to evaluate potential carcinogenic effects from ingestion, dermal and inhalation exposures to COPCs. CSFs quantitatively describe the relationship between dose and response. A CSF represents the 95% UCL of the slope of the dose-response curve and is derived using a low-dose extrapolation procedure that assumes linearity at low doses. By applying a CSF to a particular exposure level of a potential carcinogen, the upper bound lifetime probability of an individual developing cancer related to that exposure can be estimated.

CSFs have been developed for the oral and inhalation (dust particulates) exposure routes; IURs have been developed for the inhalation exposure route. CSFs for oral and IURs for inhalation exposures were identified from the following sources, in the following descending order of priority:

- USEPA (2012a) IRIS.
- USEPA PPRTVs. Current values were obtained directly from the USEPA.
- CalEPA (2012) OEHHA Toxicity Criteria Database.
- USEPA (1997b) HEAST.

As is the case for noncarcinogenic toxicity, the USEPA has not developed dermal CSFs for use in risk assessment. Dermal CSFs were calculated in a manner similar to that of noncarcinogenic RfDs for dermal exposure by dividing the oral CSFs by the ABSGI AF (USEPA 2004a). CSFs are presented in Table 3-13.

3.2.3 Sulfolane Toxicity Values

Toxicity values for sulfolane are not presented in IRIS (USEPA 2012a). However, a PPRTV chronic oral RfD of 0.001 mg/kg-day and a PPRTV subchronic oral RfD of 0.01 mg/kg-day have been prepared for sulfolane (USEPA 2012b).

The PPRTV Scenario risk assessment presents estimated hazards for potential sulfolane exposures using the USEPA (2012b) PPRTV oral RfDs for sulfolane

3.2.4 Toxicity Equivalence Factors for Polynuclear Aromatic Hydrocarbons

As shown in Tables 3-2a and 3-2b, some carcinogenic PAHs have been identified as COPCs in soil. Following ADEC (2010a) guidance, toxicity equivalence factors (TEFs) were used to assess risks to carcinogenic PAHs, including benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene and indeno(1,2,3-c,d)pyrene). TEFs were applied to EPCs of all carcinogenic PAHs in surface and subsurface soil to equivalent concentrations of benzo(a)pyrene (USEPA 2011c) and total risk was derived for the carcinogenic PAH COPCs. The assessment of potential exposures to other PAHs also included PAHs identified as COPCs in soil based on analytical data collected during the 2011 field season.

3.3 Risk Characterization – Provisional Peer Reviewed Toxicity Value Scenario

This section presents the PPRTV Scenario and provides estimated ELCRs and hazard indices (HIs) for potentially complete and significant exposure pathways identified in Section 3.1.1.4 for on- or offsite potential receptors, based on the USEPA (2012a) PPRTV toxicity criteria for sulfolane and the exposure parameters presented in Table 3-12.

3.3.1 Risk Characterization – PPRTV Scenario

The risk characterization integrates results of the data evaluation, exposure assessment and toxicity assessment to evaluate potential risks associated with exposure to site COPCs. The basis for the risk characterization is the quantitative evaluation of potential exposure by potential receptors to COPCs, which consists of estimating carcinogenic risk and noncarcinogenic hazard. This quantitative evaluation of risk and hazard generally provides a health-protective representation of the upper end (potentially highest exposures) for a receptor. The quantitative methods used to calculate noncarcinogenic hazard and carcinogenic risk are presented below. Consistent with USEPA (1989) guidance, the potential for carcinogenic and noncarcinogenic risks were evaluated separately.

3.3.1.1 Carcinogenic Risk

For potential carcinogens, risk was estimated as the incremental probability of an individual developing cancer during a lifetime as a result of RME to a potential carcinogen and was calculated as follows:

$$ELCR = LADDi \times CSFi$$

Where:

ELCR = excess lifetime cancer risk (unitless)

LADDi = lifetime average daily dose for the *i* th constituent (mg/kg BW-day)

CSFi = cancer slope factor for the *i* th constituent $(\text{mg/kg BW-day})^{-1.}$

The CSF converts intake averaged over a lifetime of exposure to the incremental lifetime risk of an individual developing cancer. This linear equation is only valid at low risk levels (i.e., below estimated risks of one in 100) and is an upper-bound estimate based on the 95% UCL of the slope of the dose-response curve. Therefore, the actual risk will be lower than the predicted risk. Potential risk was assumed to be additive, and risks from different possible and probable carcinogens and pathways were summed to evaluate the overall risk. Pathway-specific risks were calculated as the sum of risks from potential carcinogenic COPCs within each exposure pathway, and the total ELCR for each receptor was calculated by summing the risk estimates for the exposure pathways evaluated.

For inhalation of COPCs, the following equation from USEPA (2009a) RAGS Part F was used to assess ELCRs:

$$ELCR = LAEC * IUR$$

Where:

ELCR = excess lifetime cancer risk (unitless)

LAEC = lifetime average exposure concentration ($\mu g/m^3$)

IUR = inhalation unit risk $(\mu g/m^3)^{-1}$

Scientific notation was used to express potential carcinogenic risks. For example, a value of $1x10^{-6}$ is equal to one in 1 million (or 0.000001). For individual constituents, the ADEC (2010a) compares risk estimates to an acceptable cumulative ELCR of 1×10^{-5}. The acceptable cancer risk (or range of risks) is the incremental risk attributed to the estimated upper-bound exposure (i.e., RME) to COPCs at the site. This acceptable risk is, by definition, independent of risks associated with non-site-related constituent exposures and other background cancer risks (USEPA 1989).) It is standard USEPA and ADEC practice, however, to assess risks and hazards first with background constituents included and then discuss the risks in the absence of the background impacts to inform the decision makers about the risks of site-related constituents.

3.3.1.2 Noncarcinogenic Hazard

The HQ approach was used to characterize the overall potential for noncarcinogenic effects associated with exposure to multiple constituents. This approach assumes that chronic and subchronic exposures to multiple constituents are additive. For direct contact and inhalation of particulates exposures, the HQ was calculated as follows:

$$HQ = ADD / RfD$$

Where:

HQ = hazard quotient (unitless)

ADD = average daily dose (mg/kg-day)

RfD = reference dose $(mg/kg\text{-}day)^{-1}$

For inhalation of volatile COPCs, the following equation from USEPA (2009a) RAGS Part F was used to assess noncancer hazards:

$$HQ = AEC / RfC$$

Where:

HQ = hazard quotient (unitless)

AEC = average exposure concentration (micrograms per cubic centimeter [$\mu g/cm^3$])

RfC = inhalation reference concentration $(\mu g/cm^3)^{-1}$

The HQ represents the comparison of exposure (dose) over a specified period of time to an RfD for a similar time period. The estimates of exposure (dose) were calculated based on chronic or subchronic exposures. If the HQ exceeds a value of 1, there is a possibility of adverse health effects. The magnitude of the HQ is not a mathematical prediction of the severity or incidence of the effects, but rather indicates that effects may occur. The likelihood of effects occurring at levels above an HQ=1 is based on the nature of the effects used to set the RfD and the magnitude of the composite uncertainty factor used in the RfD derivation. The constituent HQs were summed to calculate an HI for a pathway or site, and the USEPA (1989) recommends that the total HI for the constituents and pathways assessed not exceed a value of 1. An HI of less than 1 indicates that adverse health effects are not likely to occur from exposure to assessed constituents. HQs or HIs of greater than 1 do not indicate that significant risks are present, but rather that additional evaluation may be required to better define the level of risk.

According to the USEPA (1989), noncarcinogenic effects should be evaluated based on target organ(s) or toxicity endpoints. The USEPA believes that the assumption of dose additivity is one of the major limitations of the HI approach because it may overestimate the potential for health effects that most likely will not occur if the COPCs affect different organs or act by different mechanisms of action. The USEPA counters the potential for overestimation by specifying segregation of COPCs by effect and mechanism of action, and derivation of separate HIs for each group (USEPA 1989). If the total HI exceeds a value of 1, the specific substances will be evaluated so that only substances that affect similar target organs or exhibit a similar mode of action (i.e., similar effects in the same target organs via the same mechanism) are summed. Quantitative estimates of carcinogenic risk and noncarcinogenic hazard were presented for each receptor.

3.3.1.3 Risk Characterization of Petroleum Hydrocarbon Compounds

In accordance with ADEC (2008b) Cumulative Risk Guidance, individual risks from exposure to GRO, DRO and RRO were calculated using RfDs provided by ADEC (2010a). However, these risk calculations were not included in cumulative risk estimates. Consistent with ADEC (2008b) Cumulative Risk Guidance, cumulative risks for each receptor were estimated using indicator constituents, as discussed below.

In general, quantitative risk calculated from individual petroleum constituents is considered adequate to account for risk in cumulative risk calculations from petroleum mixtures (ADEC 2008b). The key constituents of petroleum products associated with risk (e.g., PAHs, BTEX, methyl tertiary butyl ether) are included in the quantitative cumulative risk calculations and should adequately describe human health risk from exposure to site media.

3.3.2 Estimated Risks and Hazards for Provisional Peer Reviewed Toxicity Value Scenario

For each total estimated ELCR and HI, the primary exposure pathway and contributing COPC(s) are indicated, as appropriate. This section presents ELCRs and hazards for potential onsite receptors (Section 3.3.2.1) and potential offsite receptors (Section 3.3.2.2). For each potential receptor, ELCRs and/or HIs are summarized based on possible exposure to maximum and/or 95% UCL-based EPC COPC concentrations. Appendices D and E present complete risk calculations for ELCRs and HIs based on maximum and 95% UCL COPC concentrations, respectively.

Summaries of the cumulative ELCRs and estimated HIs for the receptors evaluated under the PPRTV Scenario are presented in the following tables:

- Tables 3-14 and 3-15 present the ELCR and HI summaries for on and offsite receptors using the maximum detected on and offsite values and the 95% UCL on and offsite values, respectively.

- Tables 3-14, 3-16a and 3-17a present ELCR and HI summaries for potential on and offsite receptors based on maximum COPC concentrations for all wells in each EU (including EU-1 because the maximum for all offsite wells is located in this EU).

- Table 3-15 presents ELCR and HI summaries for potential on and offsite receptors at EU-1 based on 95% UCL EPCs.

- Table 3-16a presents ELCR and HI summaries for offsite receptors based on maximum COPC concentrations at EU-2 wells.

- Table 3-17a presents ELCR and HI summaries for offsite receptors based on maximum COPC concentrations at EU-3 wells.

The PPRTV scenario risk assessments are presented in Appendix D (maximum concentrations) and Appendix E (95% UCL EPCs). Appendix H provides toxicity profiles for the primary risk and hazard drivers, including: arsenic, benzene, naphthalene, sulfolane, 1,3,5-trimethylbenzene and xylenes.

The total estimated ELCRs presented in Tables 3-14 through 3-17b include arsenic as a soil COPC (arsenic was excluded as a COPC in groundwater). Based on an evaluation of arsenic in soil samples at the site, the presence of arsenic is due to background concentrations. Detected concentrations of arsenic in soil samples collected at the site are evaluated in the 2012 Revised Site Characterization Report (Barr 2012). This evaluation compared site arsenic concentrations to background studies collected in Alaska and evaluated the spatial distribution of arsenic with respect to site operations and other COPCs. The results of the evaluation concluded that the presence of arsenic in soil does not appear to be associated with refinery operations and is likely a result of background concentrations.

3.3.2.1 Estimated Risks and Hazards for Potential Onsite Receptors

Potential onsite receptors evaluated include current and future indoor and outdoor commercial workers, construction/trench workers and adult visitors. The USEPA (2012b) chronic PPRTV oral RfD was used to evaluate potential sulfolane exposures. The maximum onsite concentration of sulfolane in groundwater detected above the laboratory reporting limit between 2009 and 2011 is 10.4 mg/L. Estimated risks and hazards for the onsite receptors using maximum detected concentrations and 95% UCLs as EPCs are summarized in Table 3-14 and Table 3-15, respectively.

3.3.2.1.1 Onsite Indoor Commercial/Industrial Workers

Table D-1 (Appendix D) presents the estimated ELCRs and HIs for indoor commercial/industrial workers, based on exposures to maximum detected COPC concentrations in groundwater. Inhalation of VOCs in indoor air from groundwater is the primary exposure pathway for these potential receptors (see Table 3-14). The total estimated ELCR is 1×10^{-5} and the total estimated HI is 0.2.

Table E-1 (Appendix E) presents the estimated ELCRs and HIs for indoor commercial/industrial workers, based on exposures to 95% UCLs of detected COPC concentrations in groundwater. Inhalation of VOCs in indoor air from groundwater is the primary exposure pathway for these potential receptors (see Table 3-15). The total estimated ELCR is 1×10^{-6} and the total estimated HI is 0.02.

3.3.2.1.2 Onsite Outdoor Commercial/Industrial Workers

Table D-2 (Appendix D) presents the estimated ELCRs and HIs for outdoor commercial/industrial workers, assuming potential exposure to 95% UCLs of COPC concentrations in surface soil. Table D-2 also shows estimated ELCRs and HIs based on direct-contact exposures, including ingestion of, dermal contact with and inhalation of dust particles from surface soil. The total estimated ELCR is 5×10^{-6} and the total estimated HI is 0.05 (see Table 3-14). Soil ingestion contributes most to the total estimated ELCR and HIs. Arsenic is the primary risk and hazard driver. Excluding the estimated arsenic ELCR and HI, which are likely due to background, the total estimated ELCR is 2×10^{-7} and the total estimated HI is 0.03 (see Table D-2).

3.3.2.1.3 Onsite Construction/Trench Workers

The USEPA (2012b) PPRTV subchronic oral RfD for sulfolane was used to estimate potential construction/ trench worker hazards. Table 3-14 and Table D-3a (Appendix D) present the estimated ELCRs and HIs for construction/trench workers based on potential exposures to maximum COPC concentrations in surface and subsurface soil, assuming direct-contact exposures including ingestion, dermal contact and inhalation of dust particles. The total estimated ELCR associated with potential exposure to COPCs in soil is 1 x 10^{-6} and the total estimated HI is 0.3. The soil ingestion pathway contributes most to the total soil-related estimated ELCR and HI. Excluding the estimated arsenic ELCR, which is likely based on background, the total estimated ELCR is 3 x 10^{-7} and the total estimated HI is 0.3.

Table 3-14 and Table D-3b (Appendix D) present ELCRs and HIs based on incidental ingestion of and dermal contact with groundwater in an onsite excavation trench, and inhalation of VOCs within trench air from groundwater based on maximum COPC concentrations in groundwater. The total estimated ELCR is 3 x 10^{-4} and the total estimated HI is 49. Inhalation of VOCs in the trench air is the exposure pathway that contributes most to the cumulative ELCR and HIs. Benzene, naphthalene and ethylbenzene (as estimated in trench air from groundwater) are the primary risk drivers for the total ELCR. Benzene, naphthalene, xylenes and 1,3,5-trimethylbenzene are the risk drivers for the HI.

Table 3-15 and Table E-3a (Appendix E) present the estimated ELCRs and HIs for construction/trench workers based on 95% UCL COPC concentrations and direct-contact exposures including ingestion of, dermal contact with and inhalation of dust particles in surface and subsurface soil. The total soil-related estimated ELCR is 3 x 10^{-7} and the total soil-related estimated HI is 0.06. Soil ingestion contributes most to the total estimated ELCR and HIs. Excluding the estimated arsenic ELCR and HI, which are likely based on background, the total estimated ELCR is 2 x 10^{-8} and the total estimated HI is 0.05.

Table 3-15 and Table E-3b (Appendix E) present ELCRs and HIs based on incidental ingestion of and dermal contact with groundwater in an onsite excavation trench and inhalation of VOCs within trench air from groundwater based on 95% UCL COPC concentrations. The total estimated ELCR is 3 x 10^{-5} and the total estimated HI is 9. Inhalation of VOCs in the trench air contributes most to ELCR and HIs. Benzene is the primary risk driver for ELCRs and benzene and naphthalene are the primary risk drivers for HIs.

3.3.2.1.4 Onsite Adult Visitors

Table 3-14 and Table D-4 (Appendix D) present the estimated ELCRs and HIs for adult visitors based on maximum COPC concentrations in onsite groundwater. Inhalation of VOCs in indoor air from groundwater is the primary exposure pathway for these potential receptors. The total estimated ELCR is 2 x 10^{-7} and the total estimated HI is 0.002.

Table 3-15 and Table E-4 (Appendix E) present the estimated ELCRs and HIs for adult visitors based on 95% UCL COPC concentrations in onsite groundwater. Inhalation of VOCs in indoor air from groundwater is the primary exposure pathway for these potential receptors. The total estimated ELCR is 1 x 10^{-8} and the total estimated HI is 0.0004.

3.3.2.2 Estimated Risks and Hazards for Potential Offsite Receptors

Potential offsite receptors evaluated include current and future residents; adults (chronic exposures), children (chronic exposures) and infants (subchronic exposures); indoor and outdoor commercial workers (chronic exposures); and construction/trench workers (subchronic exposures). The estimated risks and hazards for offsite receptors using maximum detected concentrations and 95% UCLs as EPCs are summarized in Table 3-14 and Table 3-15 , respectively.

3.3.2.2.1 Offsite Adult, Child and Infant Residents

Table 3-14 and Tables D-5a and D-6a (Appendix D) present the estimated ELCRs and HIs for offsite adult and child residents, assuming potential exposure to 95% UCL COPC concentrations in ambient air from onsite surface soil (based on 95% UCL concentrations) using the USEPA (2012b) chronic PPRTV oral RfD for sulfolane. The total estimated ELCRs for adult and child residents are 4×10^{-8} and 9×10^{-9}, respectively, and the total estimated HIs are both 0.001. Excluding arsenic in soil and the estimated arsenic ELCRs and HIs, which is likely due to background, the total estimated ELCRs for adult and child residents are 4×10^{-8} and 8×10^{-9}, respectively, and the total estimated HIs are both 0.0009 (see Table D-5a [Appendix D] for adult resident and Table D-6a for child resident). Table D-7a presents the estimated ELCR and HI for offsite infant residents, assuming potential exposure to 95% UCL COPC concentrations in ambient air from onsite surface soil using the USEPA (2012b) subchronic PPRTV oral RfD for sulfolane. The total estimated ELCR for infant residents is 1×10^{-9} and the total estimated HI is 0.0007. Excluding the estimated arsenic ELCR and HI, which is likely due to background, the total estimated ELCR for infant residents is 1×10^{-9} and the total estimated HI is 0.0005.

Table 3-14 and Tables D-5b, D-6b and D-7b (Appendix D) show HIs based on ingestion of the maximum detected concentration of sulfolane in groundwater (i.e., tapwater), applied across the entire offsite area (which also includes EU-1 because the maximum value occurs in this EU), for adults (chronic exposures; Table D-5b), children (chronic exposures; Table D-6b) and infants (subchronic exposures; Table D-7b), respectively. Tables D-5c, D-6c and D-7c present the HIs associated with ingestion of homegrown produce irrigated with sulfolane-impacted groundwater (maximum detected concentration) for adults (chronic exposures; Table D-5c), children (chronic exposures; Table D-6c) and infants (subchronic exposures; Table D-7c), respectively. Tables D-11 and D-12 present the HIs associated with ingestion of surface water (maximum detected concentration) for adults (chronic exposures; Table D-11) and children (chronic exposures; Table D-12).

As shown in Table 3-14 and Tables D-5b, D-6b and D-7b (Appendix D), using the PPRTV oral RfDs for sulfolane and the maximum concentration detected in offsite groundwater, the total estimated HIs associated with ingestion of groundwater are 12 for adult residents (chronic exposure; Table D-5b), 28 for child residents (chronic exposure; Table D-6b) and 7 for infant residents (subchronic exposure; Table D-7b), respectively, based on ingestion of tapwater. Table 3-14 and Tables D-5c, D-6c and D-7c present the total estimated HIs associated with ingestion of homegrown produce, including an HI of 0.8 for adult residents (chronic exposure; Table D-5c), 2 for child residents (chronic exposure; Table D-6c) and 0.3 for infant residents (subchronic exposure; Table D-7c), respectively. These HIs are based on ingestion of homegrown produce using the USEPA (2012b) PPRTV oral RfDs for sulfolane, along with the maximum detected offsite sulfolane concentration, a BCF of 1.0 and the 95th percentile *per capita* produce ingestion rates. These exposure assumptions were used in all of the produce ingestion scenarios presented in this paragraph. As shown in Table 3-14 and Tables D-11 and D-12 (Appendix D), using the PPRTV oral RfDs for sulfolane and the maximum concentration EPC, the total estimated HIs associated with ingestion of surface-water are 0.03 for adult residents (chronic exposure; Table D-11) and 0.2 for child residents (chronic exposure; Table D-12). The surface-water HIs for this receptor group are the same for each EU (Table 3-15, Table 3-16a and Table 3-17a).

Table 3-14 presents the cumulative HIs for this receptor group for all exposure pathways combined based on maximum EPCs which are 13 for adult residents, 31 for child residents (chronic exposure), and 7 for infant residents (subchronic exposure). Table 3-14 also presents the cumulative ELCRs for this receptor group for all exposure pathways combined based on maximum EPCs which are 4×10^{-8} for adult residents, 9×10^{-9} for child residents (chronic exposure), and 1×10^{-9} for infant residents (subchronic exposure).

Table 3-15 and Tables E-5a, E-6a and E-7a (Appendix E) present the estimated ELCRs and HIs for adults, children (chronic) and infant (subchronic) residents, respectively, based on inhalation of fugitive windborne dust or vapors from onsite COPCs in surface soil, assuming 95% UCL COPC concentrations. As shown in Table E-5a the total estimated ELCR is 4×10^{-8} and the total estimated HI is 0.001 for adult residents (chronic exposure; Table E-5a). For a child resident (chronic exposure), the total estimated ELCR is 9×10^{-9} and the total estimated HI is 0.001 (Table E-6a). The total estimated ELCR is 1×10^{-9} and the total estimated HI is 0.0007 for the infant resident (subchronic exposure; Table E-7a).

Assuming the 95% UCL concentration for sulfolane in EU-1, Table 3-15 and Tables E-5b, E-6b and E-7b in Appendix E) show estimated HIs based on ingestion of 95% UCL sulfolane concentrations in groundwater (i.e., tapwater) at EU-1 by resident receptors. Using the USEPA (2012b) PPRTV oral RfDs for sulfolane, the estimated HIs associated with ingestion of water are 5 for the adult resident (chronic exposure; Table E-5b), 11 for child resident (chronic exposure; Table E-6b) and 3 for infant resident (subchronic exposure; Table E-7b). Tables E-5c, E-6c and E-7c present the total estimated HIs associated with consumption of homegrown produce irrigated with water containing sulfolane in EU-1. The HIs are 0.3 for adult residents (chronic exposure), 0.9 for child residents (chronic exposure) and 0.1 for an infant resident (subchronic exposure), using the USEPA (2012b) PPRTV oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

Table 3-16a and Tables D-13a, D-13b, D-14a, D-14b, D-15a and D-15b (Appendix D) present HIs based on ingestion of the maximum sulfolane concentration in groundwater (i.e., tapwater) within EU-2 for resident receptors. Using the USEPA (2012b) PPRTV oral RfDs for sulfolane, the total estimated HIs associated with ingesting tapwater containing maximum sulfolane concentrations in EU-2 are 4 for an adult resident (chronic exposure; Table D-13a), 9 for a child resident (chronic exposure; Table D-14a) and 2 for an infant resident (subchronic exposure; Table D-15a). In addition, Table 3-16a presents HIs associated with consumption of homegrown produce irrigated with groundwater containing the maximum sulfolane concentrations at EU-2. The estimated HIs for consumption of homegrown produce irrigated with water from EU-2 are 0.3 for an adult resident (chronic exposure; Table D-13b), 0.8 for a child resident (chronic exposure; Table D-14b) and 0.1 for an infant resident (subchronic exposure; Table D-15b), using the USEPA (2012b) PPRTV oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

Table 3-16b and Tables E-11a, E-12a and E-13a (Appendix E) present HIs based on ingestion of the 95% UCL sulfolane concentration in groundwater (i.e., tapwater) within EU-2 for resident receptors. Using the USEPA (2012b) PPRTV oral RfDs for sulfolane, the total estimated HIs associated with ingesting tapwater containing sulfolane in EU-2 are 2 for an adult resident (chronic exposure; Table E-11a), 4 for a child resident (chronic exposure; Table E-12a) and 0.9 for an infant resident (subchronic exposure; Table E-13a). In addition, Table 3-16b and Tables E-11b, E-12b and E-13b (Appendix E) present HIs associated with consumption of homegrown produce irrigated with sulfolane-impacted groundwater at EU-2. The total estimated HIs for consumption of homegrown produce irrigated with water from EU-2 are 0.1 for an adult resident (chronic exposure; Table E-11b), 0.3 for a child resident (chronic exposure; Table E-12b) and 0.04 for an infant resident (subchronic exposure; Table E-13b) respectively, using the USEPA (2012b) PPRTV oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

Table 3-17a and Tables D-19a, D-20a and D-21a (Appendix D) show the estimated HIs based on ingestion of the maximum sulfolane concentration in groundwater (i.e., tapwater) within EU-3 by resident receptors. Using the USEPA (2012b) PPRTV oral RfDs for sulfolane, the estimated HIs associated with ingestion of tapwater are 2 for an adult resident (chronic exposure; Table D-19a), 5 for a child resident (chronic exposure; Table D-20a) and 1 for an infant resident (subchronic exposure; Table D-21a). In addition to a drinking water scenario, Table 3-17a and Tables D-19b, D-20b and D-21b (Appendix D) present the HIs associated with consumption of homegrown produce irrigated with the maximum detected sulfolane concentration in groundwater in EU-3. The estimated HIs for consumption of homegrown produce are 0.1 for an adult resident (chronic exposure; Table D-19b), 0.4 for a child resident (chronic exposure; Table D-20b) and 0.06 for an infant resident (subchronic exposure; Table D-21b), using the USEPA (2012b) PPRTV oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

Table 3-17b and Tables E-17a, E-18a and E-19a (Appendix E) show the estimated HIs based on ingestion of the 95% UCL sulfolane concentration in groundwater (i.e., tapwater) within EU-3 by resident receptors. Using the USEPA (2012b) PPRTV oral RfDs for sulfolane, the estimated HIs associated with ingestion of tapwater are 0.3 for an adult resident (chronic exposure; Table E-17a), 0.7 for a child resident (chronic exposure; Table E-18a) and 0.2 for an infant resident (subchronic exposure; Table E-19a). In addition to a drinking water scenario, Table 3-17b and Tables E-17b, E-18b and E-19b (Appendix E) present the HIs associated with ingestion consumption of homegrown produce irrigated with sulfolane-impacted groundwater in EU-3. The estimated HIs for consumption of homegrown produce are 0.02 for an adult resident (Table E-17b), 0.05 for a child resident (chronic exposure; Table E-18b) and 0.007 for an infant resident (subchronic exposure; Table E-19b), using the USEPA (2012b) PPRTV oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

3.3.2.2.2 Offsite Indoor Commercial Workers

Table 3-14 and Table D-8 (Appendix D) show the HI based on ingestion of groundwater (i.e., tapwater), assuming the maximum offsite sulfolane concentration and the USEPA (2012b) PPRTV oral RfD for sulfolane. The total estimated HI is 9 for offsite indoor commercial/industrial workers (chronic exposure) based solely on ingestion of tapwater containing sulfolane (see Table D-8 [Appendix D]).

Table 3-15 and Table E-8 (Appendix E) show the HI based on ingestion of groundwater (i.e., tapwater), assuming the 95% UCL offsite sulfolane concentration for EU-1 and the USEPA (2012b) PPRTV oral RfD for sulfolane. The total estimated HI is 3 for offsite indoor commercial/industrial workers (chronic exposure) based solely on ingestion of tapwater containing sulfolane (see Table E-8 [Appendix E]).

At EU-2, two sulfolane groundwater EPCs were used to estimate potential hazards associated with ingestion of groundwater by offsite indoor commercial/industrial workers (chronic exposure). Using the maximum detected offsite sulfolane concentration at EU-2, the estimated HI is 3 (Table 3-16a). Comparatively, the HI based on the 95% UCL sulfolane concentration at EU-2 is 1. Both HIs were derived using the USEPA (2012b) PPRTV oral RfD for sulfolane (see Table D-16 [Appendix D] for maximum EPC and Table E-14 [Appendix E] for 95%UCL). Similarly, two sulfolane groundwater EPCs were used to estimate potential hazards associated with ingestion by offsite indoor commercial/industrial workers (chronic exposure) at EU-3. Table 3-17a shows the HI based on ingestion of groundwater (i.e., tapwater), assuming the maximum offsite sulfolane concentration at EU-3 and Table 3-17b shows the corresponding HI based the 95% UCL offsite sulfolane concentration at EU-3. Both HIs were derived using the USEPA (2012b) PPRTV oral RfD for sulfolane. Using the maximum detected sulfolane concentration at EU-3, the estimated HI is 2; the estimated HI is 0.2 for offsite indoor commercial/industrial workers (chronic exposure) based on the 95% UCL groundwater concentration at EU-3 (see Table D-22 [Appendix D] and Table E-20 [Appendix E], respectively).

3.3.2.2.3 Offsite Outdoor Commercial Workers

Table 3-14 presents the estimated ELCRs and HIs for offsite outdoor commercial workers potentially exposed via inhalation of dust particles from onsite surface soil (0 to 2 feet bgs), using 95% UCL COPC concentrations in onsite surface soil. The total estimated ELCR is 2 x 10^{-8} and the total estimated HI is 0.0006 (see Table D-9a [Appendix D]). Excluding the estimated arsenic concentrations in surface soil and HI, which are likely attributable to background, the total estimated ELCR is 2 x 10^{-8} and the total estimated HI is 0.0006 (Table D-9a). Table 3-14 also shows the HI for this receptor assuming ingestion of groundwater (i.e., tapwater) and assuming the maximum offsite sulfolane concentration. The estimated HI is 9 for offsite outdoor commercial/industrial workers, based on ingestion of tapwater (see Table D-9b [Appendix D]).

Table E-9a [Appendix E] shows ELCRs and HIs based on inhalation of fugitive windborne dust and vapors from onsite COPCs in surface soil, based on 95% UCL COPC concentrations and the USEPA (2012b) PPRTV oral RfD for sulfolane. It was assumed that the offsite outdoor commercial worker (chronic exposure) is located at the site boundary; therefore, the estimated ELCRs and HIs calculated for onsite commercial workers represent a health-protective estimate for an offsite commercial worker, based on inhalation of dust and vapors from the site. As shown in Table E-9a [Appendix E], the total estimated ELCR is 2 x 10^{-8} and the total estimated HI is 0.0006, based on inhalation of dust and vapors in ambient air (see Table E-9a [Appendix E]).

Assuming the 95% UCL and USEPA (2012b) PPRTV oral RfD for sulfolane in EU-1, the total estimated HI is 3 for offsite outdoor commercial/industrial workers (chronic exposure), based on ingestion of groundwater (see Table 3-15 and Table E-9b [Appendix E]).

At EU-2, two sulfolane groundwater EPCs were used to estimate potential hazards associated with ingestion of groundwater: the maximum detected concentration of sulfolane and the 95% UCL of the mean sulfolane concentrations. Using the maximum detected concentration in groundwater at EU-2, the estimated HI is 3 for offsite outdoor commercial/industrial workers (chronic exposure) based on ingestion of groundwater (see Table 3-16a and Table D-17 [Appendix D]). Using the 95% UCL sulfolane concentration, the total estimated HI is 1 for offsite outdoor commercial/industrial workers at EU-2, based on ingestion of tapwater (chronic exposure; see Table 3-16b and Table E-15 [Appendix E]). Both hazard estimates used the USEPA (2012b) PPRTV oral RfD for sulfolane.

Similarly, at EU-3, the 95% UCL and maximum sulfolane groundwater concentrations were both evaluated as distinct EPCs to estimate potential hazards associated with ingestion of groundwater by offsite commercial/industrial workers. Using the maximum sulfolane concentration at EU-3, the estimated HI is 2 (Table 3-17a and Table D-23 [Appendix D]). Using the 95% UCL sulfolane concentration, the estimated HI is 0.2 for offsite outdoor commercial/industrial workers at EU-3 (see Table 3-17b and Table E-21 [Appendix E]). Both hazard estimates are used the USEPA (2012b) PPRTV oral RfD for sulfolane.

3.3.2.2.4 Offsite Construction/Trench Workers

The estimated HIs for an offsite construction worker who is potentially exposed to maximum sulfolane concentrations by incidental ingestion of sulfolane in offsite groundwater in excavation trenches is 0.0008 (see Table 3-14 and Table D-10 [Appendix D]). This exposure is subchronic and the HI is derived assuming the maximum offsite sulfolane concentration and using the USEPA (2012b) PPRTV subchronic oral RfD for sulfolane. As discussed in Section 3.1.1.4, sulfolane is not considered to pose adverse health effects due to inhalation and dermal contact exposures. The total estimated HI is 0.0008 for offsite construction workers, based on incidental ingestion of groundwater while working in trenches.

Tables 3-15, 3-16b and 3-17b show the HIs for potential exposures by the construction worker (subchronic exposure) based on 95% UCL sulfolane concentrations for incidental ingestion of sulfolane in offsite groundwater in excavation trenches in EU-1, EU-2 and EU-3, respectively. The estimated HIs for offsite construction workers, which are based on the USEPA (2012b) PPRTV subchronic oral RfD for potential groundwater ingestion exposures of groundwater while working in trenches, and 95%UCL sulfolane concentrations, are 0.0003, 0.0001 and 0.00002 in EU-1, EU-2 and EU-3, respectively (see Tables E-10, E-16 and E-22 [Appendix E] for the hazard calculations for this receptor in EU-1, EU-2 and EU-3, respectively). Tables 3-16a and 3-17a show the corresponding HIs for this receptor group based on the maximum sulfolane groundwater concentrations at EU-2 and EU-3, respectively. The estimated HIs for offsite construction workers exposed to maximum groundwater concentrations at EU-2 and EU-3 are 0.0003 and 0.0001, respectively (see Tables D-18 and D-24 [Appendix D]).

3.3.2.2.5 Offsite Adult and Child Recreational Users

Table 3-14 and Tables D-11 and D-12 (Appendix D) show the estimated HIs for offsite adult and child (aged 1 to 6years) recreational users (i.e., swimmer who may be exposed by incidental, ingestion of sulfolane in surface water), assuming the maximum offsite sulfolane concentration in pore water and the USEPA (2012b) PPRTV chronic oral RfD for sulfolane. The total estimated HIs are 0.03 and 0.2 for offsite adult (chronic exposure) and child recreational users (chronic exposure), respectively.

3.3.3 Conclusions for Provisional Peer Reviewed Toxicity Value Scenario

Results of this Revised Draft Final HHRA indicate that the estimated ELCRs and HIs, based on maximum onsite COPC concentrations, are at or below the ADEC- established acceptable ELCR of 1×10^{-5} for current and future onsite indoor and outdoor commercial/industrial workers and adult site visitors, and below the target HI of 1 for the PPRTV Scenario. The estimated ELCRs and HIs for current and future onsite construction workers exceed the acceptable ELCR of 1×10^{-5} and target HI of 1 based on maximum COPC concentrations; however, estimated ELCRs are below the acceptable ELCR based on 95% UCL COPC concentrations.

Table 3-14 presents the estimated ELCRs and HIs using maximum COPC concentrations in onsite subsurface soil, maximum onsite COPC surface soil and groundwater concentrations, the single maximum offsite groundwater concentration of sulfolane, and the USEPA (2012b) PPRTV oral RfDs for sulfolane. The estimated HIs are below the target HI of 1 for the onsite commercial/industrial worker, onsite commercial/industrial outdoor worker, onsite visitor and offsite child recreator. The estimated HIs exceed the target HI of 1 for onsite construction/trench workers, offsite residents, and offsite indoor and outdoor commercial workers. The HI is equal to 49 for onsite construction workers based on inhalation of volatile COPCs in trench air from groundwater. Benzene, naphthalene, xylenes and 1,3,5-trimethyl benzene are the hazard drivers. For offsite adult, child and infant resident receptors, the HIs are equal to 13, 31, and 7, respectively.

Similarly, the estimated total ELCRs for the potential onsite visitor (Table 3-14) are below the ADEC acceptable ELCR of 1×10^{-5}. The estimated total ELCRs for the onsite indoor and outdoor commercial workers and onsite construction/trench workers do not exceed the ADEC acceptable ELCR. The total estimated ELCRs are equal to 1×10^{-5} and 5×10^{-6} for onsite indoor and outdoor commercial workers, respectively. The estimated ELCR for the indoor commercial worker is based on inhalation of volatile COPCs in indoor air. For the outdoor commercial worker, the estimated total ELCR is based on soil ingestion including arsenic, which is likely present due to background concentrations. For onsite construction/trench workers, the total estimated ELCR is equal to 3×10^{-4} for onsite construction/trench workers, which is based primarily on inhalation of volatile COPCs in trench air from groundwater, with benzene, naphthalene and ethylbenzene as the primary risk drivers.

Table 3-15 presents the estimated ELCRs and HIs using 95% UCL COPC concentrations in onsite soil and in EU-1, and the USEPA (2012b) PPRTV oral RfDs for sulfolane. Using the 95% UCL onsite COPC soil concentrations, the 95% UCL onsite and EU-1 offsite sulfolane groundwater concentrations, and the USEPA (2012b) PPRTV oral RfDs for sulfolane, the estimated HIs for the receptors evaluated are below the target HI of 1, with the exception of onsite construction/trench workers, offsite residents, and offsite indoor and outdoor commercial workers. The HI is equal to 9 for onsite construction workers based on inhalation of volatile COPCs in trench air from groundwater. Naphthalene and benzene are the hazard drivers. For offsite residents, the estimated total HIs are equal to 5, 12 and 3 for offsite adult, child and infant residents, respectively, with ingestion of sulfolane in tap water the primary hazard driving exposure pathway. For both the offsite indoor commercial worker and the offsite outdoor commercial worker, the estimated HI is 3, based on ingestion of sulfolane in groundwater.

Similarly, the estimated total ELCRs for the potential receptors evaluated at EU-1 are at or below the ADEC acceptable ELCR of 1×10^{-5}, with the exception of onsite commercial/ industrial outdoor workers and onsite construction/trench workers (Table 3-15). For the onsite commercial/ industrial outdoor worker, the total estimated ELCR is equal to 5×10^{-6}. The total estimated ELCR is equal to 3×10^{-5} for onsite construction/trench workers, which is based on inhalation of volatile COPCs in trench air from groundwater with benzene as the risk driver.

Table 3-16a presents the estimated ELCRs and HIs using the maximum COPC sulfolane concentrations in EU-2. Under the PPRTV Scenario using maximum COPC concentrations in EU-2, the HI for offsite construction workers is below the target HI of 1. The estimated HIs exceed the target HI of 1 for offsite adult, child (chronic exposure) and infant residents (subchronic exposure); and offsite indoor and outdoor commercial workers. Ingestion of sulfolane in groundwater is the primary exposure pathway. Using the maximum sulfolane concentration in EU-2, the HI for offsite construction workers is below the target HI of 1.

As shown in Table 3-16b, using the 95% UCL COPC sulfolane concentrations in EU-2, the estimated HIs are either below or equal to the target HI of 1 for offsite infant resident, offsite indoor and outdoor commercial/ industrial worker receptors, and offsite construction workers. The HIs exceed the target HI of 1 for offsite resident adult and child (chronic) receptors, with ingestion of tapwater containing sulfolane as the primary hazard driver.

Table 3-17a presents the estimated ELCRs and HIs using the maximum sulfolane concentrations in EU-3. Under the PPRTV Scenario, HIs exceed the target HI of 1 for offsite adult and child (chronic) residents and for indoor and outdoor commercial/industrial workers. Ingestion of groundwater is the primary exposure pathway. The HI for offsite construction workers is below the target HI of 1.

As shown in Table 3-17b, using the 95% UCL sulfolane concentrations in EU-3, the estimated HIs are below the target HI of 1 for each of the potential offsite receptors.

3.4 Evaluation of Potential Exposures to Lead in Onsite Groundwater

The USEPA's (2009b) ALM was used to evaluate current and future onsite outdoor commercial/industrial workers and construction/trench workers potentially exposed to lead in onsite groundwater. The maximum concentration of lead detected above the laboratory reporting limit in onsite groundwater is 2.05 µg/L. The USEPA's threshold lead concentration of 10 µg/dL of whole blood is based on potentially adverse neurological effects in children (CDC 2011). The 95th percentile blood lead concentration (PbB) among fetuses of onsite adult workers, assuming potential exposure to the maximum detected concentration in onsite groundwater, was calculated using the ALM (USEPA 2009b). Using the groundwater ingestion rates and exposure frequencies for current and future onsite outdoor commercial/industrial workers and construction/trench workers presented in Table 3-12, the calculated probabilities that fetal PbBs are greater than10 µg/dL are 0.005 and 0.002%, respectively. Thus, potential exposures to lead in groundwater at the site are below the regulatory level of concern and are not expected to pose adverse health effects to current and future onsite outdoor commercial/industrial workers and construction/trench workers. The Calculations of Blood Lead Concentrations spreadsheet is provided in Appendix I.

Based on the results of the ALM (USEPA 2009b), the maximum detected concentration of lead in onsite groundwater is not expected to pose adverse health effects to current and future onsite outdoor commercial/industrial workers or construction/trench workers.

3.5 Uncertainty Assessment – PPRTV Scenario

Each exposure parameter value and toxicity value incorporated into the HHRA is associated with some degree of uncertainty; these uncertainties may contribute to an overestimation or underestimation of risks at the site (ADEC 2011c). Therefore, key uncertainties associated with each HHRA component (i.e., data evaluation, COPC selection, toxicity assessment, exposure assessment and risk/hazard characterization) were evaluated.

3.5.1 Data Evaluation

Soil and onsite groundwater samples were analyzed for a large suite of constituents from multiple samples collected throughout the site over time. These samples were analyzed using accepted analytical methodologies. It is unlikely that constituents were overlooked or underestimated by the analytical methods employed. The laboratory method used for soil sulfolane analyses in 2010 and 2011 was not final at the time, but the analytical results have been validated with an approved method.

The release-related constituents detected in soil (e.g., BTEX) were measured in more than 250 soil samples, of which 88 were surface soil samples. The large data set provides high confidence in the 95% UCL on the mean concentrations and in the representativeness of the use of this statistic for EPCs.

A large number of samples of key constituents detected at the site are available for use in the data evaluation. For example, for sulfolane in offsite groundwater, more than 429 samples were grouped by concentration ranges with each range having a high number of samples to represent that zone (i.e., 105 samples in the greater than 100 μg/L EU, 72 samples in the greater than 25 μg/L EU and 252 samples in the EU with detections up to 25 μg/L). The number of samples increases the representativeness of the EPCs based on these groupings of data and it is unlikely that the EPC based on the 95% UCL on the mean concentration underestimates potential exposures to sulfolane given the number of samples. The maximum detected concentration of sulfolane (443 μg/L) is 1.4 times higher than the next highest detection of sulfolane in offsite wells and 3 times greater than the 95% UCL on the mean concentration for the greater than 100 μg/L EU.

Data for onsite wells with multiple sampling rounds were averaged together and these temporal average well concentrations were grouped to calculate 95% UCL concentrations on the mean. Each temporal average concentration represents multiple sampling events and provides a reliable measure of constituent concentrations in that well. Grouping the data by well to estimate EPCs reduced the number of samples upon which the statistical analysis could be based. Where too few wells were available to reliably estimate 95% UCL values, the highest temporal well average was used to represent the EPC, which is an overestimate of potential exposure.

3.5.2 Constituent of Potential Concern Selection

COPCs were selected from a list of COIs known or suspected to have been used at the site. The approaches used to characterize the site were intended to identify the COPCs in environmental media associated with current and historical site operations. Sampling events were sequentially conducted based on the knowledge obtained from past sampling events. It is likely that these events identified the majority of areas with residual COPCs. While it is possible that some substances may have been omitted, the probability of those substances being important in driving risk is expected to be low. The suite of analyses that was selected represents those constituents that would most likely result from site operations and are therefore the most relevant and appropriate constituents for estimating risks and hazards. Note that analyses of isopropanol and propylene glycol were inadvertently missed during recent groundwater sampling events. Although the potential presence of these constituents is not expected to change the outcome of the risk evaluation, these COPCs will be evaluated once data have been collected.

3.5.3 Toxicity Assessment

Dose-response values are sometimes based on limited toxicological data. For this reason, a margin of safety is built into estimates of both carcinogenic and noncarcinogenic risk, and actual risks are lower than those estimated. The two major areas of uncertainty introduced in the dose-response assessment are: (1) animal to human extrapolation and (2) high to low dose extrapolation. These are discussed below.

Human dose-response values are often extrapolated, or estimated, using the results of animal studies. Extrapolation from animals to humans introduces a great deal of uncertainty in the risk assessment because in most instances, it is not known how differently a human may react to the constituent compared to the animal species used to test the constituent. The procedures used to extrapolate from animals to humans involve conservative assumptions and incorporate several uncertainty factors that overestimate the potential adverse effects associated with a specific dose. As a result, overestimation of the potential for adverse effects to humans is more likely than underestimation.

Predicting potential health effects from exposure to media containing COPCs requires the use of models to extrapolate the observed health effects from the high doses used in laboratory studies to the anticipated human health effects from low doses experienced in the environment. The models contain conservative assumptions to account for the large degree of uncertainty associated with this extrapolation (especially for potential carcinogenic effects) and therefore, tend to be more likely to overestimate than underestimate potential risks.

Oral RfDs for sulfolane have been derived using different approaches and laboratory studies. For the PPRTV Scenario, the USEPA (2012b) PPRTV chronic oral RfD of 0.001 mg/kg-day and PPRTV subchronic oral RfD of 0.01 mg/kg-day were used to derive HIs. In the ARCADIS Comparative Scenario, alternate chronic and subchronic RfDs of 0.01 mg/kg-day and 0.1 mg/kg-day that were derived by ARCADIS from scientific literature were used to derive HIs. As expected, with the alternate sulfolane oral RfD values, the HIs decrease. The reasoning for the ARCADIS derivation is provided in Section 4 and Appendices H and K.

3.5.4 Exposure Assessment

According to USEPA (2001) guidance, screening-level estimates of exposure and risk calculations use assumptions that maximize the estimate of risk to ensure that only those constituents that represent a *de minimis* risk are eliminated from further consideration, and those that potentially pose an unacceptable risk will be retained for consideration in subsequent steps of the risk assessment process. As requested by the ADEC, maximum concentrations of COPCs were used as EPCs in the risk calculations for the potential receptors evaluated for the PPRTV Scenario. More often, a conservative estimate of average concentrations of constituents is used to represent EPCs (USEPA 1989, 2002c, 2006b, 2007). Potential receptors are more likely to be exposed to a range of these concentrations represented by the average or 95% UCL concentration.

Concentrations of VOCs in indoor air of current and future onsite commercial/industrial structures were estimated using concentrations of VOCs in groundwater at the site. Due to the uncertainties associated with partitioning from soil to soil gas, ITRC (2007b) does not recommend using soil data as a source of COPCs to evaluate potential vapor intrusion. Thus, use of soil data to evaluate potential soil vapor concerns is inappropriate. USEPA (2002a) and ITRC (2007a) recommendations concluded that there is insufficient scientific support for this procedure. ITRC (2007a) notes “Scientific studies have failed to show good correlation between soil and soil gas sampling and analysis on a consistent basis.” They conclude by recommending that soil data should be used only as a secondary line of evidence and not as a primary line. Overall, the scientific evidence indicates that use of soil data is not a reliable approach for identifying potential vapor intrusion concerns.

Dermal contact with COPCs in groundwater by current and future onsite outdoor commercial/industrial workers was considered an insignificant exposure pathway. Onsite use of groundwater beneath the site is limited to infrequent fire extinguishing. Fires at the site are very rare and the period of exposure would likely be relatively very short. Thus, exclusion of this potential exposure pathway would not significantly impact ELCR and HI estimates for these possible onsite receptors.

For the offsite CSM, it was assumed that groundwater may be connected with surface water, and pore-water data were collected to evaluate potentially complete exposure pathways for surface water. Pore-water piezometer installation methods needed to be revised for two of the three offsite locations because the surface-water body was frozen and pore-water samples could not be collected. However, the groundwater samples collected were able to be evaluated for human health risk. Because sulfolane degrades more rapidly in the presence of nutrients and oxygen that would be present in the surface water (ADHSS 2010), and given the limited groundwater-surface water interchange due to a frozen surface-water body, the groundwater collected adjacent to two of the three surface-water bodies in 2012 likely overestimates the surface water concentrations at those locations. Thus, the data used for the swimming scenario overestimate human health risk.

Ingestion of offsite groundwater by current and future offsite residents was the primary exposure pathway for these potential receptors and resulted in the relatively highest HIs, including for infants (0 to 1 year). The ingestion rate used for this age group slightly exceeded that used for children (0 to 6 years). It was also assumed that infants do not breastfeed and that their formula was made with tapwater instead of pediatrician-recommended distilled water. Thus, it is highly likely that HI estimates for this receptor were overestimated.

Only potential ingestion exposures were quantitatively assessed for sulfolane. This analysis suggests that dermal contact and inhalation exposure routes are not significant for sulfolane, which is supported by ATSDR (2010 and 2011) Health Consultations and animal studies (Brown et al. 1966, Andersen et al. 1977). Although these exposure routes were excluded, inclusion of them would likely not contribute significantly to overall hazard estimates. As described in Section 3.1.1.4, dermal contact and inhalation exposure routes are not significant for sulfolane. These assumptions are based on animal studies that have shown that sulfolane is not readily absorbed through human skin because of its low permeability and is not expected to pose a significant risk via an inhalation exposure route due to its low volatility. Ingestion of sulfolane in impacted environmental media is the appropriate exposure route to assess potential hazards to on and offsite receptors. Estimated hazards based on inhalation and dermal exposure routes are insignificant relative to hazards estimated based on the ingestion exposure route.

The ingestion rates of homegrown fruit and vegetables for offsite residents are not known. In the PPRTV Scenario, ingestion of fruit and vegetables by offsite residents was evaluated based on an assumed consumption rate equivalent to 95% of the population. As is described in the Uncertainty Assessment in Section 4, ARCADIS selected mean *per capita* ingestion rates.

HIs using the mean *per capita* ingestion rates would be approximately five times lower for the ingestion of produce exposure pathway. For the PPRTV Scenario, a groundwater-to-produce BCF value of 1 was assumed. HIs for the ingestion of homegrown produce pathway calculated using a BCF of 0.32 (the derivation of which is described in Section 4.5.4) would be approximately three times lower than the HIs calculated in the PPRTV Scenario. The cumulative impact of using both the mean per capita ingestion rates (factor of approximately 2.8) and a BCF of 0.32 (factor of approximately 3.1) result in HIs that are approximately nine times lower than the HIs calculated in the PPRTV Scenario. However, even using high end exposure and uptake assumptions for ingestion of homegrown produce, this is an insignificant exposure pathway compared to ingestion of groundwater.

In the PPRTV Scenario, swimming was assumed to occur 60 days per year for 1 hour per day with surface-water ingestion rates at the maximum ingestion rate for adults and the 97th percentile ingestion rate for children age 18 and under. HIs based on an EF of 30 days per year for 0.5 hour per day at recommended mean value ingestion rates (USEPA, 2011a), which are the exposure parameters selected by ARCADIS as described in the Uncertainty Assessment in Section 4, would be approximately ten times (a factor of 9.7) lower than those calculated for the PPRTV Scenario.

3.5.5 Risk/Hazard Characterization

Some HIs exceed the USEPA and the ADEC acceptable target HI equal to 1, particularly those estimated for onsite construction/worker exposures to volatile COPCs in the air of a trench, which have been modeled from groundwater concentrations. For this Revised Draft Final HHRA, endpoint-specific HIs were not calculated and summing all HQs regardless of endpoint is a health-protective approach. The USEPA acknowledges that adding all HQ or HI values may overestimate hazards, because the assumption of additivity is likely appropriate only for those chemicals that exert their toxicity by the same mechanism (USEPA 1989). Application of endpoint-specific HIs is expected to reduce total HI estimates.

The child scenario has been assessed in this section using the chronic oral reference dose, which is by definition a daily dose that is protective for sensitive receptors for lifetime exposures. Many USEPA programs such as the drinking water program use adult scenarios to protect both adults and children. For instance, Federal drinking water standards are derived using adult receptors, and USEPA states that such standards are protective for both adults and children. The use of the child exposure levels and body weights coupled with a chronic reference dose in this section provides an additional margin of exposure, but it is uncertain whether it provides additional public health protection. Appendices H and K provide additional information on sulfolane’s toxicological profile. These documents show that sulfolane presents no special concerns to children, and that focusing public health protection efforts on adult receptors using a chronic reference dose adequately protects children.

4. ARCADIS Comparative Scenario

This section presents the ARCADIS Comparative Scenario estimated ELCRs and HIs for the same potentially complete and significant exposure pathways identified in Section 3.1.1.4 for the same potential receptors located on and offsite. In this section, the toxicity value for sulfolane that was selected by ARCADIS, as described in Appendix H, is used, with the same exposure parameters presented in Table 3-12. For each total estimated ELCR and HI, the primary exposure pathway and COPC(s) are indicated, as appropriate. In the ARCADIS Comparative Scenario, chronic oral RfDs were used to evaluate child exposures. Child and subchronic oral reference doses were used to evaluate child exposures in the ARCADIS Scenario, presented in the Uncertainty Assessment (Section 4.5.4) Supportive reasoning for these choices is provided in Appendices H and K.

4.1 Exposure Assessment

ARCADIS conducted an HHRA to evaluate the potential for human health risk from exposure to site-related constituents, following protocols presented in the June 8, 2000 ADEC Risk Assessment Procedures Manual that are adopted into regulation in 18 AAC 75. The primary ADEC references for this Revised Draft Final HHRA include the Draft Risk Assessment Procedures Manual (ADEC 2010a and 2011d), Cleanup Levels Guidance (ADEC 2008a), Cumulative Risk Guidance (ADEC 2008b), and 18 AAC 75 Oil and Other Hazardous Substances Pollution Control guidance (ADEC 2008c). Other references used include RAGS (USEPA 1989, 1991, 2001, 2004a and 2009a), Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (USEPA 2002a), Vapor Intrusion Pathway: A Practical Guide (ITRC 2007a) and Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios (ITRC 2007b).

4.1.1 Human Health Conceptual Site Models

Two preliminary human health CSMs (one onsite CSM and one offsite CSM) were prepared and submitted to the ADEC with the Site Characterization Work Plan (Barr 2010b). After this submittal, a substantial amount of additional site assessment data was collected and in April 2011 the updated CSMs were submitted to the ADEC to reflect the enhanced understanding of site conditions. In the RAWP submitted to ADEC in December 2011 (ARCADIS 2011a), the CSMs were further refined to better reflect existing site conditions. The updated CSMs were developed following the Human Health Conceptual Site Model Graphic and Scoping Forms and the Policy Guidance on Developing Conceptual Site Models (ADEC 2010b and 2010c, respectively). Due to the significant difference in COPC occurrence onsite (petroleum hydrocarbon constituents and sulfolane) versus offsite (sulfolane only), two human health CSM graphic forms (Figures 3-1 and 3-2) were prepared and updated to more clearly portray and distinguish potential exposure pathways for possible on- and offsite receptors.

This section describes the CSMs submitted to the ADEC in December 2011 and revisions to the offsite CSM based on ADEC comments discussed during the meeting held on January 24, 2012. Human health CSMs for on- and offsite locations are presented on Figures 3-1 and 3-2, respectively, and are discussed in the following subsections.

4.1.1.1 Potential Sources

During site operations, various materials associated with the crude oil refining process have been released in operating areas of the site, including the crude oil processing units, extraction unit, loading racks, wastewater lagoons, sumps and drain systems. In addition, spills and/or leaks to surface soil from ASTs, pumps and associated piping during routine operations constitute potential sources of petroleum constituents at the site. Petroleum hydrocarbons have also been detected in historical groundwater samples collected from onsite monitoring wells.

Onsite impacted environmental media may include surface (0 to 2 feet bgs) and subsurface (to a depth of 15 feet bgs, the maximum depth at which human exposure is likely to occur) soil, groundwater, indoor and outdoor air, surface water, sediment and biota. Offsite impacted media may include groundwater, surface water, sediment, wild food (such as fish) and homegrown produce.

4.1.1.2 Potential Fate and Transport Mechanisms

As described in Section 4.1.1.1, the primary sources of COPCs are spills and releases to soil and groundwater during facility operations. COPCs may be retained in site soils or subject to constituent fate and transport mechanisms at the site. Fate and transport mechanisms may include soil sorption; biodegradation; wind erosion and transport; migration to groundwater; advective/dispersive transport in groundwater, on or offsite; and volatilization into soil gas, outdoor air or indoor air.

Potential current and future onsite receptors may be directly exposed to COPCs in surface and subsurface soil via incidental ingestion, dermal contact and inhalation of dust particles in air. In addition, COPCs adhered onto dust particles may migrate from exposed surface or subsurface soil to outdoor air and be breathed by potential offsite receptors. When bound to surface soils, compounds sorbed to soil particles may be subject to wind erosion and windblown transport in outdoor air. Due to the nature of the site, the majority of operational areas are covered with asphalt pavement or gravel. However, exposed and unpaved areas do exist at the site. Therefore, although limited, windborne particulate transport is possible at the site, and this potential pathway was evaluated during the HHRA.

COPCs may leach from soil to groundwater by percolation or may have been directly released to groundwater. Based on groundwater samples collected from onsite wells, sulfolane is the only COPC that is known to have migrated offsite. Potential direct-contact exposures to COPCs in groundwater (e.g., tapwater ingestion and inhalation of volatiles in water) are not expected to occur for current and future onsite commercial/industrial workers because onsite groundwater is only used for industrial purposes (e.g., fire suppression). However, current and future onsite outdoor commercial/industrial receptors may be exposed to COPCs in groundwater by dermal contact while extinguishing fires, if they occur. In addition, due to the relatively shallow average depth to groundwater onsite (historically from 8 to 10 feet bgs), current and future onsite construction/trench workers may be exposed by incidental ingestion of and dermal contact with COPCs in groundwater that has pooled in excavated trenches.

The city provides municipal water for drinking and other potable uses at the site. Current onsite receptors consume drinking water from a municipal source and are expected to consume drinking water from this source in the future. Current and future offsite receptors may be exposed to sulfolane in groundwater that has migrated from the site to wells used for tapwater. In addition, groundwater may be used offsite to irrigate homegrown produce. Sulfolane in groundwater may be taken up by homegrown produce and consumed by offsite residents.

Onsite surface water consists of water that is stored in two lagoons and two gravel pits. Runoff and erosion from soil to surface water may be transport mechanisms. Groundwater from the site flows offsite in a north-northwesterly direction and groundwater is recharged by surface water from the Tanana River. COPCs in groundwater may eventually flow to offsite surface-water bodies and to sediment, which may be contacted by offsite recreational users. Pore-water data were collected to evaluate the potential for exposure at the groundwater/surface-water interface. Some of the samples used for this HHRA were collected when the adjacent surface-water body was frozen; therefore, the degree of connectivity with the surface water, if any, could not be established.

For this HHRA, potential ingestion of sulfolane in surface water by adult and child recreational users while swimming is considered a potentially complete exposure pathway offsite. The collected pore-water samples likely reflect higher sulfolane concentrations than would be expected in true pore-water samples because of limited surface water to groundwater interchange during frozen conditions. Pore-water samples will generally reflect higher sulfolane concentrations than would be encountered by actual recreational users of the surface water bodies because sulfolane degrades more rapidly in the presence of nutrients and oxygen that would be present in the surface water (ADHSS 2010). Accordingly, the data presented in this Revised Draft Final HHRA provide a health-protective assessment of risk to swimmers.

Volatilization is another fate and transport mechanism at the site for lighter petroleum hydrocarbon compounds and other VOCs. VOCs may volatilize from subsurface soil into soil gas, with eventual diffusion and/or advection into outdoor air and/or indoor air in onsite buildings. VOCs may also leach from soil to groundwater, where dissolved-phase VOCs may be transported downgradient both on and offsite. VOCs may volatilize from shallow exposed groundwater in excavations directly into outdoor air. VOCs may volatilize from groundwater into soil gas, with eventual diffusion and/or advection into outdoor air and/or indoor air of on- and/or offsite buildings. VOCs may also be subject to degradation by microorganisms in subsurface soils and groundwater. Heavier petroleum hydrocarbon compounds, such as PAHs, adsorb to solids and do not tend to volatilize. As such, these compounds generally tend to remain in place, where they are subject to aerobic biodegradation by microorganisms. Sulfolane is not expected to volatilize under the conditions observed at the site, as discussed in Section 4.1.1.4.

4.1.1.3 Potential Receptors

Potential human receptors were identified based on current and reasonably foreseeable future land use at the site. A review of current and future land use identified the following potential human receptors at the site.

- **Current and future onsite indoor commercial/industrial workers** were considered to be individuals from 18 to 65 years old. It was assumed that these receptors perform commercial and/or industrial work activities (e.g., office work, laboratory analyses, shipping or warehouse inventory management) indoors onsite, under current or future (redeveloped) land use scenarios. Potential exposures to COPCs in soil are considered to be insignificant for onsite indoor commercial/industrial workers. These potential receptors may be exposed to COPCs in indoor air during a standard 40-hour work week for 25 years, for 250 days per year. Potential inhalation of outdoor air is insignificant. Inhalation of VOCs in indoor air was evaluated following USEPA (2009a) RAGS Part F.

- **Current and future onsite outdoor commercial/industrial workers** were considered to be individuals from 18 to 65 years old. These receptors were assumed to perform commercial and/or industrial work activities (e.g., maintenance work for ASTs or associated piping) outdoors at the site under current or future (redeveloped) land use scenarios. These individuals may occasionally use site groundwater for industrial purposes (e.g., fire suppression). Direct-contact exposures with groundwater are considered insignificant because fires are rare onsite and the exposure period is expected to be short. This exposure pathway was not quantitatively evaluated. These potential receptors may be exposed to COPCs in site media during a standard 40-hour work week for 25 years, for 250 days per year. Following ADEC (2010a) guidance, it was assumed that onsite outdoor workers with an average BW of 70 kg are exposed to 100 mg/day COPCs in surface soil and that 100 percent of the FI is from onsite surface soil.

  FHRA requires all onsite workers to wear long-sleeved shirts, long pants and shoes. Thus, the adult commercial/industrial worker outdoor receptor was assumed to wear a long-sleeved shirt, long pants and shoes, which limits the exposed skin surface to the head and hands. The recommended USEPA (2011a) SSA exposed to impacted soil for the adult commercial/industrial worker outdoor receptor is 2,230 cm^2, which is the average of the adult male and adult female mean values for head and hands. The USEPA (2004a) recommended weighted soil-to-skin AF for a commercial/industrial adult worker of

0.2 mg/cm^2 based on the 50th percentile weighted AF for utility workers (i.e., the activity determined to represent a high-end contact activity) was used. Potential inhalation of indoor air was considered insignificant for the outdoor commercial/industrial worker. Inhalation of volatile COPCs and dust in outdoor air was evaluated following USEPA (2009a) RAGS Part F.

- **Current and future onsite construction/trench workers** were considered to be individuals from 18 to 65 years old. These receptors were assumed to perform short-term maintenance and emergency repair activities on underground utilities or facility piping at the site. These receptors may be exposed to COPCs in surface and/or subsurface soil during the work day while performing the maintenance and/or repair task. Because the depth to groundwater at the site generally ranges from 8 to 10 feet bgs, construction/trench workers may be exposed to COPCs in groundwater that has pooled in a trench during performance of the maintenance and/or repair task. It was assumed that the same worker will provide maintenance and/or repair tasks.

  Potential construction/trench worker receptors were assumed to be exposed to COPCs in onsite soil (down to a depth of 15 feet bgs) and groundwater for 1 hour each day of a standard 5-day work week, for 125 days, for 1 year. This EF is a modification from that proposed in the RAWP (250 days per year). This deviation is justified because most of the utilities at the site are located aboveground and trenching activities typically do not occur during 6 months of each year, when the ground is frozen. It is assumed that soil may be accessible for trenching activities (i.e., not frozen) for 6 months per year.

  Construction/trench workers with an average BW of 70 kg are assumed to be exposed to 330 mg/day (USEPA 2002b) of COPCs in surface and subsurface soil, and 100 percent of the FI is assumed to be from surface and subsurface soil. It was assumed that onsite construction/trench workers incidentally ingest 0.0037 L/day of groundwater pooled in a trench. This rate is based on the mean ingestion rate for wading/splashing presented in the USEPA (2011a) EFH Table 3-93 (3.7 milliliters per hour * 1 hour per day). This consumption rate is likely to overestimate actual exposure, because dewatering usually occurs at excavation sites where water has pooled in trenches.

  FHRA requires all onsite workers to wear long-sleeved shirts, long pants and shoes. Therefore, the onsite adult construction worker receptor was assumed to wear a long-sleeved shirt, long pants and shoes, and the exposed SSA was limited to the head and hands. The USEPA (2011a) recommended SSA exposed to impacted soil for the adult construction worker receptor is 2,230 cm^2. The USEPA (2002b) recommended weighted soil-to-skin AF for a construction worker of 0.3 mg/cm^2-day was used. Inhalation of volatile COPCs and dust in outdoor air were evaluated following USEPA (2009a) RAGS Part F.

- **Current and future onsite visitors and trespassers.** Occasional visitors or trespassers may also be present onsite. However, the site does not and is not expected to attract trespassers because of the character and location of the site (i.e., an industrial setting with controlled access). Moreover, it is anticipated that a trespasser's exposure at the site would be very infrequent. Onsite visitors are typically adults with limited access across the site. Children rarely visit the site. Thus, potential direct-contact exposures to COPCs in soil and groundwater by current and future onsite trespassers and visitors are insignificant. Potential inhalation of outdoor air is also insignificant. However, assuming the adult visitor is located in an onsite building, inhalation of volatile COPCs in indoor air by this potential receptor was evaluated following USEPA (2009a) RAGS Part F. Current and future onsite adult visitors (18 to 65 years of age) are assumed to be exposed to COPCs in indoor air for 2 hours per day, 12 days per year for 30 years.

- **Current and future offsite residents** were evaluated as infants (0 to 1 year of age), children (1 to 6 years of age) and adults (18 to 65 years of age). HHRAs do not typically focus on infant exposures as a separate receptor group, but infants are included here because the ATSDR (2011) and the ADHSS (2012) have addressed infants as a separate receptor group in their Health Consultations. There is evidence that sulfolane does not present a significant risk for developmental effects and it is not mutagenic, mitigating infant-specific exposure concerns. Resident receptors were assumed to be located downgradient of the site and may be exposed to sulfolane in groundwater that has migrated from the site. No other COPCs associated with site operations are known to be present in offsite groundwater. These potential offsite receptors may ingest sulfolane in groundwater as tapwater. In addition, it was assumed that these potential receptors consume homegrown produce, which may have taken up sulfolane from groundwater. It was assumed that potential resident receptors may be exposed to sulfolane in tapwater for a 1-, 6- and 30-year duration for infants, children and adults, respectively, for 350 days per year.

  Current and future offsite adult, child and infant residents may also inhale dust from the site. Inhalation of dust in outdoor air by these potential receptors was evaluated following USEPA (2009a) RAGS Part F.

  Following ADEC (2010a) guidance, it was assumed that 70 kg adult residents consume 2 L/day of tapwater. Following USEPA (1989) guidance, it was assumed that 15 kg child residents consume 1 L/day of tapwater. Infants were assumed to weigh an average of 6.75 kg (the average of the age-group specific mean values from 0 to 1 year) and to consume 1.05 L/day (the time-weighted average of the *per capita* age-group-specific 95th percentile values from 0 to 1 year) of tapwater based on USEPA (2011a) guidance. The groundwater ingestion exposure parameters for infants likely overestimate potential exposure because it was assumed that they do not breastfeed and do not consume formula made with distilled water (a typical pediatric guideline for the first several months of life).

Fractions of homegrown fruit and vegetables ingested, water-to-produce BCFs and ingestion rates for offsite adult and child residents for the ARCADIS Comparative Scenario are discussed in Section 4.1.3.1.6.

- **Current and future offsite indoor and outdoor commercial/industrial workers** were considered to be individuals from 18 to 65 years old. It was assumed that these potential receptors perform commercial and/or industrial work activities indoors or outdoors at offsite locations under current or future land use scenarios during a standard 40-hour work week for 25 years, for 250 days per year. These receptors may ingest sulfolane in groundwater as tapwater. Following ADEC (2010a) guidance, it was assumed that 70 kg offsite adult commercial/industrial workers consume 2 L/day of tapwater. In addition, they may inhale dust that may have been released onsite via wind erosion. Potential exposures to COPCs in dust were considered to be insignificant for offsite indoor commercial/industrial workers. Inhalation of dust in outdoor air by outdoor commercial/industrial workers was evaluated following USEPA (2009a) RAGS Part F.

- **Current and future offsite recreational users.** Sulfolane may potentially migrate offsite via groundwater to surface water and to sediment in downgradient surface-water bodies. Access to downgradient, offsite surface-water bodies is minimal due to surrounding industrial land use and hazardous physical conditions, and direct contact with surface water and sediment by human receptors is limited. Regardless, for this HHRA, ingestion of surface water by offsite adult and child recreational users while swimming is considered a potentially complete exposure pathway. Recreational user exposure assumptions for the ARCADIS Comparative scenario are discussed in Section 4.1.3.3.

- **Current and future offsite construction/trench workers** were considered to be individuals from 18 to 65 years old. These receptors were assumed to perform short-term maintenance and emergency repair activities on underground utilities at offsite properties. These potential receptors may be exposed to sulfolane in groundwater that has pooled in a trench during performance of the maintenance and/or repair task. It was assumed that offsite construction/trench workers incidentally ingest 0.0037 L/day of groundwater pooled in a trench. This rate is based on the mean ingestion rate for wading/splashing presented in the USEPA (2011a) EFH Table 3-93 (3.7 milliliters per hour * 1 hour per day). This consumption rate is conservative, because dewatering usually occurs at excavation sites where water has pooled in trenches. It was conservatively assumed that the same worker performs multiple maintenance and/or repair tasks. These potential receptors (70 kg for adults) may be exposed to sulfolane in groundwater for 1 hour each day of a standard 5-day work week, for 125 days per year, for 1 year.

4.1.1.4 Exposure Pathway Evaluation.

Potential exposure pathways selected for quantitative evaluation are shown in the on- and offsite human health CSMs. An exposure pathway was retained for further evaluation if it was considered potentially complete. Each of the following components must be present in order for an exposure pathway to be considered complete (USEPA 1989):

- Source and/or constituent release mechanism
- Retention or transport medium
- Receptor at a point of potential exposure
- Exposure route at the exposure point.

Complete exposure pathways were evaluated for identified COPCs. Only potential ingestion exposures were quantitatively assessed for sulfolane. Dermal contact and inhalation exposure routes are not significant for sulfolane. The ATSDR (2010 and 2011) Health Consultations support these conclusions. Animal studies have shown that sulfolane is not readily absorbed through human skin because of its low permeability (Brown et al. 1966) and is not expected to pose a significant risk via an inhalation exposure route due to its low volatility (Andersen et al. 1977). Brown et al. (1966) studied the skin and eye irritant and skin sensitizing properties of acute exposures to sulfolane on two animal species. This study concluded that sulfolane did not irritate or sensitize the skins of guinea pigs or rabbits and, undiluted, was only very mildly irritating on the eyes of rabbits.

Andersen et al. (1977) conducted acute and subacute investigations of the inhalation toxicity of sulfolane on four animal species including monkey, dog, guinea pig and rat. A no-observed-effect level for sulfolane of 20 mg/m^3 was reported, and the authors concluded that airborne concentrations of sulfolane as high as those investigated are unlikely to be encountered on any but an emergency basis. Andersen et al. (1977) reported that sulfolane has a relatively low vapor pressure (approximately 0.13 millimeter of mercury at 32 °C and only unusual conditions would produce an extensive release of aerosolized sulfolane. Andersen et al. (1977) further noted that if sulfolane is handled at room temperature in an area with proper ventilation, it should not be regarded as posing an unusual hazard.

Potentially complete and significant exposure pathways were identified for the following receptors, with the exception that dermal and inhalation exposures to sulfolane are incomplete (as noted above):

- Onsite indoor commercial/industrial worker (current and future):
  - Inhalation of volatile COPC vapors in indoor air from groundwater.
- Onsite outdoor commercial/industrial worker (current and future):

  - Ingestion of, dermal contact with and inhalation (particulates) of COPCs in surface soil.
  - Dermal contact with COPCs in groundwater while extinguishing fires was qualitatively evaluated.
  - Inhalation of volatile COPC vapors in outdoor air volatilized from surface and subsurface soil and groundwater.
- Onsite construction/trench worker (current and future):
  - Ingestion of, dermal contact with and inhalation (particulates) of COPCs in surface and subsurface soil.
  - Inhalation of volatile COPC vapors in trench air from surface and subsurface soil and groundwater.
  - Ingestion of and dermal contact with COPCs in groundwater in excavation trenches.
- Onsite adult visitor (current and future):
  - Inhalation of volatile COPC vapors in indoor air from groundwater.
- Offsite adult, child and infant residents (current and future):
  - Ingestion of sulfolane in groundwater (i.e., tapwater).
  - Ingestion of homegrown produce irrigated with sulfolane-impacted groundwater.
  - Inhalation of fugitive windborne dust from onsite COPCs in surface soil.
- Offsite indoor and outdoor commercial/industrial worker (current and future):
  - Ingestion of sulfolane in groundwater (i.e., tapwater).
  - Inhalation of fugitive windborne dust from onsite COPCs in surface soil (outdoor worker only).
- Offsite construction/trench worker (current and future):
  - Ingestion of sulfolane in groundwater (i.e., in excavation trenches).
- Offsite adult and child recreational users (current and future):

– Ingestion of sulfolane in surface water (i.e., pore water).

4.1.2 Data Evaluation, Constituent of Potential Concern Selection and Identification of Data Gaps

The proposed methods for data evaluation, identification of data gaps, selection of COPCs and proposed sampling to address data gaps are discussed below. Both maximum and 95% UCL on the mean constituent concentrations for groundwater were evaluated.

4.1.2.1 Data Evaluation

The available data that were used include analytical results from soil investigations conducted at the site since 2001. Data from four sets of soil samples were evaluated, including samples collected in March and May 2001, July 2004, October 2010 and October 2011. One soil sample collected in 2010 (O-2 [7.5-9]) was determined to be unusable in a Level four data validation, so this sample was not included in EPC calculations.

Groundwater and surface-water data collected during the last two years were also included. SWI provided the soil and groundwater analytical data used in the HHRA in an electronic format. Initially, the data were separated into individual datasets by environmental media, including: onsite groundwater, offsite (downgradient) groundwater, onsite surface soil (0 to 2 feet bgs) and onsite subsurface soil (2 to 15 feet bgs).

The quality of the data is acceptable for risk assessment use. Parameters evaluated in the data quality assessment include spatial and vertical coverage and representativeness of sampling locations, analytical methods and reporting limits used by the laboratories, and data qualifiers applied during data validation. The HHRA relies on validated data supplied by SWI as presented in the Revised Site Characterization Report (Barr 2012). Data collected for this evaluation were collected per ADEC-approved sampling and analysis plans. Consideration was given to the recently developed standard procedure for analyzing sulfolane in groundwater (isotope dilution) and the historical variability between analytical results. The data relied upon in this risk assessment met the following criteria for data usability for risk assessment as recommended in ADEC (2010a) guidance:

- Analytical data sufficient for adequate site characterization were available.
- Data were collected consistent with ADEC and USEPA guidance.
- Sampling and analytical procedures gave accurate constituent-specific concentrations.

- Level two data validation was performed on analytical laboratory data used for this evaluation. Validation reports for the 2011 soil and groundwater data, and for the 2012 pore-water data prepared by SWI, were included in the Revised Site Characterization Report (Barr 2012). Level four data validation was performed on the 2010 sulfolane in soil analyses.

- Method detection limits and sample quantitation limits were below screening criteria.

- Qualified data were used in the risk assessment; potential bias from qualified data and how it might result in an over or under estimation of risk is discussed in Section 4.5.

- Rejected data were not used for risk assessment purposes.

- For a given well, if all samples were reported as non-detects, then the lowest detection limit associated with any sampling event at that well was used to represent the well.

- If a well had both detected concentrations and reported non-detects for a given COPC, then the non-detect was represented by a value equal to one-half the detection limit associated with that COPC in that sampling event.

Offsite groundwater has been sampled at monitoring wells and private residential wells. At the request of ADEC, the off-site area was delineated into smaller EUs for the purposes of the 95% UCL evaluation. Accordingly, ARCADIS developed three separate EUs (e.g., EU-1, EU-2 and EU-3) for statistical evaluation. These EUs were based on estimated sulfolane isocontour lines developed from fourth quarter 2011 groundwater sampling data, and generally reflect spatially contiguous areas that represent certain ranges of concentration and portions of the sulfolane plume in groundwater. Some data points outside of the concentration range are present within each of the defined EUs and are the result of data collected from well screens of varying depths. These data points were included in the analysis, because it is reasonable to assume that any hypothetical exposures to water from drinking water wells within any given unit may also include exposures to groundwater generated at varying depths. The EUs are bounded by the concentration contours of greater than (>) 100 µg/L, >25 µg/L and detectable sulfolane (Figure 3-3). These contour intervals were selected and drawn using the combined offsite well data set and are based on best professional judgment. Guidance presented in the Data Quality Assessment: Statistical Methods for Practitioners (USEPA 2006a) was considered during selection of the off-site groundwater dataset(s). The data from wells within a given EU were used to estimate the 95% UCL on the mean concentration as a health-protective and representative EPC. ProUCL version 4.1 (USEPA 2011b) was used to derive the 95% UCL on the mean of the constituent concentrations.

The utility of the soil and groundwater analytical data identified in the SWI (2000 and 2001) contaminant characterization studies conducted for the site was evaluated for the HHRA. The characterization study conducted at the site in 2001 was performed to collect additional soil and groundwater data to address data gaps from the site investigation conducted in 2000. In general, for both media, the analytical methods used included those for GRO, DRO, RRO, BTEX, selected metals, VOCs, SVOCs and sulfolane (for groundwater only).

4.1.2.2 Constituents of Potential Concern

COPCs have been identified from a list of potential COIs, such as those that were likely used or spilled at the site. COPCs for each dataset were carried through the HHRA process.

Preliminary lists of COIs and COPCs in soil and groundwater at the site were presented in the Site Characterization and First Quarter 2011 Groundwater Monitoring Report (Barr 2011). The lists were revised in the Addendum (ARCADIS 2011b) based on the ADEC (2011a) Comment Matrix on the site characterization report. The lists of preliminary COIs and COPCs were also presented in the RAWP (ARCADIS 2011a).

As noted in the RAWP (ARCADIS 2011a), the list of COIs was developed according to the following process:

1. FHRA compiled a list of spills based on staff interviews, refinery records and a review of spill records retained by the ADEC.

2. The list of spills was refined by eliminating:

    a. Spills less than 10 gallons.
    b. Spills that were reportedly contained.
    c. Spills that were remediated and had confirmation sampling.

For many spills on the list, the material spilled was specific to one ingredient (e.g., propylene glycol) or was a material with obvious and limited ingredients (e.g., kerosene). However, the individual ingredients (e.g., oily water) of the other materials reportedly spilled were not provided. Refinery specialists such as chemists, wastewater experts and production leads were consulted to apply operational knowledge of the refinery to determine the ingredients that made up this set of materials. By this process, the list of spills was then distilled down to the “ingredients” or the primary constituents that make up the material spilled. This ingredient list was also compared to constituents that had been included in laboratory analyses of facility wastewater. The resulting ingredient list was then used to make up a list of COIs for the site. The COI list also included constituents that were analyzed during previous site characterization studies, regardless of whether they were detected above the PQL. The list of COIs for the site is shown in Table 3-1. Constituents in the ingredient list that were analyzed for but not detected were not removed from this list. If a constituent was previously detected at the site and/or was included in the ingredient list, it was considered a COI.

Table 3-1 indicates if a constituent was previously analyzed in soil or groundwater samples collected at the site. Table 3-1 also indicates if a constituent was included in the ingredient list; the last four columns of the table summarize whether toxicity data are available from the IRIS (USEPA 2012a).

For this Revised Draft Final HHRA, maximum detected concentrations and/or the laboratory reporting limits of COIs in soil and groundwater are compared with ADEC screening levels corresponding to a 1 x 10^{-6} target ELCR and 0.1 target HQ, as shown in Table 3-2a. COI soil concentrations were compared with ADEC screening levels protective of potential migration to groundwater based on a zone with less than 40 inches of annual precipitation, direct-contact exposures and outdoor inhalation (ADEC 2008a [Table B-1 of 18 AAC 75, Method Two]). If ADEC soil screening levels were unavailable, then COI concentrations in soil were compared with USEPA RSLs (USEPA 2011c), adjusted to a target ELCR of 1 x 10^{-6} (if necessary) and a HQ equal to 0.1, for the applicable exposure pathway. Soil screening levels for GRO, DRO and RRO were from ADEC (2008a) Table B-2 Method Two. COI groundwater concentrations were compared with ADEC groundwater screening levels (ADEC 2008a; Table C). If ADEC groundwater screening levels were unavailable, then COI concentrations were compared with USEPA RSLs (USEPA 2011c) based on tapwater ingestion.

The higher of either the maximum COI concentration detected above the laboratory reporting limit or maximum detection limit was compared with the selected ADEC screening levels. The selected soil screening levels were based on the lesser of the migration to groundwater, $^{1}/_{10}$ the direct contact or $^{1}/_{10}$ the outdoor air screening levels. COIs with concentrations exceeding the selected soil screening level were identified as COPCs. Table 3-2a lists the COPCs identified in soil and groundwater based on ADEC (2010a) COPC selection guidance applied to the COIs identified in Table 3-1.

The preliminary COPCs identified at the site, as presented in Table 3-2a, are COIs that were detected in site media and exceeded ADEC screening levels. COIs not detected in site media but that had practical quantitation limits exceeding ADEC screening levels and COIs identified by the refinery as ingredients that could have been released are also considered COPCs. Arsenic was eliminated as a COPC in groundwater based on published background concentrations for the area of the site (U.S. Geological Survey 2001). However, it was retained as a COPC in soil in the RAWP (ARCADIS 2011a). An evaluation of the 2011 arsenic in soil data was presented in the Revised Site Characterization Report (Barr 2012). Based on this evaluation, it is likely that the presence of detectable arsenic in soil samples collected at the site is attributable to background concentrations. No other metal COIs were eliminated from the list of COPCs based on background concentrations. In accordance with ADEC (2010a) guidance, Table 3-2a has been provided to the ADEC in Microsoft® Excel format.

Table 3-2b summarizes COPCs by environmental media.

4.1.2.3 Data Gaps

Based on a review of the preliminary human health CSMs and available analytical data for environmental samples collected at the site, and discussions held during the June 24, 2011 Risk Assessment Scoping Meeting, four potential risk assessment data gaps were indicated:

- Limited surface soil data were available for the evaluation of potential risks and hazards to onsite human receptors.
- Onsite containment of COPCs other than sulfolane must be supported.
- Possible connection between groundwater at the site and surface water must be determined.
- No soil gas data were available to evaluate onsite vapor intrusion concerns.

4.1.2.4 Sampling Plans to Address Data Gaps

Sampling plans for additional data collection are described in the Addendum (ARCADIS 2011b). With respect to risk assessment data gaps identified in Section 3.1.2.3, the following field activities have been conducted:

- Onsite soil assessment activities, to characterize soil impacts and provide data for risk assessment activities. The soil data collected in 2011 adequately characterized the nature and extent of surface and subsurface impacts for the purposes of this HHRA evaluation. Additional sampling is planned for 2012 to complete characterization for the purposes of a remediation feasibility study. The 2011 soil data were validated and included in this evaluation.
- Additional groundwater sampling, during the third and fourth quarters 2011, confirmed that no other COPCs (except sulfolane) have migrated offsite.
- A pore-water investigation was conducted to better characterize sulfolane concentrations in the groundwater/surface-water interface and the potential for surface-water sulfolane impacts. The March 2012 samples were collected when the adjacent surface-water body was frozen; therefore, the degree of connectivity with surface water, if any, could not be established. Therefore, the piezometer samples were likely more representative of groundwater. Because sulfolane degrades more rapidly in the presence of nutrients and oxygen that would be present in the surface water (ADHSS 2010), and given the limited groundwater-surface water interchange adjacent to a frozen surface-water body, the groundwater collected adjacent to two of the three surface-water bodies in 2012 likely overestimates the

surface water concentrations at those locations. The data presented in this Revised Draft Final HHRA provide a health-protective estimate of risk to swimmers.

Soil gas data were not collected to evaluate potential vapor intrusion concerns. Instead, onsite groundwater data were used to evaluate the vapor intrusion exposure pathway. All onsite groundwater analytical data collected during the last 2 years (2009 through 2011) were used to predict indoor air concentrations of volatile COPCs and to estimate risks and hazards to current and future onsite indoor commercial workers. The maximum detected groundwater concentration for each COPC was used as the source term for J&E groundwater-to-indoor air modeling (USEPA 2004b) in the maximum exposure scenario. The 95% UCL concentration calculated from the average concentration in each onsite well was used as the source term in the 95% UCL scenario.

4.1.3 Quantification of Exposure

The objective of the exposure assessment was to estimate the type and magnitude of potential receptor exposure to COPCs. Results of the exposure assessment were then combined with constituent-specific toxicity values in the toxicity assessment (see Section 4.2) to characterize potential risks (USEPA 1989).

4.1.3.1 Dose/Intake Equations

Exposures were quantified using standard exposure equations consistent with RAGS (USEPA 1989, 1991, 2004a and 2009a) for the potentially complete exposure pathways identified in Section 4.1.1.4.

The general algorithms presented below were used to estimate the LADD for carcinogenic compounds and the ADD for noncarcinogenic COPCs for direct-contact pathways (i.e., ingestion and dermal contact) by combining environmental media concentrations with the receptor-specific exposure parameters that constitute “intake factors.” Both the ADD and the LADD are in units of mg/kg-day (USEPA 1989). For inhalation exposure pathways, exposure was estimated as an AEC for noncarcinogenic COPCs or LAEC for carcinogenic COPCs. Both the AEC and the LAEC are in units of mg/m^3 (USEPA 2009a).

The dose equations and parameter descriptions used are provided in the following subsections.

4.1.3.1.1 Incidental Ingestion of Soil

The doses of COPCs associated with incidental ingestion of soil were calculated as follows:

$$\text{Dose} = \underline{\quad EPC_s * IR_s * FI * EF * ED * CF \quad} * RAF$$

$$BW * AT$$

Where:

Dose = ADD or LADD (mg/kg-day)

EPC_s = EPC in soil (mg/kg)

IR_s = soil ingestion rate (milligrams soil per day)

FI = fraction ingested (unitless)

EF = exposure frequency (days per year)

ED = exposure duration (years)

CF = conversion factor ($1x10^{-6}$ kg/mg)

BW = body weight (kg)

AT = averaging time (days), for carcinogens is equal to 70 years * 365 days per year, and for noncarcinogens is equal to ED * 365 days per year

RAF = relative absorption factor (unitless), assumed to equal 1

The USEPA (1989) defines FI as a "pathway-specific" value that should be applied to consider constituent location and population activity patterns. FI accounts for the fraction of the site covered with asphalt or vegetation, which reduces potential exposure. Following the ADEC's (2010a) guidance, an FI of 1 was assumed for the current and future onsite outdoor commercial/industrial worker and future onsite construction/trench worker to provide a health-protective estimate of risk.

4.1.3.1.2 Dermal Contact with Soil

Absorbed doses of constituents associated with dermal contact with soil were calculated as follows:

$$Dose = \frac{EPC_s * SSA_s * AF * FC * ABS_d * EV_s * EF * ED * CF}{BW * AT}$$

Where:

Dose = ADD or LADD (mg/kg-day)

EPC_s = EPC in soil (mg/kg)

SSA_s = SSA available for contact (cm^2/event)

AF = soil-to-skin adherence factor (mg/cm^2-event)

FC = fraction in contact with soil (unitless)

ABS_d = dermal absorption factor (unitless)

EV_s = event frequency (soil) (events/day), assumed to be 1 per day unless otherwise noted

EF = exposure frequency (days/year)

ED = exposure duration (years)

CF = conversion factor (1×10^{-6} kg/mg)

BW = body weight (kg)

AT = averaging time (days), for carcinogens is equal to 70 years * 365 days per year, and for noncarcinogens is equal to ED * 365 days per year

Constituent-specific dermal parameters, such as SSA_s, AF and ABS_d were provided from USEPA (2004a) RAGS Part E. ABS_d are presented in Table 3-13.

Similar to FI for the soil ingestion pathway, FC was added to the dermal contact equation to account for the fraction of the site covered with asphalt or vegetation, which reduces potential exposure. Following the ADEC's (2010a) guidance, an FC of 1 was assumed for the current and future onsite commercial/industrial worker and future onsite construction/trench worker to provide a health-protective estimate of risk.

4.1.3.1.3 Ingestion of Groundwater

The doses of COPCs associated with ingestion of groundwater were calculated as follows:

$$\text{Dose} = \frac{EPC_w * IR_w * EF * ED}{BW * AT}$$

Where:

Dose = ADD or LADD (mg/kg-day)

EPC_w = EPC in water (mg/L)

IR_w = water ingestion rate (liters water/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT = averaging time (days), for carcinogens is equal to 70 years * 365 days per year, and for noncarcinogens is equal to ED * 365 days per year

4.1.3.1.4 Dermal Contact with Groundwater

Absorbed doses of constituents associated with dermal contact with groundwater were calculated as follows:

$$\text{Dose} = \frac{DA_{event} * SSA_w * EV_w * EF * ED}{BW * AT}$$

Where for organics ($t_{event} \leq t^*$):

$$DA_{event} = 2 * FA * K_p * EPC_w * CF * \sqrt{\frac{6 * \tau_{event} * t_{event}}{\pi}}$$

Where for organics ($t_{event} > t^*$):

$$DA_{event} = FA * K_p * EPC_w * CF * \left[\left(\frac{t_{event}}{(1+B)}\right) + \left(2\tau_{event}\left[\frac{1+3B+3B^2}{(1+B)^2}\right]\right)\right]$$

Where for inorganics:

$$DA_{event} = K_p * EPC_w * CF * t_{event}$$

Dose = ADD or LADD (mg/kg-day)

DA_{event} = dose per event (mg/cm^2-event)

SSA_w = SSA available for contact with water (cm^2/event)

EV_w = event frequency (water) (events/day), assumed to be 1 per day unless otherwise noted

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

t* = time to reach steady state (hours), equivalent to 2.4 x τ_{event}

AT = averaging time (days), for carcinogens is equal to 70 years * 365 days per year, and for noncarcinogens is equal to ED * 365 days per year

FA = fraction absorbed (unitless)

K_p = permeability coefficient (centimeter/hour)

EPC_w = EPC in water (mg/L)

CF = conversion factor ($1x10^{-3}$ liters per cubic centimeter)

τ_{event} = lag time per event (hours/event)

B = permeability ratio (unitless)

t_{event} = event duration (hours/event)

4.1.3.1.5 Inhalation of Outdoor or Indoor Air

Exposure concentrations associated with the inhalation of vapors or particulates in outdoor or indoor air are calculated using USEPA (2009a) RAGS Part F methodology as follows:

$$\text{AEC or LAEC} = \frac{EPC_a * EF * ED * ET}{AT}$$

Where:

AEC or LAEC = average or lifetime exposure concentration in air (µg/m^3)

EPC_a = EPC in outdoor or indoor air (µg/m^3)

EF = exposure frequency (days/year)

ED = exposure duration (years)

ET = exposure time (hours/day)

AT = averaging time (hours), for carcinogens is equal to 70 years * 365 days per year * 24 hours per day, and for noncarcinogens AT is equal to ED (in years) * 365 days per year * 24 hours per day

4.1.3.1.6 Ingestion of Homegrown Produce

Groundwater from the site may be used to irrigate locally grown crops, creating the potential for sulfolane to be taken up into plants that are then consumed by humans. In the few studies that have been conducted on the topic of uptake in plants, sulfolane has been demonstrated to be taken up into plants as the result of the constituent's high miscibility with water. Sulfolane is carried, along with water, through the roots, into the xylem and ultimately into the leaves of the plants. When water is lost through the leaves due to evapotranspiration, the sulfolane, due to its low volatility, tends to remain in the leaves where it may accumulate. Based on this information, it is assumed that if sulfolane is taken up by plants, it would predominantly be present in the leaves rather than in the roots or fruit.

This assumption is corroborated by the Final Results of the North Pole Garden Sampling Project (ADEC 2011b), which demonstrated that concentrations in roots were substantially lower than those in the stems and leaves. In the ADEC (2011b) study, which was led by ADHSS, 27 types of plant parts from multiple gardens irrigated with sulfolane-containing groundwater were collected from July to September 2010. Approximately one-half of the plant samples were reported as not detected, but 14 of the plant types tested were confirmed to contain sulfolane, primarily in the leaves and stems. Using data from the Final Results of the North Pole Garden Sampling Project (ADEC 2011b), the ADHSS evaluated the potential for risk to consumers of vegetables irrigated with sulfolane-containing water and concluded that sulfolane levels in the plants were low and not likely to cause any adverse health effects. However, because of the limited number of gardens sampled and the fact that the data were collected during only one growing season, the results of the investigation were considered preliminary and the exposure pathway was further evaluated in this assessment.

Following USEPA (2005) guidance, bioaccumulation of sulfolane in locally grown crops was evaluated using a biotransfer factor to estimate concentrations in plant tissues based on groundwater concentrations. There are no accepted values developed for sulfolane, but there is evidence to suggest that the uptake of sulfolane does not follow standard models based on partitioning coefficients (e.g., K_{ow}); therefore, an appropriate surrogate was not identified. Given the lack of constituent-specific information available in the literature, the ADEC has requested use of a factor of 1. Use of this value assumes that the concentration of sulfolane in the edible portions of the plant tissues is equivalent to the concentration of sulfolane in groundwater. To allow a direct risk comparison between this and the PPRTV Scenario, with only the toxicity criteria differing, ARCADIS has adopted this BCF for the purposes of this scenario.

After estimating the EPC, the doses of sulfolane associated with resident ingestion of homegrown fruits and vegetables were calculated using the following equation:

$$\text{Dose} = \frac{EPC_p * (IRP_{fr} + IRP_{vg}) * FI * EF * ED * CF}{BW * AT}$$

Where:

Dose = ADD (mg/kg-day)

EPC_p = EPC in produce (mg/kg) = EPC_w * BCF

Where:

EPC_w = EPC in water (mg/L)

BCF = water-to-produce bioconcentration factor (unitless)

IRP_{fr} = fruit ingestion rate (mg/day)

IRP_{vg} = vegetable ingestion rate (mg/day)

FI = fraction ingested (unitless)

EF = exposure frequency (days/year)

ED = exposure duration (years)

CF = conversion factor (1×10^{-6} kg/mg)

BW = body weight (kg)

AT = for the noncarcinogen sulfolane is equal to ED * 365 days per year

For the ARCADIS Comparative Scenario, the same produce consumption rates described for the PPRTV Scenario (Table 3-12) were used.

4.1.3.1.7 Ingestion of Surface Water

The doses of sulfolane associated with ingestion of surface water while swimming were calculated as follows:

$$\text{Dose} = \frac{EPC_w * ET * EF * ED * CR_w}{BW * AT}$$

Where:

Dose = ADD (mg/kg-day)

EPC_w = EPC in water (mg/L)

ET = exposure time (hours per day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

CR_w = contact rate of surface water (liters/hour)

BW = body weight (kg)

AT = for the noncarcinogen sulfolane is equal to ED * 365 days per year

For this Scenario, as shown in Table 3-12, the offsite adult and child recreational user surface-water ingestion rates of 0.071 and 0.12 liter/hour, respectively, were based on the upper percentile values for swimmers presented in the USEPA (2011a) EFH Table 3-5 representing the maximum ingestion rate for adults and the 97th percentile ingestion rate for children age 18 and under. Adult and child recreational users were assumed to swim for 30 and 6 years, respectively, for 60 days per year for 1 hour per day.

4.1.3.2 Exposure Point Concentrations

Per ADEC (2010a) guidance, "the exposure point concentration is used to assess risk and should be estimated using a 95% UCL on the mean of the contaminant concentrations." The EPC represents the average concentration of a COPC in an environmental medium that is potentially contacted by a receptor during the exposure period (USEPA 1989). The USEPA (1989) also recommends the use of the 95%

UCL as a conservative estimate of the EPC, because it represents the average concentration for which we have 95 percent confidence that the true mean concentration has not been exceeded. Unless there is site-specific evidence to the contrary, an individual receptor is assumed to be equally exposed to media within all portions of the EU during the time of the risk assessment (USEPA 2002c). For this HHRA ADEC has also requested evaluation of maximum COPC concentrations in groundwater as EPCs in the ARCADIS Comparative Scenario. Note that the ADEC Draft Risk Assessment Procedures Manual was updated during preparation of this HHRA (ADEC 2011c). The updated manual includes guidance on the use of maximum groundwater concentrations for EPCs. Because groundwater data collected from off-site wells indicate that offsite sulfolane concentrations are generally not increasing, the use of the maximum concentration will overestimate the true risk for most, actual receptors.

EPCs are estimated separately for each medium. Consistent with USEPA (2006b, 2007) guidance, surface soil, subsurface soil and groundwater EPCs were estimated using the 95% UCL of the mean for datasets with at least eight samples and at least five detected values. For this HHRA, a “dataset” was considered the aggregate of samples for one COPC, for one pathway, within a particular EU (onsite or offsite). Calculation of a 95% UCL depends on the distribution of the dataset and variability in the data. To assess statistical validity, data evaluation, distribution testing and 95% UCL calculations were performed using the USEPA’s ProUCL version 4.1 (http://www.epa.gov/osp/hstl/tsc/software.htm) and according to the recommendations provided in the associated technical documentation (USEPA 2006, 2007, 2011b). Analytical data used for the HHRA are provided in Appendix A and ProUCL output files are included in Appendix B. For datasets with fewer than eight samples or fewer than five detected values, the EPC was the maximum detected concentration. Soil and groundwater datasets for most COPCs have more than eight samples each.

To combine data collected from monitoring wells and private residential wells, individual well means were calculated. The following methods were used to normalize the groundwater data in a manner that provides equal representation between wells with different numbers of observations:

- For a given well, if all samples were reported as non-detects, then the lowest detection limit associated with any sampling event at that well was used to represent the well.
- If a well had both detected concentrations and reported non-detects for a given COPC, then any non-detect was represented as one-half the detection limit associated with that sampling event for that COPC.

With the individual well means calculated as described above, ProUCL was used to estimate the 95% UCL of the mean of sulfolane across all wells in an EU (Figure 3-3). EU-1 represents approximate sulfolane concentrations in groundwater of ≥100 µg/L, EU-2 where detected sulfolane concentrations range from ≥25 to 99.9 µg/L, and EU-3 where sulfolane was from not detected above the laboratory reporting limit to 24.9 µg/L. Given the sizable area of each EU, some results included in the data analyses are different from others in each EU. For example, some non-detect results occur in EU-1 and EU-3. These values are primarily attributable to groundwater samples collected from variable screen depths. It is reasonable to assume that groundwater extracted from a variety of screen lengths may be ingested by potential receptors that might use groundwater as drinking water. Therefore, these data points were included in the EPC calculations for each EU. Non-detect observations for the COPCs in soil and groundwater were addressed using the methods described above.

In addition, per ADEC (2010a) guidance for duplicate samples, the highest detected value from the primary and duplicate samples was used to represent that sample result. For any COPC, if the 95% UCL COPC of the mean concentration exceeded the maximum detected concentration, then the maximum detected concentration was the EPC. Summary statistics for the COPCs are presented in the risk characterization, including detection frequency, number of samples, minimum and maximum detected concentrations, and calculated 95% UCL concentrations.

The same EPCs used for the PPRTV scenario (Tables 3-3 through 3-10) were used in the ARCADIS Comparative Scenario. EPCs were estimated separately for each exposure medium:

- Surface soil (0 to 2 feet bgs; see Table 3-3 for 95% UCL COPC concentrations
- Subsurface soil (0 to 15 feet bgs; see Table 3-4a for maximum COPC concentrations and Table 3-4b for 95% UCL COPC Concentrations Onsite groundwater (see Table 3-5a for maximum COPC concentrations Table 3-5b for 95% UCL COPC Concentrations
- Offsite groundwater in all wells (see Table 3-6 for maximum sulfolane concentration)
- Offsite groundwater in EU-1 (see Table 3-7 for 95% UCL sulfolane concentration)
- Offsite groundwater in EU-2 (see Table 3-8a for maximum sulfolane concentration Table 3-8b for 95% UCL sulfolane concentration)
- Offsite groundwater in EU-3 (see Table 3-9a for maximum sulfolane concentration Table 3-9b for 95% UCL sulfolane concentration)
- Offsite surface water (see Table 3-10 for maximum sulfolane concentration from pore water).

Soil, groundwater, outdoor air, indoor air, homegrown produce and surface-water EPCs are further discussed below.

4.1.3.2.1 Soil Exposure Point Concentrations

Onsite receptors may potentially contact surface soil or a combination of surface and subsurface soil. According to ADEC guidance 18 AAC 75.340(j)(2), “human exposure from ingestion, direct contact or inhalation of a volatile substance must be attained in the surface soil and the subsurface soil to a depth of at least 15 feet, unless an institutional control or site conditions prevent human exposure to the subsurface” (ADEC 2008c). Currently and in the future, FHRA will have institutional controls in place (i.e., permits) that provide worker protection (i.e., appropriate personal protective equipment) in the event of planned excavation of onsite soil. For this HHRA, two soil EPCs are calculated for each COPC. Surface soil is considered to occur from 0 to 2 feet bgs (Table 3-3) and subsurface soil is considered to occur from 0 to 15 feet bgs (Tables 3-4a and 3-4b). EPCs for soil were calculated using the 95% UCL on the mean of the dataset for surface soil exposures, or the maximum detected COPC concentrations for surface and subsurface soil exposures (relevant to potential onsite construction/trench workers).

4.1.3.2.1.1 Surface Soil Exposure Point Concentrations

For this HHRA, it is presumed that onsite commercial/industrial workers may potentially contact surface soil onsite that is not covered with pavement or vegetation. Therefore, surface soil EPCs were calculated and used to evaluate potential exposure by onsite commercial/industrial workers, using analytical data from the surface soil dataset in uncovered portions of the site (i.e., soil samples collected from ground surface to 2 feet bgs). The 95% UCL of the mean concentrations of COPCs in surface soil collected from 0 to 2 feet bgs were used to evaluate:

- Direct-contact exposure pathways to onsite outdoor commercial/industrial workers
- Potential inhalation of fugitive windborne dust from onsite surface soil by onsite outdoor commercial/ industrial workers, offsite residents and offsite outdoor commercial/industrial workers.

4.1.3.2.1.2 Surface and Subsurface Soil Exposure Point Concentrations

The 95% UCL of the mean concentrations of surface soil collected from 0 to 2 feet bgs were used to evaluate direct-contact exposure pathways to onsite outdoor commercial/industrial workers, and potential inhalation of fugitive windborne dust from onsite soil by onsite and offsite outdoor commercial/industrial workers. The onsite construction/trench worker may be directly exposed to surface and subsurface soil during excavation activities. Therefore, EPCs for evaluating exposure by the onsite construction/trench worker were generated using analytical data from the combined surface and subsurface soil dataset (i.e., soil samples collected from ground surface to as deep as 15 feet bgs). The maximum detected concentrations in the combined surface and subsurface soil sample dataset were used to estimate surface and subsurface soil EPCs for direct-contact pathways for the onsite construction/trench worker because that exposure may be localized rather than averaged over the entire site. In addition, in accordance with ADEC guidance (2010a), surface and subsurface soil EPCs based on the 95% UCLs were also used to evaluate potential exposures by the construction/trench worker.

4.1.3.2.2 Groundwater Exposure Point Concentrations

For COPCs in groundwater, COPC EPCs were distinguished for both on- and offsite potential exposures as described in the following sections.

4.1.3.2.2.1 Onsite Groundwater Exposure Point Concentrations

Groundwater EPCs were used to estimate direct-contact exposure (i.e., dermal contact) by the onsite outdoor worker and incidental ingestion and dermal contact by onsite construction/trench workers during excavation activities. Groundwater COPC EPCs based on 95% UCL concentrations were estimated using the last 2 years of data (i.e., 2009 to 2011) collected from onsite groundwater monitoring wells. In addition to evaluating the potential exposures to COPCs in groundwater over an EU using 95% UCL concentrations, the ADEC also requested that groundwater EPCs be calculated using the maximum detected concentration during the last 2 years of groundwater monitoring (see Tables 3-5a and 3-5b).

4.1.3.2.2.2 Offsite Groundwater Exposure Point Concentrations

Offsite sulfolane groundwater EPCs were used to estimate direct-contact exposure (i.e., incidental ingestion) by offsite construction/trench workers during excavation activities and to estimate direct-contact exposure (i.e., ingestion) by offsite residents and commercial/industrial receptors. In addition to evaluating the potential exposures to sulfolane in groundwater using a 95% UCL concentration for each of the EUs depicted on Figure 3-3, the ADEC also requested risk calculations using the maximum detected sulfolane concentration during the last 2 years of groundwater monitoring (i.e., 2009 to 2011), applied to the entire offsite area. EPCs for the ARCADIS Comparative Scenario were derived for each offsite EU identified on Figure 3-3 including:

- All offsite wells (Table 3-6), evaluated using the maximum offsite concentration as the EPC
- EU-1 (Table 3-7), evaluated using the 95% UCL concentration in offsite wells in EU-1
- EU-2 (Table 3-8a for maximum concentrations and Table 3-8b for 95% UCL concentrations)
- EU-3 (Table 3-9a for maximum concentrations and Table 3-9b for 95% UCL concentrations.

In summary, the maximum detected concentrations of sulfolane in offsite groundwater from EU-1, EU-2 and EU-3 were used to estimate risks and hazards for relevant receptors for the ARCADIS Comparative

Scenario. In addition, for each EU, EPCs based on the 95% UCL were also used to estimate risks and hazards for relevant receptors at each of the offsite groundwater offsite EUs (EU-1, EU-2 and EU-3), per USEPA (1989) guidance and ARCADIS professional judgment.

4.1.3.2.3 Outdoor Air Exposure Point Concentrations

In accordance with the USEPA (1989), exposure to constituents in outdoor air was evaluated as exposure to fugitive dust emissions (for non-VOCs, from soil only) or volatile emissions (for VOCs, from soil or groundwater). The USEPA (2002b) recommendations for media transfer factors to evaluate these exposures are described below.

4.1.3.2.3.1 Estimating Outdoor Air Exposure Point Concentrations from Soil Concentrations

A PEF for non-volatile COPCs was used to estimate EPCs in outdoor air from soil. The industrial PEF (1.36×10^9 m^3/kg) obtained from the Supplemental Guidance for Developing Soil Screening Levels for Contaminated Sites (USEPA 2002b) was used to estimate outdoor air EPCs of non-volatile COPCs for onsite outdoor commercial/industrial workers and construction/trench workers potentially exposed to particulate emissions from soil.

A VF for VOCs was used to estimate EPCs of volatile COPCs in outdoor air from soil (VF_{soil}). Outdoor air EPCs were estimated for the onsite outdoor commercial/industrial worker and onsite construction/trench worker using the EPC for the combined surface and subsurface soil dataset. Constituent-specific VFs_{soil} were obtained from the USEPA (2011c) RSL spreadsheets, where they exist, to estimate outdoor air EPCs of volatile COPCs for onsite outdoor commercial/industrial workers and construction/trench workers potentially exposed to volatile COPCs emanating from surface and subsurface soil. For volatile COPCs not listed in the USEPA's RSL table, VFs were derived according to USEPA guidance (USEPA 2002b). If not otherwise obtained from RSL spreadsheets, the VFs used in this assessment are shown on Table 3-11.

The following equation was used to calculate outdoor air EPCs from soil EPCs using either a PEF or VF_{soil}:

$$EPC_a = \frac{EPC_s}{PEF \text{ or } VF_{soil}}$$

Where:

EPC_a = EPC in air (mg/m^3)

EPC_s = EPC in soil (mg/kg)

PEF = particulate emission factor (m^3/kg)

VF_{soil} = volatilization factor (soil) (m^3/kg)

4.1.3.2.3.2 Estimating Outdoor Air Exposure Point Concentrations from Groundwater Concentrations

Construction workers (i.e., trench workers) may also be exposed to VOCs released from shallow groundwater that may pool in a trench and volatilize to trench air. Groundwater occurs as shallow as 8 feet bgs in portions of the site. To estimate the potential concentrations of COPCs that could volatilize from groundwater to trench air, volatilization factors (VF_{gw}) obtained from the Virginia Department of Environmental Quality (2012) were used to estimate trench air EPCs from groundwater. The trench air EPCs were used to evaluate potential exposures by on and offsite construction/trench workers potentially exposed to volatile COPCs emanating directly from shallow groundwater in an excavation trench. The equation for using VF_{gw} to calculate trench air EPCs from groundwater EPCs is as follows:

$$EPC_a = EPC_{gw} * VF_{gw}$$

Where:

EPC_a = EPC in trench air (mg/m^3)

EPC_{gw} = EPC in groundwater (mg/L) (see Section 4.1.3.2.2 for discussion about on and offsite groundwater EPCs)

VF_{gw} = volatilization factor (groundwater) (liter per cubic meter)

For onsite exposures, the trench air EPCs are presented in Table 3-5a (maximum EPC) and Table 3-5b (95% UCL EPC). For offsite exposures, the trench air EPCs are presented in Tables 3-6 through 3-9b.

Onsite construction/trench workers may potentially be exposed to vapors emanating from soil during trench excavation. Therefore, potential exposures to volatile EPCs in trench air from both soil and shallow groundwater sources, as well as COPCs as fugitive dust from soil were estimated for onsite construction/trench workers. For offsite construction/trench workers, sulfolane in trench air from offsite groundwater is the only potential exposure onsite.

4.1.3.2.4 Indoor Air Exposure Point Concentrations

The Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (USEPA 2002a), Vapor Intrusion Pathway: A Practical Guide (ITRC 2007a) and Vapor Intrusion Pathway: Investigative Approaches for Typical Scenarios (ITRC 2007b) were used to assess vapor intrusion. The J&E model was used to estimate indoor air concentrations resulting from intrusion of vapors from sub-slab soil gas into onsite buildings. The J&E model is a one-dimensional, screening-level model used to evaluate subsurface vapor intrusion into buildings. It incorporates both convective and diffusive mechanisms to estimate the transport of constituent vapors emanating from soil gas into indoor spaces located directly above the source (J&E 1991, USEPA 2004b). When estimating the concentration of COPC vapors in indoor air, the J&E model assumes the following:

- Constant, infinite source of constituents (e.g., in groundwater or soil gas)
- Steady-state diffusion through the unsaturated zone
- Convective and diffusive transport through the basement floor or slab
- Complete mixing within the building, estimated using an air exchange rate.

Due to the uncertainties associated with partitioning from soil to soil gas, ITRC (2007b) does not recommend using soil data as a source of COPCs to evaluate potential vapor intrusion. Therefore, source concentrations were estimated using the groundwater data as discussed in Section 2.6.2. Source concentrations for the model consisted of the groundwater EPCs based on maximum detected COPC concentrations in groundwater as well as the 95% UCL of the mean groundwater concentrations (see Section 4.1.3.2.2). Site-specific parameters, such as soil type and average soil temperature, were used in the J&E model where available. The top 3 to 5 feet of soil was assumed to be sand. Geotechnical data show that this depth interval is silty sand. An average soil temperature of 5 °C was used. The remaining parameter values, including constituent-specific parameter values, were estimated using the default values provided by the USEPA (2004b) in the User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings and the associated model spreadsheets. Appendix C presents the results of the USEPA’s J&E-based model to predict indoor air COPC concentrations from COPC concentrations in onsite groundwater. For onsite exposures, the indoor air EPCs are presented in Table 3-5a (maximum EPC) and Table 3-5b (95% UCL EPC). For offsite exposures, the indoor air EPCs are presented in Tables 3-6 through 3-9b.

4.1.3.2.5 Homegrown Produce Exposure Point Concentrations

Residents who consume homegrown produce that has been irrigated with offsite groundwater were evaluated. Homegrown produce EPCs were calculated using BCFs applied to offsite groundwater EPCs (Tables 3-6 through 3-9b). The Final Results of the North Pole Garden Sampling Project (ADEC 2011b) showed that sulfolane was taken up into garden plants at concentrations below adult risk-based screening criterion developed by the ADHSS. However, a BCF equal to 1 was used predict uptake of sulfolane into both aboveground and belowground vegetables, as described in Section 3.1.3.1.6.

4.1.3.2.6 Surface-Water Exposure Point Concentrations

Recreational users who ingest surface water that has migrated from groundwater beneath the site were evaluated. The maximum detected concentration of sulfolane collected during the 2012 field season from adjacent to a frozen surface-water body was assumed to represent groundwater that has migrated offsite to downgradient water bodies. Summary statistics and the surface-water EPC are presented in Table 3-10.

4.1.3.3 Exposure Parameters

Exposure parameter values that were identified for each receptor at the site for the ARCADIS Comparative Scenario are provided in Table 3-12. The exposure parameters were identical to the exposure parameters used in the PPRTV Scenario, and were based primarily on those provided in ADEC (2010a) and USEPA (1989, 1991, 1997a and 2004a) as well as other sources, as noted. These exposure parameters meet or exceed the USEPA (1989) approach for estimating RME, which is the maximum exposure that is reasonably expected to occur in a population. Its intent is to estimate a high end exposure case (i.e., well above the average case) that is still within the range of possible exposures (USEPA 1989). Mathematically, the RME estimate for each exposure pathway combines high end values and assumptions with average values and assumptions. These assumptions tend to maximize estimates of exposure, such as choosing a value near the high end of the concentration or intake range. Therefore, the RME estimates tend to be at the high end of the exposure range, generally greater than the 90th percentile of the population.

4.1.3.4 Assessment of Potential Lead Exposures

The potential hazard associated with lead exposure was evaluated by comparing the predicted blood-lead concentrations to the CDC blood-lead threshold concentration. The threshold lead concentration is 10 µg/dL of whole blood based on potentially adverse neurological effects in children (CDC 2011). A blood-lead concentration of less than 10 µg/dL was deemed acceptable. The USEPA's (2009b) ALM model, which estimates the blood-lead levels of workers and the fetus of a pregnant worker, was used to evaluate the potential onsite exposure to lead in groundwater for the receptors evaluated.

4.2 Toxicity Assessment

The toxicity assessment identified toxicity values that relate exposure (dose) to potential risk or hazard for each COPC. Toxicity values derived from dose-response data were combined with estimates of exposure to characterize potential noncarcinogenic hazard and carcinogenic risk. Toxicity profiles were provided for risk/hazard drivers and sulfolane. Selection of toxicity values followed the hierarchies described below.

4.2.1 Noncarcinogenic Toxicity Values

Chronic and subchronic RfDs were used to evaluate potential adverse effects from ingestion, dermal and inhalation (dust) exposures to noncarcinogenic COPCs. Chronic RfDs, which correspond to 7 or more years of exposure, are specifically developed to be protective of long-term exposures to a constituent with a considerable margin of safety, which usually exceeds 1,000-fold. The USEPA (1989) defines the chronic RfD as “a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime.”

As described in detail in Appendix H, ARCADIS scientifically evaluated the existing RfDs and equivalent toxicological reference values for sulfolane and derived chronic and subchronic RfDs per its best professional judgment in accordance with USEPA guidance for evaluation of primary toxicology studies (USEPA 2002d, 2003) and the derivation of RfDs (USEPA 1994, 2002e). Additional context for these decisions is provided in Appendix K. For all other COPCs, the following sources were used to identify chronic toxicological reference values:

- USEPA (2012a) IRIS.
- USEPA PPRTVs, derived by the USEPA's Superfund Health Risk Technical Support Center for the USEPA Superfund program. Current values were obtained directly from the USEPA.
- CalEPA reference exposure levels from the California OEHHA.
- ATSDR MRLs (ATSDR 2012) Chronic MRLs were used to evaluate chronic exposure.
- USEPA (1997b) HEAST.

The USEPA (1989) defines exposures lasting between 2 weeks and 7 years as subchronic exposures. As a result, the short-duration and intermittent nature of construction/trench worker and child and infant exposures require consideration of subchronic toxicity values (subchronic RfDs) to estimate the potential for effects. Subchronic RfDs are developed to be protective of subchronic exposures to constituents with a considerable measure of safety, which usually exceeds 1,000-fold (USEPA 1989). Subchronic RfDs for ingestion (oral) and inhalation (dust and vapor) exposure were identified from the following sources, in the following order of priority, for constituents other than sulfolane:

- USEPA PPRTVs. Current values were obtained directly from the USEPA.
- ATSDR MRLs (ATSDR 2012). Intermediate MRLs were used to evaluate subchronic exposure.
- USEPA (1997b) HEAST.

For the ARCADIS Comparative Scenario, subchronic RfDs, if available, were used to evaluate potential exposures to onsite construction/trench workers and offsite infants given that the period of exposure for these potential receptors is less than 7 years. If subchronic RfDs were unavailable, then only chronic RfDs were used. Despite the 6 year exposure frequency of the child offsite resident, chronic RfDs were used in the ARCADIS Comparative Scenario to evaluate potential exposures to this receptor. Refer to Section 4.5 for a discussion of uncertainties related to the use of chronic values for the child receptor.

Current USEPA guidance recommends calculating a dermal RfD by multiplying the oral RfD by the ABSGI. This recommendation requires one of the following:

- A critical study upon which the toxicity value is based employed an administered dose (e.g., delivery in diet or by gavage) in its design.

- A scientifically defensible database exists that demonstrates that the gastrointestinal absorption of the constituent in question from a medium (e.g., water, feed) similar to the one employed in the critical study is significantly less than 100 percent (e.g., less than 50 percent).

Values for ABSGI were obtained from RAGS (USEPA 2004a). Chronic and subchronic RfDs are presented in Table 3-13.

4.2.2 Carcinogenic Toxicity Values

Oral CSFs and IUR factors were used to evaluate potential carcinogenic effects from ingestion, dermal and inhalation exposures to COPCs. CSFs quantitatively describe the relationship between dose and response. A CSF represents the 95% UCL of the slope of the dose-response curve and is derived using a low-dose extrapolation procedure that assumes linearity at low doses. By applying a CSF to a particular exposure level of a potential carcinogen, the upper bound lifetime probability of an individual developing cancer related to that exposure can be estimated.

CSFs have been developed for the oral and inhalation (dust particulates) exposure routes; IURs have been developed for the inhalation exposure route. CSFs for oral and IURs for inhalation exposures were identified from the following sources, in the following descending order of priority:

- USEPA (2012a) IRIS.
- USEPA PPRTVs. Current values were obtained directly from the USEPA.
- CalEPA (2012) OEHHA Toxicity Criteria Database.
- USEPA (1997b) HEAST.

As is the case for noncarcinogenic toxicity, the USEPA has not developed dermal CSFs for use in risk assessment. Dermal CSFs were calculated in a manner similar to that of noncarcinogenic RfDs for dermal exposure by dividing the oral CSFs by the ABSGI AF (USEPA 2004a). CSFs are presented in Table 3-13.

4.2.3 Sulfolane Toxicity Values

Toxicity values for sulfolane are not presented in IRIS (USEPA 2012a). However, a PPRTV chronic oral RfD of 0.001 mg/kg-day and a PPRTV subchronic oral RfD of 0.01 mg/kg-day have been prepared for sulfolane (USEPA 2012b). The study and approach used to develop the oral RfDs were evaluated to assess potential sulfolane exposures and hazards at the site. In addition, the studies and approaches used by several other regulatory agencies to derive oral RfDs or Public Health Action Levels were evaluated.

Based on a careful and extensive review of this information, ARCADIS derived and documented the ARCADIS oral RfDs of 0.01 mg/kg-day (chronic) and 0.1 mg/kg-day (subchronic).

The ARCADIS evaluation is outlined in Appendix H with complete reference citations. As explained there, the USEPA derived a PPRTV for sulfolane using a no adverse effect level (NOAEL) approach rather than deriving a benchmark dose as has been recommended in USEPA guidance (USEPA 2000a) since 2000 and is favored in the United States for derivation of toxicological reference values for HHRA. The USEPA stated that a benchmark dose could not be derived from the sulfolane data because of a lack of “fit” of the data. The USEPA did not explain why it did not proceed to log transform the data, a step that is appropriately taken per USEPA guidance and practice. When the sulfolane data are log transformed, an excellent “fit” is obtained. Therefore, using benchmark dose modeling in this situation is preferable to using an NOAEL approach, because the model will allow the value to be informed more fully by the data and by the inferences we can reasonably draw from the data. For this and other reasons, ARCADIS disagreed with the science policy decisions made in deriving the sulfolane PPRTVs and derived alternative RfDs

Appendix H also provides the reasons why the Public Health Action Levels derived by ATSDR (2010, 2011) were not meant to be used and should not be used to derive an oral RfD for sulfolane for use in an HHRA.

In addition to evaluating sulfolane’s toxicological profile, ARCADIS has considered the analysis offered by former USEPA official William Farland. Dr. Farland’s credentials and scientific evaluation of sulfolane are contained in Appendix K. Dr. Farland has taken a holistic view of the available information about sulfolane and has assessed its known toxicological profile.

According to Dr. Farland, the sulfolane database has been evolving during the last three decades. Relatively speaking, compared to other industrial chemicals encountered in the environment, the available data and details of their generation are quite robust. A picture emerges of sulfolane as a minimally toxic chemical at low levels in a variety of animal test systems. The effects seen at low doses represent subtle changes that are generally considered to be of unclear toxicological significance and may represent reversible, "adaptive" responses rather than precursors to toxicity. The recent assessments have illustrated the differences in opinion and policy judgments that can arise when subtle effects with questionable toxicological significance identify points of departure for risk assessment purposes. This lack of consensus on which study to use as the "critical study" and the lack of a consistent method of assessment supports the argument that the observations in these studies provide an uncertain basis for health risk assessment and provide "screening-level values."

The assessment activities discussed above have produced a provisional health guidance value (ATSDR) and PPRTVs, including a provisional RfD (USEPA 2012b). It is important to remember that these RfD-equivalent values are not a boundary between safety and risk. A variety of uncertainties are present when extrapolating from such effects in animals to human populations and from partial lifetime studies in animals to longer term potential exposures in humans. Many of these uncertainties are inherent in the policy choices available to risk assessors and are compounded when multiple policy choices are chosen in a given assessment, such as for sulfolane.

The ARCADIS Comparative Scenario risk assessment presents estimated hazards for potential sulfolane exposures using the ARCADIS-derived oral RfDs for sulfolane (Appendices F and G).

4.2.4 Toxicity Equivalence Factors for Polynuclear Aromatic Hydrocarbons

As shown in Tables 3-2a and 3-2b, some carcinogenic PAHs have been identified as COPCs in soil. Following ADEC (2010a) guidance, TEFs were used to assess risks to carcinogenic PAHs, including benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene and indeno(1,2,3-c,d)pyrene). TEFs were applied to EPCs of all carcinogenic PAHs in surface and subsurface soil to equivalent concentrations of benzo(a)pyrene (USEPA 2011c) and total risk was derived for the carcinogenic PAH COPCs. The assessment of potential exposures to other PAHs also included PAHs identified as COPCs in soil based on analytical data collected during the 2011 field season.

4.3 Risk Characterization – ARCADIS Comparative Scenario

This section presents the ARCADIS Comparative Scenario and provides estimated ELCRs and HIs for potentially complete and significant exposure pathways identified in Section 4.1.1.4 for on- or offsite potential receptors, based on the ARCADIS-derived toxicity criteria for sulfolane and the exposure parameters presented in Table 3-12.

4.3.1 Risk Characterization

The risk characterization integrates results of the data evaluation, exposure assessment and toxicity assessment to evaluate potential risks associated with exposure to site COPCs. The basis for the risk characterization is the quantitative evaluation of potential exposure by potential receptors to COPCs, which consists of estimating carcinogenic risk and noncarcinogenic hazard. This quantitative evaluation of risk and hazard generally provides a health-protective representation of the upper end (potentially highest exposures) for a receptor. The quantitative methods used to calculate noncarcinogenic hazard and carcinogenic risk are presented below. Consistent with USEPA (1989) guidance, the potential for carcinogenic and noncarcinogenic risks were evaluated separately.

4.3.1.1 Carcinogenic Risk

For potential carcinogens, risk was estimated as the incremental probability of an individual developing cancer during a lifetime as a result of RME to a potential carcinogen and was calculated as follows:

$$ELCR = LADDi \times CSFi$$

Where:

ELCR = excess lifetime cancer risk (unitless)

LADDi = lifetime average daily dose for the *i* th constituent (mg/kg BW-day)

CSFi = cancer slope factor for the *i* th constituent (mg/kg BW-day)$^{-1.}$

The CSF converts intake averaged over a lifetime of exposure to the incremental lifetime risk of an individual developing cancer. This linear equation is only valid at low risk levels (i.e., below estimated risks of one in 100) and is an upper-bound estimate based on the 95% UCL of the slope of the dose-response curve. Therefore, the actual risk will be lower than the predicted risk. Potential risk was assumed to be additive, and risks from different possible and probable carcinogens and pathways were summed to evaluate the overall risk. Pathway-specific risks were calculated as the sum of risks from potential carcinogenic COPCs within each exposure pathway, and the total ELCR for each receptor was calculated by summing the risk estimates for the exposure pathways evaluated.

For inhalation of COPCs, the following equation from USEPA (2009a) RAGS Part F was used to assess ELCRs:

$$ELCR = LAEC * IUR$$

Where:

ELCR = excess lifetime cancer risk (unitless)

LAEC = lifetime average exposure concentration (µg/m^3)

IUR = inhalation unit risk $(\mu g/m^3)^{-1}$

Scientific notation was used to express potential carcinogenic risks. For example, a value of $1\text{x}10^{-6}$ is equal to one in 1 million (or 0.000001). The ADEC (2010a) compares individual constituent risk estimates to an acceptable cumulative ELCR of 1 x 10^{-5} (1 in 100,000. The acceptable cancer risk is the incremental risk attributed to the estimated upper-bound exposure (i.e., RME) to COPCs at the site. This acceptable risk is, by definition, independent of risks associated with non-site-related constituent exposures and other background cancer risks (USEPA 1989). It is standard USEPA and ADEC practice, however, to assess risks and hazards first with background constituents included and then discuss the risks in the absence of the background impacts to inform the decision makers about the risks of site-related constituents.

4.3.1.2 Noncarcinogenic Hazard

The HQ approach was used to characterize the overall potential for noncarcinogenic effects associated with exposure to multiple constituents. This approach assumes that chronic exposures to multiple constituents are additive. For direct-contact and inhalation of particulates exposures, the HQ was calculated as follows:

$$HQ = ADD / RfD$$

Where:

HQ = hazard quotient (unitless)

ADD = average daily dose (mg/kg-day)

RfD = reference dose $(\text{mg/kg-day})^{-1}$

For inhalation of volatile COPCs, the following equation from USEPA (2009a) RAGS Part F was used to assess noncancer hazards:

$$HQ = AEC / RfC$$

Where:

HQ = hazard quotient (unitless)

AEC = average exposure concentration (µg/cm^3)

RfC = inhalation reference concentration (µg/cm^3)$^{-1}$

The HQ represents the comparison of exposure (dose) over a specified period of time to an RfD for a similar time period. The estimates of exposure (dose) were calculated based on chronic or subchronic exposures. If the HQ exceeds a value of 1, there is a possibility of adverse health effects. The magnitude of the HQ is not a mathematical prediction of the severity or incidence of the effects, but rather indicates that effects may occur. The constituent HQs were summed to calculate an HI for a pathway or site, and the USEPA (1989) recommends that the total HI for the constituents and pathways assessed not exceed a value of 1. An HI of less than 1 indicates that adverse health effects are not likely to occur from exposure to assessed constituents. HQs or HIs of greater than 1 do not indicate that significant risks are present, but rather that additional evaluation may be required to better define the level of risk.

According to the USEPA (1989), noncarcinogenic effects should be evaluated based on target organ(s) or toxicity endpoints. The USEPA believes that the assumption of dose additivity is one of the major limitations of the HI approach because it may overestimate the potential for health effects that most likely will not occur if the COPCs affect different organs or act by different mechanisms of action. The USEPA counters the potential for overestimation by specifying segregation of COPCs by effect and mechanism of action and derivation of separate HIs for each group (USEPA 1989). If the total HI exceeds a value of 1, the specific substances will be evaluated so that only substances that affect similar target organs or exhibit a similar mode of action (i.e., similar effects in the same target organs via the same mechanism) are summed. Quantitative estimates of carcinogenic risk and noncarcinogenic hazard were presented for each receptor.

4.3.1.3 Risk Characterization of Petroleum Hydrocarbon Compounds

In accordance with ADEC (2008b) Cumulative Risk Guidance, individual risks from exposure to GRO, DRO and RRO were calculated using RfDs provided by ADEC (2010a). However, these risk calculations were not included in cumulative risk estimates. Consistent with ADEC (2008b) Cumulative Risk Guidance, cumulative risks for each receptor were estimated using indicator constituents, as discussed below.

In general, quantitative risk calculated from individual petroleum constituents is considered adequate to account for risk in cumulative risk calculations from petroleum mixtures (ADEC 2008b). The key constituents of petroleum products associated with risk (e.g., PAHs, BTEX, methyl tertiary butyl ether) are included in the quantitative cumulative risk calculations and should adequately describe human health risk from exposure to site media.

4.3.2 Estimated Risks and Hazards for ARCADIS Comparative Scenario

For each total estimated ELCR and HI, the primary exposure pathway and contributing COPC(s) are indicated, as appropriate. This section presents ELCRs and HIs for potential onsite receptors (Section 4.3.2.1) and for potential offsite receptors (Section 4.3.2.2). For each potential receptor, ELCRs and/or HIs are summarized based on possible exposure to maximum and/or 95% UCL-based EPC COPC concentrations. Appendices D and E present complete risk calculations for ELCRs and HIs based on maximum (onsite construction/trench worker and recreational user exposures only) and 95% UCL COPC concentrations, respectively.

Summaries of the cumulative ELCRs and estimated HIs for the receptors evaluated under the ARCADIS Comparative Scenario are presented in the following tables:

- Tables 4-1 and 4-2 present the ELCR and HI summaries for on and offsite receptors using the maximum detected on and offsite values and the 95% UCL on and offsite values, respectively.

- Tables 4-1, 4-3a and 4-4a present ELCR and HI summaries for potential on and offsite receptors based on maximum COPC concentrations for all wells in each EU (including EU-1 because the maximum for all offsite wells is located in this EU).

- Table 4-2 presents ELCR and HI summaries for potential on and offsite receptors at EU-1 based on 95% UCL EPCs.

- Table 4-3a presents ELCR and HI summaries for offsite receptors based on maximum COPC concentrations at EU-2 wells.

- Table 4-4a presents ELCR and HI summaries for offsite receptors based on maximum COPC concentrations at EU-3 wells.

The ARCADIS Comparative scenario risk calculations are presented in Appendix D (maximum concentrations) and Appendix E (95% UCL EPCs).

The total estimated ELCRs presented in Tables 4-1 through 4-4b include arsenic as a soil COPC (arsenic was excluded as a COPC in groundwater). Based on an evaluation of arsenic in soil samples at the site, the presence of arsenic is due to background concentrations. Detected concentrations of arsenic in soil samples collected at the site are evaluated in the 2012 Revised Site Characterization Report (Barr 2012). This evaluation compared site arsenic concentrations to background studies collected in Alaska and evaluated the spatial distribution of arsenic with respect to site operations and other COPCs. The results of the evaluation concluded that the presence of arsenic in soil does not appear to be associated with refinery operations and is likely a result of background concentrations.

4.3.2.1 Estimated Risks and Hazards for Potential Onsite Receptors

Potential onsite receptors evaluated include current and future indoor and outdoor commercial workers, construction/trench workers and adult visitors. The ARCADIS-derived oral RfD was used to evaluate potential sulfolane exposures. The maximum onsite concentration of sulfolane in groundwater detected above the laboratory reporting limit between 2009 and 2011 is 10.4 mg/L. Estimated risks and hazards for the onsite receptors using maximum detected concentrations and 95% UCLs as EPCs are summarized in Table 4-1 and Table 4-2, respectively.

4.3.2.1.1 Onsite Indoor Commercial/Industrial Workers

Table D-25 (Appendix D) presents the estimated ELCRs and HIs for indoor commercial/industrial workers, based on exposures to maximum detected COPC concentrations in groundwater. Inhalation of VOCs in indoor air from groundwater is the primary exposure pathway for these potential receptors (see Table 4-1). The total estimated ELCR is 1 x 10^{-5} and the total estimated HI is 0.2.

Table E-23 (Appendix E) presents the estimated ELCRs and HIs for indoor commercial/industrial workers, based on exposures to 95% UCLs of detected COPC concentrations in groundwater. Inhalation of VOCs in indoor air from groundwater is the primary exposure pathway for these potential receptors (see Table 4-2). The total estimated ELCR is 1 x 10^{-6} and the total estimated HI is 0.02.

4.3.2.1.2 Onsite Outdoor Commercial/Industrial Workers

Table D-26 (Appendix D) presents the estimated ELCRs and HIs for outdoor commercial/industrial workers, assuming potential exposure to 95% UCLs of COPC concentrations in surface soil. Table D-26 also shows estimated ELCRs and HIs based on direct-contact exposures, including ingestion of, dermal contact with and inhalation of dust particles from surface soil. The total estimated ELCR is 5 x 10^{-6} and the total estimated HI is 0.05 (see Table 4-1). Soil ingestion contributes most to the total estimated ELCR and HIs. Arsenic is the primary risk and hazard driver. Excluding the estimated arsenic ELCR and HI, which are likely due to background, the total estimated ELCR is 2 x 10^{-7} and the total estimated HI is 0.03 (see Table D-26).

4.3.2.1.3 Onsite Construction/Trench Workers

The ARCADIS-derived subchronic oral RfD for sulfolane was used to estimate potential construction/ trench worker hazards in the ARCADIS Comparative Scenario. Table 4-1 and Table D-27a (Appendix D) present the estimated ELCRs and HIs for construction/trench workers based on potential exposures to maximum COPC concentrations in surface and subsurface soil, assuming direct-contact exposures including ingestion, dermal contact and inhalation of dust particles. The total estimated ELCR associated with potential exposure to COPCs in soil is 1 x 10^{-6} and the total estimated HI is 0.3. The soil ingestion pathway contributes most to the total soil-related estimated ELCR and HI. Excluding the estimated arsenic ELCR, which is likely based on background, the total estimated ELCR is 3 x 10^{-7} and the total estimated HI is 0.3.

Table 4-1 and Table D-27b (Appendix D) present ELCRs and HIs based on incidental ingestion of and dermal contact with groundwater in an onsite excavation trench, and inhalation of VOCs within trench air from groundwater based on maximum COPC concentrations in groundwater. The total estimated ELCR is 3 x 10^{-4} and the total estimated HI is 49. Inhalation of VOCs in the trench air is the exposure pathway that contributes most to the cumulative ELCR and HIs. Benzene, naphthalene and ethylbenzene (as estimated in trench air from groundwater) are the primary risk drivers for the total ELCR. Benzene, naphthalene, xylenes and 1,3,5-trimethylbenzene are the risk drivers for the HI.

Table 4-2 and Table E-25a (Appendix E) present the estimated ELCRs and HIs for construction/trench workers based on 95% UCL COPC concentrations and direct-contact exposures including ingestion of, dermal contact with and inhalation of dust particles in surface and subsurface soil. The total soil-related estimated ELCR is 3 x 10^{-7} and the total soil-related estimated HI is 0.06. Soil ingestion contributes most to the total estimated ELCR and HIs. Excluding the estimated arsenic ELCR and HI, which are likely based on background, the total estimated ELCR is 2 x 10^{-8} and the total estimated HI is 0.05.

Table 4-2 and Table E-25b (Appendix E) present ELCRs and HIs based on incidental ingestion of and dermal contact with groundwater in an onsite excavation trench and inhalation of VOCs within trench air from groundwater based on 95% UCL COPC concentrations. The total estimated ELCR is 3 x 10^{-5} and the total estimated HI is 9. Inhalation of VOCs in the trench air contributes most to ELCR and HIs. Benzene is the primary risk driver for ELCRs and benzene and naphthalene are the primary risk drivers for HIs.

4.3.2.1.4 Onsite Adult Visitors

Table 4-1 and Table D-28 (Appendix D) present the estimated ELCRs and HIs for adult visitors based on maximum COPC concentrations in onsite groundwater. Inhalation of VOCs in indoor air from groundwater is the primary exposure pathway for these potential receptors. The total estimated ELCR is 2 x 10^{-7} and the total estimated HI is 0.002.

Table 4-2 and Table E-26 (Appendix E) present the estimated ELCRs and HIs for adult visitors based on 95% UCL COPC concentrations in onsite groundwater. Inhalation of VOCs in indoor air from groundwater is the primary exposure pathway for these potential receptors. The total estimated ELCR is 1 x 10^{-8} and the total estimated HI is 0.0002.

4.3.2.2 Estimated Risks and Hazards for Potential Offsite Receptors

In the ARCADIS Comparative Scenario, potential offsite receptors evaluated include current and future residents; adults (chronic exposures), children (chronic exposures) and infants (subchronic exposures); indoor and outdoor commercial workers (chronic exposures); and construction/trench workers (subchronic exposures). The estimated risks and hazards for offsite receptors using maximum detected concentrations and 95% UCLs as EPCs are summarized in Table 4-1 and Table 4-2, respectively.

4.3.2.2.1 Offsite Adult, Child and Infant Residents

Table 4-1 and Tables D-29a and D-30a (Appendix D) present the estimated ELCRs and HIs for offsite adult and child residents, assuming potential exposure to 95% UCL COPC concentrations in ambient air from onsite surface soil (based on 95% UCL concentrations) using the ARCADIS-derived chronic oral RfD for sulfolane. The total estimated ELCRs for adult and child residents are 4 x 10^{-8} and 9 x 10^{-9}, respectively, and the total estimated HIs are both 0.001. Excluding arsenic in soil and the estimated arsenic ELCRs and HIs, which is likely due to background, the total estimated ELCRs for adult and child residents are 4 x 10^{-8} and 8 x 10^{-9}, respectively, and the total estimated HIs are both 0.0009 (see Table D-5a [Appendix D] for adult resident and Table D-6a for child resident). Table D-31a presents the estimated ELCR and HI for offsite infant residents, assuming potential exposure to 95% UCL COPC concentrations in ambient air from onsite surface soil using the USEPA (2012b) subchronic ARCADIS-derived oral RfD for sulfolane. The total estimated ELCR for infant residents is 1 x 10^{-9} and the total estimated HI is 0.0007. Excluding the estimated arsenic ELCR and HI, which is likely due to background, the total estimated ELCR for infant residents is 1 x 10^{-9} and the total estimated HI is 0.0005.

Table 4-1 and Tables D-29b, D-30b and D-31b (Appendix D) show HIs based on ingestion of the maximum detected concentration of sulfolane in groundwater (i.e., tapwater), applied across the entire offsite area (which also includes EU-1 because the maximum value occurs in this EU), for adults (chronic exposures; Table D-29b), children (chronic exposures; Table D-30b) and infants (subchronic exposures; Table D-31b), respectively. Tables D-29c, D-30c and D-31c present the HIs associated with ingestion of homegrown produce irrigated with sulfolane-impacted groundwater (maximum detected concentration) for adults (chronic exposures; Table D-29c), children (chronic exposures; Table D-30c) and infants (subchronic exposures; Table D-31c), respectively. Tables D-35 and D-36 present the HIs associated with ingestion of surface water (maximum detected concentration) for adults (chronic exposures; Table D-35) and children (chronic exposures; Table D-36).

As shown in Table 4-1 and Tables D-29b, D-30b and D-31b (Appendix D), using the ARCADIS-derived oral RfDs for sulfolane and the maximum concentration detected in offsite groundwater, the total estimated HIs associated with ingestion of groundwater are 1.2 for adult residents (chronic exposure; Table D-29b), 2.8 for child residents (chronic exposure; Table D-30b) and 0.7 for infant residents (subchronic exposure; Table D-31b), respectively, based on ingestion of tapwater. Table 4-1 and Tables D-29c, D-30c and D-31c present the total estimated HIs associated with ingestion of homegrown produce, including an HI of 0.08 for adult residents (chronic exposure; Table D-29c), 0.2 for child residents (chronic exposure; Table D-30c) and 0.03 for infant residents (subchronic exposure; Table D-31c), respectively. These HIs are based on ingestion of homegrown produce using the ARCADIS oral RfDs for sulfolane, along with the maximum detected offsite sulfolane concentration, a BCF of 1.0 and the 95th percentile *per capita* produce ingestion rates. As shown in Table 4-1 and Tables D-35 and D-36 (Appendix D), using the ARCADIS oral RfDs for sulfolane and the maximum concentration EPC, the total estimated HIs associated with ingestion of surface-water are 0.003 for adult residents (chronic exposure; Table D-35) and 0.02 for child residents (chronic exposure; Table D-36). The surface-water HIs for this receptor group are the same for each EU (Table 4-2, Table 4-3a and Table 4-4a).

Table 4-1 presents the cumulative HIs for this receptor group for all exposure pathways combined based on maximum EPCs which are 1.3 for adult residents, 3.1 for child residents (chronic exposure), and 0.7 for infant residents (subchronic exposure). Table 4-2 also presents the cumulative ELCRs for this receptor group for all exposure pathways combined based on maximum EPCs which are 4 x 10^{-8} for adult residents, 9 x 10^{-9} for child residents (chronic exposure), and 1x 10^{-9} for infant residents (subchronic exposure).

Table 4-2 and Tables E-27a, E-28a and E-29a (Appendix E) present the estimated ELCRs and HIs for adults, children (chronic) and infant (subchronic) residents, respectively, based on inhalation of fugitive windborne dust or vapors from onsite COPCs in surface soil, assuming 95% UCL COPC concentrations. As shown in Table E-27a the total estimated ELCR is 4 x 10^{-8} and the total estimated HI is 0.001 for adult residents (chronic expo sure). For a child resident (chronic exposure), the total estimated ELCR is 9 x 10^{-9} and the total estimated HI is 0.001 (Table E-28a). The total estimated ELCR is 1 x 10^{-9} and the total estimated HI is 0.0007 for the infant resident (subchronic exposure; Table E-29a).

Assuming the 95% UCL concentration for sulfolane in EU-1, Table 4-2 and Tables E-27b, E-28b and E-29b in Appendix E) show estimated HIs based on ingestion of 95% UCL sulfolane concentrations in groundwater (i.e., tapwater) at EU-1 by resident receptors. Using the ARCADIS oral RfDs for sulfolane, the estimated HIs associated with ingestion of water are 0.5 for the adult resident (chronic exposure; Table E-27b), 1.1 for child resident (chronic exposure; Table E-28b) and 0.3 for infant resident (subchronic exposure; Table E-29b). Tables E-27c, E-28c and E-29c present the total estimated HIs associated with consumption of homegrown produce irrigated with water containing sulfolane in EU-1. The HIs are 0.03 for adult residents (chronic exposure), 0.09 for child residents (chronic exposure) and 0.01 for an infant resident (subchronic exposure), using the ARCADIS oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

Table 4-3a and Tables D-37a, D-38b, D-39a, D-37b, D-38a and D-39b (Appendix D) present HIs based on ingestion of the maximum sulfolane concentration in groundwater (i.e., tapwater) within EU-2 for resident receptors. Using the ARCADIS oral RfDs for sulfolane, the total estimated HIs associated with ingesting tapwater containing maximum sulfolane concentrations in EU-2 are 0.4 for an adult resident (chronic exposure; Table D-37a), 0.9 for a child resident (chronic exposure; Table D-38a) and 0.2 for an infant resident (subchronic exposure; Table D-39a). In addition, Table 4-3a presents HIs associated with consumption of homegrown produce irrigated with groundwater containing the maximum sulfolane concentrations at EU-2. The estimated HIs for consumption of homegrown produce irrigated with water from EU-2 are 0.03 for an adult resident (chronic exposure; Table D-37b), 0.08 for a child resident (chronic exposure; Table D-38b) and 0.01 for an infant resident (subchronic exposure; Table D-38b), using the ARCADIS oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

Table 4-3b and Tables E-33a, E-34a and E-35a (Appendix E) present HIs based on ingestion of the 95% UCL sulfolane concentration in groundwater (i.e., tapwater) within EU-2 for resident receptors. Using the ARCADIS oral RfDs for sulfolane, the total estimated HIs associated with ingesting tapwater containing sulfolane in EU-2 are 0.2 for an adult resident (chronic exposure; Table E-33a), 0.4 for a child resident (chronic exposure; Table E-34a) and 0.09 for an infant resident (subchronic exposure; Table E-35a). In addition, Table 4-3b and Tables E-33b, E-34b and E-35b (Appendix E) present HIs associated with consumption of homegrown produce irrigated with sulfolane-impacted groundwater at EU-2. The total estimated HIs for consumption of homegrown produce irrigated with water from EU-2 are 0.01 for an adult resident (chronic exposure; Table E-33b), 0.03 for a child resident (chronic exposure; Table E-34b) and 0.004 for an infant resident (subchronic exposure; Table E-35b) respectively, using the ARCADIS-derived oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

Table 4-4a and Tables D-43a, D-44a and D-45a (Appendix D) show the estimated HIs based on ingestion of the maximum sulfolane concentration in groundwater (i.e., tapwater) within EU-3 by resident receptors. Using the ARCADIS oral RfDs for sulfolane, the estimated HIs associated with ingestion of tapwater are 0.2 for an adult resident (chronic exposure; Table D-43a), 0.5 for a child resident (chronic exposure; Table D-44a) and 0.1 for an infant resident (subchronic exposure; Table D-45a). In addition to a drinking water scenario, Table 4-4a and Tables D-43b, D-44b and D-45b (Appendix D) present the HIs associated with consumption of homegrown produce irrigated with the maximum detected sulfolane concentration in groundwater in EU-3. The estimated HIs for consumption of homegrown produce are 0.01 for an adult resident (chronic exposure; Table D-43b), 0.04 for a child resident (chronic exposure; Table D-44b) and 0.006 for an infant resident (subchronic exposure; Table D-45b), using the ARCADIS oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

Table 4-4b and Tables E-39a, E-40a and E-41a (Appendix E) show the estimated HIs based on ingestion of the 95% UCL sulfolane concentration in groundwater (i.e., tapwater) within EU-3 by resident receptors. Using the ARCADIS-derived oral RfDs for sulfolane, the estimated HIs associated with ingestion of tapwater are 0.03 for an adult resident (chronic exposure; Table E-39a), 0.07 for a child resident (chronic exposure; Table E-40a) and 0.02 for an infant resident (subchronic exposure; Table E-41a). In addition to a drinking water scenario, Table 4-4b and Tables E-39b, E-40b and E-41b (Appendix E) present the HIs associated with ingestion consumption of homegrown produce irrigated with sulfolane-impacted groundwater in EU-3. The estimated HIs for consumption of homegrown produce are 0.002 for an adult resident (Table E-39b), 0.005 for a child resident (chronic exposure; Table E-40b) and 0.0007 for an infant resident (subchronic exposure; Table E-41b), using the ARCADIS oral RfDs for sulfolane, along with a BCF of 1.0, and the 95th percentile per capita produce ingestion rates.

4.3.2.2.2 Offsite Indoor Commercial Workers

Table 4-1 and Table D-32 (Appendix D) show the HI based on ingestion of groundwater (i.e., tapwater), assuming the maximum offsite sulfolane concentration and the ARCADIS oral RfD for sulfolane. The total estimated HI is 0.9 for offsite indoor commercial/industrial workers (chronic exposure) based solely on ingestion of tapwater containing sulfolane (see Table D-32 [Appendix D]).

Table 4-2 and Table E-30 (Appendix E) show the HI based on ingestion of groundwater (i.e., tapwater), assuming the 95% UCL offsite sulfolane concentration for EU-1 and the ARCADIS oral RfD for sulfolane. The total estimated HI is 0.3 for offsite indoor commercial/industrial workers (chronic exposure) based solely on ingestion of tapwater containing sulfolane (see Table E-30 [Appendix E]).

At EU-2, two sulfolane groundwater EPCs were used to estimate potential hazards associated with ingestion of groundwater by offsite indoor commercial/industrial workers (chronic exposure). Using the maximum detected offsite sulfolane concentration at EU-2, the estimated HI is 0.3 (Table 4-3a). Comparatively, the HI based on the 95% UCL sulfolane concentration at EU-2 is 0.1. Both HIs were derived using the ARCADIS oral RfD for sulfolane (see Table D-40 [Appendix D] for maximum EPC and Table E-36 [Appendix E] for 95%UCL). Similarly, two sulfolane groundwater EPCs were used to estimate potential hazards associated with ingestion by offsite indoor commercial/industrial workers (chronic exposure) at EU-3. Table 4-4a shows the HI based on ingestion of groundwater (i.e., tapwater), assuming the maximum offsite sulfolane concentration at EU-3 and Table 4-4b shows the corresponding HI based the 95% UCL offsite sulfolane concentration at EU-3. Both HIs were derived using the ARCADIS oral RfD for sulfolane. Using the maximum detected sulfolane concentration at EU-3, the estimated HI is 0.2; the estimated HI is 0.02 for offsite indoor commercial/industrial workers (chronic exposure) based on the 95% UCL groundwater concentration at EU-3 (see Table D-46 [Appendix D] and Table E-42 [Appendix E], respectively).

4.3.2.2.3 Offsite Outdoor Commercial Workers

Table 4-1 presents the estimated ELCRs and HIs for offsite outdoor commercial workers potentially exposed via inhalation of dust particles from onsite surface soil (0 to 2 feet bgs), using 95% UCL COPC concentrations in onsite surface soil. The total estimated ELCR is 2 x 10^{-8} and the total estimated HI is 0.0006 (see Table D-33a [Appendix D]). Excluding the estimated arsenic concentrations in surface soil and HI, which are likely attributable to background, the total estimated ELCR is 2 x 10^{-8} and the total estimated HI is 0.0006 (Table D-9a). Table 4-1 also shows the HI for this receptor assuming ingestion of groundwater (i.e., tapwater) and assuming the maximum offsite sulfolane concentration. The estimated HI is 0.9 for offsite outdoor commercial/industrial workers, based on ingestion of tapwater (see Table D-33b [Appendix D]).

Table E-31a [Appendix E] shows ELCRs and HIs based on inhalation of fugitive windborne dust and vapors from onsite COPCs in surface soil, based on 95% UCL COPC concentrations and the ARCADIS oral RfD for sulfolane. It was assumed that the offsite outdoor commercial worker (chronic exposure) is located at the site boundary; therefore, the estimated ELCRs and HIs will over estimate risk for many offsite commercial worker, based on inhalation of dust and vapors from the site. As shown in Table E-31a [Appendix E], the total estimated ELCR is 2 x 10^{-8} and the total estimated HI is 0.0006, based on inhalation of dust and vapors in ambient air.

Assuming the 95% UCL and ARCADIS oral RfD for sulfolane in EU-1, the total estimated HI is 0.3 for offsite outdoor commercial/industrial workers (chronic exposure), based on ingestion of groundwater (see Table 4-2 and Table E-31 [Appendix E]).

At EU-2, two sulfolane groundwater EPCs were used to estimate potential hazards associated with ingestion of groundwater: the maximum detected concentration of sulfolane and the 95% UCL of the mean sulfolane concentrations. Using the maximum detected concentration in groundwater at EU-2, the estimated HI is 0.3 for offsite outdoor commercial/industrial workers (chronic exposure) based on ingestion of groundwater (see Table 4-3a and Table D-41 [Appendix D]). Using the 95% UCL sulfolane concentration, the total estimated HI is 0.1 for offsite outdoor commercial/industrial workers at EU-2, based on ingestion of tapwater (chronic exposure; see Table 4-3b and Table E-37 [Appendix E]). Both hazard estimates used the ARCADIS oral RfD for sulfolane.

Similarly, at EU-3, the 95% UCL and maximum sulfolane groundwater concentrations were both evaluated as distinct EPCs to estimate potential hazards associated with ingestion of groundwater by offsite commercial/industrial workers. Using the maximum sulfolane concentration at EU-3, the estimated HI is 0.2 (Table 4-4a and Table D-47 [Appendix D]). Using the 95% UCL sulfolane concentration, the estimated HI is 0.02 for offsite outdoor commercial/industrial workers at EU-3 (see Table 4-4b and Table E-43 [Appendix E]). Both hazard estimates are used the ARCADIS oral RfD for sulfolane.

4.3.2.2.4 Offsite Construction/Trench Workers

The estimated HIs for an offsite construction worker who is potentially exposed to maximum sulfolane concentrations by incidental ingestion of sulfolane in offsite groundwater in excavation trenches is 0.00008 (see Table 4-1 and Table D-34 [Appendix D]). This exposure is subchronic and the HI is derived assuming the maximum offsite sulfolane concentration and using the ARCADIS subchronic oral RfD for sulfolane. As discussed in Section 3.1.1.4, sulfolane is not considered to pose adverse health effects due to inhalation and dermal contact exposures. The total estimated HI is 0.00008 for offsite construction workers, based on incidental ingestion of groundwater while working in trenches.

Tables 4-2, 4-3b and 4-4b show the HIs for potential exposures by the construction worker (subchronic exposure) based on 95% UCL sulfolane concentrations for incidental ingestion of sulfolane in offsite groundwater in excavation trenches in EU-1, EU-2 and EU-3, respectively. The estimated HIs for offsite construction workers, which are based on the ARCADIS subchronic oral RfD for potential groundwater ingestion exposures of groundwater while working in trenches, and 95%UCL sulfolane concentrations, are 0.00003, 0.00001 and 0.000002 in EU-1, EU-2 and EU-3, respectively (see Tables E-32, E-38 and E-44 [Appendix E] for the hazard calculations for this receptor in EU-1, EU-2 and EU-3, respectively). Tables 4-3a and 4-4a show the corresponding HIs for this receptor group based on the maximum sulfolane groundwater concentrations at EU-2 and EU-3, respectively. The estimated HIs for offsite construction workers exposed to maximum groundwater concentrations at EU-2 and EU-3 are 0.00003 and 0.00001, respectively (see Tables D-42 and D-48 [Appendix D]).

4.3.2.2.5 Offsite Adult and Child Recreational Users

Table 4-1 and Tables D-35 and D-36 (Appendix D) show the estimated HIs for offsite adult and child (aged 1 to 6 years) recreational users (i.e., swimmer who may be exposed by incidental, ingestion of sulfolane in surface water), assuming the maximum offsite sulfolane concentration in pore water and the ARCADIS chronic oral RfD for sulfolane. The total estimated HIs are 0.003 and 0.02 for offsite adult (chronic exposure) and child recreational users (chronic exposure), respectively.

4.3.3 Conclusions for ARCADIS Comparative Scenario

Table 4-1 presents the estimated ELCRs and HIs using maximum COPC concentrations in onsite subsurface soil, maximum onsite COPC surface soil and groundwater concentrations, maximum offsite groundwater concentrations of sulfolane, and the ARCADIS oral RfDs for sulfolane. The estimated HIs are below the target HI of 1 for the onsite commercial/industrial worker, onsite commercial/industrial outdoor worker, onsite visitor, offsite indoor and outdoor commercial workers, off-site construction/trench workers, and offsite adult and child recreators. The estimated HIs exceed the target HI of 1 for onsite construction/trench workers, and offsite adult and child residents. The HI is equal to 49 for onsite construction workers based on inhalation of volatile COPCs in trench air from groundwater. Benzene, naphthalene, xylenes and 1,3,5-trimethyl benzene are the hazard drivers in the construction worker inhalation scenario. For offsite adult and child resident receptors, the HIs are equal to 1.3 and 3.1, respectively.

As shown in Table 4-2, using the 95% UCL COPC sulfolane concentrations in EU-1, the HIs and ELCRs for offsite construction workers, offsite adult and infant residents (subchronic exposure); and offsite indoor and outdoor commercial workers, and offsite recreators are below the target levels. Assuming the 95% UCL concentration for sulfolane in EU-1, the estimated HIs associated with ingestion of water is 1.1 for a child resident (chronic exposure; Table E-28b).

Table 4-3a presents the estimated ELCRs and HIs using the maximum COPC sulfolane concentrations in EU-2. Under the ARCADIS Comparative Scenario using maximum COPC concentrations in EU-2, the HIs and ELCRs for offsite construction workers, offsite adult, child (chronic exposure) and infant residents (subchronic exposure); and offsite indoor and outdoor commercial workers, and offsite recreators are below the target levels.

As shown in Table 4-3b, using the 95% UCL COPC sulfolane concentrations in EU-2, the HIs and ELCRs for offsite construction workers, offsite adult, child (chronic exposure) and infant residents (subchronic exposure); and offsite indoor and outdoor commercial workers, and offsite recreators are below the target levels.

Table 4-4a presents the estimated ELCRs and HIs using the maximum COPC sulfolane concentrations in EU-2. Under the ARCADIS Comparative Scenario using maximum COPC concentrations in EU-3, the HIs and ELCRs for offsite construction workers, offsite adult, child (chronic exposure) and infant residents (subchronic exposure); and offsite indoor and outdoor commercial workers, and offsite recreators are below the target levels.

As shown in Table 4-4b, using the 95% UCL COPC sulfolane concentrations in EU-3, the HIs and ELCRs for offsite construction workers, offsite adult, child (chronic exposure) and infant residents (subchronic exposure); and offsite indoor and outdoor commercial workers, and offsite recreators are below the target levels.

4.4 Evaluation of Potential Exposures to Lead in Onsite Groundwater

The USEPA's (2009b) ALM was used to evaluate current and future onsite outdoor commercial/industrial workers and construction/trench workers potentially exposed to lead in onsite groundwater. The maximum concentration of lead detected above the laboratory reporting limit in onsite groundwater is 2.05 µg/L. The USEPA's threshold lead concentration of 10 µg/dL of whole blood is based on potentially adverse neurological effects in children (CDC 2011). The 95th percentile PbB among fetuses of onsite adult workers, assuming potential exposure to the maximum detected concentration in onsite groundwater, was calculated using the ALM (USEPA 2009b). Using the groundwater ingestion rates and exposure frequencies for current and future onsite outdoor commercial/industrial workers and construction/trench workers presented in Table 3-12, the calculated probabilities that fetal PbBs are greater than10 µg/dL are 0.005 and 0.002%, respectively. Thus, potential exposures to lead in groundwater at the site are below the regulatory level of concern and are not expected to pose adverse health effects to current and future onsite outdoor commercial/industrial workers and construction/trench workers. The Calculations of Blood Lead Concentrations spreadsheet is provided in Appendix I.

Based on the results of the ALM (USEPA 2009b), the maximum detected concentration of lead in onsite groundwater is not expected to pose adverse health effects to current and future onsite outdoor commercial/industrial workers or construction/trench workers.

4.5 Uncertainty Assessment – ARCADIS Scenario

Each exposure parameter value and toxicity value incorporated into the HHRA is associated with some degree of uncertainty; these uncertainties may contribute to an overestimation or underestimation of risks at the site (ADEC 2011c). Therefore, key uncertainties associated with each HHRA component (i.e., data evaluation, COPC selection, toxicity assessment, exposure assessment and risk/hazard characterization) were evaluated in the following subsections. In particular, separate analyses were conducted to assess uncertainties related to oral RfDs for sulfolane, BCFs used for plant uptake of sulfolane into homegrown produce, homegrown fruit and vegetable ingestion rates, and exposure assumptions for contact with surface water. To allow a direct comparison illustrating the effect of the toxicity value selection, the ARCADIS Comparative Scenario in Section 4 has been presented with all the exposure parameters requested and approved by ADEC. For further comparison, ARCADIS also has evaluated risk for all receptors based on the ARCADIS-derived toxicity value and the exposure parameters that ARCADIS selected after its literature and data review. These results are presented in Tables4-5 through 4-9 and addressed throughout this Uncertainty Section. Wherever presented, these results are referred to as the "ARCADIS Scenario."

It is ARCADIS' expert scientific opinion that this Scenario is health protective and reflects the use of supportable science policy decisions that are consistent with USEPA guidance and current risk assessment practices.

4.5.1 Data Evaluation

Soil and onsite groundwater samples were analyzed for a large suite of constituents from multiple samples collected throughout the site over time. These samples were analyzed using accepted analytical methodologies. It is unlikely that constituents were overlooked or underestimated by the analytical methods employed. The laboratory data used for soil sulfolane analyses in 2010 and 2011 was not final at the time, but the analytical results have been validated with an approved method.

The release-related constituents detected in soil (e.g., BTEX) were measured in more than 250 soil samples, of which 88 were surface soil samples. The large data set provides high confidence in the 95% UCL on the mean concentrations and in the representativeness of the use of this statistic for EPCs.

A large number of samples of key constituents detected at the site are available for use in the data evaluation. For example, for sulfolane in offsite groundwater, more than 429 samples were grouped by concentration ranges with each range having a high number of samples to represent that zone (i.e., 105 samples in the greater than 100 µg/L EU, 72 samples in the greater than 25 µg/L EU and 252 samples in the EU with detections up to 25 µg/L). The number of samples increases the representativeness of the EPCs based on these groupings of data and it is unlikely that the EPC based on the 95% UCL on the mean concentration underestimates potential exposures to sulfolane given the number of samples. The maximum detected concentration of sulfolane (443 µg/L) is 1.4 times higher than the next highest detection of sulfolane in offsite wells and 3 times greater than the 95% UCL on the mean concentration for the greater than 100 µg/L EU. The ARCADIS Scenario presented in this Uncertainty Section evaluates potential exposures to COPCs in groundwater over each EU using 95% UCL concentrations.

Data for onsite wells with multiple sampling rounds were averaged together and these temporal average well concentrations were grouped to calculate 95% UCL concentrations on the mean. Each temporal average concentration represents multiple sampling events and provides a reliable measure of constituent concentrations in that well. Grouping the data by well to estimate EPCs reduced the number of samples upon which the statistical analysis could be based. Where too few wells were available to reliably estimate 95% UCL values, the highest temporal well average was used to represent the EPC, which is an overestimate of potential exposure.

4.5.2 Constituent of Potential Concern Selection

COPCs were selected from a list of COIs known or suspected to have been used at the site. The approaches used to characterize the site were intended to identify the COPCs in environmental media associated with current and historical site operations. Sampling events were sequentially conducted based on the knowledge obtained from past sampling events. It is likely that these events identified the majority of areas with residual COPCs. While it is possible that some substances may have been omitted, the probability of those substances being important in driving risk is expected to be low. The suite of analyses that was selected represents those constituents that would most likely result from site operations and are therefore the most relevant and appropriate constituents for estimating risks and hazards. Note that analyses of isopropanol and propylene glycol were inadvertently missed during recent groundwater sampling events. Although the potential presence of these constituents is not expected to change the outcome of the risk evaluation, these COPCs will be evaluated once data have been collected.

4.5.3 Toxicity Assessment

Dose-response values are sometimes based on limited toxicological data. For this reason, a margin of safety is built into estimates of both carcinogenic and noncarcinogenic risk, and actual risks are lower than those estimated. The two major areas of uncertainty introduced in the dose-response assessment are: (1) animal to human extrapolation and (2) high to low dose extrapolation. These are discussed below.

Human dose-response values are often extrapolated, or estimated, using the results of animal studies. Extrapolation from animals to humans introduces a great deal of uncertainty in the risk assessment because in most instances, it is not known how differently a human may react to the constituent compared to the animal species used to test the constituent. The procedures used to extrapolate from animals to humans involve conservative assumptions and incorporate several uncertainty factors that overestimate the potential adverse effects associated with a specific dose. As a result, overestimation of the potential for adverse effects to humans is more likely than underestimation.

Predicting potential health effects from exposure to media containing COPCs requires the use of models to extrapolate the observed health effects from the high doses used in laboratory studies to the anticipated human health effects from low doses experienced in the environment. The models contain conservative assumptions to account for the large degree of uncertainty associated with this extrapolation (especially for potential carcinogenic effects) and therefore, tend to be more likely to overestimate than underestimate potential risks.

Oral RfDs for sulfolane have been derived using different approaches and laboratory studies. For this Revised Draft Final HHRA, two potential chronic oral RfDs for sulfolane were used to evaluate hazards:

USEPA (2012b) PPRTV chronic oral RfD of 0.001 mg/kg-day and the ARCADIS-derived chronic oral RfD of 0.01, was derived by ARCADIS. As expected, with a lower sulfolane oral RfD value, the HIs are higher. For example, for the current and future offsite adult resident, based on ingestion of the 95% UCL concentration of sulfolane in groundwater in EU-1, the estimated HIs ranged from 5 using USEPA PPRTV chronic oral RfD of 0.001 mg/kg-day to 0.5 using the ARCADIS-derived chronic oral RfD of 0.01 mg/kg-day that was derived directly from the scientific literature. For the current and future offsite adult resident, based on ingestion of the maximum concentration of sulfolane in groundwater in EU-1, the estimated HI would be 12 using the USEPA PPRTV chronic oral RfD of 0.001 mg/kg-day and 1.2 using the ARCADIS-derived chronic oral RfD of 0.01 mg/kg-day. In addition, two potential subchronic RfDs were used to evaluate hazards associated with subchronic exposures: USEPA (2012b) PPRTV subchronic oral RfD of 0.01 mg/kg-day and the ARCADIS-derived subchronic oral RfD of 0.1 mg/kg-day, which was derived directly from the scientific literature.

For the PPRTV Scenario presented in Section 3, the USEPA PPRTV chronic oral RfD for sulfolane was used to assess potential exposures to children. In the ARCADIS Comparative Scenario presented in Section 4.3, the ARCADIS-derived chronic oral RfD for sulfolane was used to assess potential exposures to children. In the ARCADIS scenario presented in this uncertainty section, two sets of child exposures are presented: one based on the ARCADIS-derived chronic oral RfDs for sulfolane and the other based on the ARCADIS–derived chronic oral RfDs for sulfolane. The subchronic ARCADIS-derived oral RfD for sulfolane was used to assess potential exposures to children (1 to 6 yrs old) in the ARCADIS scenario because chronic RfDs correspond to 7 or more years of exposure and are developed to be protective of long-term exposures to a constituent with a considerable margin of safety, which is typically over 1,000-fold.

As noted in Dr. Farland's toxicological assessment of sulfolane provided in Appendix K, a variety of uncertainties are present when extrapolating from subtle effects in animals to human populations and from partial lifetime studies in animals to longer term potential exposures in humans. Many of these uncertainties are inherent in the policy choices available to risk assessors and are compounded when multiple policy choices are chosen in a given assessment. Risk assessments that evaluate available information and rely on scientific judgment, applied to the chemical constituent and its site-specific exposure characteristics, are typically preferred over risk assessments that make significant use of default positions.

Calculation of a "safe" drinking water level based on the policy choices incorporated for sulfolane would be up to thousands of times below the level where the subtlest potential adverse effects were NOT seen in the animal studies and even many more times below the level where these subtle effects of unknown toxicologic significance were seen. In its recent Health Consultation, the ADHSS (2012) concluded after its own evaluation that "it is unlikely that North Pole residents who drank well water with levels of sulfolane higher than ATSDR's recommended levels would experience health effects resulting from exposure to sulfolane."

4.5.4 Exposure Assessment

According to USEPA (2001) guidance, screening-level estimates of exposure and risk calculations use assumptions that maximize the estimate of risk to ensure that only those constituents that represent a *de minimis* risk are eliminated from further consideration, and those that potentially pose an unacceptable risk will be retained for consideration in subsequent steps of the risk assessment process. As requested by the ADEC, maximum concentrations of COPCs were used as EPCs in the risk calculations for the potential receptors evaluated for the PPRTV Scenario (Section 3) and the ARCADIS Comparative Scenario (Section 4.3). More often, a conservative estimate of average concentrations of constituents is used to represent EPCs (USEPA 1989, 2002c, 2006b, 2007). Potential receptors are more likely to be exposed to a range of these concentrations represented by the average or 95% UCL concentration. As such, the PPRTV Scenario and the ARCADIS Comparative Scenario also present risk results based on the 95% UCL concentrations. Because groundwater data collected from off-site wells indicate that offsite sulfolane concentrations are generally not increasing, the use of the maximum concentration will overestimate the true risk for most, actual receptors.

Concentrations of VOCs in indoor air of current and future onsite commercial/industrial structures were estimated using concentrations of VOCs in groundwater at the site. Due to the uncertainties associated with partitioning from soil to soil gas, ITRC (2007b) does not recommend using soil data as a source of COPCs to evaluate potential vapor intrusion. Thus, use of soil data to evaluate potential soil vapor concerns is inappropriate. USEPA (2002a) and ITRC (2007a) recommendations concluded that there is insufficient scientific support for this procedure. ITRC (2007a) notes “Scientific studies have failed to show good correlation between soil and soil gas sampling and analysis on a consistent basis.” They conclude by recommending that soil data should be used only as a secondary line of evidence and not as a primary line. Overall, the scientific evidence indicates that use of soil data is not a reliable approach for identifying potential vapor intrusion concerns.

Dermal contact with COPCs in groundwater by current and future onsite outdoor commercial/industrial workers was considered an insignificant exposure pathway. Onsite use of groundwater beneath the site is limited to infrequent fire extinguishing. Fires at the site are very rare and the period of exposure would likely be relatively very short. Thus, exclusion of this potential exposure pathway would not significantly impact ELCR and HI estimates for these possible onsite receptors.

For the offsite CSM, it was assumed that groundwater may be connected with surface water, and pore-water data were collected to evaluate potentially complete exposure pathways for surface water. Pore-water piezometer installation methods needed to be revised for two of the three offsite locations because the surface-water body was frozen and true pore-water samples could not be collected. However, the groundwater samples collected were able to be evaluated for human health risk. Because sulfolane degrades more rapidly in the presence of nutrients and oxygen that would be present in the surface water

(ADHSS 2010), and given the limited groundwater- surface water interchange, the results from these samples likely overestimate the concentration of COPCs in surface water. Thus, the data used for the swimming scenario overestimate human health risk.

Ingestion of offsite groundwater by current and future offsite residents was the primary exposure pathway for these potential receptors and resulted in the relatively highest HIs, including for infants (0 to 1 year). The ingestion rate used for this age group slightly exceeded that used for children (0 to 6 years). It was also assumed that infants do not breastfeed and that their formula was made with tapwater instead of pediatrician-recommended distilled water. Thus, it is highly likely that HI estimates for this receptor were overestimated.

Only potential ingestion exposures were quantitatively assessed for sulfolane. This analysis suggests dermal contact and inhalation exposure routes are not significant for sulfolane, which is supported by ATSDR (2010 and 2011) Health Consultations and animal studies (Brown et al. 1966, Andersen et al. 1977). Although these exposure routes were excluded, inclusion of them would likely not contribute significantly to overall hazard estimates. As described in Section 4.1.1.4, dermal contact and inhalation exposure routes are not significant for sulfolane. These assumptions are based on animal studies that have shown that sulfolane is not readily absorbed through human skin because of its low permeability and is not expected to pose a significant risk via an inhalation exposure route due to its low volatility. Ingestion of sulfolane in impacted environmental media is the appropriate exposure route to assess potential hazards to on and offsite receptors. Estimated hazards based on inhalation and dermal exposure routes are insignificant relative to hazards estimated based on the ingestion exposure route.

Both the ingestion rates of homegrown fruit and vegetables and the FI of each for offsite residents are not known. In the PPRTV Scenario and the ARCADIS Comparative Scenario, ingestion of fruit and vegetables by offsite residents was evaluated based on an assumed consumption rate at a level equivalent to 95% of the population (Table 3-12). However, the USEPA (2011a) recommends use of mean homegrown produce ingestion rates because mean values from their surveys are more stable than upper percentile values and because USEPA's RME scenario is defined as a combination of high end and mean exposure assumptions (USEPA 1989, 1991). Accordingly, the ARCADIS Scenario incorporates the use of mean values.

Alternate exposure parameters used in the ARCADIS Scenario are presented on Table 4-5. This third scenario uses produce consumption parameters per USEPA guidance, which translate to adult fruit and vegetable ingestion rates of 63,000 and 175,000 mg/day, respectively; child resident fruit and vegetable ingestion rates of 69,000 and 81,000 mg/day, respectively; and infant resident fruit and vegetable ingestion rates of 41,850 and 33,750 mg/day, respectively, based on mean *per capita* intakes presented in the USEPA (2011a) EFH Table 9-3. These calculations translate into the assumption that adults will consume approximately 2.2 ounces of fruits and 6 ounces of vegetables a day; children will consume approximately 2.5 ounces of fruits and 2.9 ounce of vegetables a day; and infants will consume approximately 1.5 ounces of fruits and 1.1 ounces of vegetables a day. The risk assessment in the ARCADIS Scenario (Section 4.5.6, below) assumes that during their first year of life, infants will ingest approximately 59 pounds of homegrown fruits and vegetables. For children and adults, the produce consumption rate is assumed to be approximately 123 and 187 pounds per year of homegrown fruits and vegetables, respectively.

HIs would be approximately three times lower for the ingestion of produce exposure pathway when using the mean *per capita* ingestion rates and keeping all other assumptions the same as presented in Table 3-12. However, even using high-end exposure and uptake assumptions for ingestion of homegrown produce, this is an insignificant exposure pathway compared to ingestion of groundwater.

For the PPRTV Scenario and the ARCADIS Comparative Scenario, a groundwater-to-produce BCF value of 1 was assumed. The ARCADIS Scenario (Section 4.5.6, below) uses a lower groundwater-to-produce BCF value based on literature review and derived from data presented in the Final Results of the North Pole Garden Sampling Project (ADEC 2011b). Specifically, plant tissue concentrations were combined with measured groundwater concentrations from the corresponding drinking water wells to derive a BCF for each plant species using the following equation:

BCF = [sulfolane concentration in plant tissue from garden]/
[sulfolane concentration in water used to irrigate the garden]

Average species-specific BCF values ranged from 0.06 to 0.61, with the lower values associated with roots and vegetable fruits (e.g., tomatoes) and the higher values associated with stems and leaves. These values were further evaluated to calculate a 95% UCL value of 0.32. This BCF was used in the ARCADIS Scenario to evaluate offsite resident ingestion of homegrown produce that has been irrigated with groundwater impacted by sulfolane. Using this BCF and other exposure assumptions for the ARCADIS Scenario (Table 4-5), the HIs for the produce exposure pathway are:

- EU-1 (Table 4-7): 0.003 for adult residents (chronic exposure), 0.01 for child residents (chronic exposure) and 0.001 for infant residents (subchronic exposure).

- EU-2 (Table 4-8): 0.001 for adult residents (chronic exposure), 0.003 for child residents (chronic exposure) and 0.0004 for infant residents (subchronic exposure).

- EU-3 (Table 4-9): 0.0002 for adult residents (chronic exposure), 0.0006 for child residents (chronic exposure) and 0.00007 for infant residents (subchronic exposure).

For the ARCADIS Scenario (Section 4.5.6, below), the adult and child recreational user surface-water ingestion rates of 0.021 and 0.049 liter/hour, respectively, were based on USEPA (2011a) recommended mean values for swimmers from the EFH Table 3-5. Adult and child recreational users were assumed to swim for 30 and 6 years, respectively, for 30 days per year for 0.5 hour per day. ARCADIS chose its exposure parameters to reflect the short time during which surface-water bodies near North Pole, Alaska may be warm enough to promote swimming. As noted in Tables 4-7, 4-8, and 4-9, HIs calculated for the ARCADIS Scenario that uses the assumptions described in this paragraph are approximately ten times lower (factor of 9.7) than the ARCADIS Comparative Scenario.

4.5.5 Risk Characterization

Some HIs exceed the ADEC acceptable target HI equal to 1, particularly those estimated for onsite construction/worker exposures to volatile COPCs in the air of a trench, which have been modeled from groundwater concentrations. For this Revised Draft Final HHRA, endpoint-specific HIs were not calculated and summing all HQs regardless of endpoint is health-protective. The USEPA acknowledges that adding all HQ or HI values may overestimate hazards, because the assumption of additivity is probably appropriate only for those chemicals that exert their toxicity by the same mechanism (USEPA 1989). Application of endpoint-specific HIs is expected to reduce total HI estimates.

As noted above, the child scenario has been assessed using the chronic oral reference dose, which is by definition a daily dose that is protective for sensitive receptors for lifetime exposures. Many USEPA programs such as the drinking water program use adult scenarios to protect both adults and children. For instance, Federal drinking water standards are derived using adult receptors, and USEPA states that such standards are protective for both adults and children. The use of the child exposure levels and body weights coupled with a chronic reference dose in this section provides an additional margin of exposure, but it is uncertain whether it provides additional public health protection. Appendices and H and K provide additional information on sulfolane's toxicological profile which shows that sulfolane presents no special concerns to children and that focusing public health protection efforts on adult receptors using a chronic reference dose adequately protects children.

4.5.6 Estimated Risk and Hazards for Uncertainty Assessment - ARCADIS Scenario

This section presents a detailed summary of ELCRs and HIs for potential offsite receptors (Section 4.3.2.2) under the ARCADIS Scenario. For each potential receptor, ELCRs and/or HIs are summarized based on possible exposure to maximum soil EPC COPC concentrations and/or 95% UCL-based soil and groundwater EPC COPC concentrations. Potential ELCRs and HIs related to offsite surface water exposures are also presented in this section. Appendix G presents complete risk calculations for onsite and offsite receptors based on 95% UCL soil and groundwater COPC concentrations and maximum assumed surface water concentrations.

Summaries of the cumulative ELCRs and estimated HIs for the receptors evaluated under the ARCADIS Scenario are presented in the following tables:

- Table 4-7 presents ELCR and HI summaries for potential offsite receptors at EU-1 based on 95% UCL soil and groundwater EPCs, as well ELCR and HI summaries for potential offsite surface water exposure based on maximum pore water (assumed surface water) EPCs.

- Table 4-8 presents ELCR and HI summaries for potential offsite receptors based on 95% UCL soil EPCs and 95% UCL groundwater EPCs at EU-2 wells. ELCR and HI summaries for potential offsite surface water exposure based on maximum pore water (assumed surface water) EPCs are also presented in Table 4-8.

- Table 4-9 presents ELCR and HI summaries for potential offsite receptors based on 95% UCL soil EPCs and 95% UCL groundwater EPCs at EU-3 wells. ELCR and HI summaries for potential offsite surface water exposure based on maximum pore water (assumed surface water) EPCs are also presented in Table 4-8.

As noted above, tables 4-6 to 4-9 present ELCR and HI summaries for potential offsite receptors based on 95% UCL COPC groundwater concentrations in each of the offsite EUs (95% UCL COPC groundwater concentrations are presented in Tables 4-6 and 4-7 for EU-1, Table 4-8 for EU-2, and Table 4-9 for EU-3). Potential dust exposures from onsite surface soil are based on 95% UCL surface soil (0 to 2 feet bgs) COPC concentrations.

4.5.6.1 Estimated Risks and Hazards for Potential Offsite Resident Receptors

Potential offsite receptors evaluated in the ARCADIS Scenario include current and future residents (adults, children and infants) and off-site recreators. In these ARCADIS scenarios, potential exposures were evaluated using the ARCADIS-derived oral RfDs for sulfolane that were derived from the scientific literature. Specifically, the ARCADIS-derived chronic oral RfD for sulfolane was used to evaluate potential exposures to adult residents and adult recreational users. Both the chronic and subchronic oral RfDs for sulfolane were used to evaluate child residents and child recreational users, and only the subchronic oral RfD for sulfolane was used to evaluate infant residents exposures.

4.5.6.1.1 Offsite Adult, Child and Infant Residents

Use of the maximum detected concentration of sulfolane in groundwater is overly conservative and over estimates HIs for offsite residents (chronic exposure), as is demonstrated by available data. Evaluation of separate EU data and corresponding 95% UCL concentrations sulfolane concentrations is a more appropriate approach for the reasons discussed previously.

Table 4-7 and Tables G-5a, G-6a and G-7a (Appendix G) present the estimated ELCRs and HIs for offsite resident receptors including resident adults (chronic exposure), resident children (chronic and subchronic exposure) and resident infants (subchronic exposure), respectively, based on inhalation of soil COPCs associated with fugitive windborne dust or vapors from onsite COPCs in surface soil, assuming 95% UCL COPC concentrations. The total estimated ELCR is 4 x 10^{-8} and the total estimated HI is 0.001 for an adult resident receptor (chronic exposure; Table G-5a). The total estimated ELCR is 9 x 10^{-9} and the total estimated HI is 0.001 for child resident receptor (chronic exposure; Table G-6a). For the infant resident receptor (subchronic exposure), the total estimated ELCR is 1 x 10^{-9} and the total estimated HI is 0.0007 (Table G-7a).

For potential exposures to 95% UCL sulfolane concentrations in groundwater at EU-1, the estimated HIs for offsite residents potentially exposed via ingestion of groundwater (i.e., tapwater) from EU-1 are presented in Table 4-7. The total estimated HIs for offsite resident receptors are 0.5 for adult resident (chronic exposure; Table G-5b [Appendix G]), 1 for child resident (chronic exposure; Table G-6b [Appendix G]) and 0.3 for infant resident (subchronic exposure; Table G-7b [Appendix G]). For potential exposure to sulfolane in homegrown produce irrigated with groundwater in EU-1, the estimated HI for an adult resident is 0.003 (chronic exposure; Table G-5b [Appendix G]), the estimated HI for a child resident is 0.01 (chronic exposure; Table G-6c [Appendix G]) and the estimated HI for an infant resident is 0.001 (subchronic exposure; Table G-7c [Appendix G]). Tables G-11 and G-12 present the HIs associated with ingestion of surface water for adults (chronic exposures; Table G-11) and children (chronic exposures; Table G-12a).

Separate hazards were also evaluated for the resident child receptor based on subchronic toxicity values because the ED for this receptor (6 years) meets the definition of subchronic exposure. Table 4-7 and Table G-6d (Appendix G) presents the estimated ELCRs and HIs for offsite child residents in EU-1, assuming potential exposure to 95% UCL COPC concentrations in ambient air from onsite surface soil using subchronic RfDs, including the ARCADIS-derived subchronic oral RfD for sulfolane. The total estimated ELCR is 9 x 10^{-9} and the total estimated HI is 0.0007. Excluding the estimated arsenic ELCR and HI, which are likely attributable to background, the total estimated ELCR is 8 x 10^{-9} and the total estimated HI is 0.0005 (see Table G-6d [Appendix G]).

Table 4-7 and tables G-6e and G-6f (Appendix G) present the estimated HIs for a child resident in EU-1 based on ingestion of the 95% UCL detected concentration of sulfolane in groundwater (i.e., tapwater) and ingestion of homegrown produce, respectively. These scenarios were evaluated using the ARCADIS-derived subchronic oral RfD for sulfolane. The estimated HIs for a child resident assuming subchronic exposures at EU-1 are 0.1 and 0.001 based on ingestion of tapwater and ingestion of homegrown produce, respectively (see Tables G-6e and G-6f [Appendix G]).

Table 4-8 presents the estimated HIs associated with offsite resident receptors potentially exposed to groundwater at EU-2. Assuming the 95% UCL of sulfolane in groundwater at EU-2 and using the alternative oral RfDs for sulfolane derived directly from the scientific literature by ARCADIS, the estimated HI for an adult resident is 0.2 (chronic exposure; Table G-13a [Appendix G]), the estimated HI for a child resident is

0.4 (chronic exposure; Table G-14a [Appendix G]) and the estimated HI for an infant resident is 0.09 (subchronic exposure; Table G-15a [Appendix G]), based on ingestion of tap water. For consumption of homegrown produce irrigated with groundwater from EU-2 (95% UCL), the estimated HIs for offsite resident receptors are 0.001 for adult residents (chronic exposure; Table G-13b [Appendix G]), 0.003 for child residents (chronic exposure; Table G-14b [Appendix G]) and 0.0004 for infant residents (subchronic exposure; Table G-15b [Appendix G]).

Assuming subchronic exposures by a resident child, Table 4-8 includes the estimated HIs using the ARACADIS-derived subchronic oral RfD for sulfolane. The estimated HI is 0.04 for the offsite child resident receptor ingesting groundwater (i.e., tapwater) from ingestion of EU-2 (95% UCL concentration of sulfolane in groundwater (i.e., tapwater) (see Table G-14c [Appendix G]). The estimated HI for this receptor based on subchronic exposure and ingestion of homegrown produce irrigated with groundwater from EU-2 (95% UCL sulfolane concentration) is 0.0003 (see Table G-14d [Appendix G]).

Table 4-9 presents the hazard estimates for potential exposures by offsite resident receptors at EU-3, based on ingestion of tapwater and ingestion of homegrown produce, respectively, assuming the 95% UCL for sulfolane in groundwater and ARCADIS-derived oral RfD for sulfolane. For offsite resident receptors ingesting groundwater (i.e., tapwater), the estimated HIs are 0.03 for the adult resident (chronic exposure; Table G-19a [Appendix G]), 0.07 for the child resident (chronic exposures; Table G-20a [Appendix G]) and 0.02 for the infant resident (subchronic exposures; Table G-21a [Appendix G]). For potential exposures from consumption of homegrown produce in EU-3, the estimated HIs are 0.0002 for the adult resident (chronic exposure; Table G-19b [Appendix G]), 0.0006 for the child resident (chronic exposures; see Table G-20b [Appendix G]) and 0.00007 for the infant resident (subchronic exposures; Table G-21b [Appendix G]).

Assuming subchronic exposures by a resident child, Table 4-9 includes the estimated HIs using the alternative subchronic oral RfD for sulfolane. The estimated HI is 0.007 for the offsite child resident receptor ingesting groundwater (i.e., tapwater) from EU-3 (95% UCL concentration of sulfolane) (Table G-20c [Appendix G]). The estimated HI is 0.00006 for this receptor based on subchronic ingestion of homegrown produce irrigated with groundwater from EU-3 (95% UCL sulfolane concentration) (see Table G-20d [Appendix G]).

4.5.6.1.2 Offsite Adult and Child Recreational Users

The estimated HIs for an offsite adult recreational user (i.e., swimmer) who may incidentally ingest sulfolane in surface water are presented in Table 4-7, 4-8, and 4-9. The estimated HIs are based on the maximum offsite sulfolane concentration in pore water and the ARCADIS-derived chronic oral RfDs for sulfolane. For offsite adult recreational users, the estimated HI is 0.0002 (chronic exposure; Table G-11 [Appendix G]). Tables 4-7, 4-8, and 4-9 also show the estimated HIs for the offsite child (aged 1 to 6 years) recreational user (i.e., swimmer) who may incidentally ingest sulfolane in surface water, assuming the maximum offsite sulfolane concentration in pore water and using both the ARCADIS-derived chronic and subchronic oral RfDs for sulfolane, respectively. For offsite child recreational users, the HI is 0.002 assuming chronic exposure (Table G-12a [Appendix G]) and 0.0002 assuming subchronic exposures (Table G-12b [Appendix G]).

4.5.7 Conclusions for ARCADIS Scenario

Table 4-7 presents the estimated ELCRs and HIs using 95% UCL COPC concentrations in EU-1. Using the 95% UCL onsite COPC soil concentrations, the 95% UCL onsite and EU-1 offsite sulfolane groundwater concentrations, the ARCADIS-derived oral RfDs for sulfolane, and the alternate ARCADIS exposure assumptions (Table 4-5), the estimated HIs for all receptors evaluated in the ARCADIS Scenario are equal to or below the target HI of 1.

The estimated total ELCRs for the potential receptors evaluated in the ARCADIS Scenario are equal to or below the ADEC acceptable ELCR of 1 x 10^{-5}.

As shown in Table 4-8, using the 95% UCL COPC concentrations in onsite surface soil and 95% UCL sulfolane concentration in groundwater in EU-2, the estimated HIs are below the target HI of 1 for the potential receptors evaluated. The estimated total ELCRs for the receptors evaluated are below the ADEC acceptable ELCR of 1 x 10^{-5}.

As shown in Table 4-9, using the 95% UCL COPC concentrations in onsite surface soil and 95% UCL sulfolane concentration in groundwater in EU-3, the estimated HIs are below the target HI of 1 for the potential receptors evaluated. The estimated total ELCRs for the receptors evaluated are below the ADEC acceptable ELCR of 1 x 10^{-5}.

As demonstrated in this section and in Tables 4-6 through 4-9, there are no offsite potential receptors that exceed the target HI of 1 and no offsite EUs that exceed the acceptable ELCR when the ARCADIS-derived toxicity value is used in combination with the ARCADIS exposure parameters.

5. Site-Specific Alternative Cleanup Levels

The Draft Risk Assessment Procedures Manual (ADEC 2010a, 2011d) provides for ACLs to be calculated for receptors who exceed a target risk level, by setting the total carcinogenic risk to 1 x 10^{-5} or the HI to 1 and solving for the concentration term for each COPC in each medium that contributes significantly to total potential risk ("risk drivers"). Under this method, using the exposure parameters set forth in the PPRTV and ARCADIS Comparative Scenarios, and individual COPC ELCR target risk of 1 x 10^{-5} and HI of 1, ACLs of 0.6, 0.03, 3.5 and 0.09 mg/L were calculated for benzene, naphthalene, xylenes and 1,3,5-trimethylbenzene, respectively, based on incidental ingestion of groundwater in a trench, dermal contact with groundwater and inhalation of trench air by onsite construction workers. Table 5-1 presents the ACLs for the PPRTV, ARCADIS Comparative, and ARCADIS Scenarios, Appendix J provides the calculations.

The ADEC and FHRA continue to discuss and evaluate an appropriate ACL for sulfolane; therefore, no ACL is proposed for sulfolane at this time. Using the various exposure scenarios, toxicological reference values and exposure assumptions presented in this Revised Draft Final HHRA, the range of potential ACLs includes:

- 14 µg/L, derived from the PPRTV RfD and ADEC-approved exposure assumptions (PPRTV Scenario), for a child with chronic exposure

- 145 µg/L, derived from the ARCADIS RfD and ADEC-approved exposure assumptions (ARCADIS Comparative Scenario), for a child with chronic exposure

- 362 µg/L, derived from the ARCADIS RfD and the alternate exposure assumptions (ARCADIS Scenario), for an adult with chronic exposure.

Based on the Margin of Exposure evaluation presented in Appendix K, ARCADIS and Dr. Farland conclude that an ACL within this range would be protective of human health. Table 5-2 provides the ACLs that correspond to the PPRTV, ARCADIS Comparative, and ARCADIS Scenarios for infant (subchronic), child (subchronic and chronic) and adult (chronic) exposures.

In the meantime, as potential sulfolane ACLs are considered, offsite residents and commercial workers located immediately north of the site obtain drinking water from the city's new water supply wells. Individuals located outside the city water service area but within or near the dissolved sulfolane plume have been provided with alternative water supplies by FHRA (including treatment systems, bulk water tanks or continued supplies of bottled water) to eliminate potential ingestion of groundwater impacted with sulfolane.

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Tables

Table 3-1
Constituents of Interest in Soil and Groundwater

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent of Interest	Constituent Included in Analyte List: 2000 Characterization Study-Soil [a]	2001 Characterization Study-Soil [b]	2009-2010 Characterization Study-Soil [c]	Historical Groundwater [d]	Included on Refinery Laboratory Spilled Material "Ingredient" List	Toxicity Values Available from USEPA: Oral CSF	IUR	Oral RfD	Inhalation RfC
VOCs									
1,1-Dichloroethene		X	X	X				X	X
1,2,4-Trimethylbenzene		X	X	X	X				X
1,3,5-Trimethylbenzene		X	X	X				X	
1-Chloronaphthalene				X				X	
4-Isopropyltoluene(p-cymene)		X	X	X					
Benzene	X	X	X	X	X	X	X	X	X
Chlorobenzene			X	X				X	X
cis-1,2-Dichloroethene		X		X				X	
Cyclohexane					X				X
Ethylbenzene	X	X	X	X	X	X	X	X	X
Isopropylbenzene (cumene)		X	X	X	X			X	X
Methyl tert-butyl ether (MTBE)				X		X	X		X
Methylene chloride	X			X		X	X	X	X
n-Butylbenzene			X	X				X	
n-Hexane					X			X	X
N-Propylbenzene		X	X	X				X	X
Propylene gylcol (1,2,-Propanediol)					X			X	
Pyridine		X		X				X	
sec-Butylbenzene		X	X	X					
tert-Butylbenzene		X	X	X					
Toluene	X	X	X	X	X			X	X
Trichlorofluoromethane (Freon 11)		X		X				X	X
Xylenes	X	X	X	X	X			X	X
SVOCs									
1,2-Dichlorobenzene		X	X	X				X	X
1,2-Diphenylhydrazine (as Azobenzene)		X		X		X	X		
1,3-Dichlorobenzene		X	X	X					
1-Methylnaphthalene				X		X		X	
2,4,5-Trichlorophenol		X	X	X				X	
2,4,6-Trichlorophenol		X	X	X		X	X	X	
2,4-Dichlorophenol		X	X	X				X	
2,4-Dimethylphenol		X		X				X	
2,4-Dinitrophenol		X	X	X				X	
2,4-Dinitrotoluene		X	X	X		X	X	X	
2,6-Dinitrotoluene		X	X	X				X	
2-Chloronaphthalene		X	X	X				X	
2-Chlorophenol		X	X	X				X	
2-Methylnaphthalene		X	X	X				X	
2-Methylphenol (o-Cresol)		X	X	X				X	X
2-Nitroaniline		X	X	X				X	X
2-Nitrophenol		X	X	X					
3 & 4-Methylphenol (m,p-Cresol)		X	X	X				X	X
3,3-Dichlorobenzidine		X	X	X		X	X		
3-Nitroaniline		X	X	X					
4,6-Dinitro-2-methylphenol		X	X	X					
4-Bromophenyl phenyl ether		X	X	X					
4-Chloro-3-methylphenol		X	X	X					
4-Chloroaniline		X	X	X		X		X	
4-Chlorophenyl phenyl ether		X	X	X					
4-Nitroaniline		X	X	X				X	X
4-Nitrophenol		X	X	X					
Acenaphthene		X	X	X				X	
Acenaphthylene		X	X	X					
Anthracene		X	X	X				X	
Benzo (a) anthracene		X	X	X		X	X		
Benzo (a) pyrene		X	X	X		X	X		
Benzo (b) fluoranthene		X	X	X		X	X		
Benzo (g,h,i) perylene		X	X	X					
Benzo (k) fluoranthene		X	X	X		X	X		
Benzidine				X		X	X	X	
Benzoic Acid		X	X	X				X	
Benzyl alcohol		X	X	X				X	
Bis(2-chloroethoxy)methane		X	X	X				X	
Bis(2-chloroethyl)ether		X	X	X		X	X		
Bis(2-chloroisopropyl)ether		X	X	X		X	X	X	
Bis(2-ethylhexyl)phthalate		X	X	X		X	X	X	
Butyl benzyl phthalate		X	X	X		X		X	
Carbazole				X					
Chrysene		X	X	X		X	X		
Dibenzo (a,h) anthracene		X	X	X		X	X		
Dibenzofuran		X	X	X					
Diethyl phthalate		X	X	X				X	
Dimethyl phthalate		X	X	X					
Di-n-butyl phthalate		X	X	X				X	
Di-n-Octylphthalate			X	X					
Fluoranthene		X	X	X				X	
Fluorene		X	X	X				X	
Hexachlorobenzene		X	X	X		X	X	X	
Hexachlorobutadiene		X	X	X		X	X	X	
Hexachlorocyclopentadiene		X	X	X				X	X
Hexachloroethane		X	X	X		X	X	X	
Indeno (1,2,3-cd) pyrene		X	X	X		X	X		
Isophorone		X	X	X		X		X	X
Isopropanol (propanol)					X				X
Naphthalene		X	X	X	X		X	X	X
Nitrobenzene		X	X	X			X	X	X
N-Nitrosodimethylamine		X	X	X		X	X	X	X
N-Nitrosodi-n-propylamine		X	X	X		X	X		
N-Nitrosodiphenylamine		X	X	X		X	X		
Pentachlorophenol		X	X	X		X	X	X	
Phenanthrene		X	X	X					
Phenol		X	X	X				X	X
Pyrene		X	X	X				X	

Table 3-1
Constituents of Interest in Soil and Groundwater

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

	Constituent Included in Analyte List					Toxicity Values Available from USEPA			
Constituent of Interest	**2000 Characterization Study-Soil [a]**	**2001 Characterization Study-Soil [b]**	**2009-2010 Characterization Study-Soil [c]**	**Historical Groundwater [d]**	**Included on Refinery Laboratory Spilled Material "Ingredient" List**	**Oral CSF**	**IUR**	**Oral RfD**	**Inhalation RfC**
Metals									
Antimony	X	X		X				X	
Arsenic	X	X		X	X	X	X	X	X
Barium		X		X	X			X	X
Cadmium		X		X	X		X	X	X
Chromium Total	X	X		X	X	X	X	X	X
Copper				X	X			X	
Iron				X	X			X	
Lead		X		X	X				
Mercury		X		X	X			X	X
Nickel				X	X		X	X	X
Selenium	X			X	X			X	X
Silver		X		X				X	
Zinc				X	X			X	
Other									
Alkanol amines					X				
Alkylamines					X				
Alkylene amines					X				
Calcium					X				
Chloride					X				
Cyanide					X			X	
Di-n-Octylphthalate				X					
Dinonylnaphthylsulfonic acid					X				
Fluoroalkyl Surfactant					X				
Iron Oxides					X				
Isopropanol (propanol)					X				X
2-Methoxymethylethoxy propanol					X				
Monoethanolamine					X				
Montmorillonite, calcined					X				
Phenol					X			X	X
Propylene glycol (1,2-Propanediol)					X			X	
Silica					X				X
Sulfate				X					
Sulfolane			X	X	X			X	
GRO		X	X	X					
DRO		X	X	X					
RRO		X	X	X					
Heavy aromatic naptha (Naphtha, High Flash Aromatic [HFAN])					X				
Heavy paraffinic distillate (mixture)					X				

Notes:

a - Shannon and Wilson, Inc. 2000. Draft Site Characterization and Corrective Action Plan, Williams Alaska Petroleum, Inc., North Pole Refinery. December 2000.

b - Shannon and Wilson, Inc. 2001. Contaminant Characterization Study, Williams Alaska Petroleum, Inc., North Pole Refinery, North Pole, Alaska. October 2001.

c - Barr Engineering Company. 2011. Site Characterization and First Quarter 2011 Groundwater Monitoring Report. May 2011.

d - Included in SWI groundwater database, dated June 2011

USEPA = United States Environmental Protection Agency Integrated Risk Information System (2011)

CSF = Cancer Slope Factor

IUR= Inhalation Unit Risk

RfD = Reference Dose

RfC = Reference Concentration

VOCs - volatile organic compounds

SVOCs - semi-volatile organic compounds

Note, lead is evaluated based on blood lead level.

Table 3-2a
Constituents of Potential Concern in Soil and Groundwater

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituents of Interest	Maximum Soil Concentration (mg/kg) [a]	Maximum Observation or MRL Location	ADEC Soil Cleanup Level Based on Migration to Groundwater (mg/kg)	ADEC Soil Cleanup Level Based on Direct Contact (mg/kg)	ADEC Soil Cleanup Level Based on Outdoor Inhalation (mg/kg)	Selected Soil Screening Level [h] (mg/kg)	Soil COPC Selected in the RAWP [b]	Soil COPC in the 2012 HHRA [c]
VOCs								
1,1-Dichloroethene	<1.36	SB-151 (6.7 - 8.4)	0.03	14	0.85	0.03	Yes	Yes
1,2,4-Trimethylbenzene	205	O-2	23	5,100	49	4.9	Yes	Yes
1,3,5-Trimethylbenzene	81.1	10/20/2010 at O-2	23	5,100	42	4.2	Yes	Yes
1-Chloronaphthalene	--		na	na	na	na	No [i]	No [i]
4-Isopropyltoluene (p-cymene)	20.2	10/20/2010 at O-2	na	na	na	na	Yes	Yes
Benzene	82	MW-135	0.025	150	11	0.025	Yes	Yes
Chlorobenzene	<1.36	SB-151 (6.7 - 8.4)	0.63	2,000	200	0.63	Yes	Yes
cis-1,2-Dichloroethene	<1.36	SB-151 (6.7 - 8.4)	0.24	1,000	130	0.24	Yes	Yes
Cyclohexane	44.9	SB-160 (6.4 - 8.4)	13	7,000	na	13	Yes	Yes
Ethylbenzene	111	O-2	6.9	10,100	110	6.9	Yes	Yes
Isopropylbenzene (cumene)	41.6	O-2	51	10,100	62	6.2	Yes	Yes
Methyl tert-butyl ether	<5.4	SB-151 (6.7 - 8.4)	1.3	4,600	290	1.3	Yes	Yes
Methylene chloride	0.188	SB-123 (3.5 - 5.2) & Dup	0.016	1,100	160	0.016	Yes	Yes
n-Butylbenzene	107	O-2	15	1,000	42	4.2	Yes	Yes
n-Hexane	13	SB-123 (6.0 - 8.0)	6.2	570	na	6.2	Yes	Yes
n-Propylbenzene	72.7	O-2	15	1,000	42	4.2	Yes	Yes
Propylene gylcol (1,2,-Propanediol)	--		150	1,200,000	na	150	Yes	No [i]
Pyridine	<35.9	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
sec-Butylbenzene	25.3	O-2	12	1,000	41	4.1	No	Yes
tert-Butylbenzene	2.56	MW-176C	12	1,000	70	7	Yes	No
Toluene	392	MW-135	6.5	8,100	220	6.5	Yes	Yes
Trichlorofluoromethane (Freon 11)	22.7	3/8/2001 at MW135	86	30,400	990	86	No	No
Xylenes	706	SB-180 (5.5 - 7.2)	63	20,300	63	6.3	Yes	Yes
SVOCs								
1,2-Dichlorobenzene	<35.9	5/30/2001 at B1-4	5.1	9,100	45	4.5	Yes	Yes
1,2-Diphenylhydrazine (as Azobenzene)	<35.9	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
1,3-Dichlorobenzene	<35.9	5/30/2001 at B1-4	28	9,100	69	6.9	Yes	Yes
1-Methylnaphthalene	88.5	O-21 (4.0-6.0)	6.2	280	760	6.2	Yes	Yes
2,4,5-Trichlorophenol	<35.9	5/30/2001 at B1-4	67	6,500	na	67	No	No
2,4,6-Trichlorophenol	<35.9	5/30/2001 at B1-4	1.4	460	4,100	1.4	Yes	Yes
2,4-Dichlorophenol	<35.9	5/30/2001 at B1-4	1.3	230	na	1.3	Yes	Yes
2,4-Dimethylphenol	<35.9	5/30/2001 at B1-4	8.8	1,300	na	8.8	Yes	Yes
2,4-Dinitrophenol	<182	5/30/2001 at B1-4	0.54	160	na	0.54	Yes	Yes
2,4-Dinitrotoluene	<35.9	5/30/2001 at B1-4	0.0093	8.8	na	0.0093	Yes	Yes
2,6-Dinitrotoluene	<35.9	5/30/2001 at B1-4	0.0094	8.9	na	0.0094	Yes	Yes
2-Chloronaphthalene	<35.9	5/30/2001 at B1-4	120	4,700	na	120	No	No
2-Chlorophenol	<35.9	5/30/2001 at B1-4	1.5	510	2,300	1.5	Yes	Yes
2-Methylnaphthalene	240	O-2	6.1	280	750	6.1	Yes	Yes
2-Methylphenol (o-Cresol)	<35.9	5/30/2001 at B1-4	15	3,200	na	15	Yes	Yes
2-Nitroaniline	<182	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
2-Nitrophenol	<35.9	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
3 & 4-Methylphenol (m,p-Cresol)	<35.9	5/30/2001 at B1-4	1.5	350	na	1.5	Yes	Yes
3,3-Dichlorobenzidine	<73	5/30/2001 at B1-4	0.19	11	na	0.19	Yes	Yes
3-Nitroaniline	<182	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
4,6-Dinitro-2-methylphenol	<182	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
4-Bromophenyl phenyl ether	<35.9	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
4-Chloro-3-methylphenol	<73	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
4-Chloroaniline	<73	5/30/2001 at B1-4	0.057	90	na	0.057	Yes	Yes
4-Chlorophenyl phenyl ether	<35.9	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
4-Nitroaniline	<35.9	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
4-Nitrophenol	<182	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
Acenaphthene	<35.9	5/30/2001 at B1-4	180	2,800	na	180	No	No
Acenaphthylene	0.0102	SB-168 (0.0 - 2.0)	180	2,800	na	180	No	No
Anthracene	0.431	SB-134 (5.0 - 6.8)	2,000	20,600	na	2,000	No	No
Benzidine	--		na	na	na	na	No [i]	No [i]
Benzo (a) anthracene	0.0988	DO-21 (6.0-8.0)	3.6	4.9	na	0.49	Yes	Yes [k]
Benzo (a) pyrene	0.0952	DO-21 (6.0-8.0)	2.1	0.49	na	0.049	Yes	Yes [k]
Benzo (b) fluoranthene	0.108	SB-168 (0.0 - 2.0)	12	5	na	0.49	Yes	Yes [k]
Benzo (g,h,i) perylene	0.186	O-12 (0.0 - 2.0)	38,700	1,400	na	140	No	No
Benzo (k) fluoranthene	0.0404	SB-168 (0.0 - 2.0)	120	49	na	4.9	Yes	Yes [k]
Benzoic Acid	<182	5/30/2001 at B1-4	410	317,000	na	410	No	No
Benzyl alcohol	<35.9	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
Bis(2-chloroethoxy)methane	<35.9	5/30/2001 at B1-4	na	na	na	na	No [i]	No [i]
Bis(2-chloroethyl)ether	<35.9	5/30/2001 at B1-4	0.0022	7.5	3.3	0.0022	Yes	Yes
Bis(2-chloroisopropyl)ether	<35.9	5/30/2001 at B1-4	na	na	na	na	No [j]	No [j]
Bis(2-ethylhexyl)phthalate	0.0958	SB-105 (5.0 - 6.2)	13	220	na	13	Yes	No
Butyl benzyl phthalate	<35.9	5/30/2001 at B1-4	920	2,900	na	290	No	No
Carbazole	--		6.5	290	na	6.5	No	No
Chrysene	0.783	SB-108 (0.0 - 2.0)	360	490	na	49	No	Yes [k]
Dibenzo (a,h) anthracene	0.018	DO-21 (6.0-8.0)	4	0.49	na	0.049	Yes	Yes [k]

Table 3-2a
Constituents of Potential Concern in Soil and Groundwater

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituents of Interest	Maximum Soil Concentration (mg/kg) [a]	Maximum Observation or MRL Location	ADEC Soil Cleanup Level Based on Migration to Groundwater (mg/kg)	ADEC Soil Cleanup Level Based on Direct Contact (mg/kg)	ADEC Soil Cleanup Level Based on Outdoor Inhalation (mg/kg)	Selected Soil Screening Level [h] (mg/kg)	Soil COPC Selected in the RAWP [b]	Soil COPC in the 2012 HHRA [c]
Dibenzofuran	1.31	O-2	11	200	na	11	Yes	No
Diethyl phthalate	<35.9	5/30/2001 at B1-4	130	61,900	na	130	No	No
Dimethyl phthalate	<35.9	5/30/2001 at B1-4	1,100	773,000	na	1,100	No	No
Di-n-butyl phthalate	<35.9	5/30/2001 at B1-4	80	7,900	na	80	No	No
Di-n-Octylphthalate	<35.9	5/30/2001 at B1-4	3,800	3,100	na	310	No	No
Fluoranthene	0.258	DO-21 (6.0-8.0)	1,400	1,900	na	190	No	No
Fluorene	2.56	MW-176C	220	2,300	na	220	No	No
Hexachlorobenzene	<35.9	5/30/2001 at B1-4	0.047	3.2	1.5	0.047	Yes	Yes
Hexachlorobutadiene	<35.9	5/30/2001 at B1-4	0.12	13	3.8	0.12	Yes	Yes
Hexachlorocyclopentadiene	<35.9	5/30/2001 at B1-4	1.3	390	2	0.2	Yes	Yes
Hexachloroethane	<35.9	5/30/2001 at B1-4	0.21	63	170	0.21	Yes	Yes
Indeno (1,2,3-cd) pyrene	0.0688	SB-168 (0.0 - 2.0)	41	5	na	0.49	Yes	Yes [k]
Isophorone	<35.9	5/30/2001 at B1-4	3.1	5,300	na	3.1	Yes	Yes
Isopropanol (propanol)	--		na	na	na	na	Yes	Yes
Naphthalene	125	O-2	20	1,400	28	2.8	Yes	Yes
Nitrobenzene	<35.9	5/30/2001 at B1-4	0.094	51	120	0.094	Yes	Yes
N-Nitrosodimethylamine	<35.9	5/30/2001 at B1-4	0.000053	0.16	0.19	0.000053	Yes	Yes
N-Nitrosodi-n-propylamine	<35.9	5/30/2001 at B1-4	0.0011	0.52	na	0.0011	Yes	Yes
N-Nitrosodiphenylamine	<35.9	5/30/2001 at B1-4	15	750	na	15	Yes	Yes
Pentachlorophenol	<182	5/30/2001 at B1-4	0.0047	39	na	0.0047	Yes	Yes
Phenanthrene	5.6	MW-176C	3,000	20,600	na	2,060	No	No
Phenol	<35.9	5/30/2001 at B1-4	68	23,200	na	68	No	No
Pyrene	0.278	DO-21 (6.0-8.0)	1,000	1,400	na	140	No	No
Metals								
Antimony	0.366	B3	3.6	41	na	3.6	Yes	No
Arsenic	17.6	SB-101 (0.0 - 2.0)	3.9	4.5	na	0.45	Yes	Yes
Barium	103	5/30/2001 at B-3	1,100	20,300	na	1,100	No	No
Cadmium	0.469	5/30/2001 at B-3	5	79	na	5	No	No
Chromium, Total	50.9	SB-157 (0.0 - 2.0)	25	300	na	25	Yes	Yes
Copper	52.4	SB-140 (3.0 - 5.0)	460	4,100	na	410	Yes	No
Iron	29000	SB-101 (0.0 - 2.0)	640	55,000	na	640	Yes	Yes
Lead	7.48	5/30/2001 at B-3	na	400	na	40	No	No
Mercury	<0.0418	3/8/2001 at MW135	1.4	30	18	1.4	No	No
Nickel	38	SB-118 (2.0 - 3.7)	8.6	2,000	na	8.6	Yes	Yes
Selenium	0.635	SB-140 (3.0 - 5.0)	3.4	510	na	3.4	Yes	No
Silver	0.107	B3	11.2	510	na	11.2	No	No
Zinc	83.7	SB-140 (3.0 - 5.0)	4,100	30,400	na	3,040	Yes	No
Other								
Alkanol amines	--		na	na	na	na	Yes[o]	Yes[o]
Alkylamines	--		na	na	na	na	Yes[o]	Yes[o]
Alkylene amines	--		na	na	na	na	Yes[o]	Yes[o]
Calcium	--						No[l]	No[l]
Chloride	--						No[l]	No[l]
Dinonylnaphthylsulfonic acid	--		na	na	na	na	Yes[o]	Yes[o]
Fluoroalkyl Surfactant	--		na	na	na	na	Yes[o]	Yes[o]
Heavy aromatic naptha (Naphtha, High Flash Aromatic [HFAN])	--						No[m]	No[m]
Heavy paraffinic distillate (mixture)	--						No[m]	No[m]
Iron Oxides	--		na	na	na	na	Yes[o]	Yes[o]
2-Methoxymethylethoxy propanol	--		na	na	na	na	Yes[o]	Yes[o]
Monoethanolamine	--		na	na	na	na	Yes[o]	Yes[o]
Montmorillonite, calcined	--		na	na	na	na	Non	Non
Silica	--		na	na	na	na	Yes[o]	Yes[o]
Cyanide	0.15	SB-101 (0.0 - 2.0)	27	2,000	na	27	Yes[o]	No
Sulfate	--		na	na	na	na	No [j]	No [j]
Sulfolane	58.9	O-2	0.073	250	na	0.073	Yes	Yes
GRO	7,730	3/8/2001 at MW135	300	1,400	1,400	140	Yes	Yes
DRO	18800	SB-160 (6.4-8.4)	250	10,250	12,500	250	Yes	Yes
RRO	64700	1236-072804-009	11,000	10,000	22,000	1,000	Yes	Yes

Table 3-2a
Constituents of Potential Concern in Soil and Groundwater

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituents of Interest	Maximum Groundwater Concentration (ug/L) [d,k]	Maximum Observation or MRL Location	ADEC Groundwater Screening Level (ug/L)	Source	Groundwater COPC in RAWP [b]	Groundwater COPC in 2012 HHRA [c]
VOCs						
1,1-Dichloroethene	<16.96	MW-125 & Dup	0.7	[e]	Yes	Yes
1,2,4-Trimethylbenzene	614	MW-139 & Dup	180	[e]	Yes	Yes
1,3,5-Trimethylbenzene	184	MW-139 & Dup	180	[e]	Yes	Yes
1-Chloronaphthalene	<21.3	11/17/2006 at MW-106	290	[f]	No[i]	No[i]
4-Isopropyltoluene (p-cymene)	60.4	MW-139 & Dup	na		Yes	Yes
Benzene	18500	MW-135	0.5	[e]	Yes	Yes
Chlorobenzene	< 1 - <400	04/17/2007 at MW-138	10	[e]	No	No
cis-1,2-Dichloroethene	2.84	5/10/2001 at MW-116	7	[e]	No	No
Cyclohexane	542	MW-125 & Dup	1,300	[f]	Yes	No
Ethylbenzene	2750	MW-135	70	[e]	Yes	Yes
Isopropylbenzene (cumene)	106	5/10/2001 at MW-116	370	[e]	No	No
Methyl tert-butyl ether	7.1	MW-127 & Dup	47	[e]	Yes	No
Methylene chloride	<12.16	MW-125 & Dup	0.5	[e]	Yes	Yes
n-Butylbenzene	14.3	5/10/2001 at MW-116	37	[e]	No	No
n-Hexane	64.8	MW-135	88	[f]	Yes	No
n-Propylbenzene	122	MW-139 & Dup	37	[e]	Yes	Yes
Propylene gylcol (1,2,-Propanediol)	<2000	MW-110	73,000	[f]	Yes	No
Pyridine	<21.3	11/17/2006 at MW-106	3.7	[f]	No[i]	No[i]
sec-Butylbenzene	18.6	5/10/2001 at MW-116	37	[e]	No	No
tert-Butylbenzene	<0.002	5/10/2001 at MW-116	37	[e]	No	No
Toluene	30100	MW-135	100	[e]	Yes	Yes
Trichlorofluoromethane (Freon 11)	<2	2001 all MWs analyzed	1,100	[e]	No	No
Xylenes	14,090	MW-135	1,000	[e]	Yes	Yes
SVOCs						
1,2-Dichlorobenzene	1.4	04/17/2007 at MW-116	60	[e]	No	No
1,2-Diphenylhydrazine (as Azobenzene)	<21.3	11/17/2006 at MW-106	0.084	[f]	No[i]	No[i]
1,3-Dichlorobenzene	< 1-< 400	04/17/2007 at MW-138	330	[e]	No	No
1-Methylnaphthalene	35	MW-139 & Dup	15	[e]	Yes	Yes
2,4,5-Trichlorophenol	<10.6	11/17/2006 at MW-106	370	[e]	No	No
2,4,6-Trichlorophenol	<10.6	11/17/2006 at MW-106	7.7	[e]	No[i]	No[i]
2,4-Dichlorophenol	<10.6	11/17/2006 at MW-106	11	[e]	No	No
2,4-Dimethylphenol	22	5/10/2001 at MW-116	73	[e]	No	No
2,4-Dinitrophenol	<21.3	11/17/2006 at MW-106	7.3	[e]	No[i]	No[i]
2,4-Dinitrotoluene	<10.6	11/17/2006 at MW-106	0.13	[e]	No[i]	No[i]
2,6-Dinitrotoluene	<10.6	11/17/2006 at MW-106	0.13	[e]	No[i]	No[i]
2-Chloronaphthalene	<10.6	11/17/2006 at MW-106	290	[f]	No	No
2-Chlorophenol	<10.6	11/17/2006 at MW-106	18	[e]	No	No
2-Methylnaphthalene	30.9	MW-139 & Dup	15	[e]	Yes	Yes
2-Methylphenol (o-Cresol)	<10.6	11/17/2006 at MW-106	180	[e]	No	No
2-Nitroaniline	<21.3	11/17/2006 at MW-106	37	[f]	No	No
2-Nitrophenol	<10.6	11/17/2006 at MW-106	na		No[i]	No[i]
3 & 4-Methylphenol (m,p-Cresol)	<10.6	11/17/2006 at MW-106	18	[e]	No	No
3,3-Dichlorobenzidine	<21.3	11/17/2006 at MW-106	0.19	[e]	No[i]	No[i]
3-Nitroaniline	<10.6	11/17/2006 at MW-106	na		No[i]	No[i]
4,6-Dinitro-2-methylphenol	<10.6	11/17/2006 at MW-106	na		No[i]	No[i]
4-Bromophenyl phenyl ether	<10.6	11/17/2006 at MW-106	na		No[i]	No[i]
4-Chloro-3-methylphenol	<10.6	11/17/2006 at MW-106	na		No[i]	No[i]
4-Chloroaniline	<10.6	11/17/2006 at MW-106	1.6	[e]	No[i]	No[i]
4-Chlorophenyl phenyl ether	<10.6	11/17/2006 at MW-106	na		No[i]	No[i]
4-Nitroaniline	<10.6	11/17/2006 at MW-106	3.4		No[i]	No[i]
4-Nitrophenol	<10.6	11/17/2006 at MW-106	na		No[i]	No[i]
Acenaphthene	<0.0588	MW-106	220	[e]	No	No
Acenaphthylene	<0.0588	MW-106	220	[e]	No	No
Anthracene	<0.0588	MW-106	1,100	[e]	No	No
Benzidine	<21.3	11/17/2006 at MW-106	0.000094	[f]	No[i]	No[i]
Benzo (a) anthracene	<0.0588	MW-106	0.12	[e]	Yes	No [k]
Benzo (a) pyrene	<0.0588	MW-106	0.012	[e]	Yes	No [k]
Benzo (b) fluoranthene	<0.0588	MW-106	0.12	[e]	Yes	No [k]
Benzo (g,h,i) perylene	<0.0588	MW-106	110	[e]	No	No
Benzo (k) fluoranthene	<0.0588	MW-106	1.2	[e]	Yes	No [k]
Benzoic Acid	< 106	11/17/2006 at MW-106	15,000	[e]	No	No
Benzyl alcohol	<10.6	11/17/2006 at MW-106	370	[f]	No	No
Bis(2-chloroethoxy)methane	<10.6	11/17/2006 at MW-106	11	[f]	No	No
Bis(2-chloroethyl)ether	<10.6	11/17/2006 at MW-106	0.077	[e]	No[i]	No[i]
Bis(2-chloroisopropyl)ether	<10.6	11/17/2006 at MW-106	na		No	No
Bis(2-ethylhexyl)phthalate	< 53.2	11/17/2006 at MW-106	0.6	[e]	No[i]	No[i]
Butyl benzyl phthalate	<10.6	11/17/2006 at MW-106	730	[e]	No	No
Carbazole	<10.6	11/17/2006 at MW-106	4.3	[e]	No[i]	No[i]
Chrysene	<0.0588	MW-106	12	[e]	No	No [k]
Dibenzo (a,h) anthracene	<0.0588	MW-106	0.012	[e]	Yes	No [k]

Table 3-2a
Constituents of Potential Concern in Soil and Groundwater

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituents of Interest	Maximum Groundwater Concentration (ug/L) [d,k]	Maximum Observation or MRL Location	ADEC Groundwater Screening Level (ug/L)	Source	Groundwater COPC in RAWP [b]	Groundwater COPC in 2012 HHRA [c]
Dibenzofuran	<6.4	MW-135	7.3	[e]	Yes	No
Diethyl phthalate	<10.6	11/17/2006 at MW-106	2,900	[e]	No	
Dimethyl phthalate	<10.6	11/17/2006 at MW-106	37,000	[e]	No	No
Di-n-butyl phthalate	<10.6	11/17/2006 at MW-106	na		No[i]	No[i]
Di-n-Octylphthalate	12	5/10/2001 at MW-225	150	[e]	No	No
Fluoranthene	<0.0588	MW-106	150	[e]	No	No
Fluorene	<0.0588	MW-106	150	[e]	No	No
Hexachlorobenzene	<10.6	11/17/2006 at MW-106	0.1	[e]	No [i]	No
Hexachlorobutadiene	<10.6	11/17/2006 at MW-106	0.73	[e]	No [i]	No
Hexachlorocyclopentadiene	<10.6	11/17/2006 at MW-106	5	[e]	No [i]	No
Hexachloroethane	<10.6	11/17/2006 at MW-106	4	[e]	No [i]	No
Indeno (1,2,3-cd) pyrene	<0.0588	MW-106	0.12	[e]	Yes	No [k]
Isophorone	<10.6	11/17/2006 at MW-106	90	[e]	No	No
Isopropanol (propanol)	<400	MW-113	na		Yes	Yes
Naphthalene	300	MW-139 & Dup	73	[e]	Yes	Yes
Nitrobenzene	<10.6	11/17/2006 at MW-106	1.8	[e]	No [i]	No [i]
N-Nitrosodimethylamine	<21.3	11/17/2006 at MW-106	0.0017	[e]	No [i]	No [i]
N-Nitrosodi-n-propylamine	<10.6	11/17/2006 at MW-106	0.012	[e]	No [i]	No [i]
N-Nitrosodiphenylamine	<10.6	11/17/2006 at MW-106	17	[e]	No	No
Pentachlorophenol	<10.6	11/17/2006 at MW-106	0.1	[e]	No [i]	No [i]
Phenanthrene	<0.0588	MW-106	1,100	[e]	No	No
Phenol	<10.6	11/17/2006 at MW-106	1,100	[e]	No	No
Pyrene	<0.0588	MW-106	110	[e]	No	No
Metals						
Antimony	0.389	MW-110	0.6	[e]	Yes	No
Arsenic	68.5	5/10/2001 at MW-116	1	[e]	No [j]	No [j]
Barium	481	MW-110	200	[e]	Yes	Yes
Cadmium	<1.2	MW-110	0.5	[c]	Yes	Yes
Chromium, Total	3	MW-110	10	[e]	Yes	No
Copper	9.07	MW-149A	100	[e]	No	No
Iron	56,900	MW-110	2,600	[f]	Yes	Yes
Lead	2.05	MW-110	1.5	[e]	Yes	Yes
Mercury	<0.2	2001 all MWs analyzed	0.2	[e]	No	No
Nickel	9.57	3/4/2011 at MW-171A	10	[e]	No	No
Selenium	2.86	MW-141	5	[e]	Yes	No
Silver	5.02	5/10/2001 at MW-115	10	[e]	No	No
Zinc	9.17	3/8/2011 MW-171A	500	[e]	No	No
Other						
Alkanol amines	--		na		Yes[o]	Yes[o]
Alkylamines	--		na		Yes[o]	Yes[o]
Alkylene amines	--		na		Yes[o]	Yes[o]
Calcium	--		na		No[l]	No[l]
Chloride	--		na		No[l]	No[l]
Dinonylnaphthylsulfonic acid	--		na		Yes[o]	Yes[o]
Fluoroalkyl Surfactant	--		na		Yes[o]	Yes[o]
Heavy aromatic naptha (Naphtha, High Flash Aromatic [HFAN])	--		na		No[m]	No[m]
Heavy paraffinic distillate (mixture)	--		na		No[m]	No[m]
Iron Oxides	--		na		Yes[o]	Yes[o]
2-Methoxymethylethoxy propanol	--		na		Yes[o]	Yes[o]
Monoethanolamine	--		na		Yes[o]	Yes[o]
Montmorillonite, calcined	--		na		No[n]	No[n]
Silica	--		na		Yes[o]	Yes[o]
Cyanide	5.6	MW-125	20	[e]	Yes[o]	No
Sulfate	38600	MW-131	na		No [j]	No [j]
Sulfolane	10400	O-1	5	[e]	Yes	Yes
GRO	20800	MW-135	220	[e]	Yes	Yes
DRO	2150	MW-110	150	[e]	Yes	Yes
RRO	278	MW-135	110	[e]	Yes	Yes

Table 3-2a
Constituents of Potential Concern in Soil and Groundwater

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:
"mg/kg" = milligrams per kilogram.
"µg/L" = micrograms per liter.
"ADEC" = Alaska Department of Environmental Conservation.
"BaP TEQ" = benzo(a) pyrene toxicty equivalent
"COPC" = constituent of potential concern
"DRO" = Total petroleum hydrocarbons diesel range organics = DRO
"GRO" = Total petroleum hydrocarbons gasoline range organics = GRO
"MDL" = method detection limit
"PAH" = polycyclic aromatic hydrocarbon
"RRO" = Total petroleum hydrocarbons residual range organics = RRO
"<" = not detected at the PQL indicated.
"--" = not analyzed.
"na" = not available.

[a] Values from the soil HHRA dataset (available electronically), plus maximum reporting limits from historical documents for non-detected compounds that were not analyzed in the HHRA dataset.
[b] As presented in Table 2 of the RAWP (ARCADIS, 2011).
[c] Revised COPC list selected based on the 2012 HHRA dataset and historical reporting limits, as presented in this table. The following rules were used to select COPCs:

1. If the maximum detected concentration exceeds the selected screening level, the constituent is retained as a COPC
2. If the maximum reporting limit exceeds the selected screening level, the constituent is retained as a COPC
3. If no screening level is available, the constituent is retained as a COPC
4. Constituents not included in the ingredient list but analyzed in soil or groundwater as part of full-scan VOC analyses were excluded as COPCs if never detected above the MDL.
5. Constituents detected within range of regional background levels were not selected as a COPC (USGS Fact Sheet FS-111-01)
6. PAHs included in the BaP TEQ calculation are included as COPCs if BaP TEQ is a COPC.

[d] Values from the onsite groundwater dataset (2009-2011) used in the 2012 HHRA.
[e] ADEC 2009 Table C Method Two groundwater cleanup level modified to 1E-6 target risk or 0.1 hazard quotient
[f] USEPA (2011) Regional Screening Level modified to 1E-6 target risk or 0.1 hazard quotient.
[g] SWI 2010, Table 3
[h] Based on the lowest of: migration to groundwater CUL, or 1/10th of the direct contact or outdoor inhalation CUL, provided in Tables B1 and B2 of 18 AAC75
[i] COI not included on ingredient list, but was analyzed in soil and/or groundwater as part of full-scan VOC analyses. Not selected as COPC because constituent was not detected above the MDL.
[j] concentrations within range of regional background levels, not selected as a COPC (USGS Fact Sheet FS-111-01)
[k] Included in Benzo(a)pyrene TEQ calculation
[l] ubiquitous in natural waters, not selected as a COPC
[m] compound is a petroleum distillate composed of several individual substances, not selected as a COPC
[n] this is a type of clay, not selected as a COPC
[o] subject to further discussion with ADEC
The USEPA (2010) Regional Screening Level Tables were the source of screening levels for 1,2-Diphenylhydrazine (as Azobenzene), and Benzidine
The USEPA (2010) Regional Screening Level Tables were adjusted for a hazard index of 0.1 for non-cancer screening levels for 1-Chloronaphthalene, 2-Chloronaphthalene, 2-Nitroaniline, Benzyl alcohol, Bis(2-chloroethoxy)methane, Cyclohexane, h-Hexane, Iron, Propylene glycol, and Pyridine.
Sulfolane values based on calculations provided in ADEC (2008) Cleanup Level Guidance
USEPA = United States Environmental Protection Agency Integrated Risk Information System (2011)

Table 3-2b
Summary of Constituents of Potential Concern

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Surface Soil COPC [a,b]	Surface and Subsurface Soil COPC [a,c]	Soil Gas COPC [d]	Onsite Groundwater COPC [a,e]	Sitewide COPC [a]	Offsite COPC [a]
Metals						
Antimony	N	N	N	N	N	N
Arsenic	Y	Y	--	--	Y	N
Barium	--	N	N	Y	Y	N
Cadmium	--	N	N	Y	Y	N
Chromium, Total	Y	Y	N	N	Y	N
Copper	N	N	N	N	N	N
Iron	Y	Y	N	Y	Y	N
Lead	--	N	N	Y	Y	N
Mercury	--	N	--	--	N	N
Nickel	Y	Y	--	--	Y	N
Selenium	N	N	N	N	N	N
Silver	--	N	--	--	N	N
Zinc	N	N	--	--	N	N
VOCs						
1,1-Dichloroethene	Y	Y	Y	Y	Y	N
1,2,4-Trimethylbenzene	Y	Y	Y	Y	Y	N
1,3,5-Trimethylbenzene	Y	Y	Y	Y	Y	N
1-Chloronaphthalene	--	--	--	--	N	N
4-Isopropyltoluene (p-cymene)	Y	Y	Y	Y	Y	N
Benzene	Y	Y	Y	Y	Y	N
Chlorobenzene	Y	Y	--	--	Y	N
cis-1,2-Dichloroethene	Y	Y	--	--	Y	N
Cyclohexane	Y	Y	N	N	Y	N
Ethylbenzene	Y	Y	Y	Y	Y	N
Isopropylbenzene (cumene)	Y	Y	--	--	Y	N
Methyl tert-butyl ether	Y	Y	N	N	Y	N
Methylene chloride	Y	Y	Y	Y	Y	N
n-Butylbenzene	Y	Y	--	--	Y	N
n-Hexane	Y	Y	N	N	Y	N
n-Propylbenzene	Y	Y	Y	Y	Y	N
Propylene gylcol (1,2,-Propanediol)	--	--	N	N	N	N
Pyridine	--	--	--	--	N	N
sec-Butylbenzene	--	Y	--	--	Y	N
tert-Butylbenzene	N	N	--	--	N	N
Toluene	Y	Y	Y	Y	Y	N
Trichlorofluoromethane (Freon 11)	--	N	--	--	N	N
Xylenes	Y	Y	Y	Y	Y	N
SVOCs						
1,2-Dichlorobenzene	Y	Y	--	--	Y	N
1,2-Diphenylhydrazine (as Azobenzene)	--	--	--	--	N	N
1,3-Dichlorobenzene	Y	Y	--	--	Y	N
1-Methylnaphthalene	Y	Y	Y	Y	Y	N
2,4,5-Trichlorophenol	--	--	--	--	N	N
2,4,6-Trichlorophenol	Y	Y	--	--	Y	N
2,4-Dichlorophenol	Y	Y	--	--	Y	N
2,4-Dimethylphenol	Y	Y	--	--	Y	N
2,4-Dinitrophenol	Y	Y	--	--	Y	N
2,4-Dinitrotoluene	Y	Y	--	--	Y	N
2,6-Dinitrotoluene	Y	Y	--	--	Y	N
2-Chloronaphthalene	--	--	--	--	N	N
2-Chlorophenol	Y	Y	--	--	Y	N
2-Methylnaphthalene	Y	Y	Y	Y	Y	N
2-Methylphenol (o-Cresol)	Y	Y	--	--	Y	N
2-Nitroaniline	--	--	--	--	N	N
2-Nitrophenol	--	--	--	--	N	N
3 & 4-Methylphenol (m,p-Cresol)	Y	Y	--	--	Y	N
3,3-Dichlorobenzidine	Y	Y	--	--	Y	N
3-Nitroaniline	--	--	--	--	N	N
4,6-Dinitro-2-methylphenol	N	N	--	--	N	N
4-Bromophenyl phenyl ether	--	--	--	--	N	N
4-Chloro-3-methylphenol	--	--	--	--	N	N
4-Chloroaniline	Y	Y	--	--	Y	N
4-Chlorophenyl phenyl ether	--	--	--	--	N	N
4-Nitroaniline	--	--	--	--	N	N
4-Nitrophenol	--	--	--	--	N	N
Benzidine	--	--	--	--	N	N
Benzoic Acid	N	N	--	--	N	N
Benzyl alcohol	N	N	--	--	N	N
Bis(2-chloroethoxy)methane	N	N	--	--	N	N
Bis(2-chloroethyl)ether	Y	Y	--	--	Y	N
Bis(2-chloroisopropyl)ether	--	--	--	--	N	N
Bis(2-ethylhexyl)phthalate	N	N	--	--	N	N
Butyl benzyl phthalate	N	N	--	--	N	N
Carbazole	--	--	--	--	N	N

Table 3-2b
Summary of Constituents of Potential Concern

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Surface Soil COPC [a,b]	Surface and Subsurface Soil COPC [a,c]	Soil Gas COPC [d]	Onsite Groundwater COPC [a,e]	Sitewide COPC [a]	Offsite COPC [a]
Dibenzofuran	N	N	N	N	N	N
Diethyl phthalate	N	N	--	--	N	N
Dimethyl phthalate	--	--	--	--	N	N
Di-n-butyl phthalate	N	N	--	--	N	N
Di-n-Octylphthalate	--	--	--	--	N	N
Hexachlorobenzene	Y	Y	--	--	Y	N
Hexachlorobutadiene	Y	Y	--	--	Y	N
Hexachlorocyclopentadiene	Y	Y	--	--	Y	N
Hexachloroethane	Y	Y	--	--	Y	N
Isophorone	Y	Y	--	--	Y	N
Isopropanol (propanol)	--	--	N	Y	Y	N
Nitrobenzene	Y	Y	--	--	Y	N
N-Nitrosodimethylamine	Y	Y	--	--	Y	N
N-Nitrosodi-n-propylamine	Y	Y	--	--	Y	N
N-Nitrosodiphenylamine	Y	Y	--	--	Y	N
Pentachlorophenol	Y	Y	--	--	Y	N
Phenol	N	N	--	--	N	N
PAHs						
Acenaphthene	N	N	N	N	N	N
Acenaphthylene	N	N	N	N	N	N
Anthracene	N	N	N	N	N	N
Benzo (a) anthracene	Y	Y	N	N	Y	N
Benzo (a) pyrene	Y	Y	N	N	Y	N
Benzo (b) fluoranthene	Y	Y	N	N	Y	N
Benzo (g,h,i) perylene	N	N	N	N	N	N
Benzo (k) fluoranthene	Y	Y	N	N	Y	N
Chrysene	Y	Y	N	N	Y	N
Dibenzo (a,h) anthracene	Y	Y	N	N	Y	N
Fluoranthene	N	N	N	N	N	N
Fluorene	N	N	N	N	N	N
Indeno (1,2,3-cd) pyrene	Y	Y	N	N	Y	N
Naphthalene	Y	Y	Y	Y	Y	N
Phenanthrene	N	N	N	N	N	N
Pyrene	N	N	N	N	N	N
Total Benzo(a)pyrene TEQ	Y	Y	N	N	Y	N
Miscellaneous						
Alkanol amines	--	--	--	--	N	N
Alkylamines	--	--	--	--	N	N
Alkylene amines	--	--	--	--	N	N
Calcium	--	--	--	--	N	N
Chloride	--	--	--	--	N	N
Dinonylnaphthylsulfonic acid	--	--	--	--	N	N
Fluoroalkyl Surfactant	--	--	--	--	N	N
Heavy aromatic naptha (Naphtha, High Flash Aromatic [HFAN])	--	--	--	--	N	N
Heavy paraffinic distillate (mixture)	--	--	--	--	N	N
Iron Oxides	--	--	--	--	N	N
2-Methoxymethylethoxy propanol	--	--	--	--	N	N
Monoethanolamine	--	--	--	--	N	N
Montmorillonite, calcined	--	--	--	--	N	N
Silica	--	--	--	--	N	N
Cyanide	N	N	N	N	N	N
Sulfate	--	--	N	N	N	N
Sulfolane	Y	Y	N	Y	Y	Y
GRO	Y	Y	N	Y	Y	N
DRO	Y	Y	N	Y	Y	N
RRO	Y	Y	N	Y	Y	N

Notes:

[a] COPCs are defined as described in the main text and in Table 3-2a.
[b] Soil data from the 0 to 2.5 ft bgs interval was used to evaluate exposure to surface soil.
[c] Soil data from the 0 to 15.5 ft bgs interval was used to evaluate exposure to surface and subsurface soil.
[d] Volatile compounds selected as groundwater COPCs were selected as soil gas COPCs.
[e] Groundwater data from the most recent two years of sampling (2009 through 2011) for wells without LNAPL were used to evaluate exposure to groundwater.
bgs = below ground surface
COPC = constituent of potential concern
FOD = frequency of detection
TEQ = toxicity equivalents
PAH = polycyclic aromatic hydrocarbon
VOC = volatile organic compound
N = no; Constituent is not a COPC
Y = yes; Constituent is a COPC
-- = no data available; Constituent is not a COPC

Table 3-3
Area-Wide Summary Statistics and UCL Exposure Point Concentrations for Surface Soil (0 to 2 ft below ground surface)

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

COPC [a]	Sample Size	Number of Detects	FOD (%) [b]	Min [c]	Max [c]	Mean [c]	Median [c]	SD	UCL Method	UCL	EPC [d]
Metals											
Arsenic	26	26	100	2.45	17.6	6.386	5.095	3.501	95% Approximate Gamma UCL	7.601	7.6E+00
Chromium, Total	26	26	100	8.83	50.9	16.99	14.9	8.051	95% Approximate Gamma UCL	19.39	1.9E+01
Iron	26	26	100	7790	29000	15081	12900	5471	95% Approximate Gamma UCL	16960	1.7E+04
Nickel	26	26	100	11.2	28.5	18.63	18.05	4.884	95% Student's-t UCL	20.27	2.0E+01
VOCs											
1,3,5-Trimethylbenzene	26	2	8	0.0141	0.0223	0.0182	0.0182	0.0058	--	--	2.2E-02
4-Isopropyltoluene (p-cymene)	26	2	8	0.0118	0.0182	0.015	0.015	0.00453	--	--	1.8E-02
Benzene	104	26	25	0.00243	0.597	0.0664	0.00937	0.135	95% Chebyshev (Mean, Sd) UCL	0.0508	5.1E-02
Cyclohexane	26	5	19	0.00949	0.1	0.0306	0.0129	0.0391	95% Chebyshev (Mean, Sd) UCL	0.0293	2.9E-02
Ethylbenzene	104	20	19	0.00544	2.36	0.374	0.0196	0.68	95% Chebyshev (Mean, Sd) UCL	0.218	2.2E-01
Methylene chloride	26	3	12	0.0286	0.0604	0.0477	0.0541	0.0168	--	--	6.0E-02
n-Hexane	26	4	15	0.0131	0.116	0.0532	0.0419	0.0486	--	--	1.2E-01
Toluene	104	19	18	0.00663	1.04	0.131	0.0217	0.254	95% Chebyshev (Mean, Sd) UCL	0.0815	8.2E-02
Xylenes	104	25	24	0.0161	10.3	0.935	0.0572	2.26	95% Chebyshev (Mean, Sd) UCL	0.739	7.4E-01
SVOCs											
1-Methylnaphthalene	104	23	22	0.0019	3.21	0.349	0.05	0.747	95% Chebyshev (Mean, Sd) UCL	0.242	2.4E-01
2-Methylnaphthalene	104	25	24	0.00182	3.66	0.356	0.0266	0.836	95% Chebyshev (Mean, Sd) UCL	0.274	2.7E-01
PAHs											
Benzo (a) anthracene	104	2	2	0.0241	0.0605	0.0423	0.0423	0.0257	--	--	6.1E-02
Benzo (a) pyrene	104	2	2	0.0311	0.0924	0.0618	0.0618	0.0433	--	--	9.2E-02
Benzo (b) fluoranthene	104	9	9	0.00173	0.108	0.0184	0.00282	0.0358	95% Chebyshev (Mean, Sd) UCL	0.0155	1.6E-02
Benzo (k) fluoranthene	104	2	2	0.0132	0.0404	0.0268	0.0268	0.0192	--	--	4.0E-02
Chrysene	104	18	17	0.00201	0.783	0.118	0.0249	0.214	95% Chebyshev (Mean, Sd) UCL	0.0659	6.6E-02
Dibenzo (a,h) anthracene	104	1	1	0.0171	0.0171	0.0171	0.0171	N/A	--	--	1.7E-02
Indeno (1,2,3-cd) pyrene	104	3	3	0.00161	0.0688	0.029	0.0165	0.0353	--	--	6.9E-02
Naphthalene	104	18	17	0.00176	0.631	0.106	0.0113	0.182	95% Chebyshev (Mean, Sd) UCL	0.0592	5.9E-02
Total Benzo(a)pyrene TEQ	104	24	23	0.00356	0.225	0.0383	0.0178	0.0578	95% Chebyshev (Mean, Sd) UCL	0.0317	3.2E-02

Table 3-3
Area-Wide Summary Statistics and UCL Exposure Point Concentrations for Surface Soil (0 to 2 ft below ground surface)

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

COPC [a]	Sample Size	Number of Detects	FOD (%) [b]	Min [c]	Max [c]	Mean [c]	Median [c]	SD	UCL Method	UCL	EPC [d]
Miscellaneous											
Sulfolane	99	3	3	0.00515	0.0377	0.0188	0.0135	0.0169	--	--	3.8E-02
GRO	26	4	15	0.604	5.35	2.216	1.456	2.204	--	--	5.4E+00
DRO	26	17	65	7.65	869	93.16	25.9	206.7	95% Chebyshev (Mean, Sd) UCL	209.1	2.1E+02
RRO	26	22	85	19.6	8450	524.7	71	1785	95% Chebyshev (Mean, Sd) UCL	1853	1.9E+03

Notes:

[a] COPCs are defined as described in the main text and Table 3-2a.

[b] FOD is based on inclusion of some historical data for which only detected concentrations are reported. FOD is not considered accurate for the entire dataset.

[d] The EPC is defined as the 95% UCL calculated using ProUCL v. 4.00.05.

[c] Minimum, maximum, mean, and median concentrations are based on detected concentrations.
The maximum detected concentration was used to represent the EPC when fewer than five detected concentrations and eight samples were available.

All concentrations are in units of mg/kg.
BCA = bias corrected accelerated
COPC = constituent of potential concern
DRO = Diesel range organics
EPC = exposure point concentration
FOD = frequency of detection
GRO = Gasoline range organics
KM = Kaplan-Meier
mg/kg = milligram(s) per kilogram
N/A = not available; insufficient data
PAH = polycyclic aromatic hydrocarbon
RRO = Residual range organics
TEQ = toxicity equivalents
SD = standard deviation
SVOCs = semi-volatile organic compounds
UCL = upper confidence limit on the mean
VOCs = volatile organic compounds

Table 3-4a
Area-Wide Summary Statistics and Maximum Exposure Point Concentrations for Subsurface Soil (0 to 15 ft below ground surface)

Human Health Risk Assessment - PPRTV Scenario and ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

COPC [a]	Sample Size	Number of Detects	FOD (%) [b]	Min [c]	Max [c]	Mean [c]	Median [c]	SD	UCL Method	UCL	EPC [d]
Metals											
Arsenic	69	69	100	2.16	17.6	5.525	4.18	3.406	95% Chebyshev (Mean, Sd) UCL	7.313	1.8E+01
Chromium, Total	69	69	100	7.69	50.9	15.84	13.9	7.03	95% Approximate Gamma UCL	17.15	5.1E+01
Iron	62	62	100	7330	29000	13815	11450	5719	95% Modified-t UCL	15048	2.9E+04
Nickel	62	62	100	8.88	38	17.58	15.7	6.458	95% Approximate Gamma UCL	18.94	3.8E+01
VOCs											
1,2,4-Trimethylbenzene	90	26	29	0.0567	205	30.46	13.6	47.56	95% Chebyshev (Mean, Sd) UCL	22.03	2.1E+02
1,3,5-Trimethylbenzene	89	27	30	0.0141	81.1	10.6	4.57	18.14	95% Chebyshev (Mean, Sd) UCL	8.31	8.1E+01
4-Isopropyltoluene (p-cymene)	90	24	27	0.0118	20.2	2.745	1.165	4.575	95% Chebyshev (Mean, Sd) UCL	2.026	2.0E+01
Benzene	318	122	38	0.00243	82	3.904	0.232	10.35	95% Chebyshev (Mean, Sd) UCL	3.131	8.2E+01
Cyclohexane	62	21	34	0.00949	44.9	5.395	0.0375	10.95	95% Chebyshev (Mean, Sd) UCL	5.585	4.5E+01
Ethylbenzene	318	122	38	0.00544	111	12.7	0.947	22.96	95% Chebyshev (Mean, Sd) UCL	8.659	1.1E+02
Isopropylbenzene (cumene)	90	24	27	0.0102	41.6	5.561	1.845	9.393	95% Chebyshev (Mean, Sd) UCL	3.96	4.2E+01
Methylene chloride	63	7	11	0.0282	0.188	0.0643	0.0541	0.0561	95% Chebyshev (Mean, Sd) UCL	0.29	1.9E-01
n-Butylbenzene	90	16	18	0.00998	107	11.72	3.34	26.79	95% Chebyshev (Mean, Sd) UCL	7.626	1.1E+02
n-Hexane	62	17	27	0.0126	13	3.024	0.116	4.717	95% Chebyshev (Mean, Sd) UCL	2.369	1.3E+01
n-Propylbenzene	90	23	26	0.0145	72.7	10.49	3.8	17.46	95% Chebyshev (Mean, Sd) UCL	7.203	7.3E+01
sec-Butylbenzene	28	11	39	0.162	25.3	5.162	2.25	7.488	95% Chebyshev (Mean, Sd) UCL	6.552	2.5E+01
Toluene	318	100	31	0.00659	392	24.38	0.654	67.73	95% Chebyshev (Mean, Sd) UCL	17.34	3.9E+02
Xylenes	318	132	42	0.0161	706	62.17	0.991	127.8	95% Chebyshev (Mean, Sd) UCL	47.25	7.1E+02
SVOCs											
1-Methylnaphthalene	287	123	43	0.00159	88.5	5.827	0.463	11.78	95% Chebyshev (Mean, Sd) UCL	4.614	8.9E+01
2-Methylnaphthalene	314	139	44	0.00159	240	9.68	0.711	25.24	95% Chebyshev (Mean, Sd) UCL	8.584	2.4E+02
PAHs											
Benzo (a) anthracene	287	14	5	0.00198	0.0988	0.0329	0.0279	0.0289	95% Chebyshev (Mean, Sd) UCL	0.0117	9.9E-02
Benzo (a) pyrene	287	13	5	0.00294	0.0952	0.0364	0.0283	0.0345	95% Chebyshev (Mean, Sd) UCL	0.0119	9.5E-02
Benzo (b) fluoranthene	287	20	7	0.00166	0.108	0.0216	0.00698	0.0316	95% Chebyshev (Mean, Sd) UCL	0.0206	1.1E-01
Benzo (k) fluoranthene	287	9	3	0.00214	0.0404	0.0132	0.011	0.013	95% Chebyshev (Mean, Sd) UCL	0.0194	4.0E-02
Chrysene	287	56	20	0.00201	0.783	0.0713	0.0234	0.142	95% Chebyshev (Mean, Sd) UCL	0.0354	7.8E-01
Dibenzo (a,h) anthracene	287	6	2	0.002	0.018	0.0104	0.0103	0.00718	95% Chebyshev (Mean, Sd) UCL	0.00988	1.8E-02
Indeno (1,2,3-cd) pyrene	287	12	4	0.00161	0.0688	0.0247	0.018	0.0224	95% Chebyshev (Mean, Sd) UCL	0.0109	6.9E-02
Naphthalene	314	132	42	0.00165	125	5.055	0.347	13.55	95% Chebyshev (Mean, Sd) UCL	4.371	1.3E+02
Total Benzo(a)pyrene TEQ	228	62	27	0.00356	0.225	0.0366	0.0179	0.0508	95% Chebyshev (Mean, Sd) UCL	0.0257	2.3E-01

Table 3-4a
Area-Wide Summary Statistics and Maximum Exposure Point Concentrations for Subsurface Soil (0 to 15 ft below ground surface)

Human Health Risk Assessment - PPRTV Scenario and ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

COPC [a]	Sample Size	Number of Detects	FOD (%) [b]	Min [c]	Max [c]	Mean [c]	Median [c]	SD	UCL Method	UCL	EPC [d]
Miscellaneous											
Sulfolane	277	70	25	0.00434	18.4	0.411	0.0496	2.204	95% Chebyshev (Mean, Sd) UCL	0.454	1.8E+01
GRO	76	28	37	0.604	7730	782.8	127	1611	95% Chebyshev (Mean, Sd) UCL	808.3	7.7E+03
DRO	106	71	67	7.65	18800	1546	226	2905	95% Chebyshev (Mean, Sd) UCL	2111	1.9E+04
RRO	121	89	74	0.162	64700	5042	108	13078	95% Chebyshev (Mean, Sd) UCL	8236	6.5E+04

Notes:
All concentrations are in units of mg/kg.
[a] COPCs are defined as described in the main text and Table 3-2a.
[b] FOD is based on inclusion of some historical data for which only detected concentrations are reported. FOD is not considered accurate for the entire dataset.
[c] Minimum, maximum, mean, and median concentrations are based on detected concentrations.
[d] The maximum detected concentration was used to represent the EPC.
BCA = bias corrected accelerated
COPC = constituent of potential concern
EPC = exposure point concentration
DRO = Diesel range organics
FOD = frequency of detection
GRO = Gasoline range organics
KM = Kaplan-Meier
mg/kg = milligram(s) per kilogram
N/A = not available; insufficient data
PAH = polycyclic aromatic hydrocarbon
RRO = Residual range organics
SD = standard deviation
SVOCs = semi-volatile organic compounds
TEQ = toxicity equivalents
TPH = total petroleum hydrocarbons
UCL = upper confidence limit on the mean
VOC = volatile organic compound

Table 3-4b
Area-Wide Summary Statistics and UCL Exposure Point Concentrations for Subsurface Soil (0 to 15 ft below ground surface)

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

COPC [a]	Sample Size	Number of Detects	FOD (%) [b]	Min [c]	Max [c]	Mean [c]	Median [c]	SD	UCL Method	UCL	EPC [d]
Metals											
Arsenic	69	69	100	2.16	17.6	5.525	4.18	3.406	95% Chebyshev (Mean, Sd) UCL	7.313	7.3E+00
Chromium, Total	69	69	100	7.69	50.9	15.84	13.9	7.03	95% Approximate Gamma UCL	17.15	1.7E+01
Iron	62	62	100	7330	29000	13815	11450	5719	95% Modified-t UCL	15048	1.5E+04
Nickel	62	62	100	8.88	38	17.58	15.7	6.458	95% Approximate Gamma UCL	18.94	1.9E+01
VOCs											
1,2,4-Trimethylbenzene	90	26	29	0.0567	205	30.46	13.6	47.56	95% Chebyshev (Mean, Sd) UCL	22.03	2.2E+01
1,3,5-Trimethylbenzene	89	27	30	0.0141	81.1	10.6	4.57	18.14	95% Chebyshev (Mean, Sd) UCL	8.31	8.3E+00
4-Isopropyltoluene (p-cymene)	90	24	27	0.0118	20.2	2.745	1.165	4.575	95% Chebyshev (Mean, Sd) UCL	2.026	2.0E+00
Benzene	318	122	38	0.00243	82	3.904	0.232	10.35	95% Chebyshev (Mean, Sd) UCL	3.131	3.1E+00
Cyclohexane	62	21	34	0.00949	44.9	5.395	0.0375	10.95	95% Chebyshev (Mean, Sd) UCL	5.585	5.6E+00
Ethylbenzene	318	122	38	0.00544	111	12.7	0.947	22.96	95% Chebyshev (Mean, Sd) UCL	8.659	8.7E+00
Isopropylbenzene (cumene)	90	24	27	0.0102	41.6	5.561	1.845	9.393	95% Chebyshev (Mean, Sd) UCL	3.96	4.0E+00
Methylene chloride	63	7	11	0.0282	0.188	0.0643	0.0541	0.0561	95% Chebyshev (Mean, Sd) UCL	0.29	2.9E-01
n-Butylbenzene	90	16	18	0.00998	107	11.72	3.34	26.79	95% Chebyshev (Mean, Sd) UCL	7.626	7.6E+00
n-Hexane	62	17	27	0.0126	13	3.024	0.116	4.717	95% Chebyshev (Mean, Sd) UCL	2.369	2.4E+00
n-Propylbenzene	90	23	26	0.0145	72.7	10.49	3.8	17.46	95% Chebyshev (Mean, Sd) UCL	7.203	7.2E+00
sec-Butylbenzene	28	11	39	0.162	25.3	5.162	2.25	7.488	95% Chebyshev (Mean, Sd) UCL	6.552	6.6E+00
Toluene	318	100	31	0.00659	392	24.38	0.654	67.73	95% Chebyshev (Mean, Sd) UCL	17.34	1.7E+01
Xylenes	318	132	42	0.0161	706	62.17	0.991	127.8	95% Chebyshev (Mean, Sd) UCL	47.25	4.7E+01
SVOCs											
1-Methylnaphthalene	287	123	43	0.00159	88.5	5.827	0.463	11.78	95% Chebyshev (Mean, Sd) UCL	4.614	4.6E+00
2-Methylnaphthalene	314	139	44	0.00159	240	9.68	0.711	25.24	95% Chebyshev (Mean, Sd) UCL	8.584	8.6E+00
PAHs											
Benzo (a) anthracene	287	14	5	0.00198	0.0988	0.0329	0.0279	0.0289	95% Chebyshev (Mean, Sd) UCL	0.0117	1.2E-02
Benzo (a) pyrene	287	13	5	0.00294	0.0952	0.0364	0.0283	0.0345	95% Chebyshev (Mean, Sd) UCL	0.0119	1.2E-02
Benzo (b) fluoranthene	287	20	7	0.00166	0.108	0.0216	0.00698	0.0316	95% Chebyshev (Mean, Sd) UCL	0.0206	2.1E-02
Benzo (k) fluoranthene	287	9	3	0.00214	0.0404	0.0132	0.011	0.013	95% Chebyshev (Mean, Sd) UCL	0.0194	1.9E-02
Chrysene	287	56	20	0.00201	0.783	0.0713	0.0234	0.142	95% Chebyshev (Mean, Sd) UCL	0.0354	3.5E-02
Dibenzo (a,h) anthracene	287	6	2	0.002	0.018	0.0104	0.0103	0.00718	95% Chebyshev (Mean, Sd) UCL	0.00988	9.9E-03
Indeno (1,2,3-cd) pyrene	287	12	4	0.00161	0.0688	0.0247	0.018	0.0224	95% Chebyshev (Mean, Sd) UCL	0.0109	1.1E-02
Naphthalene	314	132	42	0.00165	125	5.055	0.347	13.55	95% Chebyshev (Mean, Sd) UCL	4.371	4.4E+00
Total Benzo(a)pyrene TEQ	228	62	27	0.00356	0.225	0.0366	0.0179	0.0508	95% Chebyshev (Mean, Sd) UCL	0.0257	2.6E-02

Table 3-4b
Area-Wide Summary Statistics and UCL Exposure Point Concentrations for Subsurface Soil (0 to 15 ft below ground surface)

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

COPC [a]	Sample Size	Number of Detects	FOD (%) [b]	Min [c]	Max [c]	Mean [c]	Median [c]	SD	UCL Method	UCL	EPC [d]
Miscellaneous											
Sulfolane	277	70	25	0.00434	18.4	0.411	0.0496	2.204	95% Chebyshev (Mean, Sd) UCL	0.454	4.5E-01
GRO	76	28	37	0.604	7730	782.8	127	1611	95% Chebyshev (Mean, Sd) UCL	808.3	8.1E+02
DRO	106	71	67	7.65	18800	1546	226	2905	95% Chebyshev (Mean, Sd) UCL	2111	2.1E+03
RRO	121	89	74	0.162	64700	5042	108	13078	95% Chebyshev (Mean, Sd) UCL	8236	8.2E+03

Notes:

[a] COPCs are defined as described in the main text and Table 3-2.
[b] FOD is based on inclusion of some historical data for which only detected concentrations are reported. FOD is not considered accurate for the entire dataset.
[c] Minimum, maximum, mean, and median concentrations are based on detected concentrations.
[d] The EPC is defined as the 95% UCL calculated using ProUCL v. 4.00.05.
The maximum detected concentration was used to represent the EPC when fewer than five detected concentrations and eight samples were available.
All concentrations are in units of mg/kg.
BCA = bias corrected accelerated
COPC = constituent of potential concern
EPC = exposure point concentration
DRO = Diesel range organics
FOD = frequency of detection
GRO = Gasoline range organics
KM = Kaplan-Meier
mg/kg = milligram(s) per kilogram
N = no
N/A = not available; insufficient data
PAH = polycyclic aromatic hydrocarbon
RRO = Residual range organics
SD = standard deviation
SVOCs = semi-volatile organic compounds
TEQ = toxicity equivalents
TPH = total petroleum hydrocarbons
UCL = upper confidence limit on the mean
VOC = volatile organic compound
Y = yes

Table 3-5a
Area-Wide Summary Statistics and Maximum Exposure Point Concentrations for Onsite Groundwater (2009 through 2011)

Human Health Risk Assessment - PPRTV Scenario and ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

COCC [a]	Sample Size [b]	Number of Detects [b]	FOD (%)	Min [b]	Max [b]	Mean [b]	Median [b]	SD [b]	Groundwater EPC [c] (ug/L)	VF [d] (L/m^3)	Trench Air EPC [d] (ug/m^3)	Predicted Soil Gas Concentration [e] (ug/m^3)	AF [e]	Indoor Air EPC [e] (ug/m^3)
Metals														
Barium	19	19	100	39.3	481	193	182	124	4.8E+02					
Iron	19	15	79	1900	56900	13910	6090	16000	5.7E+04					
Lead	19	3	16	0.35	2.05	1.05	0.74	0.89052	2.1E+00					
VOCs														
1,2,4-Trimethylbenzene	62	16	26	4.35	614	128	57.3	177	6.1E+02	7.5E+00	4.6E+03	3.97E+04	1.12E-05	4.46E-01
1,3,5-Trimethylbenzene	19	7	37	1.93	184	50.7	21.2	64.2	1.8E+02	7.6E+00	1.4E+03	1.14E+04	1.27E-05	1.45E-01
4-Isopropyltoluene (p-cymene)	19	6	32	0.8	60.4	13.3	5.34	23.2	6.0E+01	7.2E+00	4.3E+02			
Benzene	330	148	45	0.17	18500	1802	91	3516	1.9E+04	9.3E+00	1.7E+05	1.66E+06	1.03E-05	1.72E+01
Ethylbenzene	330	97	29	0.44	2750	421	66.1	656	2.8E+03	8.0E+00	2.2E+04	2.74E+05	7.54E-06	2.07E+00
n-Propylbenzene	19	7	37	1	122	37.9	22.4	43.1	1.2E+02	7.6E+00	9.2E+02	1.42E+04	6.46E-06	9.18E-02
Toluene	330	58	18	0.39	30100	5715	2090	8395	3.0E+04	8.6E+00	2.6E+05	2.86E+06	8.71E-06	2.49E+01
Xylenes	330	122	37	0.57	14090	2097	424	3121	1.4E+04	8.0E+00	1.1E+05	1.35E+06	8.42E-06	1.14E+01
SVOCs														
1-Methylnaphthalene	10	6	60	0.0231	35	9.27	5.39	13.3	3.5E+01	6.3E+00	2.2E+02	1.10E+02	1.12E-04	1.22E-02
2-Methylnaphthalene	10	8	80	0.016	30.9	6.29	1.14	10.6	3.1E+01	6.3E+00	2.0E+02	9.67E+01	1.12E-04	1.08E-02
PAHs														
Naphthalene	29	9	31	0.0829	300	49.7	18.1	95.9	3.0E+02	6.6E+00	2.0E+03	1.31E+03	9.45E-05	1.24E-01
Miscellaneous														
Sulfolane	566	340	60	3.4	10400	251	105	634	1.0E+04	[f]	[f]	[f]	[f]	[f]
GRO	21	7	33	408	20800	4869	2110	7189	2.1E+04	N/A				
DRO	21	11	52	227	2150	1001	537	779	2.2E+03	N/A				
RRO	19	3	16	199	278	230	212	42.4	2.8E+02	N/A				

Notes:

All concentrations are in units of ug/L, unless noted otherwise.

[a] COPCs are defined as described in the main text and Table 3-2a.

[b] Statistics were calculated using the most recent two years of groundwater data (2009 through 2011) for all onsite wells without LNAPL.

[c] The maximum detected concentration was used to represent the EPC.

[d] Calculated using the Virginia Department of Environmental Quality Trench Air Model (VDEQ, 2012) for groundwater occurring at less than 15 feet below ground surface.

[e] Calculated using the Johnson & Ettinger Model for groundwater (DTSC, 2009). A commercial air exchange rate of 1 per hour was assumed.

[f] Sulfolane was not evaluated for inhalation pathways, as described in the RAWP (ARCADIS, 2011).

AF = Attenuation factor
COPC = constituent of potential concern
DRO = Diesel range organics
EPC = exposure point concentration
FOD = frequency of detection
GRO = Gasoline range organics
ug/L = microgram(s) per liter
ug/m^3 = microgram(s) per cubic meter
L/m^3 = liters per cubic meter
LNAPL = light non-aqueous phase liquid
N/A = not available; insufficient data
PAH = polycyclic aromatic hydrocarbon
RRO = Residual range organics
SD = standard deviation
SVOCs = semi-volatile organic compounds
TEQ = toxicity equivalents
UCL = upper confidence limit on the mean
VF = volatilization factor
VOC = volatile organic compound

Table 3-5b
Area-Wide Summary Statistics and UCL Exposure Point Concentrations for Onsite Groundwater (2009 through 2011)

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

COPC [a]	Sample Size [b]	Number of Detects [b]	FOD (%)	Min [b]	Max [b]	Mean [b]	Median [b]	SD [b]	UCL Method	UCL [b]	Groundwater EPC [a] (ug/L)	VF [e] (L/m^3)	Trench Air EPC [e] (ug/m^3)	Predicted Soil Gas Concentration [d] (ug/m^3)	AF [d]	Indoor Air EPC [d] (ug/m^3)
Metals																
Barium	19	19	100	39.3	481	193	182	124	95% Student's-t UCL	262	2.6E+02					
Iron	19	15	79	1900	56900	13910	6090	16000	95% Approximate Gamma UCL	28060	2.8E+04					
Lead	19	3	16	0.35	2.05	1.05	0.74	0.89052	Highest temporal average	1.18	1.2E+00					
VOCs																
1,2,4-Trimethylbenzene	62	16	26	4.35	614	128	57.3	177	95% Chebyshev (Mean, Sd) UCL	113	1.1E+02	7.5E+00	8.5E+02	7.31E+03	1.12E-05	8.20E-02
1,3,5-Trimethylbenzene	19	7	37	1.93	184	50.7	21.2	64.2	Highest temporal average	121	1.2E+02	7.6E+00	9.2E+02	7.48E+03	1.27E-05	9.50E-02
4-Isopropyltoluene (p-cymene)	19	6	32	0.8	60.4	13.3	5.34	23.2	Highest temporal average	33.4	3.3E+01	7.2E+00	2.4E+02			
Benzene	330	148	45	0.17	18500	1802	91	3516	95% Chebyshev(Mean, Sd) UCL	1334	1.3E+03	9.3E+00	1.2E+04	1.20E+05	1.03E-05	1.24E+00
Ethylbenzene	330	97	29	0.44	2750	421	66.1	656	95% Chebyshev (Mean, Sd) UCL	180	1.8E+02	8.0E+00	1.4E+03	1.80E+04	7.54E-06	1.35E-01
n-Propylbenzene	19	7	37	1	122	37.9	22.4	43.1	Highest temporal average	80.3	8.0E+01	7.6E+00	6.1E+02	9.36E+03	6.46E-06	6.04E-02
Toluene	330	58	18	0.39	30100	5715	2090	8395	95% Chebyshev (Mean, Sd) UCL	1427	1.4E+03	8.6E+00	1.2E+04	1.35E+05	8.71E-06	1.18E+00
Xylenes	330	122	37	0.57	14090	2097	424	3121	95% Chebyshev(Mean, Sd) UCL	1184	1.2E+03	8.0E+00	9.5E+03	1.13E+05	8.42E-06	9.55E-01
SVOCs																
1-Methylnaphthalene	10	6	60	0.0231	35	9.27	5.39	13.3	Highest temporal average	35	3.5E+01	6.3E+00	2.2E+02	1.10E+02	1.12E-04	1.22E-02
2-Methylnaphthalene	10	8	80	0.016	30.9	6.29	1.14	10.6	95% Hall's Bootstrap UCL	25.2	2.5E+01	6.3E+00	1.6E+02	7.88E+01	1.12E-04	8.81E-03
PAHs																
Naphthalene	29	9	31	0.0829	300	49.7	18.1	95.9	95% Hall's Bootstrap UCL	145	1.5E+02	6.6E+00	9.6E+02	6.35E+02	9.45E-05	6.00E-02
Miscellaneous																
Sulfolane	566	340	60	3.4	10400	251	105	634	95% Chebyshev (Mean, Sd) UCL	833	8.3E+02	[f]	[f]	[f]	[f]	[f]
GRO	21	7	33	408	20800	4869	2110	7189	Highest temporal average	20800	2.1E+04	N/A				
DRO	21	11	52	227	2150	1001	537	779	95% Chebyshev (Mean, Sd) UCL	1549	1.5E+03	N/A				
RRO	19	3	16	199	278	230	212	42.4	Highest temporal average	278	2.8E+02	N/A				

Notes:

[a] The EPC is defined as the 95% UCL calculated using ProUCL v. 4.00.05.
All concentrations are in units of ug/L, unless noted otherwise.
[b] Statistics were calculated using the most recent two years of groundwater data (2009 through 2011) for all onsite wells without LNAPL.
[a] COPCs are defined as described in the main text and Table 3-2.
COPC = constituent of potential concern
[d] Calculated using the Johnson & Ettinger Model for groundwater (DTSC, 2009). A commercial air exchange rate of 1 per hour was assumed.
[e] Calculated using the Virginia Department of Environmental Quality Trench Air Model (VDEQ, 2012) for groundwater occurring at less than 15 feet below ground surface.
[f] Sulfolane was not evaluated for inhalation pathways, as described in the RAWP (ARCADIS, 2011).
AF = Attenuation factor
EPC = exposure point concentration
DRO = Diesel range organics
FOD = frequency of detection
GRO = Gasoline range organics
ug/L = microgram(s) per liter
ug/m^3 = microgram(s) per cubic meter
L/m^3 = liters per cubic meter
LNAPL = light non-aqueous phase liquid
N = no
N/A = not available; insufficient data
PAH = polycyclic aromatic hydrocarbon
RRO = Residual range organics
SD = standard deviation
SVOCs = semi-volatile organic compounds
TEQ = toxicity equivalents
UCL = upper confidence limit on the mean
VF = volatilization factor
VOC = volatile organic compound
Y = yes

Table 3-6
Area-Wide Summary Statistics and Maximum Exposure Point Concentrations for Offsite Groundwater in All Wells (2009 through 2011)

Human Health Risk Assessment - PPRTV Scenario and ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Sample Size [b]	Number of Detects [b]	FOD (%)	Min [b]	Max [b]	Mean [b]	Median [b]	SD [b]	COPC? [c] (Y/N)	Groundwater EPC [a] (ug/L)
Miscellaneous										
Sulfolane	700	367	52	3.48	443	56.1	21.6	68.7	Y	4.4E+02

Notes:
[a] The maximum detected concentration was used to represent the EPC.
All concentrations are in units of ug/L, unless noted otherwise.
[b] Statistics were calculated using the most recent two years of groundwater data (2009 through 2011) for offsite wells without LNAPL.
[c] COPCs are defined as described in the main text and Table 3-2a.
COPC = constituent of potential concern
EPC = exposure point concentration
FOD = frequency of detection
ug/L = microgram(s) per liter
LNAPL = light non-aqueous phase liquid
N = no
SD = standard deviation
Y = yes

Table 3-7
Area-Wide Summary Statistics and UCL Exposure Point Concentrations for Offsite Groundwater in Exposure Unit 1 (2009 through 2011)

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Sample Size [b]	Number of Detects [b]	FOD (%)	Min [b]	Max [b]	Mean [b]	Median [b]	SD [b]	UCL Method	UCL [b]	COPC? [c] (Y/N)	Groundwater EPC [a] (ug/L)
Miscellaneous												
Sulfolane	105	104	99	15.8	443	139	122	72.8	95% Chebyshev (Mean, Sd) UCL	170	Y	1.7E+02

Notes:

[a] The EPC is defined as the 95% UCL calculated using ProUCL v. 4.00.05.

All concentrations are in units of ug/L, unless noted otherwise.

[b] Statistics were calculated using the most recent two years of groundwater data (2009 through 2011) for offsite wells in Exposure Unit 1 without LNAPL.

[c] COPCs are defined as described in the main text and Table 3-2a.

COPC = constituent of potential concern

EPC = exposure point concentration

FOD = frequency of detection

Groundwater wells in Exposure Unit 1 were defined by a boundary that includes all wells with maximum concentrations greater than 100 ug/L.

ug/L = microgram(s) per liter

LNAPL = light non-aqueous phase liquid

N = no

SD = standard deviation

UCL = upper confidence limit on the mean

Y = yes

Table 3-8a
Area-Wide Summary Statistics and Maximum Exposure Point Concentrations for Offsite Groundwater in Exposure Unit 2 (2009 through 2011)

Human Health Risk Assessment - PPRTV Scenario and ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Sample Size [b]	Number of Detects [b]	FOD (%)	Min [b]	Max [b]	Mean [b]	Median [b]	SD [b]	COPC? [c] (Y/N)	Groundwater EPC [a] (ug/L)
Miscellaneous										
Sulfolane	73	72	99	8.63	144	53.3	46.9	7.51	Y	1.4E+02

Notes:

[a] The maximum detected concentration was used to represent the EPC.

All concentrations are in units of ug/L, unless noted otherwise.

[b] Statistics were calculated using the most recent two years of groundwater data (2009 through 2011) for offsite wells in Exposure Unit 2 without LNAPL.

[c] COPCs are defined as described in the main text and Table 3-2a.

COPC = constituent of potential concern

EPC = exposure point concentration

FOD = frequency of detection

Groundwater wells in Exposure Unit 2 were defined by a boundary that includes all wells with maximum concentrations greater than 25 ug/L but less than than 100 ug/L.

ug/L = microgram(s) per liter

LNAPL = light non-aqueous phase liquid

N = no

SD = standard deviation

UCL = upper confidence limit on the mean

Y = yes

Table 3-8b
Area-Wide Summary Statistics and UCL Exposure Point Concentrations for Offsite Groundwater in Exposure Unit 2 (2009 through 2011)

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Sample Size [b]	Number of Detects [b]	FOD (%)	Min [b]	Max [b]	Mean [b]	Median [b]	SD [b]	UCL Method	UCL [b]	COPC? [c] (Y/N)	Groundwater EPC [a] (ug/L)
Miscellaneous												
Sulfolane	73	72	99	8.63	144	53.3	46.9	29.8	95% Approximate Gamma UCL	59.1	Y	5.9E+01

Notes:

[a] The EPC is defined as the 95% UCL calculated using ProUCL v. 4.00.05.

All concentrations are in units of ug/L, unless noted otherwise.

[b] Statistics were calculated using the most recent two years of groundwater data (2009 through 2011) for offsite wells in Exposure Unit 2 without LNAPL.

[c] COPCs are defined as described in the main text and Table 3-2a.

COPC = constituent of potential concern

EPC = exposure point concentration

FOD = frequency of detection

Groundwater wells in Exposure Unit 2 were defined by a boundary that includes all wells with maximum concentrations greater than 25 ug/L but less than 100 ug/L.

ug/L = microgram(s) per liter

LNAPL = light non-aqueous phase liquid

N = no

SD = standard deviation

UCL = upper confidence limit on the mean

Y = yes

Table 3-9a
Area-Wide Summary Statistics and Maximum Exposure Point Concentrations for Offsite Groundwater in Exposure Unit 3 (2009 through 2011)

Human Health Risk Assessment - PPRTV Scenario and ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Sample Size [b]	Number of Detects [b]	FOD (%)	Min [b]	Max [b]	Mean [b]	Median [b]	SD [b]	COPC? [c] (Y/N)	Groundwater EPC [a] (ug/L)
Miscellaneous										
Sulfolane	294	177	60	3.48	80.2	10.9	9.04	7.51	Y	8.0E+01

Notes:

[a] The maximum detected concentration was used to represent the EPC.

All concentrations are in units of ug/L, unless noted otherwise.

[b] Statistics were calculated using the most recent two years of groundwater data (2009 through 2011) for offsite wells in Exposure Unit 3 without LNAPL.

[c] COPCs are defined as described in the main text and Table 3-2a.

COPC = constituent of potential concern

EPC = exposure point concentration

FOD = frequency of detection

Groundwater wells in Exposure Unit 3 were defined by a boundary that includes all wells with maximum concentrations greater than the detection limit but less than than 25 ug/L.

ug/L = microgram(s) per liter

LNAPL = light non-aqueous phase liquid

N = no

SD = standard deviation

UCL = upper confidence limit on the mean

Y = yes

Table 3-9b
Area-Wide Summary Statistics and UCL Exposure Point Concentrations for Offsite Groundwater in Exposure Unit 3 (2009 through 2011)

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Sample Size [b]	Number of Detects [b]	FOD (%)	Min [b]	Max [b]	Mean [b]	Median [b]	SD [b]	UCL Method	UCL [b]	COPC? [c] (Y/N)	Groundwater EPC [a] (ug/L)
Miscellaneous												
Sulfolane	294	177	60	3.48	80.2	10.9	9.04	7.51	95% Chebyshev (Mean, Sd) UCL	10.2	Y	1.0E+01

Notes:

[a] The EPC is defined as the 95% UCL calculated using ProUCL v. 4.00.05.
All concentrations are in units of ug/L, unless noted otherwise.
[b] Statistics were calculated using the most recent two years of groundwater data (2009 through 2011) for offsite wells in Exposure Unit 3 without LNAPL.
[c] COPCs are defined as described in the main text and Table 3-2a.
COPC = constituent of potential concern
EPC = exposure point concentration
FOD = frequency of detection
Groundwater wells in Exposure Unit 3 were defined by a boundary that includes all wells with maximum concentrations greater than the detection limit but less than than 25 ug/L.
ug/L = microgram(s) per liter
LNAPL = light non-aqueous phase liquid
N = no
SD = standard deviation
UCL = upper confidence limit on the mean
Y = yes

Table 3-10
Area-Wide Summary Statistics and Maximum Exposure Point Concentrations for Offsite Surface Water (Estimated from Porewater Surrogate Data)

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Sample Size [b]	Number of Detects [b]	FOD (%)	Min [b]	Max [b]	Mean [b]	Median [b]	SD [b]	COPC? [c] (Y/N)	Surface Water EPC [a] (ug/L)
Miscellaneous										
Sulfolane	3	2	67	28.7	156	92.35	92.35	90.01	Y	1.6E+02

Notes:
[a] The maximum detected concentration was used to represent the EPC.
All concentrations are in units of ug/L, unless noted otherwise.
[b] Statistics were calculated using porewater data collected in 2012.
[c] COPCs are defined as described in the main text and Table 3-2a.
COPC = constituent of potential concern
EPC = exposure point concentration
FOD = frequency of detection
ug/L = microgram(s) per liter
N = no
SD = standard deviation
Y = yes

Table 3-11
Chemical Specific Information and Soil Volatilization Factors for Human Health Risk Assessment

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituents	Volatile? [a]	Molecular Weight (g/mol)	Henry's Law Constant (atm-m^3/mol)	Henry's Law Constant (unitless)	Solubility in Water (mg/L-water)	Diffusivity in Air (cm^2/sec)	Diffusivity in Water (cm^2/sec)	Koc (cm^3/g)	Kd [b] (cm^3/g)	Apparent Diffusivity [c] Calculated (cm^2/sec)	Soil to Air Volatilization Factor Calculated[a] (m^3/kg)	Soil to Air Volatilization Factor Published (m^3/kg)	Soil to Air Volatilization Factor Selected Value (m^3/kg)	Soil Saturation Limit Calculated (mg/kg)	Soil Saturation Limit Published (mg/kg)	Soil Saturation Limit Selected Value (mg/kg)
Metals																
Antimony	N	1.22E+02 RSL	--	--	--	--	--	7.50E+03 RSL	4.50E+01 RSL	--	--	--	--	--	--	--
Arsenic	N	7.49E+01 RSL	--	--	--	--	--	4.83E+03 RSL	2.90E+01 RSL	--	--	--	--	--	--	--
Barium	N	1.37E+02 RSL	--	--	--	--	--	6.67E+02 RSL	4.00E+00 RSL	--	--	--	--	--	--	--
Cadmium	N	1.12E+02 RSL	--	--	--	--	--	1.25E+04 RSL	7.50E+01 RSL	--	--	--	--	--	--	--
Chromium, Total	N	5.20E+01 RSL	--	--	--	--	--	3.00E+08 RSL	1.80E+06 RSL	--	--	--	--	--	--	--
Copper	N	6.36E+01 RSL	--	--	--	--	--	5.83E+03 RSL	3.50E+01 RSL	--	--	--	--	--	--	--
Lead	N	2.07E+02 RSL	--	--	--	--	--	1.50E+05 RSL	9.00E+02 RSL	--	--	--	--	--	--	--
Nickel	N	5.87E+01 RSL	--	--	--	--	--	1.08E+04 RSL	6.50E+01 RSL	--	--	--	--	--	--	--
Selenium	N	7.90E+01 RSL	--	--	--	--	--	8.33E+02 RSL	5.00E+00 RSL	--	--	--	--	--	--	--
Silver	N	1.08E+02 RSL	--	--	--	--	--	1.38E+03 RSL	8.30E+00 RSL	--	--	--	--	--	--	--
Zinc	N	6.54E+01 RSL	--	--	--	--	--	1.03E+04 RSL	6.20E+01 RSL	--	--	--	--	--	--	--
VOCs																
1,2,4-Trimethylbenzene	Y	1.20E+02 RSL	6.16E-03 RSL	2.52E-01 RSL	5.70E+01 RSL	6.07E-02 RSL	7.92E-06 RSL	6.14E+02 RSL	3.69E+00 RSL	2.06E-04 RSL	8.72E+03	8.52E+03 RSL	8.52E+03 RSL	2.18E+02	2.19E+02 RSL	2.19E+02 RSL
1,3,5-Trimethylbenzene	Y	1.20E+02 RSL	8.77E-03 RSL	3.59E-01 RSL	4.82E+01 RSL	6.02E-02 RSL	7.84E-06 RSL	6.02E+02 RSL	3.61E+00 RSL	2.96E-04 RSL	7.28E+03	7.12E+03 RSL	7.12E+03 RSL	1.82E+02	1.82E+02 RSL	1.82E+02 RSL
4-Isopropyltoluene (p-cymene)	Y	1.34E+02 EPI&RAIS	1.10E-02 EPI&RAIS	4.51E-01 EPI&RAIS	2.34E+01 EPI&RAIS	5.27E-02 EPI&RAIS	7.32E-06 EPI&RAIS	1.12E+03 EPI&RAIS	6.72E+00 EPI&RAIS	1.78E-04 EPI&RAIS	9.38E+03	--	9.38E+03 calc	1.62E+02	--	1.62E+02 calc
Benzene	Y	7.81E+01 RSL	5.55E-03 RSL	2.27E-01 RSL	1.79E+03 RSL	8.95E-02 RSL	1.03E-05 RSL	1.46E+02 RSL	8.75E-01 RSL	1.03E-03 RSL	3.90E+03	3.81E+03 RSL	3.81E+03 RSL	1.82E+03	1.82E+03 RSL	1.82E+03 RSL
Ethylbenzene	Y	1.06E+02 RSL	7.88E-03 RSL	3.22E-01 RSL	1.69E+02 RSL	6.85E-02 RSL	8.46E-06 RSL	4.46E+02 RSL	2.68E+00 RSL	4.03E-04 RSL	6.24E+03	6.10E+03 RSL	6.10E+03 RSL	4.79E+02	4.80E+02 RSL	4.80E+02 RSL
Isopropylbenzene (cumene)	Y	1.20E+02 RSL	1.15E-02 RSL	4.70E-01 RSL	6.13E+01 RSL	6.03E-02 RSL	7.86E-06 RSL	6.98E+02 RSL	4.19E+00 RSL	3.36E-04 RSL	6.84E+03	6.68E+03 RSL	6.68E+03 RSL	2.68E+02	2.68E+02 RSL	2.68E+02 RSL
Methyl tert-butyl ether	Y	8.82E+01 RSL	5.87E-04 RSL	2.40E-02 RSL	5.10E+04 RSL	7.53E-02 RSL	8.59E-06 RSL	1.16E+01 RSL	6.94E-02 RSL	5.38E-04 RSL	5.40E+03	5.28E+03 RSL	5.28E+03 RSL	8.87E+03	8.87E+03 RSL	8.87E+03 RSL
Methylene chloride	Y	8.49E+01 RSL	3.25E-03 RSL	1.33E-01 RSL	1.30E+04 RSL	9.99E-02 RSL	1.25E-05 RSL	2.17E+01 RSL	1.30E-01 RSL	2.69E-03 RSL	2.41E+03	2.36E+03 RSL	2.36E+03 RSL	3.32E+03	3.32E+03 RSL	3.32E+03 RSL
n-Butylbenzene	Y	1.34E+02 EPI&RAIS	1.59E-02 EPI&RAIS	6.50E-01 EPI&RAIS	1.18E+01 EPI&RAIS	5.28E-02 EPI&RAIS	7.33E-06 EPI&RAIS	1.48E+03 EPI&RAIS	8.89E+00 EPI&RAIS	1.95E-04 EPI&RAIS	8.97E+03	8.77E+03 RSL	8.77E+03 RSL	1.08E+02	1.08E+02 RSL	1.08E+02 RSL
n-Propylbenzene	Y	1.20E+02 RSL	1.05E-02 RSL	4.29E-01 RSL	5.22E+01 RSL	6.02E-02 RSL	7.83E-06 RSL	8.13E+02 RSL	4.88E+00 RSL	2.64E-04 RSL	7.71E+03	7.53E+03 RSL	7.53E+03 RSL	2.64E+02	2.64E+02 RSL	2.64E+02 RSL
sec-Butylbenzene	Y	1.34E+02 EPI&RAIS	1.76E-02 EPI&RAIS	7.22E-01 EPI&RAIS	1.76E+01 EPI&RAIS	5.28E-02 EPI&RAIS	7.33E-06 EPI&RAIS	1.33E+03 EPI&RAIS	7.98E+00 EPI&RAIS	2.40E-04 EPI&RAIS	8.08E+03	--	8.08E+03 calc	1.45E+02	--	1.45E+02 calc
tert-Butylbenzene	Y	1.34E+02 EPI&RAIS	1.32E-02 EPI&RAIS	5.41E-01 EPI&RAIS	2.95E+01 EPI&RAIS	5.30E-02 EPI&RAIS	7.37E-06 EPI&RAIS	1.00E+03 EPI&RAIS	6.00E+00 EPI&RAIS	2.40E-04 EPI&RAIS	8.09E+03	--	8.09E+03 calc	1.83E+02	--	1.83E+02 calc
Toluene	Y	9.21E+01 RSL	6.64E-03 RSL	2.71E-01 RSL	5.26E+02 RSL	7.78E-02 RSL	9.20E-06 RSL	2.34E+02 RSL	1.40E+00 RSL	7.04E-04 RSL	4.72E+03	4.61E+03 RSL	4.61E+03 RSL	8.17E+02	8.18E+02 RSL	8.18E+02 RSL
Trichlorofluoromethane (Freon 11)	Y	1.37E+02 RSL	9.70E-02 RSL	3.97E+00 RSL	1.10E+03 RSL	6.54E-02 RSL	1.00E-05 RSL	4.39E+01 RSL	2.63E-01 RSL	1.22E-02 RSL	1.14E+03	1.11E+03 RSL	1.11E+03 RSL	1.21E+03	1.23E+03 RSL	1.23E+03 RSL
Xylenes	Y	1.06E+02 RSL	5.18E-03 RSL	2.12E-01 RSL	1.06E+02 RSL	8.47E-02 RSL	9.90E-06 RSL	3.83E+02 RSL	2.30E+00 RSL	3.81E-04 RSL	6.42E+03	6.27E+03 RSL	6.27E+03 RSL	2.58E+02	2.58E+02 RSL	2.58E+02 RSL
SVOCs																
2-Methylnaphthalene	Y	1.42E+02 RSL	5.18E-04 RSL	2.12E-02 RSL	2.46E+01 RSL	5.24E-02 RSL	7.78E-06 RSL	2.48E+03 RSL	1.49E+01 RSL	3.84E-06 RSL	6.39E+04	6.24E+04 RSL	6.24E+04 RSL	3.68E+02	3.68E+02 RSL	3.68E+02 RSL
Dibenzofuran	Y	1.68E+02 RSL	2.13E-04 RSL	8.71E-03 RSL	3.10E+00 RSL	4.10E-02 RSL	7.38E-06 RSL	9.16E+03 RSL	5.50E+01 RSL	3.37E-07 RSL	2.16E+05	2.11E+05 RSL	2.11E+05 RSL	1.71E+02	1.71E+02 RSL	1.71E+02 RSL
PAHs																
Benzo (a) anthracene	N	2.28E+02 RSL	1.20E-05 RSL	4.91E-04 RSL	9.40E-03 RSL	5.09E-02 RSL	5.94E-06 RSL	1.77E+05 RSL	1.06E+03 RSL	1.25E-09 RSL	3.54E+06	--	3.54E+06 calc	9.98E+00	--	9.98E+00 calc
Benzo (a) pyrene	N	2.52E+02 RSL	4.57E-07 RSL	1.87E-05 RSL	1.62E-03 RSL	4.76E-02 RSL	5.56E-06 RSL	5.87E+05 RSL	3.52E+03 RSL	2.33E-11 RSL	2.60E+07	--	2.60E+07 calc	5.71E+00	--	5.71E+00 calc
Benzo (b) fluoranthene	N	2.52E+02 RSL	6.57E-07 RSL	2.69E-05 RSL	1.50E-03 RSL	4.76E-02 RSL	5.56E-06 RSL	5.99E+05 RSL	3.60E+03 RSL	2.84E-11 RSL	2.35E+07	--	2.35E+07 calc	5.39E+00	--	5.39E+00 calc
Benzo (g,h,i) perylene	N	2.76E+02 SRC & RAIS	3.31E-07 SRC & RAIS	1.36E-05 SRC & RAIS	2.60E-04 SRC & RAIS	--	--	--	--	--	--	--	--	--	--	--
Benzo (k) fluoranthene	N	2.52E+02 RSL	5.84E-07 RSL	2.39E-05 RSL	8.00E-04 RSL	4.76E-02 RSL	5.56E-06 RSL	5.87E+05 RSL	3.52E+03 RSL	2.69E-11 RSL	2.42E+07	--	2.42E+07 calc	2.82E+00	--	2.82E+00 calc
Chrysene	N	2.28E+02 RSL	5.23E-06 RSL	2.14E-04 RSL	2.00E-03 RSL	2.61E-02 RSL	6.75E-06 RSL	1.81E+05 RSL	1.08E+03 RSL	3.07E-10 RSL	7.15E+06	--	7.15E+06 calc	2.17E+00	--	2.17E+00 calc
Dibenzo (a,h) anthracene	N	2.78E+02 RSL	1.41E-07 RSL	5.76E-06 RSL	2.49E-03 RSL	4.46E-02 RSL	5.21E-06 RSL	1.91E+06 RSL	1.15E+04 RSL	4.09E-12 RSL	6.19E+07	--	6.19E+07 calc	2.86E+01	--	2.86E+01 calc
Fluoranthene	N	2.02E+02 RSL	8.86E-06 RSL	3.62E-04 RSL	2.60E-01 RSL	2.76E-02 RSL	7.18E-06 RSL	5.55E+04 RSL	3.33E+02 RSL	1.69E-09 RSL	3.04E+06	--	3.04E+06 calc	8.65E+01	--	8.65E+01 calc
Fluorene	Y	1.66E+02 RSL	9.62E-05 RSL	3.93E-03 RSL	1.69E+00 RSL	4.40E-02 RSL	7.89E-06 RSL	9.16E+03 RSL	5.50E+01 RSL	1.64E-07 RSL	3.10E+05	3.03E+05 RSL	3.03E+05 RSL	9.31E+01	--	9.31E+01 calc
Indeno (1,2,3-cd) pyrene	N	2.76E+02 RSL	3.48E-07 RSL	1.42E-05 RSL	1.90E-04 RSL	4.48E-02 RSL	5.23E-06 RSL	1.95E+06 RSL	1.17E+04 RSL	5.70E-12 RSL	5.25E+07	--	5.25E+07 calc	2.22E+00	--	2.22E+00 calc
Naphthalene	Y	1.28E+02 RSL	4.40E-04 RSL	1.80E-02 RSL	3.10E+01 RSL	6.05E-02 RSL	8.38E-06 RSL	1.54E+03 RSL	9.26E+00 RSL	6.02E-06 RSL	5.11E+04	4.99E+04 RSL	4.99E+04 RSL	2.90E+02	--	2.90E+02 calc
Phenanthrene	Y	1.78E+02 SRC & RAIS	4.23E-05 SRC & RAIS	1.73E-03 SRC & RAIS	1.15E+00 SRC & RAIS	3.45E-02 SRC & RAIS	6.69E-06 SRC & RAIS	1.67E+04 SRC & RAIS	1.00E+02 SRC & RAIS	3.13E-08 SRC & RAIS	7.08E+05	--	7.08E+05 calc	1.15E+02	--	1.15E+02 calc
Pyrene	N	2.02E+02 RSL	1.19E-05 RSL	4.87E-04 RSL	1.35E-01 RSL	2.78E-02 RSL	7.25E-06 RSL	5.43E+04 RSL	3.26E+02 RSL	2.29E-09 RSL	2.62E+06	2.56E+06 RSL	2.56E+06 calc	4.40E+01	--	4.40E+01 calc
Total Benzo(a)pyrene TEQ	N	2.52E+02 RSL	4.57E-07 RSL	1.87E-05 RSL	1.62E-03 RSL	4.76E-02 RSL	5.56E-06 RSL	5.87E+05 RSL	3.52E+03 RSL	2.33E-11 RSL	2.60E+07	--	2.60E+07 calc	5.71E+00	--	5.71E+00 calc
Miscellaneous																
Cyanide	Y	2.70E+01 RSL	1.33E-04 RSL	5.44E-03 RSL	1.00E+06 RSL	2.11E-01 RSL	2.46E-05 RSL	--	--	--	--	5.01E+04 RSL	5.01E+04 RSL	--	1.00E+07 RSL	1.00E+07 RSL
Sulfolane	N	1.20E+02 EPI	1.42E-09 EPI	5.82E-08 EPI	4.56E+05 EPI	--	--	--	--	--	--	--	--	--	--	--
GRO	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
DRO	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
RRO	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 3-11
Chemical Specific Information and Soil Volatilization Factors for Human Health Risk Assessment

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:
a = Volatilization factors were calculated as described in USEPA (2011d) for chemicals with molecular weight < 200 g/mol and Henry's Law Constant >$1x10^{-5}$ (USEPA, 2004).
atm-m³/mol = atmospheres × cubic meters per mole
b = Kd values calculated by multiplying Koc by the default fraction organic carbon (0.006) from USEPA (2011d) unless provided by USEPA (1996).
c = Apparent diffisivity calculated based on equation provided by Section 4.10.2 of USEPA guidance (2011d).
cm²/sec = square centimeter(s) per second
cm^3/g = cubic centimeter(s) per gram
d = Values presented in USEPA (2011d).
e = naphthalene surrogate used
EPI = EpiSuite software v. 4.0
g/mol = gram(s) per mole
Kd = soil-water distribution coefficient (inorganic compounds)
Koc = organic carbon partition coefficient (organics)
m^3/kg = cubic meter(s) per kilogram
mg/L = milligram(s) per liter
mm Hg = millimeter(s) of mercury
PAH = polycyclic aromatic hydrocarbon
RAIS = parameter selected from ORNL (2010)
RSL = parameter selected from USEPA (2011d)
SRC = parameter selected from SRC (2010)
USEPA = U.S. Environmental Protection Agency
VOC = volatile organic compound
-- = not applicable

References:
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Table 3-12
Human Health Exposure Parameters - PPRTV Scenario and ARCADIS Comparative Scenario

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Symbol	Units	Onsite and Offsite Commercial/Industrial Indoor Worker		Onsite Commercial/Industrial Outdoor Worker		Onsite and Offsite Construction/Trench Worker		Onsite Adult Visitor		Offsite Adult Resident		Offsite Child (1-6 yr) Resident		Offsite Infant (0-1 yr) Resident		Offsite Adult Recreator		Offsite Child (1-6 yr) Recreator	
			CI		CIo		CST		VIS		ADUR		CHR		INF		AREC		CREC	
General Factors																				
Averaging Time (cancer)	ATc	days	25,550	a,b	25,550	a,b	25,550	a	25,550	a	25,550	a,b	25,550	a,b	25,550	a,b	25,550	a,b	25,550	a,b
Averaging Time (noncancer)	ATnc	days	9,125	a	9,125	a	365	a	10,950	a	10,950	a	2,190	a	365	a	10,950	a	2,190	a
Body Weight	BW	kg	70	b, d	70	b, d	70	d, f	70	b	70	b, d	15	b,d	6.75	n	70	b, d	15	o
Exposure Frequency - Soil	EF	days/year	250	b, c	250	b, c	125	d, f	12	PJ	270	b, c	270	b, c	270	b,d	–		–	
Exposure Frequency - Groundwater	EFgw	days/year	250	b, c	250	b, c	125	d, f	12	PJ	350	b	350	b	350	b,d	–		–	
Exposure Frequency - Surface water	EFsw	days/year	–		–		–		–		60	cons	60	cons	–		60	cons	60	cons
Exposure Duration	ED	years	25	b	25	b	1	PJ	30	b	30	b	6	b	1	n	30	b	6	b
Exposure Time	ET	hr/day	8	PJ	8	PJ	1	PJ	2	PJ	12	PJ	12	PJ	12	PJ	1	cons	1	cons
Groundwater - Ingestion (Oral)																				
Groundwater Ingestion Rate (drinking water)	IRgw	L/day	2	b	2	b	–		–		2	b	1	d	1.05	l	–		–	
Groundwater Ingestion Rate (incidental)	IRinc_gw	L/day	–		–		0.0037	m	–		–		–		–		–		–	
Fraction Ingested from Source	Figw	unitless	1	cons	1	cons	1	cons	–		1	cons	1	cons	1	cons	–		–	
Groundwater - Dermal Contact																				
Exposed Skin Surface Area	SSAgw	cm²	–		–		2,230	k	–		–		–		–		–		–	
Event Frequency	EvFgw	events/day	–		–		1	--	–		–		–		–		–		–	
Event Time	EvTgw	hr/event	–		–		1	PJ	–		–		–		–		–		–	
Groundwater - Inhalation of Volatiles																				
Exposure Frequency - Trench Air	EFtr	days/year	–		–		125	PJ	–		–		–		–		–		–	
Soil - Ingestion (Oral)																				
Incidental Soil Ingestion Rate	IRs	mg/day	–		100	b, f	330	i	–		–		–		–		–		–	
Fraction Ingested from Source	FI	unitless	–		1	--	1	cons	–		–		–		–		–		–	
Soil - Dermal Contact																				
Exposed Skin Surface Area	SA	cm²	–		2,230	k	2,230	k	–		–		–		–		–		–	
Skin Adherence Factor	AF	mg/cm²-day	–		0.2	b, h	0.3	i	–		–		–		–		–		–	
Fraction in Contact with Soil	FC	unitless	–		1	b	1	b	–		–		–		–		–		–	
Event Frequency	EvFs	events/day	–		1	--	1	--	–		–		–		–		–		–	
Soil - Inhalation of Dust and Vapor																				
Age-Adjusted Intake Factor, Inhalation	IFi	m³-yr/kg-day	–		–				–		–		–		–		–		–	
Particulate Emission Factor	PEF	m³/kg	–		1.32E+09	b,e	1.00E+06	e,j	–		1.32E+09	b,e	1.32E+09	e	1.32E+09	e	–		–	
Homegrown Produce Ingestion																				
Fruit Ingestion Rate	IRPfr	mg/day	–		–		–		–		259,000	g	223,500	g	155,250	g	–		–	
Vegetable Ingestion Rate	IRPvg	mg/day	–		–		–		–		413,000	g	201,000	g	109,350	g	–		–	
Fraction Ingested from Source	Flp	unitless	–		–		–		–		0.25	PJ	0.25	PJ	0.25	PJ	–		–	
Bioconcentration Factor	BCF	L/kg ww	–		–		–		–		1	cons	1	cons	1	cons				
Surface water - Ingestion (Oral)																				
Surface water Ingestion Rate (incidental)	IRinc_sw	L/hour	–		–		–		–		0.071	p	0.12	p	–		0.071	p	0.12	p
Fraction Ingested from Source	Fisw	unitless	–		–		–		–		1	cons	1	cons	–		1	cons	1	cons

Table 3-12
Human Health Exposure Parameters - PPRTV Scenario and ARCADIS Comparative Scenario

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

a. The averaging period for cancer risk is the expected lifespan of 70 years expressed in days (70 years * 365 days/year). The averaging period for non-cancer risk is the total exposure period expressed in days (ED * 365 days/year).
b. ADEC (2010). Risk Assessment Procedures Manual. July.
c. Soil exposure frequency is based on the climate zone in which the site is located, consistent with ADEC's Cleanup Level Guidance (DEC 2008). Residential and recreation/subsistence user soil exposure frequency is 270 d/yr for the under 40-inch zone. For commercial/industrial workers the soil exposure frequency is 250 d/yr for the
d. USEPA. 1989. Risk Assessment Guidance for Superfund.Volume I, Human Health Evaluation Manual (Part A) . EPA/540/1-89-002. December.
e. CALEPA. 2011. Human Health RIsk Assessment Note 1. Recommended DTSC Default Exposure Factors for Use in Risk Assessment at California Hazardous Waste Sites and Permitted Facilities. May.
f. USEPA. 1991. Standard Default Exposure Factors, Interim Final . OSWER Directive: 9285.6-03. March.
g. USEPA (2011). Exposure Factors Handbook. For fruit: Table 9-3, 95th percentile per capita intake (value for ages 3-5 years used for child). For vegetables: Table 9-3, 95th percentile per capita intake of all vegetables (value for ages 3-5 years used for child). IRPs in EFH were multiplied by body weight.
h. USEPA (2004). Risk Assessment Guidance for Superfund, Vol 1, Part E, Supplemental Guidance for Dermal Risk Assessment. Office of Emergency and Remedial
i. USEPA (2002a). Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. December.
j. This PEF value corresponds to a respirable dust concentration of 1 mg/m3. This is based on a maximum concentration of dust in air of 10 mg/m3 recommended by the American Conference of Governmental Industrial Hygienists (ACGIH 2004, Threshold Limit Values and Biological Exposure Indices), and the assumption that 10 percent of the mass of particles are in the respirable PM10 range.
k. USEPA (2011). Exposure Factors Handbook. Table 7-2, average of adult male and adult female mean values for head and hands.
l. USEPA (2011). Exposure Factors Handbook. Table 3-1, time-weighted 95th percentile ingestion rate for infants.
m. USEPA (2011). Exposure Factors Handbook. Table 3-93, mean incidental ingestion of water during wading/spashing activities.
n. USEPA. 2008. Child-Specific Exposure Factors Handbook. EPA/600/R-06/096F. September.
o. See footnotes b and d.
p. USEPA (2011). Exposure Factors Handbook. Recommended upper percentile values for swimmers from Table 3-5: maximum for adults, 97th percentile for children age 18 and under.

Exposure equations are presented in Section 3 of the main text.
Exposure parameters with alternate values in the PPRTV and ARCADIS Scenarios are highlighted in gray.

cm	Centimeter.
cons	Conservative assumption (see text).
hr	Hour.
kg	Kilogram.
L	liter
m	Meter.
mg	milligrams
PJ	Professional judgement
ww	wet weight
yr	year

Table 3-13
Human Health Toxicity Values

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Constituents		CSFo $(mg/kg\text{-}day)^{-1}$		CSFd $(mg/kg\text{-}day)^{-1}$		IUR $(\mu g/m^3)^{-1}$		Chronic RfDo mg/kg-day		Chronic RfDd mg/kg-day		Chronic RfC mg/m^3		Subchronic RfDo mg/kg-day		Subchronic RfDd mg/kg-day		Subchronic RfC mg/m^3		ABSo unitless	ABSd unitless
Metals																					
Antimony		NC	-	NC	-	NC	-	4.0E-04	I	6.0E-05	Calc	NA	-	4.0E-04	PROV	6.0E-05	Calc	NA	Chronic	0.15	0.00
Arsenic		1.5E+00	I	1.5E+00	Calc	4.3E-03	I	3.0E-04	I	3.0E-04	Calc	1.5E-05	C	5.0E-03	PROV	5.0E-03	Calc	1.5E-05	Chronic	1	0.03
Barium		NC	-	NC	-	NC	-	2.0E-01	I	1.4E-02	Calc	5.0E-04	H	7.0E-02	HEAST	4.9E-03	Calc	5.0E-03	HEAST	0.07	0.00
Cadmium	a	NC	-	NC	-	1.8E-03	I	1.0E-03	I	2.5E-05	Calc	2.0E-05	C	1.0E-03	Chronic	2.5E-05	Calc	9.0E-04	PROV	0.025	0.001
Chromium, Total	b	NC	-	NC	-	NC	-	1.5E+00	I	2.0E-02	Calc	NA	-	1.5E+00	HEAST	2.0E-02	Calc	NA	Chronic	0.013	0.00
Copper		NC	-	NC	-	NC	-	4.0E-02	H	4.0E-02	Calc	NA	-	4.0E-02	HEAST	4.0E-02	Calc	NA	Chronic	1	0.00
Iron		NC	-	NC	-	NC	-	7.0E-01	P	7.0E-01	Calc	NA	-	7.0E-01	PROV	7.0E-01	Calc	NA	Chronic	1	0.00
Lead	c	NE	-	NE	-	NE	-	NE	-	NE	-	NE	-	NE	-	NE	-	NE	-	1	0.00
Nickel		NC	-	NC	-	2.6E-04	C	2.0E-02	I	8.0E-04	Calc	9.0E-05	A	2.0E-02	HEAST	8.0E-04	Calc	9.0E-05	Chronic	0.04	0.00
Selenium		NC	-	NC	-	NC	-	5.0E-03	I	5.0E-03	Calc	2.0E-02	C	5.0E-03	HEAST	5.0E-03	Calc	2.0E-02	Chronic	1	0.00
Silver		NC	-	NC	-	NC	-	5.0E-03	I	2.0E-04	Calc	NA	-	5.0E-03	HEAST	2.0E-04	Calc	NA	Chronic	0.04	0.00
Zinc		NC	-	NC	-	NC	-	3.0E-01	I	3.0E-01	Calc	NA	-	3.0E-01	HEAST	3.0E-01	Calc	NA	Chronic	1	0.00
VOCs																					
1,2,4-Trimethylbenzene		NC	-	NC	-	NC	-	NA	-	NA	Calc	7.0E-03	P	NA	Chronic	NA	Calc	7.0E-02	PROV	1	0.00
1,3,5-Trimethylbenzene		NC	-	NC	-	NC	-	1.0E-02	X	1.0E-02	Calc	NA	-	1.0E-01	PROV	1.0E-01	Calc	1.0E-02	PROV	1	0.00
4-Isopropyltoluene (p-cymene)		NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.00
Benzene		5.5E-02	I	5.5E-02	Calc	7.8E-06	I	4.0E-03	I	4.0E-03	Calc	3.0E-02	I	1.0E-02	PROV	1.0E-02	Calc	8.0E-02	PROV	1	0.00
Cyclohexane		NC	-	NC	-	NC	-	NA	-	NA	Calc	6.0E+00	I	NA	Chronic	NA	Calc	6.0E+00	Chronic	1	0.00
Ethylbenzene		1.1E-02	C	1.1E-02	Calc	2.5E-06	C	1.0E-01	I	1.0E-01	Calc	1.0E+00	I	5.0E-02	PROV	5.0E-02	Calc	9.0E+00	PROV	1	0.00
Isopropylbenzene (cumene)		NC	-	NC	-	NC	-	1.0E-01	I	1.0E-01	Calc	4.0E-01	I	4.0E-01	HEAST	4.0E-01	Calc	9.0E-02	HEAST	1	0.00
Methyl tert-butyl ether		1.8E-03	C	1.8E-03	Calc	2.6E-07	C	NA	-	NA	Calc	3.0E+00	I	NA	Chronic	NA	Calc	3.0E+00	Chronic	1	0.00
Methylene chloride		7.5E-03	I	7.5E-03	Calc	4.7E-07	I	6.0E-02	I	6.0E-02	Calc	1.0E+00	A	6.0E-02	HEAST	6.0E-02	Calc	3.0E+00	HEAST	1	0.00
n-Butylbenzene		NC	-	NC	-	NC	-	5.0E-02	P	5.0E-02	Calc	NA	-	1.0E-01	PPRTV	1.0E-01	Calc	NA	Chronic	1	0.00
n-Hexane		NC	-	NC	-	NC	-	6.0E-02	H	6.0E-02	Calc	7.0E-01	I	3.0E-01	PROV	3.0E-01	Calc	2.0E+00	PROV	1	0.00
n-Propylbenzene		NC	-	NC	-	NC	-	1.0E-01	X	1.0E-01	Calc	1.0E+00	X	1.0E-01	PROV	1.0E-01	Calc	1.0E+00	PROV	1	0.10
sec-Butylbenzene		NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.00
tert-Butylbenzene		NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.00
Toluene		NC	-	NC	-	NC	-	8.0E-02	I	8.0E-02	Calc	5.0E+00	I	8.0E-01	PROV	8.0E-01	Calc	5.0E+00	PROV	1	0.00
Trichlorofluoromethane (Freon 11)		NC	-	NC	-	NC	-	3.0E-01	I	3.0E-01	Calc	7.0E-01	H	7.0E-01	HEAST	7.0E-01	Calc	1.0E+00	PROV	1	0.00
Xylenes		NC	-	NC	-	NC	-	2.0E-01	I	2.0E-01	Calc	1.0E-01	I	4.0E-01	PROV	4.0E-01	Calc	4.0E-01	PROV	1	0.00
SVOCs																					
1-Methylnaphthalene		2.9E-02	P	2.9E-02	Calc	NC	-	7.0E-02	A	7.0E-02	Calc	NA	-	7.0E-02	Chronic	7.0E-02	Calc	NA	Chronic	1	0.00
2-Methylnaphthalene		NC	-	NC	-	NC	-	4.0E-03	I	4.0E-03	Calc	NA	-	4.0E-03	PROV	4.0E-03	Calc	NA	Chronic	1	0.00
Bis(2-ethylhexyl)phthalate		1.4E-02	I	1.4E-02	Calc	2.4E-06	C	2.0E-02	I	2.0E-02	Calc	NA	-	2.0E-02	Chronic	2.0E-02	Calc	NA	Chronic	1	0.10
Dibenzofuran		NC	-	NC	-	NC	-	1.0E-03	X	1.0E-03	Calc	NA	-	4.0E-03	PROV	4.0E-03	Calc	NA	Chronic	1	0.00
PAHs																					
Acenaphthylene		NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Anthracene		NC	-	NC	-	NC	-	3.0E-01	I	3.0E-01	Calc	NA	-	1.0E+00	PROV	1.0E+00	Calc	NA	Chronic	1	0.13
Benzo (a) anthracene	f	C-TEQ	I	C-TEQ	Calc	C-TEQ	I	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Benzo (a) pyrene	f	7.3E+00	I	7.3E+00	Calc	1.1E-03	C	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Benzo (b) fluoranthene	f	C-TEQ	I	C-TEQ	Calc	C-TEQ	I	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Benzo (g,h,i) perylene		NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Benzo (k) fluoranthene	f	C-TEQ	I	C-TEQ	Calc	C-TEQ	I	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Chrysene	f	C-TEQ	I	C-TEQ	Calc	C-TEQ	I	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Dibenzo (a,h) anthracene	f	C-TEQ	I	C-TEQ	Calc	C-TEQ	I	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Fluoranthene		NC	-	NC	-	NC	-	4.0E-02	I	4.0E-02	Calc	NA	-	4.0E-01	HEAST	4.0E-01	Calc	NA	Chronic	1	0.13
Fluorene		NC	-	NC	-	NC	-	4.0E-02	I	4.0E-02	Calc	NA	-	4.0E-01	HEAST	4.0E-01	Calc	NA	Chronic	1	0.13
Indeno (1,2,3-cd) pyrene	f	C-TEQ	I	C-TEQ	Calc	C-TEQ	I	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Naphthalene		NC	-	NC	-	3.4E-05	C	2.0E-02	I	2.0E-02	Calc	3.0E-03	I	2.0E-02	Chronic	2.0E-02	Calc	3.0E-03	Chronic	1	0.13
Phenanthrene		NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Pyrene		NC	-	NC	-	NC	-	3.0E-02	I	3.0E-02	Calc	NA	-	3.0E-01	PROV	3.0E-01	Calc	NA	Chronic	1	0.13
Total Benzo(a)pyrene TEQ	f	7.3E+00	I	7.3E+00	Calc	1.1E-03	C	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.13
Miscellaneous																					
Cyanide		NC	-	NC	-	NC	-	2.0E-02	I	2.0E-02	Calc	NA	-	2.0E-02	HEAST	2.0E-02	Calc	NA	Chronic	1	0.00
Sulfate		NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	0.00
Sulfolane	d	NC	-	NC	-	NC	-	1.0E-03	PPRTV	1.0E-03	Calc	NA	-	1.0E-02	PPRTV	1.0E-02	Calc	NA	Chronic	1	0.00
Sulfolane	d	NC	-	NC	-	NC	-	1.0E-02	ARCADIS	1.0E-02	Calc	NA	-	1.0E-01	ARCADIS	1.0E-01	Calc	NA	Chronic	1	0.00
GRO	e	NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	NA
DRO	e	NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	NA
RRO	e	NC	-	NC	-	NC	-	NA	-	NA	Calc	NA	-	NA	Chronic	NA	Calc	NA	Chronic	1	NA

Table 3-13
Human Health Toxicity Values

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:
ABSd = dermal absorption factor, obtained from CalEPA (1999) *Preliminary Endangerment Assessment Manual*
ABSo = oral absorption factor, obtained from USEPA (2004) *Risk Assessment Guidance for Superfund* , Part E
ARCADIS = Literature-derived toxicity value, as presented in the main text.
A = Agency for Toxic Substances and Disease Registry (ATSDR) as cited in the USEPA (2011) RSLs
C = CalEPA Office of Environmental Health Hazard Asssessment (OEHHA) Toxicity Criteria Database
C-TEQ = carcingogenic PAH evaluated using Benzo(a)pyrene TEQ. See footnote "c" below.
Calc = calculated using oral absorption fraction folllowing USEPA (2004) *Risk Assessment Guidelines for Superfund* , Part E.
CSFd = dermal cancer slope factor
CSFo = oral cancer slope factor
DRO = diesel range organic
GRO = gasoline range organic
H = HEAST Tables, as cited in the USEPA (2011) RSLs
HEAST = Health Effects Assessment Summary Tables (HEAST; USEPA, 1997) as cited in the USEPA (2011) Risk Assessment Information System (RAIS) database
I = Integrated Risk Information System (IRIS)
IUR = inhalation unit risk
kg = kilogram(s)
m^3 = cubic meter(s)
mg = milligram(s)
µg = microgram(s)
NA = value not available
NC = not classified by USEPA as a carinogen by the specific exposure route
NE = not evaluated using dose-based toxicity values
PAH = polycyclic aromatic hydrocarbon
PPRTV = Final Peer-Reviewed Toxicity Value for Sulfolane. (USEPA, 2012)
PROV = Provisional Peer-Reviewed Toxicity Values (PPRTVs) as cited in the USEPA (2011) Risk Assessment Information System (RAIS) database
P = Provisional Peer-Reviewed Toxicity Values (PPRTVs) as cited in the USEPA (2011) RSLs
RfC = reference concentration
RfDd = dermal reference dose
RfDo = oral reference dose
RRO = residual range organic
SVOC = semi-volatile organic compound
VOC = volatile organic compound
X = PPRTV Appendix as cited in the USEPA (2011) RSLs
-- = not available

a. Cadmium toxicity values for dietary exposure are used.
b. Toxicity values for Chromium III are used for total chromium.
c. Lead evaluated separately using USEPA exposure models.
d. Sulfolane toxicity values from PPRTV (USEPA, 2012) used in the PPRTV Scenario evaluation, toxicity values derived by ARCADIS from the literature used in the ARCADIS Scenario.
e. Total petroluem hydrocarbon (TPH) mixtures evaluated separately using indicator compounds, as described in Alaska Cumulative Risk Guidance (ADEC, 2008).
f. PAHs considered potential human carcinogens are evaluated in accordance with USEPA (1993) guidance. Accordingly, the estimated "Total Benzo(a)pyrene Toxic Equivalent Concentration" (BaP-TEQ) is evaluated using the toxicity of benzo(a)pyrene

Table 3-14
Human Health Risk Summary for Onsite and Offsite Receptors - UCL and Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] PPRTV Scenario				Contributing COPCs	EPC of Contributing COPC					
	ELCR	Contributing COPCs	HI	Contributing COPCs		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
ONSITE RECEPTORS											
Onsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	1E-05		2E-01		Benzene	2E+01	--	2E+03	2E-02	--	MAX
Soil Gas Total	1E-05	Benzene (93%)	2E-01	--							
Grand Total	**1E-05**	See Soil Gas Total	**2E-01**	--							
Onsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
oral	4E-06		5E-02		Arsenic	--	8E+00	--	--	--	UCL
dermal	6E-07		3E-03		NA	--	--	--	--	--	UCL
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	5E-06	Arsenic (97%)	5E-02	--							
Grand Total	**5E-06**	--	**5E-02**	--							
Onsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Subsurface Soil (0 to 15 ft bgs)											
oral	8E-07		2E-01		NA	--	--	--	--	--	MAX
dermal	5E-08		3E-03		NA	--	--	--	--	--	MAX
inhalation of outdoor air	8E-08		7E-02		NA	--	--	--	--	--	MAX
Soil Total	1E-06	--	3E-01	--							
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	3E-07		6E-02		NA	--	--	--	--	--	MAX
dermal exposure in a trench	4E-06		6E-01		NA	--	--	--	--	--	MAX
inhalation of trench air	3E-04		4.8E+01		Benzene	2E+01	--	--	2E+02	--	MAX
					Ethylbenzene	3E+00	--	--	2E+01	--	MAX
					Naphthalene	3E-01	--	--	2E+00	--	MAX
					Xylenes	1E+01	--	--	1E+02	--	MAX
					1,3,5-Trimethylbenzene	2E-01	--	--	1E+00	--	MAX
Groundwater Total	3E-04	Benzene(92%), Naphthalene (5%), Ethylbenzene (4%) See Inhalation of trench air	4.9E+01	Benzene (64%), Naphthalene (19%), Xylenes (8%), 1,3,5-Trimethylbenzene (4%) See Inhalation of trench air							
Grand Total	**3E-04**	See Groundwater Total (Inhalation of trench air)	**4.9E+01**	See Groundwater Total (Inhalation of trench air)							
Onsite Visitor (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	2E-07		2E-03		NA	--	--	--	--	--	MAX
Soil Gas Total	2E-07		2E-03								
Grand Total	**2E-07**	--	**2E-03**	--							
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1.2E+01		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	1.2E+01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		8E-01		Sulfolane	4E-01	--	--	--	4E-01	MAX
Produce Total	0E+00	--	8E-01	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**4E-08**	--	**1.3E+01**	See Groundwater Total & Produce Total							

Table 3-14
Human Health Risk Summary for Onsite and Offsite Receptors - UCL and Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] PPRTV Scenario				Contributing COPCs	EPC of Contributing COPC					
	ELCR	Contributing COPCs	HI	Contributing COPCs		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2.8E+01		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	2.8E+01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		2E+00		Sulfolane	4E-01	--	--	--	4E-01	MAX
Produce Total	0E+00		2E+00	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**9E-09**	--	**3.1E+01**	See Groundwater Total & Produce Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		7E+00		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	7E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-01		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	3E-01	NA							
Grand Total	**1E-09**	--	**7E+00**	See Groundwater Total							
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		9E+00		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	9E+00	Sulfolane (100%)							
Grand Total	**0E+00**	--	**9E+00**	See Groundwater Total							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		9E+00		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	9E+00	Sulfolane (100%)							
Grand Total	**2E-08**	--	**9E+00**	See Groundwater Total							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		8E-04		NA	--	--	--	--	--	MAX
Groundwater Total	0E+00	--	8E-04	--							
Grand Total	**0E+00**	--	**8E-04**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**0E+00**	--	**3E-02**	--							

Table 3-14
Human Health Risk Summary for Onsite and Offsite Receptors - UCL and Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] PPRTV Scenario				Contributing COPCs	EPC of Contributing COPC					
	ELCR	Contributing COPCs	HI	Contributing COPCs		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**0E+00**	--	**2E-01**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix D.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-11 and D-12.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 3-15
Human Health Risk Summary for Onsite Receptors and Offsite Receptors in Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] PPRTV Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
ONSITE RECEPTORS											
Onsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	1E-06		2E-02		NA	--	--	--	--	--	UCL
Soil Gas Total	1E-06	--	2E-02	--							
Grand Total	**1E-06**	--	**2E-02**	--							
Onsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
oral	4E-06		5E-02		Arsenic	--	8E+00	--	--	--	UCL
dermal	6E-07		3E-03		NA	--	--	--	--	--	UCL
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	5E-06	Arsenic (97%)	5E-02	--							
Grand Total	**5E-06**	--	**5E-02**	--							
Onsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Subsurface Soil (0 to 15 ft bgs)											
oral	3E-07		4E-02		NA	--	--	--	--	--	UCL
dermal	2E-08		3E-04		NA	--	--	--	--	--	UCL
inhalation of outdoor air	1E-08		1E-02		NA	--	--	--	--	--	UCL
Soil Total	3E-07	--	6E-02	--							
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	2E-08		5E-03		NA	--	--	--	--	--	UCL
dermal exposure in a trench	3E-07		8E-02		NA	--	--	--	--	--	UCL
inhalation of trench air	3E-05		9E+00		Naphthalene	1E-01	--	--	1E+00	--	UCL
					Benzene	1E+00	--	--	1E+01	--	UCL
					1,3,5-Trimethylbenzene	1E-01	--	--	9E-01	--	UCL
Groundwater Total	3E-05	Benzene(73%), Naphthalene (24%) See Inhalation of trench air	9E+00	Naphthalene (52%), Benzene (26%), 1,3,5-Trimethylbenzene (15%); See Inhalation of trench air							
Grand Total	**3E-05**	See Groundwater Total	**9E+00**	See Groundwater Total							
Onsite Visitor (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	1E-08		2E-04		NA	--	--	--	--	--	UCL
Soil Gas Total	1E-08		2E-04								
Grand Total	**1E-08**	--	**2E-04**	--							
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		5E+00		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	5E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-01		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	3E-01	--							
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**4E-08**	--	**5E+00**	See Groundwater Total							

Table 3-15
Human Health Risk Summary for Onsite Receptors and Offsite Receptors in Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a]				Contributing COPC	EPC of Contributing COPC					
	PPRTV Scenario										
Potential Site Receptors	**ELCR**	**Contributing COPC**	**HI**	**Contributing COPC**		**Groundwater (mg/L)**	**Soil (mg/kg)**	**Soil Gas (mg/m^3)**	**Indoor / Trench Air (mg/m^3)**	**Produce (mg/kg ww)**	**EPC Type**
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1.1E+01		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	1.1E+01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		9E-01		Sulfolane	2E-01	--	--	--	2E-01	UCL
Produce Total	0E+00		9E-01	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**9E-09**	--	**1.2E+01**	See Groundwater Total & Produce Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E+00		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-01		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	1E-01	--							
Grand Total	**1E-09**	--	**3E+00**	See Groundwater Total							
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E+00		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E+00	Sulfolane (100%)							
Grand Total	**0E+00**	--	**3E+00**	See Groundwater Total							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E+00		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E+00	Sulfolane (100%)							
Grand Total	**2E-08**	--	**3E+00**	See Groundwater Total							

Table 3-15
Human Health Risk Summary for Onsite Receptors and Offsite Receptors in Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] PPRTV Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		3E-04		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-04	--							
Grand Total	**0E+00**	--	**3E-04**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**0E+00**	--	**3E-02**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**0E+00**	--	**2E-01**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU1 = Exposure Unit 1; defined by a boundary that includes all wells with maximum concentrations greater than 100 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix E.
[a] ELCRs exceeding 1x10^{-5} and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-11 and D-12.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 3-16a
Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - Maximum Groundwater and UCL Soil COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] PPRTV Scenario: ELCR	Contributing COPC	HI	Contributing COPC	Contributing COPC	EPC of Contributing COPC: Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		4E+00		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	4E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-01		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	3E-01	--							
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**4E-08**	--	**4E+00**	See Groundwater Total							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		9E+00		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	9E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		8E-01		Sulfolane	1.44E-01	--	--	--	1.44E-01	MAX
Produce Total	0E+00		8E-01	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**9E-09**	--	**1.0E+01**	See Groundwater Total & Produce Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E+00		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	2E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-01		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	1E-01	--							
Grand Total	**1E-09**	--	**2E+00**	See Groundwater Total							

Table 3-16a
Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - Maximum Groundwater and UCL Soil COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] PPRTV Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E+00		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	3E+00	Sulfolane (100%)							
Grand Total	**0E+00**	--	**3E+00**	See Groundwater Total							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E+00		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	3E+00	Sulfolane (100%)							
Grand Total	**2E-08**	--	**3E+00**	See Groundwater Total							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		3E-04		NA	--	--	--	--	--	MAX
Groundwater Total	0E+00	--	3E-04	--							
Grand Total	**0E+00**	--	**3E-04**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**0E+00**	--	**3E-02**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**0E+00**	--	**2E-01**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU2 = Exposure Unit 2; defined by a boundary that includes all wells with maximum concentrations greater than 25 ug/L and less than 100 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix D.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-11 and D-12.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 3-16b
Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] PPRTV Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E+00		Sulfolane	5.91E-02	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-01		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	1E-01								
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**4E-08**	--	**2E+00**	See Groundwater Total							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		4E+00		Sulfolane	5.91E-02	--	--	--	--	UCL
Groundwater Total	0E+00	--	4E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-01		NA	--	--	--	--	--	UCL
Produce Total	0E+00		3E-01	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**9E-09**	--	**4E+00**	See Groundwater Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		9E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	9E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		4E-02		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	4E-02	--							
Grand Total	**1E-09**	--	**9E-01**	--							

Table 3-16b
Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] PPRTV Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E+00		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E+00	--							
Grand Total	**0E+00**	--	**1E+00**	--							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E+00		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E+00	--							
Grand Total	**2E-08**	--	**1E+00**	--							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		1E-04		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E-04	--							
Grand Total	**0E+00**	--	**1E-04**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**0E+00**	--	**3E-02**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**0E+00**	--	**2E-01**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU2 = Exposure Unit 2; defined by a boundary that includes all wells with maximum concentrations greater than 25 ug/L and less than 100 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix E.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-11 and D-12.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 3-17a
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] PPRTV Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E+00		Sulfolane	8.02E-02	--	--	--	--	MAX
Groundwater Total	0E+00	--	2E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-01		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	1E-01	--							
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**4E-08**	--	**2E+00**	See Groundwater Total							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		5E+00		Sulfolane	8.02E-02	--	--	--	--	MAX
Groundwater Total	0E+00	--	5E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		4E-01		Sulfolane	8.02E-02	--	--	--	8.02E-02	MAX
Produce Total	0E+00	--	4E-01	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**9E-09**	--	**6E+00**	See Groundwater Total and Produce Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E+00		NA	--	--	--	--	--	MAX
Groundwater Total	0E+00	--	1E+00	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		6E-02		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	6E-02	--							
Grand Total	**1E-09**	--	**1E+00**	--							

Table 3-17a
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] — PPRTV Scenario: ELCR	Contributing COPC	HI	Contributing COPC	Contributing COPC	EPC of Contributing COPC: Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E+00		Sulfolane	8.02E-02	--	--	--	--	MAX
Groundwater Total	0E+00	--	2E+00	Sulfolane (100%)							
Grand Total	**0E+00**	--	**2E+00**	See Groundwater Total							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E+00		Sulfolane	8.02E-02	--	--	--	--	MAX
Groundwater Total	0E+00	--	2E+00	Sulfolane (100%)							
Grand Total	**2E-08**	--	**2E+00**	See Groundwater Total							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		1E-04		NA	--	--	--	--	--	MAX
Groundwater Total	0E+00	--	1E-04	--							
Grand Total	**0E+00**	--	**1E-04**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**0E+00**	--	**3E-02**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**0E+00**	--	**2E-01**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU3 = Exposure Unit 3; defined by a boundary that includes all wells with maximum concentrations greater than the detection limit and less than 25 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean
Complete risk and hazard calculations are presented in Appendix D.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-11 and D-12.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 3-17b
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] PPRTV Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		2E-02		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	2E-02	--							
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**4E-08**	--	**3E-01**	--							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		7E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	7E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		5E-02		NA	--	--	--	--	--	UCL
Produce Total	0E+00		5E-02	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**9E-09**	--	**9E-01**	--							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		7E-03		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	7E-03	--							
Grand Total	**1E-09**	--	**2E-01**	--							

Table 3-17b
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] PPRTV Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-01	--							
Grand Total	**0E+00**	--	**2E-01**	--							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-01	--							
Grand Total	**2E-08**	--	**2E-01**	--							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		2E-05		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-05	--							
Grand Total	**0E+00**	--	**2E-05**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-02	--							
Grand Total	**0E+00**	--	**3E-02**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-01		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-01	--							
Grand Total	**0E+00**	--	**2E-01**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU3 = Exposure Unit 3; defined by a boundary that includes all wells with maximum concentrations greater than the detection limit and less than 25 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix E.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-11 and D-12.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-1
Human Health Risk Summary for Onsite and Offsite Receptors - UCL and Maximum Groundwater COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] ARCADIS Comparative Scenario				Contributing COPCs	EPC of Contributing COPC					
Potential Site Receptors	**ELCR**	**Contributing COPCs**	**HI**	**Contributing COPCs**		**Groundwater (mg/L)**	**Soil (mg/kg)**	**Soil Gas (mg/m^3)**	**Indoor / Trench Air (mg/m^3)**	**Produce (mg/kg ww)**	**EPC Type**
ONSITE RECEPTORS											
Onsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	1E-05		2E-01		Benzene	2E+01	--	2E+03	2E-02	--	MAX
Soil Gas Total	1E-05	Benzene (93%)	2E-01	--							
Grand Total	**1E-05**	See Soil Gas Total	**2E-01**	--							
Onsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
oral	4E-06		5E-02		Arsenic	--	8E+00	--	--	--	UCL
dermal	6E-07		3E-03		NA	--	--	--	--	--	UCL
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	5E-06	Arsenic (97%)	5E-02	--							
Grand Total	**5E-06**	--	**5E-02**	--							
Onsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Subsurface Soil (0 to 15 ft bgs)											
oral	8E-07		2E-01		NA	--	--	--	--	--	MAX
dermal	5E-08		3E-03		NA	--	--	--	--	--	MAX
inhalation of outdoor air	8E-08		7E-02		NA	--	--	--	--	--	MAX
Soil Total	1E-06	--	3E-01	--							
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	3E-07		4E-02		NA	--	--	--	--	--	MAX
dermal exposure in a trench	4E-06		6E-01		NA	--	--	--	--	--	MAX
inhalation of trench air	3E-04		4.8E+01		Benzene	2E+01	--	--	2E+02	--	MAX
					Ethylbenzene	3E+00	--	--	2E+01	--	MAX
					Naphthalene	3E-01	--	--	2E+00	--	MAX
					Xylenes	1E+01	--	--	1E+02	--	MAX
					1,3,5-Trimethylbenzene	2E-01	--	--	1E+00	--	MAX
Groundwater Total	3E-04	Benzene(92%), Naphthalene (5%), Ethylbenzene (4%) See Inhalation of trench air	4.9E+01	Benzene (64%), Naphthalene (19%), Xylenes (8%), 1,3,5-Trimethylbenzene (4%) See Inhalation of trench air							
Grand Total	**3E-04**	See Groundwater Total (Inhalation of trench air)	**4.9E+01**	See Groundwater Total (Inhalation of trench air)							
Onsite Visitor (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	2E-07		2E-03		NA	--	--	--	--	--	MAX
Soil Gas Total	2E-07		2E-03								
Grand Total	**2E-07**	--	**2E-03**	--							
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1.2E+00		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	1.2E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		8E-02		Sulfolane	4E-01	--	--	--	4E-01	MAX
Produce Total	0E+00	--	8E-02	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**4E-08**	--	**1.3E+00**	See Groundwater Total & Produce Total							

Table 4-1
Human Health Risk Summary for Onsite and Offsite Receptors - UCL and Maximum Groundwater COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] ARCADIS Comparative Scenario				Contributing COPCs	EPC of Contributing COPC					
Potential Site Receptors	**ELCR**	**Contributing COPCs**	**HI**	**Contributing COPCs**		**Groundwater (mg/L)**	**Soil (mg/kg)**	**Soil Gas (mg/m^3)**	**Indoor / Trench Air (mg/m^3)**	**Produce (mg/kg ww)**	**EPC Type**
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2.8E+00		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	2.8E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		2E-01		Sulfolane	4E-01	--	--	--	4E-01	MAX
Produce Total	0E+00		2E-01	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**9E-09**	--	**3.1E+00**	See Groundwater Total & Produce Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		7E-01		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	7E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-02		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	3E-02	NA							
Grand Total	**1E-09**	--	**7E-01**	See Groundwater Total							
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		9E-01		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	9E-01	Sulfolane (100%)							
Grand Total	**0E+00**	--	**9E-01**	See Groundwater Total							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		9E-01		Sulfolane	4E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	9E-01	Sulfolane (100%)							
Grand Total	**2E-08**	--	**9E-01**	See Groundwater Total							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		8E-05		NA	--	--	--	--	--	MAX
Groundwater Total	0E+00	--	8E-05	--							
Grand Total	**0E+00**	--	**8E-05**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**0E+00**	--	**3E-03**	--							

Table 4-1
Human Health Risk Summary for Onsite and Offsite Receptors - UCL and Maximum Groundwater COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] ARCADIS Comparative Scenario				Contributing COPCs	EPC of Contributing COPC					
	ELCR	Contributing COPCs	HI	Contributing COPCs		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**0E+00**	--	**2E-02**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix D.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-35 and D-36.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-2
Human Health Risk Summary for Onsite Receptors and Offsite Receptors in Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] Arcadis Comparative Scenario: ELCR	Contributing COPC	HI	Contributing COPC	Contributing COPC	EPC of Contributing COPC: Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
ONSITE RECEPTORS											
Onsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	1E-06		2E-02		NA	--	--	--	--	--	UCL
Soil Gas Total	1E-06	--	2E-02	--							
Grand Total	**1E-06**	--	**2E-02**	--							
Onsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
oral	4E-06		5E-02		Arsenic	--	8E+00	--	--	--	UCL
dermal	6E-07		3E-03		NA	--	--	--	--	--	UCL
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	5E-06	Arsenic (97%)	5E-02	--							
Grand Total	**5E-06**	--	**5E-02**	--							
Onsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Subsurface Soil (0 to 15 ft bgs)											
oral	3E-07		4E-02		NA	--	--	--	--	--	UCL
dermal	2E-08		3E-04		NA	--	--	--	--	--	UCL
inhalation of outdoor air	1E-08		1E-02		NA	--	--	--	--	--	UCL
Soil Total	3E-07	--	6E-02	--							
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	2E-08		4E-03		NA	--	--	--	--	--	UCL
dermal exposure in a trench	3E-07		8E-02		NA	--	--	--	--	--	UCL
inhalation of trench air	3E-05		9E+00		Naphthalene	1E-01	--	--	1E+00	--	UCL
					Benzene	1E+00	--	--	1E+01	--	UCL
					1,3,5-Trimethylbenzene	1E-01	--	--	9E-01	--	UCL
Groundwater Total	3E-05	Benzene(73%), Naphthalene (24%) See Inhalation of trench air	9E+00	Naphthalene (52%), Benzene (26%), 1,3,5-Trimethylbenzene (15%); See Inhalation of trench air							
Grand Total	**3E-05**	See Groundwater Total	**9E+00**	See Groundwater Total							
Onsite Visitor (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	1E-08		2E-04		NA	--	--	--	--	--	UCL
Soil Gas Total	1E-08		2E-04								
Grand Total	**1E-08**	--	**2E-04**	--							
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		5E-01		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	5E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-02		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	3E-02	--							
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**4E-08**	--	**5E-01**	See Groundwater Total							

Table 4-2

Human Health Risk Summary for Onsite Receptors and Offsite Receptors in Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] Arcadis Comparative Scenario ELCR	Contributing COPC	HI	Contributing COPC	Contributing COPC	EPC of Contributing COPC Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1.1E+00		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	1.1E+00	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		9E-02		Sulfolane	2E-01	--	--	--	2E-01	UCL
Produce Total	0E+00		9E-02	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**9E-09**	--	**1.2E+00**	See Groundwater Total & Produce Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-01		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-02		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	1E-02	--							
Grand Total	**1E-09**	--	**3E-01**	See Groundwater Total							
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-01		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-01	Sulfolane (100%)							
Grand Total	**0E+00**	--	**3E-01**	See Groundwater Total							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-01		Sulfolane	2E-01	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-01	Sulfolane (100%)							
Grand Total	**2E-08**	--	**3E-01**	See Groundwater Total							

Table 4-2

Human Health Risk Summary for Onsite Receptors and Offsite Receptors in Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] Arcadis Comparative Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		3E-05		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-05	--							
Grand Total	**0E+00**	--	**3E-05**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**0E+00**	--	**3E-03**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**0E+00**	--	**2E-02**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU1 = Exposure Unit 1; defined by a boundary that includes all wells with maximum concentrations greater than 100 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix E.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-35 and D-36.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-3a
Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - Maximum Groundwater and UCL Soil COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Comparative Scenario				Contributing COPC	EPC of Contributing COPC					
Potential Site Receptors	**ELCR**	**Contributing COPC**	**HI**	**Contributing COPC**		**Groundwater (mg/L)**	**Soil (mg/kg)**	**Soil Gas (mg/m^3)**	**Indoor/Trench Air (mg/m^3)**	**Produce (mg/kg ww)**	**EPC Type**
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		4E-01		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	4E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-02		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	3E-02	--							
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**4E-08**	--	**4E-01**	See Groundwater Total							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		9E-01		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	9E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		8E-02		Sulfolane	1.44E-01	--	--	--	1.44E-01	MAX
Produce Total	0E+00		8E-02	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**9E-09**	--	**1.0E+00**	See Groundwater Total & Produce Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-01		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	2E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-02		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	1E-02	--							
Grand Total	**1E-09**	--	**2E-01**	See Groundwater Total							

Table 4-3a

Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - Maximum Groundwater and UCL Soil COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Comparative Scenario				Contributing COPC	EPC of Contributing COPC					
Potential Site Receptors	**ELCR**	**Contributing COPC**	**HI**	**Contributing COPC**		**Groundwater (mg/L)**	**Soil (mg/kg)**	**Soil Gas (mg/m^3)**	**Indoor/Trench Air (mg/m^3)**	**Produce (mg/kg ww)**	**EPC Type**
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-01		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	3E-01	Sulfolane (100%)							
Grand Total	**0E+00**	--	**3E-01**	See Groundwater Total							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-01		Sulfolane	1.44E-01	--	--	--	--	MAX
Groundwater Total	0E+00	--	3E-01	Sulfolane (100%)							
Grand Total	**2E-08**	--	**3E-01**	See Groundwater Total							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		3E-05		NA	--	--	--	--	--	MAX
Groundwater Total	0E+00	--	3E-05	--							
Grand Total	**0E+00**	--	**3E-05**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**0E+00**	--	**3E-03**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**0E+00**	--	**2E-02**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU2 = Exposure Unit 2; defined by a boundary that includes all wells with maximum concentrations greater than 25 ug/L and less than 100 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix D.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-35 and D-36.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-3b
Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Comparative Scenario: ELCR	Contributing COPC	HI	Contributing COPC	Contributing COPC	EPC of Contributing COPC: Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-01		Sulfolane	5.91E-02	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-02		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	1E-02								
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**4E-08**	--	**2E-01**	See Groundwater Total							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		4E-01		Sulfolane	5.91E-02	--	--	--	--	UCL
Groundwater Total	0E+00	--	4E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-02		NA	--	--	--	--	--	UCL
Produce Total	0E+00		3E-02	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**9E-09**	--	**4E-01**	See Groundwater Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		9E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	9E-02	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		4E-03		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	4E-03	--							
Grand Total	**1E-09**	--	**9E-02**	--							

Table 4-3b
Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Comparative Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E-01	--							
Grand Total	**0E+00**	--	**1E-01**	--							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E-01	--							
Grand Total	**2E-08**	--	**1E-01**	--							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		1E-05		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E-05	--							
Grand Total	**0E+00**	--	**1E-05**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**0E+00**	--	**3E-03**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**0E+00**	--	**2E-02**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU2 = Exposure Unit 2; defined by a boundary that includes all wells with maximum concentrations greater than 25 ug/L and less than 100 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix E.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-35 and D-36.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-4a
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] — ARCADIS Comparative Scenario: ELCR	Contributing COPC	HI	Contributing COPC	Contributing COPC	EPC of Contributing COPC: Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-01		Sulfolane	8.02E-02	--	--	--	--	MAX
Groundwater Total	0E+00	--	2E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-02		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	1E-02	--							
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**4E-08**	--	**2E-01**	See Groundwater Total							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		5E-01		Sulfolane	8.02E-02	--	--	--	--	MAX
Groundwater Total	0E+00	--	5E-01	Sulfolane (100%)							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		4E-02		Sulfolane	8.02E-02	--	--	--	8.02E-02	MAX
Produce Total	0E+00		4E-02	Sulfolane (100%)							
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**9E-09**	--	**6E-01**	See Groundwater Total and Produce Total							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E-01		NA	--	--	--	--	--	MAX
Groundwater Total	0E+00	--	1E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		6E-03		NA	--	--	--	--	--	MAX
Produce Total	0E+00	--	6E-03	--							
Grand Total	**1E-09**	--	**1E-01**	--							

Table 4-4a
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on Maximum COPC Concentration [a] — ARCADIS Comparative Scenario: ELCR	Contributing COPC	HI	Contributing COPC	Contributing COPC	EPC of Contributing COPC: Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-01		Sulfolane	8.02E-02	--	--	--	--	MAX
Groundwater Total	0E+00	--	2E-01	Sulfolane (100%)							
Grand Total	**0E+00**	--	**2E-01**	See Groundwater Total							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-01		Sulfolane	8.02E-02	--	--	--	--	MAX
Groundwater Total	0E+00	--	2E-01	Sulfolane (100%)							
Grand Total	**2E-08**	--	**2E-01**	See Groundwater Total							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		1E-05		NA	--	--	--	--	--	MAX
Groundwater Total	0E+00	--	1E-05	--							
Grand Total	**0E+00**	--	**1E-05**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**0E+00**	--	**3E-03**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**0E+00**	--	**2E-02**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU3 = Exposure Unit 3; defined by a boundary that includes all wells with maximum concentrations greater than the detection limit and less than 25 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean
Complete risk and hazard calculations are presented in Appendix D.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-35 and D-36.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-4b
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Comparative Scenario				Contributing COPC	EPC of Contributing COPC					
Potential Site Receptors	**ELCR**	**Contributing COPC**	**HI**	**Contributing COPC**		**Groundwater (mg/L)**	**Soil (mg/kg)**	**Soil Gas (mg/m^3)**	**Indoor/Trench Air (mg/m^3)**	**Produce (mg/kg ww)**	**EPC Type**
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-02	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		2E-03		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	2E-03	--							
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**4E-08**	--	**3E-02**	--							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		7E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	7E-02	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		5E-03		NA	--	--	--	--	--	UCL
Produce Total	0E+00		5E-03	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**9E-09**	--	**9E-02**	--							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-02	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		7E-04		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	7E-04	--							
Grand Total	**1E-09**	--	**2E-02**	--							

Table 4-4b
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Comparative Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-02	--							
Grand Total	**0E+00**	--	**2E-02**	--							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-02	--							
Grand Total	**2E-08**	--	**2E-02**	--							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		2E-06		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-06	--							
Grand Total	**0E+00**	--	**2E-06**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		3E-03		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	3E-03	--							
Grand Total	**0E+00**	--	**3E-03**	--							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-02		NA	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-02	--							
Grand Total	**0E+00**	--	**2E-02**	--							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU3 = Exposure Unit 3; defined by a boundary that includes all wells with maximum concentrations greater than the detection limit and less than 25 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix E.
[a] ELCRs exceeding 1x10^{-5} and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix D, Tables D-35 and D-36.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-5
Human Health Exposure Parameters - ARCADIS Exposure Assumptions

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	Symbol	Units	Onsite and Offsite Commercial/Industrial Indoor Worker CI		Onsite Commercial/Industrial Outdoor Worker CIo		Onsite and Offsite Construction/Trench Worker CST		Onsite Adult Visitor VIS		Offsite Adult Resident ADUR		Offsite Child (1-6 yr) Resident CHR		Offsite Infant (0-1 yr) Resident INF		Offsite Adult Recreator AREC		Offsite Child (1-6 yr) Recreator CREC	
General Factors																				
Averaging Time (cancer)	ATc	days	25,550	a,b	25,550	a,b	25,550	a	25,550	a	25,550	a,b	25,550	a,b	25,550	a,b	25,550	a,b	25,550	a,b
Averaging Time (noncancer)	ATnc	days	9,125	a	9,125	a	365	a	10,950	a	10,950	a	2,190	a	365	a	10,950	a	2,190	a
Body Weight	BW	kg	70	b, d	70	b, d	70	d, f	70	b	70	b, d	15	b,d	6.75	n	70	b, d	15	o
Exposure Frequency - Soil	EF	days/yr	250	b, c	250	b, c	125	d, f	12	PJ	270	b, c	270	b, c	270	b,d	–		–	
Exposure Frequency - Groundwater	EFgw	days/year	250	b, c	250	b, c	125	d, f	12	PJ	350	b	350	b	350	b,d	–		–	
Exposure Frequency - Surface water	EFsw	days/year	–		–		–		–		30	PJ	30	PJ	–		30	PJ	30	PJ
Exposure Duration	ED	years	25	b	25	b	1	PJ	30	b	30	b	6	b	1	n	30	b	6	b
Exposure Time	ET	hr/day	8	PJ	8	PJ	1	PJ	2	PJ	12	PJ	12	PJ	12	PJ	0.5	PJ	0.5	PJ
Groundwater - Ingestion (Oral)																				
Groundwater Ingestion Rate (drinking water)	IRgw	L/day	2	b	2	b	–		–		2	b	1	d	1.05	l				
Groundwater Ingestion Rate (incidental)	IRinc_gw	L/day	–		–		0.0037	m	–		–		–		–		–		–	
Fraction Ingested from Source	Figw	unitless	1	cons	1	cons	1	cons	–		1	cons	1	cons	1	cons	–		–	
Groundwater - Dermal Contact																	–		–	
Exposed Skin Surface Area	SSAgw	cm²	–		–		2,230	k	–		–		–		–					
Event Frequency	EvFgw	events/day	–		–		1	--	–		–		–		–		–		–	
Event Time	EvTgw	hr/event	–		–		1	PJ	–		–		–		–		–		–	
Groundwater - Inhalation of Volatiles																	–		–	
Exposure Frequency - Trench Air	EFtr	days/year	–		–		125	PJ	–		–		–		–		–		–	
Soil - Ingestion (Oral)																	–		–	
Incidental Soil Ingestion Rate	IRs	mg/day	–		100	b, f	330	i	–		–		–		–		–		–	
Fraction Ingested from Source	FI	unitless	–		1	--	1	cons	–		–		–		–		–		–	
Soil - Dermal Contact																	–		–	
Exposed Skin Surface Area	SA	cm²	–		2,230	k	2,230	k	–		–		–		–		1	b	1	b
Skin Adherence Factor	AF	mg/cm²-day	–		0.2	b, h	0.3	i	–		–		–		–		–		–	
Fraction in Contact with Soil	FC	unitless	–		1	b	1	b	–		–		–		–		–		–	
Event Frequency	EvFs	events/day	–		1	--	1	--	–		–		–		–		–		–	
Soil - Inhalation of Dust and Vapor																	–		–	
Particulate Emission Factor	PEF	m³/kg	–		1.32E+09	b,e	1.00E+06	e,j	–		1.32E+09	b,e	1.32E+09	e	1.32E+09	e	–		–	
Homegrown Produce Ingestion																				
Fruit Ingestion Rate	IRPfr	mg/day	–		–		–		–		63,000	g	69,000	g	41,850	g				
Vegetable Ingestion Rate	IRPvg	mg/day	–		–		–		–		175,000	g	81,000	g	33,750	g	–		–	
Fraction Ingested from Source	FIp	unitless	–		–		–		–		0.25	PJ	0.25	PJ	0.25	PJ	–		–	
Bioconcentration Factor	BCF	L/kg ww									0.32	q	0.32	q	0.32	q	–		–	
Surface water - Ingestion (Oral)																				
Surface water Ingestion Rate (incidental)	IRinc_sw	L/hour									0.021	p	0.049	p			0.021	p	0.049	p
Fraction Ingested from Source	Fisw	unitless									1	cons	1	cons			1	cons	1	cons

Table 4-5
Human Health Exposure Parameters - ARCADIS Exposure Assumptions

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

a. The averaging period for cancer risk is the expected lifespan of 70 years expressed in days (70 years * 365 days/year). The averaging period for non-cancer risk is the total exposure period expressed in days (ED * 365 days/year).
b. ADEC (2010). Risk Assessmenet Procedures Manual. July.
c. Soil exposure frequency is based on the climate zone in which the site is located, consistent with ADEC's Cleanup Level Guidance (DEC 2008). Residential and recreation/subsistence user soil exposure frequency is 270 d/yr for the under 40-inch zone. For commercial/industrial workers the soil exposure frequency is 250 d/yr for the
d. USEPA. 1989. Risk Assessment Guidance for Superfund.Volume I, Human Health Evaluation Manual (Part A) . EPA/540/1-89-002. December.
e. CALEPA. 2011. Human Health RIsk Assessment Note 1. Recommended DTSC Default Exposure Factors for Use in Risk Assessment at California Hazardous Waste Sites and Permitted Facilities. May.
f. USEPA. 1991. Standard Default Exposure Factors, Interim Final . OSWER Directive: 9285.6-03. March.
g. USEPA (2011). Exposure Factors Handbook. For fruit: Table 9-3, mean per capita intake (value for ages 3-5 years used for child). For vegetables: Table 9-5, mean per capita intake of leafy vegetables (value for ages 3-5 years used for child). IRPs in EFH were multiplied by body weight.
h. USEPA (2004). Risk Assessment Guidance for Superfund, Vol 1, Part E, Supplemental Guidance for Dermal Risk Assessment. Office of Emergency and Remedial
i. USEPA (2002a). Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. December.
j. This PEF value corresponds to a respirable dust concentration of 1 mg/m3. This is based on a maximum concentration of dust in air of 10 mg/m3 recommended by the American Conference of Governmental Industrial Hygienists (ACGIH 2004, Threshold Limit Values and Biological Exposure Indices), and the assumption that 10 percent of the mass of particles are in the respirable PM10 range.
k. USEPA (2011). Exposure Factors Handbook. Table 7-2, average of adult male and adult female mean values for head and hands.
l. USEPA (2011). Exposure Factors Handbook. Table 3-1, time-weighted 95th percentile ingestion rate for infants.
m. USEPA (2011). Exposure Factors Handbook. Table 3-93, mean incidental ingestion of water during wading/spashing activities.
n. USEPA (2008). Child-Specific Exposure Factors Handbook. EPA/600/R-06/096F. September.
o. See footnotes b and d.
p. USEPA (2011). Exposure Factors Handbook. Recommended mean values for swimmers from Table 3-5.
q. Derived from the literature as described in the main text.

Exposure equations are presented in Section 3 of the main text.
Exposure parameters with alternate values in the PPRTV and ARCADIS Scenarios are highlighted in gray.

cm	Centimeter.
cons	Conservative assumption (see text).
hr	Hour.
kg	Kilogram.
L	liter
m	Meter.
mg	milligrams
PJ	Professional judgement
ww	wet weight
yr	year

Table 4-6
Human Health Risk Summary for Onsite Construction/Trench Worker Receptors - Maximum and UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on Maximum and UCL COPC Concentrations [a] — ARCADIS Scenario: ELCR	Contributing COPC	HI	Contributing COPC	Contributing COPC	EPC of Contributing COPC: Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
ONSITE RECEPTORS											
Onsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Subsurface Soil (0 to 15 ft bgs)											
oral	8E-07		2E-01		NA	--	--	--	--	--	MAX
dermal	5E-08		3E-03		NA	--	--	--	--	--	MAX
inhalation of outdoor air	8E-08		7E-02		NA	--	--	--	--	--	MAX
Soil Total	1E-06	--	3E-01	--							
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	2E-08		4E-03		NA	--	--	--	--	--	UCL
dermal exposure in a trench	3E-07		8E-02		Benzene	1E+00	--	--	--	--	UCL
inhalation of trench air	3E-05		9E+00		Naphthalene	1E-01	--	--	1E+00	--	UCL
					Benzene	1E+00	--	--	1E+01	--	UCL
					1,3,5-Trimethylbenzene	1E-01	--	--	9E-01	--	UCL
Groundwater Total	3E-05	Benzene(73%), Naphthalene (24%) see inhalation of trench air	9E+00	Naphthalene (52%), Benzene (26%), 1,3,5-Trimethylbenzene (15%); see Inhalation of trench air							
Grand Total	**3E-05**	See Groundwater Total	**9E+00**	See Groundwater Total							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix F.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-7
Human Health Risk Summary for Onsite Receptors and Offsite Receptors in Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
ONSITE RECEPTORS											
Onsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	1E-06		2E-02		--	--	--	--	--	--	UCL
Soil Gas Total	1E-06	--	2E-02	--							
Grand Total	**1E-06**	--	**2E-02**	--							
Onsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
oral	4E-06		5E-02		Arsenic	--	8E+00	--	--	--	UCL
dermal	6E-07		3E-03		NA	--	--	--	--	--	UCL
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	5E-06	Arsenic (97%)	5E-02	--							
Grand Total	**5E-06**	See Soil Total	**5E-02**	--							
Onsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Subsurface Soil (0 to 15 ft bgs)											
oral	3E-07		4E-02		NA	--	--	--	--	--	UCL
dermal	2E-08		3E-04		NA	--	--	--	--	--	UCL
inhalation of outdoor air	1E-08		1E-02		NA	--	--	--	--	--	UCL
Soil Total	3E-07	--	6E-02	--							
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	2E-08	NA	4E-03		NA	--	--	--	--	--	UCL
dermal exposure in a trench	3E-07	NA	8E-02		NA	--	--	--	--	--	UCL
inhalation of trench air	3E-05		9E+00		Benzene	1E+00	--	--	1E+01	--	UCL
					Naphthalene	1E-01	--	--	1E+00	--	UCL
					1,3,5-Trimethylbenzene	1E-01	--	--	9E-01	--	UCL
Groundwater Total	3E-05	Benzene(73%), Naphthalene (24%) see Inhalation of trench air	9E+00	Naphthalene (52%), Benzene (26%), 1,3,5-Trimethylbenzene (15%) see Inhalation of trench air							
Grand Total	**3E-05**	See Groundwater Total & Inhalation of Trench Air	**9E+00**	See Groundwater Total							
Onsite Visitor (Chronic Exposure)											
Exposure to Volatiles in Soil Gas											
inhalation of indoor air	1E-08		2E-04		--	--	--	--	--	--	UCL
Soil Gas Total	1E-08		2E-04	--							
Grand Total	**1E-08**	--	**2E-04**	NA							
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		--	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		5E-01		--	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	5E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-03		--	--	--	--	--	--	UCL
Produce Total	0E+00	--	3E-03	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**4E-08**	--	**5E-01**	NA							

Table 4-7
Human Health Risk Summary for Onsite Receptors and Offsite Receptors in Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		--	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E+00		--	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E+00	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-02								UCL
Produce Total	0E+00		1E-02	--	--	--	--	--	--	--	
Exposure to Surface Water [b]											
oral	0E+00		2E-03		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-03	--							
Grand Total	**9E-09**	--	**1E+00**	NA							
Offsite Child Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		7E-04		--	--	--	--	--	--	UCL
Soil Total	9E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E-01		--	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-03		--	--	--	--	--	--	UCL
Produce Total	0E+00		1E-03	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**9E-09**	--	**1E-01**	NA							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		--	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-01		--	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-03		--	--	--	--	--	--	UCL
Produce Total	0E+00	--	1E-03	--							
Grand Total	**1E-09**	--	**3E-01**	NA							
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-01		--	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-01	--							
Grand Total	**0E+00**	--	**3E-01**	NA							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		--	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-01		--	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-01	--							
Grand Total	**2E-08**	--	**3E-01**	NA							

Table 4-7
Human Health Risk Summary for Onsite Receptors and Offsite Receptors in Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor / Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		3E-05		--	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-05	--							
Grand Total	**0E+00**	--	**3E-05**	NA							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**0E+00**	--	**2E-04**	NA							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-03		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-03	--							
Grand Total	**0E+00**	--	**2E-03**	NA							
Offsite Child Recreator (Subchronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**0E+00**	--	**2E-04**	NA							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU1 = Exposure Unit 1; defined by a boundary that includes all wells with maximum concentrations greater than 100 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix G.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix G, Tables G-11, G-12a, and G-12b.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-8
Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		1E-03		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	1E-03								
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**4E-08**	--	**2E-01**	--							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		4E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	4E-01	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-03		NA	--	--	--	--	--	UCL
Produce Total	0E+00		3E-03	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-03		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-03	--							
Grand Total	**9E-09**	--	**4E-01**	--							
Offsite Child Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	7E-04								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		4E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	4E-02	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		3E-04		NA	--	--	--	--	--	UCL
Produce Total	0E+00		3E-04	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-04		**--**	**--**	**--**	**--**	**--**	**--**	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**9E-09**	--	**4E-02**	--							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		9E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	9E-02	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		4E-04		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	4E-04	--							
Grand Total	**1E-09**	--	**9E-02**	--							

Table 4-8
Human Health Risk Summary for Offsite Receptors in Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E-01	--							
Grand Total	**0E+00**	--	**1E-01**	--							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		1E-01		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E-01	--							
Grand Total	**2E-08**	--	**1E-01**	--							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		1E-05		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	1E-05	--							
Grand Total	**0E+00**	--	**1E-05**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**0E+00**	--	**2E-04**	NA							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-03		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-03	--							
Grand Total	**0E+00**	--	**2E-03**	NA							
Offsite Child Recreator (Subchronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**0E+00**	--	**2E-04**	NA							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU2 = Exposure Unit 2; defined by a boundary that includes all wells with maximum concentrations greater than 25 ug/L and less than 100 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix G.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix G, Tables G-11, G-12a, and G-12b.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 4-9
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
OFFSITE RECEPTORS											
Offsite Adult Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	4E-08		1E-03		NA	--	--	--	--	--	UCL
Soil Total	4E-08	--	1E-03	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		3E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	3E-02	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		2E-04		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	2E-04	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**4E-08**	--	**3E-02**	--							
Offsite Child Resident (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		1E-03		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	1E-03								
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		7E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	7E-02	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		6E-04		NA	--	--	--	--	--	UCL
Produce Total	0E+00		6E-04	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-03		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-03	--							
Grand Total	**9E-09**	--	**7E-02**	--							
Offsite Child Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	9E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	9E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		7E-03	--	NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	7E-03	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		6E-05		NA	--	--	--	--	--	UCL
Produce Total	0E+00		6E-05	--							
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**9E-09**	--	**7E-03**	--							
Offsite Infant Resident (Subchronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	1E-09		7E-04		NA	--	--	--	--	--	UCL
Soil Total	1E-09	--	7E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-02	--							
Exposure Via Intake of Food											
ingestion of homegrown produce	0E+00		7E-05		NA	--	--	--	--	--	UCL
Produce Total	0E+00	--	7E-05	--							
Grand Total	**1E-09**	--	**2E-02**	--							

Table 4-9
Human Health Risk Summary for Offsite Receptors in Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Potential Site Receptors	Cumulative Risk and Hazard Estimates Based on UCL COPC Concentration [a] ARCADIS Scenario				Contributing COPC	EPC of Contributing COPC					
	ELCR	Contributing COPC	HI	Contributing COPC		Groundwater (mg/L)	Soil (mg/kg)	Soil Gas (mg/m^3)	Indoor/Trench Air (mg/m^3)	Produce (mg/kg ww)	EPC Type
Offsite Commercial/Industrial Indoor Worker (Chronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-02	--							
Grand Total	**0E+00**	--	**2E-02**	--							
Offsite Commercial/Industrial Outdoor Worker (Chronic Exposure)											
Exposure to Surface Soil (0 to 2 ft bgs)											
inhalation of outdoor air	2E-08		6E-04		NA	--	--	--	--	--	UCL
Soil Total	2E-08	--	6E-04	--							
Exposure to Groundwater / Volatiles in Groundwater											
oral	0E+00		2E-02		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-02	--							
Grand Total	**2E-08**	--	**2E-02**	--							
Offsite Construction/Trench Worker (Subchronic Exposure)											
Exposure to Groundwater / Volatiles in Groundwater											
incidental ingestion	0E+00		2E-06		NA	--	--	--	--	--	UCL
Groundwater Total	0E+00	--	2E-06	--							
Grand Total	**0E+00**	--	**2E-06**	--							
Offsite Adult Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**0E+00**	--	**2E-04**	NA							
Offsite Child Recreator (Chronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-03		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-03	--							
Grand Total	**0E+00**	--	**2E-03**	NA							
Offsite Child Recreator (Subchronic Exposure)											
Exposure to Surface Water [b]											
oral	0E+00		2E-04		--	--	--	--	--	--	MAX
Surface Water Total	0E+00	--	2E-04	--							
Grand Total	**0E+00**	--	**2E-04**	NA							

Notes:
COPC = Constituent of Potential Concern
ELCR = Excess Lifetime Cancer Risk
EPC = Exposure Point Concentration
EU3 = Exposure Unit 3; defined by a boundary that includes all wells with maximum concentrations greater than the detection limit and less than 25 ug/L.
ft bgs = feet below ground surface
HI = hazard index
NA = not applicable
UCL = Upper confidence limit on the mean

Complete risk and hazard calculations are presented in Appendix G.
[a] ELCRs exceeding $1x10^{-5}$ and HIs exceeding 1 are shown in gray.
[b] Complete risk and hazard calculations for the resident and recreator surface water (swimming) pathway are presented in Appendix G, Tables G-11, G-12a, and G-12b.
Values of 0.0 indicate that the pathway was not evaluated, due to lack of appropriate toxicity values, or no COPCs were selected for that media.
-- = not applicable

Table 5-1
Summary of Human Health Alternative Cleanup Levels for Onsite Receptors

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Exposure Medium	Receptor	Relevant Exposure Pathway(s)	Constituent of Concern	Alternative Cleanup Level	Units	Basis
Groundwater (Onsite)	Onsite Construction Worker	Incidental ingestion of groundwater in a trench, Dermal Contact with Groundwater, Inhalation of Trench Air	Benzene	5.90E-01	mg/L	NC
			Naphthalene	3.18E-02	mg/L	NC
			Xylenes	3.47E+00	mg/L	NC
			1,3,5-Trimethylbenzene	9.24E-02	mg/L	NC

Notes:
C = Cancer endpoint
mg/L = milligram(s) per liter
NC = Noncancer endpoint

See Appendix J for derivation.
ACLs based on cancer endpoint reflect a $1x10^{-5}$ target cancer risk. ACLs based on noncancer endpoint reflect target hazard index of one (1).

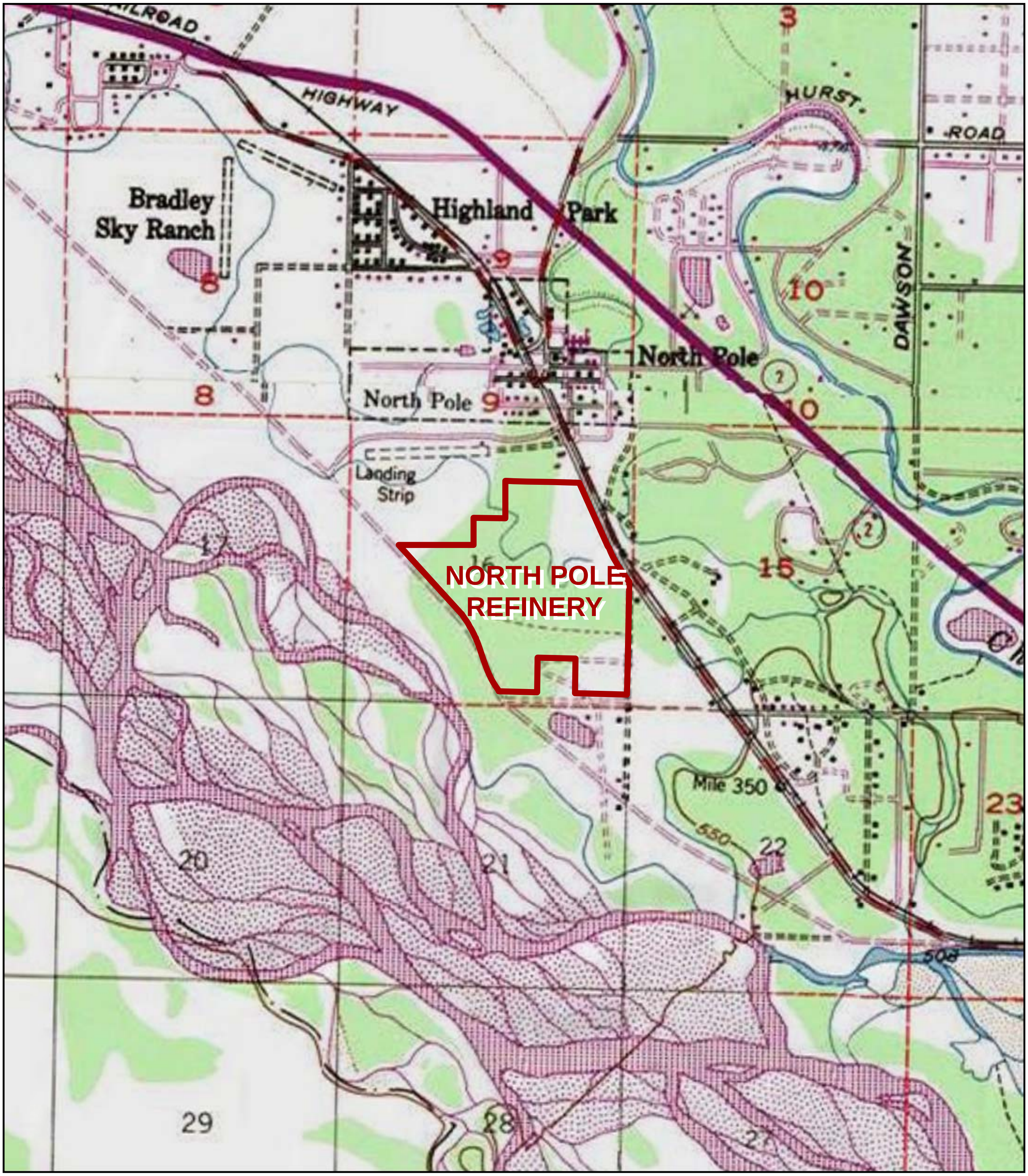
Table 5-2
Summary of Human Health Alternative Cleanup Levels for Offsite Residents
Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Exposure Medium	Receptor	Relevant Exposure Pathway(s)	Constituent of Concern	Alternative Cleanup Level -- PPRTV Scenario	Alternative Cleanup Level -- ARCADIS Comparative Scenario[1]	Alternative Cleanup Level -- ARCADIS Scenario[2]	Units	Basis
Groundwater (Offsite)	Infant (0-1 yr) -- Subchronic	Ingestion of Groundwater and Ingestion of Produce	Sulfolane	0.064	0.637	0.664	mg/L	NC
	Child (1-6 yrs) -- Chronic			0.014	0.145	0.155	mg/L	NC
	Child (1-6 yrs) -- Subchronic			--	--	1.550	mg/L	NC
	Adult -- Chronic			0.034	0.343	0.362	mg/L	NC

Notes:
NC = Not Carcinogenic
PPRTV = Provisional Peer Reviewed Toxicity Value
mg/L = milligrams per liter
RfD = Reference Dose
[1] ARCADIS Comparative Scenario assumes ARCADIS RfD plus ADEC-approved exposure assumptions
[2] ARCADIS Scenario assumes ARCADIS RfD plus ARCADIS exposure assumptions

See Appendix J (Tables J-2, J-3, and J-4) for derivation.
ACLs based on noncancer endpoint reflect target hazard index of one (1).

Figures



LEGEND:

FHRA PROPERTY BOUNDARY

0 0.5 Miles

GRAPHIC SCALE

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA

HUMAN HEALTH RISK ASSESSMENT

SITE VICINITY MAP

ARCADIS

FIGURE
1-1

CITY: SF DIV/GROUP: ENV/IM DB: K ERNST LD: G FRANCE PIC: PM: TM: TR:
Project (Project #) B0081981.0008.00004
Q:\FlintHillsResources\NorthPoleRefinery\HHRA\Report_2012\MXD\SiteLocationMap.mxd - 12/29/2011 @ 10:12:55 AM

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Project (Project #) B0081981.0008.00004
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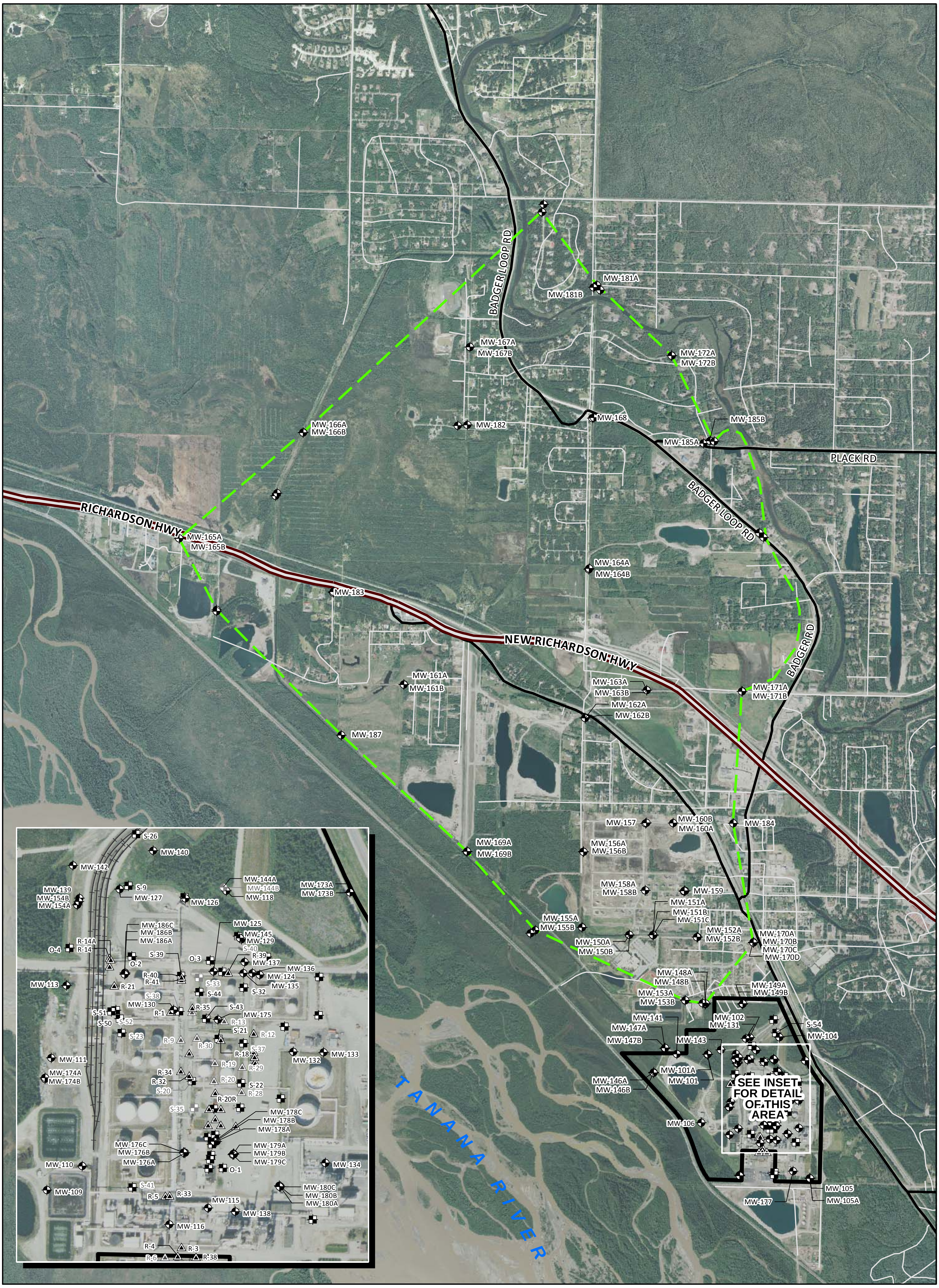

LEGEND

- MONITORING WELL
- OBSERVATION WELL
- RECOVERY WELL
- FHRA PROPERTY BOUNDARY- "ON-SITE"
- APPROXIMATE EXTENT OF "OFF-SITE" GROUNDWATER EXPOSURE UNIT
- HIGHWAY
- MAJOR ROAD
- LOCAL ROAD

0 2,000 4,000 Feet
GRAPHIC SCALE

Image Date June 9, 2007

FLINT HILLS RESOURCES ALASKA, LLC
NORTH POLE REFINERY, NORTH POLE, ALASKA

HUMAN HEALTH RISK ASSESSMENT

SITE LAYOUT

ARCADIS

FIGURE
2-1

HUMAN HEALTH CONCEPTUAL SITE MODEL GRAPHIC FORM

Site: FHR North Pole Refinery - On-Site Only

Completed By: R. Andresen
Date Completed: updated May 21, 2012

***Instructions**: Follow the numbered directions below. Do not consider contaminant concentrations or engineering/land use controls when describing pathways.*

(1) *Check the media that could be directly affected by the release.*

(2) *For each medium identified in (1), follow the top arrow and check possible transport mechanisms. Check additional media under (1) if the media acts as a secondary source.*

(3) *Check all exposure media identified in (2).*

(4) *Check all pathways that could be complete. The pathways identified in this column **must** agree with Sections 2 and 3 of the Human Health CSM Scoping Form.*

(5) *Identify the receptors potentially affected by each exposure pathway: Enter "C" for current receptors, "F" for future receptors, "C/F" for both current and future receptors, or "I" for insignificant exposure.*

Media / Transport Mechanisms

Media	Transport Mechanisms	Check
☑ Surface Soil (0-2 ft bgs)	Direct release to surface soil	check soil
	☑ Migration to subsurface	check soil
	☑ Migration to groundwater	check groundwater
	☑ Volatilization	check air
	☑ Runoff or erosion	check surface water
	☐ Uptake by plants or animals	check biota
	☐ Other (list):______	
☑ Subsurface Soil (2-15 ft bgs)	Direct release to subsurface soil	check soil
	☑ Migration to groundwater	check groundwater
	☑ Volatilization	check air
	☐ Uptake by plants or animals	check biota
	☐ Other (list):______	
☑ Ground-water	Direct release to groundwater	check groundwater
	☑ Volatilization	check air
	☑ Flow to surface water body	check surface water
	☑ Flow to sediment	check sediment
	☑ Uptake by plants or animals	check biota
	☐ Other (list):______	
☑ Surface Water	Direct release to surface water	check surface water
	☑ Volatilization	check air
	☑ Sedimentation	check sediment
	☑ Uptake by plants or animals	check biota
	☐ Other (list):______	
☐ Sediment	Direct release to sediment	check sediment
	☐ Resuspension, runoff, or erosion	check surface water
	☐ Uptake by plants or animals	check biota
	☐ Other (list):______	

Exposure Media / Exposure Pathway/Route / Current & Future Receptors

Exposure Media	Exposure Pathway/Route	Residents (adults or children)	Commercial or industrial workers	Site visitors, trespassers, or recreational users	Construction workers	Farmers or subsistence harvesters	Subsistence consumers	Other
☑ soil	☑ Incidental Soil Ingestion		C/F	I	C/F			
	☑ Dermal Absorption of Contaminants from Soil		C/F	I	C/F			
	☑ Inhalation of Fugitive Dust		C/F	I	C/F			
☑ groundwater	☑ Ingestion of Groundwater				I			
	☑ Dermal Absorption of Contaminants in Groundwater		I		C/F			
	☐ Inhalation of Volatile Compounds in Tap Water							
☑ air	☑ Inhalation of Outdoor Air		C/F	I	C/F			
	☑ Inhalation of Indoor Air		C/F	C/F				
	☑ Inhalation of Fugitive Dust		C/F	I	C/F			
☑ surface water	☐ Ingestion of Surface Water							
	☐ Dermal Absorption of Contaminants in Surface Water							
	☐ Inhalation of Volatile Compounds in Tap Water							
☑ sediment	☐ Direct Contact with Sediment							
☑ biota	☐ Ingestion of Wild or Farmed Foods							

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NORTH POLE REFINERY, NORTH POLE, ALASKA
HUMAN HEALTH RISK ASSESSMENT

HUMAN HEALTH CONCEPTUAL SITE MODEL GRAPHIC FORM - ON SITE ONLY

ARCADIS

FIGURE 3-1

HUMAN HEALTH CONCEPTUAL SITE MODEL GRAPHIC FORM

Site: FHR North Pole Refinery - Off-Site Only

Completed By: R. Andresen

Date Completed: updated May 9, 2012

***Instructions**: Follow the numbered directions below. Do not consider contaminant concentrations or engineering/land use controls when describing pathways.*

(1) *Check the media that could be directly affected by the release.*

(2) *For each medium identified in (1), follow the top arrow and check possible transport mechanisms. Check additional media under (1) if the media acts as a secondary source.*

(3) *Check all exposure media identified in (2).*

(4) *Check all pathways that could be complete. The pathways identified in this column **must** agree with Sections 2 and 3 of the Human Health CSM Scoping Form.*

(5) *Identify the receptors potentially affected by each exposure pathway: Enter "C" for current receptors, "F" for future receptors, "C/F" for both current and future receptors, or "I" for insignificant exposure.*

Media / Transport Mechanisms

Media	Transport Mechanisms	
[ ] Surface Soil (0-2 ft bgs)	Direct release to surface soil	check soil
	[ ] Migration to subsurface	check soil
	[ ] Migration to groundwater	check groundwater
	[ ] Volatilization	check air
	[ ] Runoff or erosion	check surface water
	[ ] Uptake by plants or animals	check biota
	[ ] Other (list):	
[ ] Subsurface Soil (2-15 ft bgs)	Direct release to subsurface soil	check soil
	[ ] Migration to groundwater	check groundwater
	[ ] Volatilization	check air
	[ ] Uptake by plants or animals	check biota
	[ ] Other (list):	
[x] Ground-water	Direct release to groundwater	check groundwater
	[ ] Volatilization	check air
	[x] Flow to surface water body	check surface water
	[x] Flow to sediment	check sediment
	[x] Uptake by plants or animals	check biota
	[ ] Other (list):	
[ ] Surface Water	Direct release to surface water	check surface water
	[ ] Volatilization	check air
	[ ] Sedimentation	check sediment
	[ ] Uptake by plants or animals	check biota
	[ ] Other (list):	
[ ] Sediment	Direct release to sediment	check sediment
	[ ] Resuspension, runoff, or erosion	check surface water
	[ ] Uptake by plants or animals	check biota
	[ ] Other (list):	

Exposure Media / Exposure Pathway/Route / Current & Future Receptors

Exposure Media	Exposure Pathway/Route	Residents (adults or children)	Commercial or industrial workers	Site visitors, trespassers, or recreational users	Construction workers	Farmers or subsistence harvesters	Subsistence consumers	Other
[ ] soil	[ ] Incidental Soil Ingestion							
	[ ] Dermal Absorption of Contaminants from Soil							
	[ ] Inhalation of Fugitive Dust							
[x] groundwater	[x] Ingestion of Groundwater	C/F	C/F	C/F	C/F			
	[ ] Dermal Absorption of Contaminants in Groundwater							
	[ ] Inhalation of Volatile Compounds in Tap Water							
[x] air	[ ] Inhalation of Outdoor Air							
	[ ] Inhalation of Indoor Air							
	[x] Inhalation of Fugitive Dust	C/F	C/F					
[x] surface water	[x] Ingestion of Surface Water	C/F		C/F				
	[ ] Dermal Absorption of Contaminants in Surface Water							
	[ ] Inhalation of Volatile Compounds in Tap Water							
[x] sediment	[ ] Direct Contact with Sediment							
[x] biota	[x] Ingestion of Wild or Farmed Foods	C/F		I				

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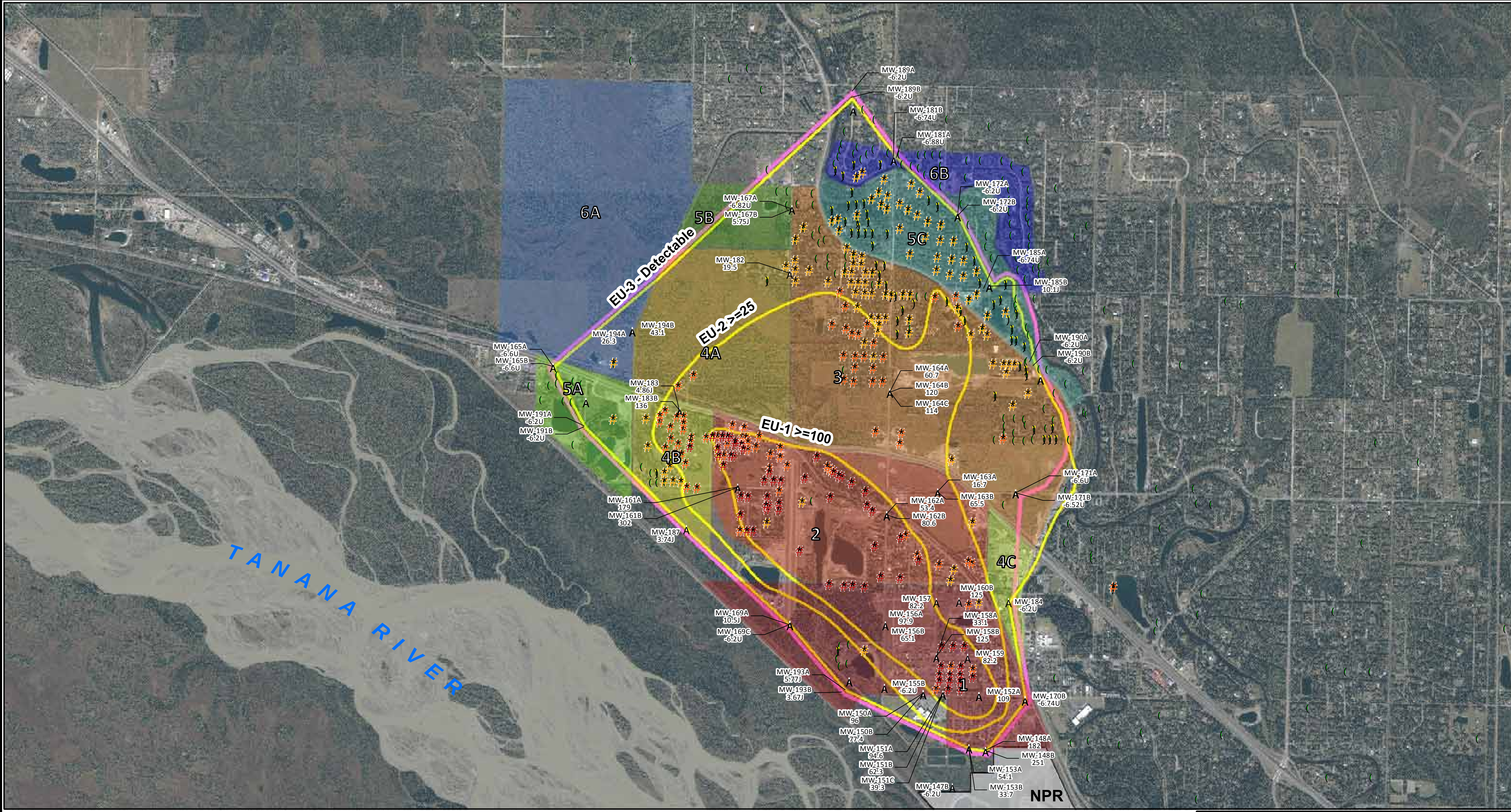
NORTH POLE REFINERY, NORTH POLE, ALASKA

HUMAN HEALTH RISK ASSESSMENT

HUMAN HEALTH CONCEPTUAL SITE MODEL GRAPHIC FORM - OFF SITE ONLY

ARCADIS

FIGURE 3-2



LEGEND

- GREATER THAN 100 µG/L
- 25 - 100 µG/L
- 10 - 25 µG/L (CONTAINS J FLAGS)
- 3.2 - 10 µG/L (J FLAGGED)
- ND
- SULFOLANE CONTOURS
- APPROXIMATE EXTENT OF "OFF-SITE" GROUNDWATER EXPOSURE UNIT

0 2,500 5,000

SCALE IN FEET

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NORTH POLE REFINERY, NORTH POLE, ALASKA
HUMAN HEALTH RISK ASSESSMENT

OFF-SITE GROUNDWATER EXPOSURE UNIT EVALUATION AREA

ARCADIS

FIGURE
3-3

CITY: SF DIV/GROUP: ENV/IM DB: K ERNST LD: G FRANCE PIC: PM: TM: TR:
Project (Project #) B0081981.0008.00004 G:\GIS_Library\TitleBlockAndBorders\2011_ARCADIS_Templates\ANSI_B_Landscape.mxd - 5/20/2011 @ 2:50:38 PM

ARCADIS

Appendix A

See CD for Electronic Tables

Appendix B

USEPA ProUCL Outputs

See CD for Electronic Tables

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Sulfolane (>100 ppb)

General Statistics

Number of Valid Observations	105	Number of Distinct Observations	91
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.443	Maximum of Log Data	-0.814
Mean	0.138	Mean of log Data	-2.127
Median	0.121	SD of log Data	0.606
SD	0.0736		
Std. Error of Mean	0.00719		
Coefficient of Variation	0.533		
Skewness	1.362		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.156	Lilliefors Test Statistic	0.117
Lilliefors Critical Value	0.0865	Lilliefors Critical Value	0.0865
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.15	95% H-UCL	0.16
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.183
95% Adjusted-CLT UCL (Chen-1995)	0.151	97.5% Chebyshev (MVUE) UCL	0.2
95% Modified-t UCL (Johnson-1978)	0.15	99% Chebyshev (MVUE) UCL	0.234
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	3.446	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0401		
MLE of Mean	0.138		
MLE of Standard Deviation	0.0745		
nu star	723.6		
Approximate Chi Square Value (.05)	662.2	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.15
Adjusted Chi Square Value	661.4	95% Jackknife UCL	0.15
		95% Standard Bootstrap UCL	0.15
Anderson-Darling Test Statistic	1.286	95% Bootstrap-t UCL	0.152
Anderson-Darling 5% Critical Value	0.757	95% Hall's Bootstrap UCL	0.151
Kolmogorov-Smirnov Test Statistic	0.0941	95% Percentile Bootstrap UCL	0.15
Kolmogorov-Smirnov 5% Critical Value	0.0886	95% BCA Bootstrap UCL	0.151
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.17
		97.5% Chebyshev(Mean, Sd) UCL	0.183
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.21
95% Approximate Gamma UCL	0.151		
95% Adjusted Gamma UCL	0.151		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.17

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Sulfolane (>25 ppb)

General Statistics

Number of Valid Observations	73	Number of Distinct Observations	71

Raw Statistics		Log-transformed Statistics	
Minimum	0.005	Minimum of Log Data	-5.298
Maximum	0.144	Maximum of Log Data	-1.938
Mean	0.0527	Mean of log Data	-3.113
Median	0.0468	SD of log Data	0.62
SD	0.0301		
Std. Error of Mean	0.00353		
Coefficient of Variation	0.572		
Skewness	1.075		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.116	Lilliefors Test Statistic	0.0505
Lilliefors Critical Value	0.104	Lilliefors Critical Value	0.104
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0585	95% H-UCL	0.0621
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0721
95% Adjusted-CLT UCL (Chen-1995)	0.0589	97.5% Chebyshev (MVUE) UCL	0.08
95% Modified-t UCL (Johnson-1978)	0.0586	99% Chebyshev (MVUE) UCL	0.0956

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	2.998	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	0.0176		
MLE of Mean	0.0527		
MLE of Standard Deviation	0.0304		
nu star	437.7		
Approximate Chi Square Value (.05)	390.2	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0467	95% CLT UCL	0.0585
Adjusted Chi Square Value	389.3	95% Jackknife UCL	0.0585
		95% Standard Bootstrap UCL	0.0584
Anderson-Darling Test Statistic	0.179	95% Bootstrap-t UCL	0.0592
Anderson-Darling 5% Critical Value	0.758	95% Hall's Bootstrap UCL	0.0595
Kolmogorov-Smirnov Test Statistic	0.0449	95% Percentile Bootstrap UCL	0.0587
Kolmogorov-Smirnov 5% Critical Value	0.105	95% BCA Bootstrap UCL	0.059
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.068
		97.5% Chebyshev(Mean, Sd) UCL	0.0747
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0878
95% Approximate Gamma UCL	0.0591		
95% Adjusted Gamma UCL	0.0592		

Potential UCL to Use		Use 95% Approximate Gamma UCL	0.0591

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Sulfolane (>detect)

General Statistics

Number of Valid Observations	294	Number of Distinct Observations	172

Raw Statistics		Log-transformed Statistics	
Minimum	0.0031	Minimum of Log Data	-5.776
Maximum	0.0802	Maximum of Log Data	-2.523
Mean	0.00855	Mean of log Data	-4.92
Median	0.00588	SD of log Data	0.516
SD	0.00651		
Std. Error of Mean	0.0003798		
Coefficient of Variation	0.761		
Skewness	5.269		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.213	Lilliefors Test Statistic	0.183
Lilliefors Critical Value	0.0517	Lilliefors Critical Value	0.0517
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.00918	95% H-UCL	0.0088
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00949
95% Adjusted-CLT UCL (Chen-1995)	0.0093	97.5% Chebyshev (MVUE) UCL	0.00999
95% Modified-t UCL (Johnson-1978)	0.0092	99% Chebyshev (MVUE) UCL	0.011
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	3.278	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00261		
MLE of Mean	0.00855		
MLE of Standard Deviation	0.00472		
nu star	1928		
Approximate Chi Square Value (.05)	1827	Nonparametric Statistics	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.00918
Adjusted Chi Square Value	1826	95% Jackknife UCL	0.00918
		95% Standard Bootstrap UCL	0.00918
Anderson-Darling Test Statistic	17.1	95% Bootstrap-t UCL	0.00935
Anderson-Darling 5% Critical Value	0.759	95% Hall's Bootstrap UCL	0.00949
Kolmogorov-Smirnov Test Statistic	0.19	95% Percentile Bootstrap UCL	0.00918
Kolmogorov-Smirnov 5% Critical Value	0.0531	95% BCA Bootstrap UCL	0.00934
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0102
		97.5% Chebyshev(Mean, Sd) UCL	0.0109
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0123
95% Approximate Gamma UCL	0.00903		
95% Adjusted Gamma UCL	0.00903		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0102

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	data.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Result (1/2 DL for NDs) (1,1-dichloroethylene)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	2
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000212	Minimum of Log Data	-8.459
Maximum	0.00031	Maximum of Log Data	-8.079
Mean	0.0002512	Mean of log Data	-8.307
Median	0.000212	SD of log Data	0.196
SD	5.061E-05		
Std. Error of Mean	1.6E-05		
Coefficient of Variation	0.201		
Skewness	0.484		

Warning: There are only 2 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.64	Shapiro Wilk Test Statistic	0.64
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0002805	95% H-UCL	0.0002845
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0003192
95% Adjusted-CLT UCL (Chen-1995)	0.0002801	97.5% Chebyshev (MVUE) UCL	0.0003487
95% Modified-t UCL (Johnson-1978)	0.0002809	99% Chebyshev (MVUE) UCL	0.0004066
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	19.99	Data do not follow a Discernable Distribution (0.05)	
Theta Star	1.257E-05		
MLE of Mean	0.0002512		
MLE of Standard Deviation	5.618E-05		
nu star	399.8		
Approximate Chi Square Value (.05)	354.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.0002775
Adjusted Chi Square Value	347.1	95% Jackknife UCL	N/A
		95% Standard Bootstrap UCL	N/A
Anderson-Darling Test Statistic	1.893	95% Bootstrap-t UCL	N/A
Anderson-Darling 5% Critical Value	0.725	95% Hall's Bootstrap UCL	N/A
Kolmogorov-Smirnov Test Statistic	0.393	95% Percentile Bootstrap UCL	N/A
Kolmogorov-Smirnov 5% Critical Value	0.266	95% BCA Bootstrap UCL	N/A
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.000321
		97.5% Chebyshev(Mean, Sd) UCL	0.0003511
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0004104
95% Approximate Gamma UCL	0.0002833		
95% Adjusted Gamma UCL	0.0002894		
Potential UCL to Use		Use 95% Student's-t UCL	0.0002805
		or 95% Modified-t UCL	0.0002809

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1,2,4-trimethylbenzene)

General Statistics

Number of Valid Observations	30	Number of Distinct Observations	10
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0000961	Minimum of Log Data	-9.25
Maximum	0.472	Maximum of Log Data	-0.751
Mean	0.0339	Mean of log Data	-6.834
Median	0.0005	SD of log Data	2.455
SD	0.0991		
Std. Error of Mean	0.0181		
Coefficient of Variation	2.92		
Skewness	3.615		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.404	Shapiro Wilk Test Statistic	0.75
Shapiro Wilk Critical Value	0.927	Shapiro Wilk Critical Value	0.927
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0647	95% H-UCL	0.185
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0585
95% Adjusted-CLT UCL (Chen-1995)	0.0764	97.5% Chebyshev (MVUE) UCL	0.0769
95% Modified-t UCL (Johnson-1978)	0.0667	99% Chebyshev (MVUE) UCL	0.113
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.213	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.16		
MLE of Mean	0.0339		
MLE of Standard Deviation	0.0736		
nu star	12.75		
Approximate Chi Square Value (.05)	5.726	**Nonparametric Statistics**	
Adjusted Level of Significance	0.041	95% CLT UCL	0.0637
Adjusted Chi Square Value	5.456	95% Jackknife UCL	0.0647
		95% Standard Bootstrap UCL	0.0632
Anderson-Darling Test Statistic	5.305	95% Bootstrap-t UCL	0.109
Anderson-Darling 5% Critical Value	0.893	95% Hall's Bootstrap UCL	0.0759
Kolmogorov-Smirnov Test Statistic	0.444	95% Percentile Bootstrap UCL	0.0692
Kolmogorov-Smirnov 5% Critical Value	0.177	95% BCA Bootstrap UCL	0.08
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.113
		97.5% Chebyshev(Mean, Sd) UCL	0.147
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.214
95% Approximate Gamma UCL	0.0756		
95% Adjusted Gamma UCL	0.0793		
Potential UCL to Use		Use 97.5% Chebyshev (Mean, Sd) UCL	0.147

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1,3,5-trimethylbenzene)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	5

Raw Statistics		Log-transformed Statistics	
Minimum	0.000113	Minimum of Log Data	-9.088
Maximum	0.121	Maximum of Log Data	-2.112
Mean	0.0213	Mean of log Data	-6.914
Median	0.000113	SD of log Data	2.968
SD	0.0412		
Std. Error of Mean	0.013		
Coefficient of Variation	1.935		
Skewness	2.062		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.61	Shapiro Wilk Test Statistic	0.73
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0452	95% H-UCL	179.8
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.107
95% Adjusted-CLT UCL (Chen-1995)	0.0518	97.5% Chebyshev (MVUE) UCL	0.143
95% Modified-t UCL (Johnson-1978)	0.0466	99% Chebyshev (MVUE) UCL	0.214
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.231	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0923		
MLE of Mean	0.0213		
MLE of Standard Deviation	0.0443		
nu star	4.613		
Approximate Chi Square Value (.05)	0.978	Nonparametric Statistics	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.0427
Adjusted Chi Square Value	0.724	95% Jackknife UCL	0.0452
		95% Standard Bootstrap UCL	0.0416
Anderson-Darling Test Statistic	1.303	95% Bootstrap-t UCL	0.151
Anderson-Darling 5% Critical Value	0.84	95% Hall's Bootstrap UCL	0.196
Kolmogorov-Smirnov Test Statistic	0.371	95% Percentile Bootstrap UCL	0.0438
Kolmogorov-Smirnov 5% Critical Value	0.292	95% BCA Bootstrap UCL	0.0509
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0781
		97.5% Chebyshev(Mean, Sd) UCL	0.103
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.151
95% Approximate Gamma UCL	0.1		
95% Adjusted Gamma UCL	0.136		
Potential UCL to Use		Use 99% Chebyshev (Mean, Sd) UCL	0.151

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1-methylnaphthalene)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	9
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000015	Minimum of Log Data	-11.11
Maximum	0.035	Maximum of Log Data	-3.352
Mean	0.00557	Mean of log Data	-8.314
Median	6.025E-05	SD of log Data	3.209
SD	0.011		
Std. Error of Mean	0.00348		
Coefficient of Variation	1.976		
Skewness	2.562		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.592	Shapiro Wilk Test Statistic	0.796
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0119	95% H-UCL	332.5
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0417
95% Adjusted-CLT UCL (Chen-1995)	0.0143	97.5% Chebyshev (MVUE) UCL	0.056
95% Modified-t UCL (Johnson-1978)	0.0124	99% Chebyshev (MVUE) UCL	0.0841
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.228	Data Follow Appr. Gamma Distribution at 5% Significance Level	
Theta Star	0.0244		
MLE of Mean	0.00557		
MLE of Standard Deviation	0.0117		
nu star	4.56		
Approximate Chi Square Value (.05)	0.954	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.0113
Adjusted Chi Square Value	0.705	95% Jackknife UCL	0.0119
		95% Standard Bootstrap UCL	0.0109
Anderson-Darling Test Statistic	0.96	95% Bootstrap-t UCL	0.0236
Anderson-Darling 5% Critical Value	0.842	95% Hall's Bootstrap UCL	0.0284
Kolmogorov-Smirnov Test Statistic	0.292	95% Percentile Bootstrap UCL	0.0114
Kolmogorov-Smirnov 5% Critical Value	0.292	95% BCA Bootstrap UCL	0.0142
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0207
		97.5% Chebyshev(Mean, Sd) UCL	0.0273
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0402
95% Approximate Gamma UCL	0.0266		
95% Adjusted Gamma UCL	0.036		
Potential UCL to Use		Use 95% Adjusted Gamma UCL	0.036

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2-methylnaphthalene)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	10

Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0000156	Minimum of Log Data	-11.07
Maximum	0.0309	Maximum of Log Data	-3.477
Mean	0.00504	Mean of log Data	-8.263
Median	7.225E-05	SD of log Data	3.115
SD	0.00973		
Std. Error of Mean	0.00308		
Coefficient of Variation	1.931		
Skewness	2.503		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.603	Shapiro Wilk Test Statistic	0.811
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0107	95% H-UCL	155.9
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0366
95% Adjusted-CLT UCL (Chen-1995)	0.0127	97.5% Chebyshev (MVUE) UCL	0.0491
95% Modified-t UCL (Johnson-1978)	0.0111	99% Chebyshev (MVUE) UCL	0.0737
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.235	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0214		
MLE of Mean	0.00504		
MLE of Standard Deviation	0.0104		
nu star	4.7		
Approximate Chi Square Value (.05)	1.016	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.0101
Adjusted Chi Square Value	0.755	95% Jackknife UCL	0.0107
		95% Standard Bootstrap UCL	0.00971
Anderson-Darling Test Statistic	0.908	95% Bootstrap-t UCL	0.0201
Anderson-Darling 5% Critical Value	0.838	95% Hall's Bootstrap UCL	0.0252
Kolmogorov-Smirnov Test Statistic	0.292	95% Percentile Bootstrap UCL	0.0102
Kolmogorov-Smirnov 5% Critical Value	0.292	95% BCA Bootstrap UCL	0.0128
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0185
		97.5% Chebyshev(Mean, Sd) UCL	0.0243
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0357
95% Approximate Gamma UCL	0.0233		
95% Adjusted Gamma UCL	0.0314		
Potential UCL to Use		Use 95% Hall's Bootstrap UCL	0.0252

In Case Bootstrap t and/or Hall's Bootstrap yields an unreasonably large UCL value, use 97.5% or 99% Chebyshev (Mean, Sd) UCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (4-isopropyltoluene (p-cymene))

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	5
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0000769	Minimum of Log Data	-9.473
Maximum	0.0334	Maximum of Log Data	-3.399
Mean	0.00428	Mean of log Data	-7.868
Median	0.0000769	SD of log Data	2.286
SD	0.0104		
Std. Error of Mean	0.00328		
Coefficient of Variation	2.422		
Skewness	3.013		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.475	Shapiro Wilk Test Statistic	0.741
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0103	95% H-UCL	0.542
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0117
95% Adjusted-CLT UCL (Chen-1995)	0.013	97.5% Chebyshev (MVUE) UCL	0.0156
95% Modified-t UCL (Johnson-1978)	0.0108	99% Chebyshev (MVUE) UCL	0.0232
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.268	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.016		
MLE of Mean	0.00428		
MLE of Standard Deviation	0.00827		
nu star	5.359		
Approximate Chi Square Value (.05)	1.322	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.00968
Adjusted Chi Square Value	1.008	95% Jackknife UCL	0.0103
		95% Standard Bootstrap UCL	0.0094
Anderson-Darling Test Statistic	1.42	95% Bootstrap-t UCL	0.0357
Anderson-Darling 5% Critical Value	0.819	95% Hall's Bootstrap UCL	0.0362
Kolmogorov-Smirnov Test Statistic	0.356	95% Percentile Bootstrap UCL	0.0106
Kolmogorov-Smirnov 5% Critical Value	0.289	95% BCA Bootstrap UCL	0.0138
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0186
		97.5% Chebyshev(Mean, Sd) UCL	0.0248
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0369
95% Approximate Gamma UCL	0.0174		
95% Adjusted Gamma UCL	0.0228		
Potential UCL to Use		Use 99% Chebyshev (Mean, Sd) UCL	0.0369

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (acenaphthene)

General Statistics

Number of Valid Observations	2	Number of Distinct Observations	1

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable Result (1/2 DL for NDs) (acenaphthene) was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Result (1/2 DL for NDs) (acenaphthylene)

General Statistics

Number of Valid Observations	2	Number of Distinct Observations	1

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable Result (1/2 DL for NDs) (acenaphthylene) was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Result (1/2 DL for NDs) (alkalinity)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	5
Raw Statistics		**Log-transformed Statistics**	
Minimum	147	Minimum of Log Data	4.99
Maximum	185	Maximum of Log Data	5.22
Mean	162.3	Mean of log Data	5.087
Median	164.5	SD of log Data	0.0867
SD	14.19		
Std. Error of Mean	5.795		
Coefficient of Variation	0.0874		
Skewness	0.473		

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.885	Shapiro Wilk Test Statistic	0.886
Shapiro Wilk Critical Value	0.788	Shapiro Wilk Critical Value	0.788
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	174	95% H-UCL	N/A
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	187.4
95% Adjusted-CLT UCL (Chen-1995)	173.1	97.5% Chebyshev (MVUE) UCL	198.2
95% Modified-t UCL (Johnson-1978)	174.2	99% Chebyshev (MVUE) UCL	219.5
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	79.6	Data appear Normal at 5% Significance Level	
Theta Star	2.039		
MLE of Mean	162.3		
MLE of Standard Deviation	18.19		
nu star	955.2		
Approximate Chi Square Value (.05)	884.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0122	95% CLT UCL	171.9
Adjusted Chi Square Value	859.6	95% Jackknife UCL	174
		95% Standard Bootstrap UCL	170.9
Anderson-Darling Test Statistic	0.456	95% Bootstrap-t UCL	175.9
Anderson-Darling 5% Critical Value	0.696	95% Hall's Bootstrap UCL	173.3
Kolmogorov-Smirnov Test Statistic	0.228	95% Percentile Bootstrap UCL	171.8
Kolmogorov-Smirnov 5% Critical Value	0.332	95% BCA Bootstrap UCL	171.5
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	187.6
		97.5% Chebyshev(Mean, Sd) UCL	198.5
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	220
95% Approximate Gamma UCL	175.3		
95% Adjusted Gamma UCL	180.4		
Potential UCL to Use		Use 95% Student's-t UCL	174

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (anthracene)

General Statistics

Number of Valid Observations	2	Number of Distinct Observations	1

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable Result (1/2 DL for NDs) (anthracene) was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Result (1/2 DL for NDs) (antimony)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	2

Raw Statistics		Log-transformed Statistics	
Minimum	0.00031	Minimum of Log Data	-8.079
Maximum	0.00035	Maximum of Log Data	-7.958
Mean	0.000314	Mean of log Data	-8.067
Median	0.00031	SD of log Data	0.0384
SD	1.265E-05		
Std. Error of Mean	0.000004		
Coefficient of Variation	0.0403		
Skewness	3.162		

Warning: There are only 2 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.366	Shapiro Wilk Test Statistic	0.366
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0003213	95% H-UCL	N/A
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0003306
95% Adjusted-CLT UCL (Chen-1995)	0.0003249	97.5% Chebyshev (MVUE) UCL	0.0003378
95% Modified-t UCL (Johnson-1978)	0.000322	99% Chebyshev (MVUE) UCL	0.0003519
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	511.4	Data do not follow a Discernable Distribution (0.05)	
Theta Star	6.14E-07		
MLE of Mean	0.000314		
MLE of Standard Deviation	1.389E-05		
nu star	10229		
Approximate Chi Square Value (.05)	9994	Nonparametric Statistics	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.0003206
Adjusted Chi Square Value	9954	95% Jackknife UCL	N/A
		95% Standard Bootstrap UCL	N/A
Anderson-Darling Test Statistic	3.295	95% Bootstrap-t UCL	N/A
Anderson-Darling 5% Critical Value	0.724	95% Hall's Bootstrap UCL	N/A
Kolmogorov-Smirnov Test Statistic	0.531	95% Percentile Bootstrap UCL	N/A
Kolmogorov-Smirnov 5% Critical Value	0.266	95% BCA Bootstrap UCL	N/A
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0003314
		97.5% Chebyshev(Mean, Sd) UCL	0.000339
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0003538
95% Approximate Gamma UCL	0.0003214		
95% Adjusted Gamma UCL	0.0003227		
Potential UCL to Use		Use 95% Student's-t UCL	0.0003213
		or 95% Modified-t UCL	0.000322

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (bap teq)

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	4

Raw Statistics		Log-transformed Statistics	
Minimum	3.465E-05	Minimum of Log Data	-10.27
Maximum	5.778E-05	Maximum of Log Data	-9.759
Mean	3.705E-05	Mean of log Data	-10.22
Median	3.465E-05	SD of log Data	0.153
SD	6.906E-06		
Std. Error of Mean	2.082E-06		
Coefficient of Variation	N/A		
Skewness	3.264		

Warning: There are only 4 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.404	Shapiro Wilk Test Statistic	0.42
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	4.082E-05	95% H-UCL	4.043E-05
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	4.442E-05
95% Adjusted-CLT UCL (Chen-1995)	4.266E-05	97.5% Chebyshev (MVUE) UCL	4.764E-05
95% Modified-t UCL (Johnson-1978)	4.116E-05	99% Chebyshev (MVUE) UCL	5.395E-05
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	30.23	Data do not follow a Discernable Distribution (0.05)	
Theta Star	1.226E-06		
MLE of Mean	3.705E-05		
MLE of Standard Deviation	6.738E-06		
nu star	665		
Approximate Chi Square Value (.05)	606.2	Nonparametric Statistics	
Adjusted Level of Significance	0.0278	95% CLT UCL	4.047E-05
Adjusted Chi Square Value	597	95% Jackknife UCL	4.082E-05
		95% Standard Bootstrap UCL	4.035E-05
Anderson-Darling Test Statistic	3.08	95% Bootstrap-t UCL	6.466E-05
Anderson-Darling 5% Critical Value	0.728	95% Hall's Bootstrap UCL	6.499E-05
Kolmogorov-Smirnov Test Statistic	0.427	95% Percentile Bootstrap UCL	4.113E-05
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	4.323E-05
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	4.612E-05
		97.5% Chebyshev(Mean, Sd) UCL	5.005E-05
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	5.776E-05
95% Approximate Gamma UCL	4.064E-05		
95% Adjusted Gamma UCL	4.127E-05		
Potential UCL to Use		Use 95% Student's-t UCL	4.082E-05
		or 95% Modified-t UCL	4.116E-05

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (barium)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	10

Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0443	Minimum of Log Data	-3.117
Maximum	0.41	Maximum of Log Data	-0.892
Mean	0.192	Mean of log Data	-1.849
Median	0.168	SD of log Data	0.692
SD	0.122		
Std. Error of Mean	0.0387		
Coefficient of Variation	0.638		
Skewness	0.987		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.871	Shapiro Wilk Test Statistic	0.942
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.262	95% H-UCL	0.357
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.385
95% Adjusted-CLT UCL (Chen-1995)	0.268	97.5% Chebyshev (MVUE) UCL	0.468
95% Modified-t UCL (Johnson-1978)	0.264	99% Chebyshev (MVUE) UCL	0.63
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.958	Data appear Normal at 5% Significance Level	
Theta Star	0.0978		
MLE of Mean	0.192		
MLE of Standard Deviation	0.137		
nu star	39.15		
Approximate Chi Square Value (.05)	25.82	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.255
Adjusted Chi Square Value	23.95	95% Jackknife UCL	0.262
		95% Standard Bootstrap UCL	0.252
Anderson-Darling Test Statistic	0.321	95% Bootstrap-t UCL	0.316
Anderson-Darling 5% Critical Value	0.733	95% Hall's Bootstrap UCL	0.707
Kolmogorov-Smirnov Test Statistic	0.17	95% Percentile Bootstrap UCL	0.255
Kolmogorov-Smirnov 5% Critical Value	0.269	95% BCA Bootstrap UCL	0.26
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.36
		97.5% Chebyshev(Mean, Sd) UCL	0.433
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.576
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.313		
Potential UCL to Use		Use 95% Student's-t UCL	0.262

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(a)anthracene)

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	4
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000015	Minimum of Log Data	-11.11
Maximum	0.000025	Maximum of Log Data	-10.6
Mean	1.604E-05	Mean of log Data	-11.05
Median	0.000015	SD of log Data	0.152
SD	2.986E-06		
Std. Error of Mean	9.004E-07		
Coefficient of Variation	N/A		
Skewness	3.264		

Warning: There are only 4 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.404	Shapiro Wilk Test Statistic	0.42
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.767E-05	95% H-UCL	1.75E-05
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.923E-05
95% Adjusted-CLT UCL (Chen-1995)	1.846E-05	97.5% Chebyshev (MVUE) UCL	2.062E-05
95% Modified-t UCL (Johnson-1978)	1.782E-05	99% Chebyshev (MVUE) UCL	2.335E-05
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	30.28	Data do not follow a Discernable Distribution (0.05)	
Theta Star	5.296E-07		
MLE of Mean	1.604E-05		
MLE of Standard Deviation	2.914E-06		
nu star	666.2		
Approximate Chi Square Value (.05)	607.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	1.752E-05
Adjusted Chi Square Value	598.1	95% Jackknife UCL	1.767E-05
		95% Standard Bootstrap UCL	1.742E-05
Anderson-Darling Test Statistic	3.079	95% Bootstrap-t UCL	2.797E-05
Anderson-Darling 5% Critical Value	0.728	95% Hall's Bootstrap UCL	2.811E-05
Kolmogorov-Smirnov Test Statistic	0.427	95% Percentile Bootstrap UCL	0.0000178
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	1.864E-05
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.996E-05
		97.5% Chebyshev(Mean, Sd) UCL	2.166E-05
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.5E-05
95% Approximate Gamma UCL	1.759E-05		
95% Adjusted Gamma UCL	1.786E-05		
Potential UCL to Use		Use 95% Student's-t UCL	1.767E-05
		or 95% Modified-t UCL	1.782E-05

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(a)pyrene)

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	4

Raw Statistics		Log-transformed Statistics	
Minimum	0.000015	Minimum of Log Data	-11.11
Maximum	0.000025	Maximum of Log Data	-10.6
Mean	1.604E-05	Mean of log Data	-11.05
Median	0.000015	SD of log Data	0.152
SD	2.986E-06		
Std. Error of Mean	9.004E-07		
Coefficient of Variation	N/A		
Skewness	3.264		

Warning: There are only 4 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.404	Shapiro Wilk Test Statistic	0.42
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	1.767E-05	95% H-UCL	1.75E-05
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.923E-05
95% Adjusted-CLT UCL (Chen-1995)	1.846E-05	97.5% Chebyshev (MVUE) UCL	2.062E-05
95% Modified-t UCL (Johnson-1978)	1.782E-05	99% Chebyshev (MVUE) UCL	2.335E-05
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	30.28	Data do not follow a Discernable Distribution (0.05)	
Theta Star	5.296E-07		
MLE of Mean	1.604E-05		
MLE of Standard Deviation	2.914E-06		
nu star	666.2		
Approximate Chi Square Value (.05)	607.3	Nonparametric Statistics	
Adjusted Level of Significance	0.0278	95% CLT UCL	1.752E-05
Adjusted Chi Square Value	598.1	95% Jackknife UCL	1.767E-05
		95% Standard Bootstrap UCL	1.743E-05
Anderson-Darling Test Statistic	3.079	95% Bootstrap-t UCL	2.797E-05
Anderson-Darling 5% Critical Value	0.728	95% Hall's Bootstrap UCL	2.811E-05
Kolmogorov-Smirnov Test Statistic	0.427	95% Percentile Bootstrap UCL	0.0000178
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	1.798E-05
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.996E-05
		97.5% Chebyshev(Mean, Sd) UCL	2.166E-05
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.5E-05
95% Approximate Gamma UCL	1.759E-05		
95% Adjusted Gamma UCL	1.786E-05		
Potential UCL to Use		Use 95% Student's-t UCL	1.767E-05
		or 95% Modified-t UCL	1.782E-05

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(b)fluoranthene)

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	4

Raw Statistics		Log-transformed Statistics	
Minimum	0.000015	Minimum of Log Data	-11.11
Maximum	0.000025	Maximum of Log Data	-10.6
Mean	1.604E-05	Mean of log Data	-11.05
Median	0.000015	SD of log Data	0.152
SD	2.986E-06		
Std. Error of Mean	9.004E-07		
Coefficient of Variation	N/A		
Skewness	3.264		

Warning: There are only 4 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.404	Shapiro Wilk Test Statistic	0.42
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	1.767E-05	95% H-UCL	1.75E-05
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.923E-05
95% Adjusted-CLT UCL (Chen-1995)	1.846E-05	97.5% Chebyshev (MVUE) UCL	2.062E-05
95% Modified-t UCL (Johnson-1978)	1.782E-05	99% Chebyshev (MVUE) UCL	2.335E-05
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	30.28	Data do not follow a Discernable Distribution (0.05)	
Theta Star	5.296E-07		
MLE of Mean	1.604E-05		
MLE of Standard Deviation	2.914E-06		
nu star	666.2		
Approximate Chi Square Value (.05)	607.3	Nonparametric Statistics	
Adjusted Level of Significance	0.0278	95% CLT UCL	1.752E-05
Adjusted Chi Square Value	598.1	95% Jackknife UCL	1.767E-05
		95% Standard Bootstrap UCL	1.743E-05
Anderson-Darling Test Statistic	3.079	95% Bootstrap-t UCL	2.797E-05
Anderson-Darling 5% Critical Value	0.728	95% Hall's Bootstrap UCL	2.811E-05
Kolmogorov-Smirnov Test Statistic	0.427	95% Percentile Bootstrap UCL	0.0000178
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	1.804E-05
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.996E-05
		97.5% Chebyshev(Mean, Sd) UCL	2.166E-05
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.5E-05
95% Approximate Gamma UCL	1.759E-05		
95% Adjusted Gamma UCL	1.786E-05		
Potential UCL to Use		Use 95% Student's-t UCL	1.767E-05
		or 95% Modified-t UCL	1.782E-05

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(g,h,i)perylene)

General Statistics

Number of Valid Observations	2	Number of Distinct Observations	1

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable Result (1/2 DL for NDs) (benzo(g,h,i)perylene) was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Result (1/2 DL for NDs) (benzo(k)fluoranthene)

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	4
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000015	Minimum of Log Data	-11.11
Maximum	0.000025	Maximum of Log Data	-10.6
Mean	1.604E-05	Mean of log Data	-11.05
Median	0.000015	SD of log Data	0.152
SD	2.986E-06		
Std. Error of Mean	9.004E-07		
Coefficient of Variation	N/A		
Skewness	3.264		

Warning: There are only 4 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.404	Shapiro Wilk Test Statistic	0.42
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.767E-05	95% H-UCL	1.75E-05
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.923E-05
95% Adjusted-CLT UCL (Chen-1995)	1.846E-05	97.5% Chebyshev (MVUE) UCL	2.062E-05
95% Modified-t UCL (Johnson-1978)	1.782E-05	99% Chebyshev (MVUE) UCL	2.335E-05
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	30.28	Data do not follow a Discernable Distribution (0.05)	
Theta Star	5.296E-07		
MLE of Mean	1.604E-05		
MLE of Standard Deviation	2.914E-06		
nu star	666.2		
Approximate Chi Square Value (.05)	607.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	1.752E-05
Adjusted Chi Square Value	598.1	95% Jackknife UCL	1.767E-05
		95% Standard Bootstrap UCL	1.74E-05
Anderson-Darling Test Statistic	3.079	95% Bootstrap-t UCL	2.797E-05
Anderson-Darling 5% Critical Value	0.728	95% Hall's Bootstrap UCL	2.811E-05
Kolmogorov-Smirnov Test Statistic	0.427	95% Percentile Bootstrap UCL	0.0000178
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	1.798E-05
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.996E-05
		97.5% Chebyshev(Mean, Sd) UCL	2.166E-05
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.5E-05
95% Approximate Gamma UCL	1.759E-05		
95% Adjusted Gamma UCL	1.786E-05		
Potential UCL to Use		Use 95% Student's-t UCL	1.767E-05
		or 95% Modified-t UCL	1.782E-05

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cadmium)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	1

Warning: There is only one distinct observation value in this data set - resulting in '0' variance!
ProUCL (or any other software) should not be used on such a data set!
The data set for variable Result (1/2 DL for NDs) (cadmium) was not processed!

If possible, compute and collect Data Quality Objectives (DQOs) based sample size and analytical results.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Result (1/2 DL for NDs) (chromium (total))

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	5
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0012	Minimum of Log Data	-6.725
Maximum	0.0021	Maximum of Log Data	-6.166
Mean	0.00131	Mean of log Data	-6.654
Median	0.0012	SD of log Data	0.173
SD	0.0002796		
Std. Error of Mean	8.842E-05		
Coefficient of Variation	0.214		
Skewness	3.092		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.449	Shapiro Wilk Test Statistic	0.474
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00147	95% H-UCL	0.00146
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00162
95% Adjusted-CLT UCL (Chen-1995)	0.00155	97.5% Chebyshev (MVUE) UCL	0.00175
95% Modified-t UCL (Johnson-1978)	0.00149	99% Chebyshev (MVUE) UCL	0.00202
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	22.67	Data do not follow a Discernable Distribution (0.05)	
Theta Star	5.775E-05		
MLE of Mean	0.00131		
MLE of Standard Deviation	0.0002749		
nu star	453.4		
Approximate Chi Square Value (.05)	405	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.00145
Adjusted Chi Square Value	397	95% Jackknife UCL	0.00147
		95% Standard Bootstrap UCL	0.00145
Anderson-Darling Test Statistic	2.518	95% Bootstrap-t UCL	0.0024
Anderson-Darling 5% Critical Value	0.724	95% Hall's Bootstrap UCL	0.00211
Kolmogorov-Smirnov Test Statistic	0.427	95% Percentile Bootstrap UCL	0.00148
Kolmogorov-Smirnov 5% Critical Value	0.266	95% BCA Bootstrap UCL	0.00157
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.00169
		97.5% Chebyshev(Mean, Sd) UCL	0.00186
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.00219
95% Approximate Gamma UCL	0.00147		
95% Adjusted Gamma UCL	0.00149		
Potential UCL to Use		Use 95% Student's-t UCL	0.00147
		or 95% Modified-t UCL	0.00149

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (chrysene)

General Statistics

Number of Valid Observations	2	Number of Distinct Observations	1

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable Result (1/2 DL for NDs) (chrysene) was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Result (1/2 DL for NDs) (co3 alkalinity)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	1

Warning: There is only one distinct observation value in this data set - resulting in '0' variance!
ProUCL (or any other software) should not be used on such a data set!
The data set for variable Result (1/2 DL for NDs) (co3 alkalinity) was not processed!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQOs) based sample size and analytical results.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Result (1/2 DL for NDs) (copper)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	7
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0018	Minimum of Log Data	-6.32
Maximum	0.00784	Maximum of Log Data	-4.849
Mean	0.00324	Mean of log Data	-5.864
Median	0.00257	SD of log Data	0.513
SD	0.00197		
Std. Error of Mean	0.0006245		
Coefficient of Variation	0.609		
Skewness	1.701		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.776	Shapiro Wilk Test Statistic	0.861
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00439	95% H-UCL	0.00475
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0055
95% Adjusted-CLT UCL (Chen-1995)	0.00463	97.5% Chebyshev (MVUE) UCL	0.00649
95% Modified-t UCL (Johnson-1978)	0.00444	99% Chebyshev (MVUE) UCL	0.00845
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	2.827	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	0.00115		
MLE of Mean	0.00324		
MLE of Standard Deviation	0.00193		
nu star	56.54		
Approximate Chi Square Value (.05)	40.26	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.00427
Adjusted Chi Square Value	37.88	95% Jackknife UCL	0.00439
		95% Standard Bootstrap UCL	0.00424
Anderson-Darling Test Statistic	0.681	95% Bootstrap-t UCL	0.00564
Anderson-Darling 5% Critical Value	0.73	95% Hall's Bootstrap UCL	0.00905
Kolmogorov-Smirnov Test Statistic	0.213	95% Percentile Bootstrap UCL	0.00435
Kolmogorov-Smirnov 5% Critical Value	0.268	95% BCA Bootstrap UCL	0.00468
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.00596
		97.5% Chebyshev(Mean, Sd) UCL	0.00714
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.00945
95% Approximate Gamma UCL	0.00455		
95% Adjusted Gamma UCL	0.00484		
Potential UCL to Use		Use 95% Approximate Gamma UCL	0.00455

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cyanide)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	6

Raw Statistics		Log-transformed Statistics	
Minimum	0.0015	Minimum of Log Data	-6.502
Maximum	0.0046	Maximum of Log Data	-5.382
Mean	0.00205	Mean of log Data	-6.257
Median	0.0017	SD of log Data	0.353
SD	0.0009504		
Std. Error of Mean	0.0003006		
Coefficient of Variation	0.464		
Skewness	2.552		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.634	Shapiro Wilk Test Statistic	0.739
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0026	95% H-UCL	0.00259
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00302
95% Adjusted-CLT UCL (Chen-1995)	0.0028	97.5% Chebyshev (MVUE) UCL	0.00345
95% Modified-t UCL (Johnson-1978)	0.00264	99% Chebyshev (MVUE) UCL	0.0043

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	5.413	Data Follow Appr. Gamma Distribution at 5% Significance Level	
Theta Star	0.0003788		
MLE of Mean	0.00205		
MLE of Standard Deviation	0.0008812		
nu star	108.3		
Approximate Chi Square Value (.05)	85.24	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.00254
Adjusted Chi Square Value	81.69	95% Jackknife UCL	0.0026
		95% Standard Bootstrap UCL	0.00251
Anderson-Darling Test Statistic	1.173	95% Bootstrap-t UCL	0.00343
Anderson-Darling 5% Critical Value	0.727	95% Hall's Bootstrap UCL	0.00443
Kolmogorov-Smirnov Test Statistic	0.257	95% Percentile Bootstrap UCL	0.00258
Kolmogorov-Smirnov 5% Critical Value	0.267	95% BCA Bootstrap UCL	0.0028
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.00336
		97.5% Chebyshev(Mean, Sd) UCL	0.00393
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.00504
95% Approximate Gamma UCL	0.0026		
95% Adjusted Gamma UCL	0.00272		

Potential UCL to Use		Use 95% Approximate Gamma UCL	0.0026

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cyclohexane)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	5
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000163	Minimum of Log Data	-8.722
Maximum	0.498	Maximum of Log Data	-0.697
Mean	0.128	Mean of log Data	-5.843
Median	0.000163	SD of log Data	3.788
SD	0.204		
Std. Error of Mean	0.0646		
Coefficient of Variation	1.591		
Skewness	1.202		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.67	Shapiro Wilk Test Statistic	0.695
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.247	95% H-UCL	951246
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.542
95% Adjusted-CLT UCL (Chen-1995)	0.261	97.5% Chebyshev (MVUE) UCL	2.078
95% Modified-t UCL (Johnson-1978)	0.251	99% Chebyshev (MVUE) UCL	3.13
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.203	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.632		
MLE of Mean	0.128		
MLE of Standard Deviation	0.285		
nu star	4.063		
Approximate Chi Square Value (.05)	0.747	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.234
Adjusted Chi Square Value	0.538	95% Jackknife UCL	0.247
		95% Standard Bootstrap UCL	0.229
Anderson-Darling Test Statistic	1.404	95% Bootstrap-t UCL	0.32
Anderson-Darling 5% Critical Value	0.856	95% Hall's Bootstrap UCL	0.196
Kolmogorov-Smirnov Test Statistic	0.385	95% Percentile Bootstrap UCL	0.237
Kolmogorov-Smirnov 5% Critical Value	0.294	95% BCA Bootstrap UCL	0.261
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.41
		97.5% Chebyshev(Mean, Sd) UCL	0.531
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.771
95% Approximate Gamma UCL	0.698		
95% Adjusted Gamma UCL	0.968		
Potential UCL to Use		Use 95% Hall's Bootstrap UCL	0.196

In Case Bootstrap t and/or Hall's Bootstrap yields an unreasonably large UCL value, use 97.5% or 99% Chebyshev (Mean, Sd) UCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (dibenzo(a,h)anthracene)

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	4
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000015	Minimum of Log Data	-11.11
Maximum	0.000025	Maximum of Log Data	-10.6
Mean	1.604E-05	Mean of log Data	-11.05
Median	0.000015	SD of log Data	0.152
SD	2.986E-06		
Std. Error of Mean	9.004E-07		
Coefficient of Variation	N/A		
Skewness	3.264		

Warning: There are only 4 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.404	Shapiro Wilk Test Statistic	0.42
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.767E-05	95% H-UCL	1.75E-05
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.923E-05
95% Adjusted-CLT UCL (Chen-1995)	1.846E-05	97.5% Chebyshev (MVUE) UCL	2.062E-05
95% Modified-t UCL (Johnson-1978)	1.782E-05	99% Chebyshev (MVUE) UCL	2.335E-05
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	30.28	Data do not follow a Discernable Distribution (0.05)	
Theta Star	5.296E-07		
MLE of Mean	1.604E-05		
MLE of Standard Deviation	2.914E-06		
nu star	666.2		
Approximate Chi Square Value (.05)	607.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	1.752E-05
Adjusted Chi Square Value	598.1	95% Jackknife UCL	1.767E-05
		95% Standard Bootstrap UCL	1.748E-05
Anderson-Darling Test Statistic	3.079	95% Bootstrap-t UCL	2.797E-05
Anderson-Darling 5% Critical Value	0.728	95% Hall's Bootstrap UCL	2.811E-05
Kolmogorov-Smirnov Test Statistic	0.427	95% Percentile Bootstrap UCL	0.0000178
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	1.864E-05
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.996E-05
		97.5% Chebyshev(Mean, Sd) UCL	2.166E-05
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.5E-05
95% Approximate Gamma UCL	1.759E-05		
95% Adjusted Gamma UCL	1.786E-05		
Potential UCL to Use		Use 95% Student's-t UCL	1.767E-05
		or 95% Modified-t UCL	1.782E-05

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (dibenzofuran)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	2

Raw Statistics		Log-transformed Statistics	
Minimum	0.0031	Minimum of Log Data	-5.776
Maximum	0.0032	Maximum of Log Data	-5.745
Mean	0.00311	Mean of log Data	-5.773
Median	0.0031	SD of log Data	0.01
SD	3.162E-05		
Std. Error of Mean	0.00001		
Coefficient of Variation	0.0102		
Skewness	3.162		

Warning: There are only 2 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.366	Shapiro Wilk Test Statistic	0.366
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.00313	95% H-UCL	N/A
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00315
95% Adjusted-CLT UCL (Chen-1995)	0.00314	97.5% Chebyshev (MVUE) UCL	0.00317
95% Modified-t UCL (Johnson-1978)	0.00313	99% Chebyshev (MVUE) UCL	0.00321
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	7651	Data do not follow a Discernable Distribution (0.05)	
Theta Star	4.065E-07		
MLE of Mean	0.00311		
MLE of Standard Deviation	3.555E-05		
nu star	153026		
Approximate Chi Square Value (.05)	152117	Nonparametric Statistics	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.00313
Adjusted Chi Square Value	151959	95% Jackknife UCL	N/A
		95% Standard Bootstrap UCL	N/A
Anderson-Darling Test Statistic	4.346	95% Bootstrap-t UCL	N/A
Anderson-Darling 5% Critical Value	0.724	95% Hall's Bootstrap UCL	N/A
Kolmogorov-Smirnov Test Statistic	0.628	95% Percentile Bootstrap UCL	N/A
Kolmogorov-Smirnov 5% Critical Value	0.266	95% BCA Bootstrap UCL	N/A
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.00315
		97.5% Chebyshev(Mean, Sd) UCL	0.00317
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.00321
95% Approximate Gamma UCL	0.00313		
95% Adjusted Gamma UCL	0.00313		
Potential UCL to Use		Use 95% Student's-t UCL	0.00313
		or 95% Modified-t UCL	0.00313

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (dro)

General Statistics

Number of Valid Observations	12	Number of Distinct Observations	9
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.18	Minimum of Log Data	-1.715
Maximum	1.92	Maximum of Log Data	0.652
Mean	0.718	Mean of log Data	-0.729
Median	0.385	SD of log Data	0.932
SD	0.66		
Std. Error of Mean	0.191		
Coefficient of Variation	0.919		
Skewness	1.01		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.787	Shapiro Wilk Test Statistic	0.851
Shapiro Wilk Critical Value	0.859	Shapiro Wilk Critical Value	0.859
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.061	95% H-UCL	1.634
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.597
95% Adjusted-CLT UCL (Chen-1995)	1.091	97.5% Chebyshev (MVUE) UCL	1.98
95% Modified-t UCL (Johnson-1978)	1.07	99% Chebyshev (MVUE) UCL	2.734
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.104	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.651		
MLE of Mean	0.718		
MLE of Standard Deviation	0.684		
nu star	26.5		
Approximate Chi Square Value (.05)	15.77	**Nonparametric Statistics**	
Adjusted Level of Significance	0.029	95% CLT UCL	1.032
Adjusted Chi Square Value	14.52	95% Jackknife UCL	1.061
		95% Standard Bootstrap UCL	1.004
Anderson-Darling Test Statistic	0.848	95% Bootstrap-t UCL	1.182
Anderson-Darling 5% Critical Value	0.748	95% Hall's Bootstrap UCL	1.019
Kolmogorov-Smirnov Test Statistic	0.27	95% Percentile Bootstrap UCL	1.05
Kolmogorov-Smirnov 5% Critical Value	0.25	95% BCA Bootstrap UCL	1.061
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.549
		97.5% Chebyshev(Mean, Sd) UCL	1.909
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.615
95% Approximate Gamma UCL	1.208		
95% Adjusted Gamma UCL	1.312		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	1.549

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (fluoranthene)

General Statistics

Number of Valid Observations	2	Number of Distinct Observations	1

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable Result (1/2 DL for NDs) (fluoranthene) was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Result (1/2 DL for NDs) (fluorene)

General Statistics

Number of Valid Observations	2	Number of Distinct Observations	1

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable Result (1/2 DL for NDs) (fluorene) was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Result (1/2 DL for NDs) (gro)

General Statistics

Number of Valid Observations	12	Number of Distinct Observations	6
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.031	Minimum of Log Data	-3.474
Maximum	20.8	Maximum of Log Data	3.035
Mean	2.311	Mean of log Data	-1.847
Median	0.0405	SD of log Data	2.36
SD	5.946		
Std. Error of Mean	1.717		
Coefficient of Variation	2.573		
Skewness	3.23		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.452	Shapiro Wilk Test Statistic	0.732
Shapiro Wilk Critical Value	0.859	Shapiro Wilk Critical Value	0.859
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	5.394	95% H-UCL	153
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	5.856
95% Adjusted-CLT UCL (Chen-1995)	6.845	97.5% Chebyshev (MVUE) UCL	7.775
95% Modified-t UCL (Johnson-1978)	5.661	99% Chebyshev (MVUE) UCL	11.55
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.252	Data do not follow a Discernable Distribution (0.05)	
Theta Star	9.156		
MLE of Mean	2.311		
MLE of Standard Deviation	4.6		
nu star	6.058		
Approximate Chi Square Value (.05)	1.67	**Nonparametric Statistics**	
Adjusted Level of Significance	0.029	95% CLT UCL	5.135
Adjusted Chi Square Value	1.344	95% Jackknife UCL	5.394
		95% Standard Bootstrap UCL	5.035
Anderson-Darling Test Statistic	1.775	95% Bootstrap-t UCL	23.31
Anderson-Darling 5% Critical Value	0.839	95% Hall's Bootstrap UCL	22.28
Kolmogorov-Smirnov Test Statistic	0.382	95% Percentile Bootstrap UCL	5.556
Kolmogorov-Smirnov 5% Critical Value	0.267	95% BCA Bootstrap UCL	7.387
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	9.794
		97.5% Chebyshev(Mean, Sd) UCL	13.03
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	19.39
95% Approximate Gamma UCL	8.385		
95% Adjusted Gamma UCL	10.42		
Potential UCL to Use		Use 99% Chebyshev (Mean, Sd) UCL	19.39

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (hardness as caco3)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	6

Raw Statistics		Log-transformed Statistics	
Minimum	166	Minimum of Log Data	5.112
Maximum	191	Maximum of Log Data	5.252
Mean	181.3	Mean of log Data	5.199
Median	186.5	SD of log Data	0.0636
SD	11.31		
Std. Error of Mean	4.616		
Coefficient of Variation	0.0624		
Skewness	-0.846		

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.793	Shapiro Wilk Test Statistic	0.788
Shapiro Wilk Critical Value	0.788	Shapiro Wilk Critical Value	0.788
Data appear Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	190.6	95% H-UCL	N/A
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	201.8
95% Adjusted-CLT UCL (Chen-1995)	187.2	97.5% Chebyshev (MVUE) UCL	210.7
95% Modified-t UCL (Johnson-1978)	190.4	99% Chebyshev (MVUE) UCL	228.2
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	150.6	Data appear Normal at 5% Significance Level	
Theta Star	1.204		
MLE of Mean	181.3		
MLE of Standard Deviation	14.78		
nu star	1807		
Approximate Chi Square Value (.05)	1709	Nonparametric Statistics	
Adjusted Level of Significance	0.0122	95% CLT UCL	188.9
Adjusted Chi Square Value	1674	95% Jackknife UCL	190.6
		95% Standard Bootstrap UCL	188.4
Anderson-Darling Test Statistic	0.722	95% Bootstrap-t UCL	188.7
Anderson-Darling 5% Critical Value	0.696	95% Hall's Bootstrap UCL	185.9
Kolmogorov-Smirnov Test Statistic	0.31	95% Percentile Bootstrap UCL	188
Kolmogorov-Smirnov 5% Critical Value	0.332	95% BCA Bootstrap UCL	187.5
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	201.5
		97.5% Chebyshev(Mean, Sd) UCL	210.2
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	227.3
95% Approximate Gamma UCL	191.7		
95% Adjusted Gamma UCL	195.7		
Potential UCL to Use		Use 95% Student's-t UCL	190.6

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Note: For highly negative-skewed data, confidence limits
(e.g., Chen, Johnson, Lognormal, and Gamma) may not be
reliable. Chen's and Johnson's methods provide
adjustments for positvely skewed data sets.

Result (1/2 DL for NDs) (hco3 alkalinity)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	5
Raw Statistics		**Log-transformed Statistics**	
Minimum	147	Minimum of Log Data	4.99
Maximum	185	Maximum of Log Data	5.22
Mean	162.3	Mean of log Data	5.087
Median	164.5	SD of log Data	0.0867
SD	14.19		
Std. Error of Mean	5.795		
Coefficient of Variation	0.0874		
Skewness	0.473		

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.885	Shapiro Wilk Test Statistic	0.886
Shapiro Wilk Critical Value	0.788	Shapiro Wilk Critical Value	0.788
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	174	95% H-UCL	N/A
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	187.4
95% Adjusted-CLT UCL (Chen-1995)	173.1	97.5% Chebyshev (MVUE) UCL	198.2
95% Modified-t UCL (Johnson-1978)	174.2	99% Chebyshev (MVUE) UCL	219.5
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	79.6	Data appear Normal at 5% Significance Level	
Theta Star	2.039		
MLE of Mean	162.3		
MLE of Standard Deviation	18.19		
nu star	955.2		
Approximate Chi Square Value (.05)	884.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0122	95% CLT UCL	171.9
Adjusted Chi Square Value	859.6	95% Jackknife UCL	174
		95% Standard Bootstrap UCL	170.8
Anderson-Darling Test Statistic	0.456	95% Bootstrap-t UCL	175.9
Anderson-Darling 5% Critical Value	0.696	95% Hall's Bootstrap UCL	173.2
Kolmogorov-Smirnov Test Statistic	0.228	95% Percentile Bootstrap UCL	171.8
Kolmogorov-Smirnov 5% Critical Value	0.332	95% BCA Bootstrap UCL	171.8
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	187.6
		97.5% Chebyshev(Mean, Sd) UCL	198.5
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	220
95% Approximate Gamma UCL	175.3		
95% Adjusted Gamma UCL	180.4		
Potential UCL to Use		Use 95% Student's-t UCL	174

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (indeno(1,2,3-cd)pyrene)

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	4
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000015	Minimum of Log Data	-11.11
Maximum	0.000025	Maximum of Log Data	-10.6
Mean	1.604E-05	Mean of log Data	-11.05
Median	0.000015	SD of log Data	0.152
SD	2.986E-06		
Std. Error of Mean	9.004E-07		
Coefficient of Variation	N/A		
Skewness	3.264		

Warning: There are only 4 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.404	Shapiro Wilk Test Statistic	0.42
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.767E-05	95% H-UCL	1.75E-05
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.923E-05
95% Adjusted-CLT UCL (Chen-1995)	1.846E-05	97.5% Chebyshev (MVUE) UCL	2.062E-05
95% Modified-t UCL (Johnson-1978)	1.782E-05	99% Chebyshev (MVUE) UCL	2.335E-05
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	30.28	Data do not follow a Discernable Distribution (0.05)	
Theta Star	5.296E-07		
MLE of Mean	1.604E-05		
MLE of Standard Deviation	2.914E-06		
nu star	666.2		
Approximate Chi Square Value (.05)	607.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	1.752E-05
Adjusted Chi Square Value	598.1	95% Jackknife UCL	1.767E-05
		95% Standard Bootstrap UCL	1.746E-05
Anderson-Darling Test Statistic	3.079	95% Bootstrap-t UCL	2.797E-05
Anderson-Darling 5% Critical Value	0.728	95% Hall's Bootstrap UCL	2.811E-05
Kolmogorov-Smirnov Test Statistic	0.427	95% Percentile Bootstrap UCL	1.778E-05
Kolmogorov-Smirnov 5% Critical Value	0.255	95% BCA Bootstrap UCL	1.871E-05
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.996E-05
		97.5% Chebyshev(Mean, Sd) UCL	2.166E-05
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.5E-05
95% Approximate Gamma UCL	1.759E-05		
95% Adjusted Gamma UCL	1.786E-05		
Potential UCL to Use		Use 95% Student's-t UCL	1.767E-05
		or 95% Modified-t UCL	1.782E-05

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (iron)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	9
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.31	Minimum of Log Data	-1.171
Maximum	50.1	Maximum of Log Data	3.914
Mean	11.38	Mean of log Data	1.501
Median	4.715	SD of log Data	1.685
SD	15.11		
Std. Error of Mean	4.778		
Coefficient of Variation	1.327		
Skewness	2.174		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.728	Shapiro Wilk Test Statistic	0.922
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	20.14	95% H-UCL	251
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	49.12
95% Adjusted-CLT UCL (Chen-1995)	22.75	97.5% Chebyshev (MVUE) UCL	64.19
95% Modified-t UCL (Johnson-1978)	20.69	99% Chebyshev (MVUE) UCL	93.79
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.525	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	21.66		
MLE of Mean	11.38		
MLE of Standard Deviation	15.7		
nu star	10.51		
Approximate Chi Square Value (.05)	4.263	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	19.24
Adjusted Chi Square Value	3.598	95% Jackknife UCL	20.14
		95% Standard Bootstrap UCL	18.88
Anderson-Darling Test Statistic	0.272	95% Bootstrap-t UCL	31.86
Anderson-Darling 5% Critical Value	0.765	95% Hall's Bootstrap UCL	47.15
Kolmogorov-Smirnov Test Statistic	0.171	95% Percentile Bootstrap UCL	19.61
Kolmogorov-Smirnov 5% Critical Value	0.278	95% BCA Bootstrap UCL	23.4
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	32.21
		97.5% Chebyshev(Mean, Sd) UCL	41.22
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	58.92
95% Approximate Gamma UCL	28.06		
95% Adjusted Gamma UCL	33.25		
Potential UCL to Use		Use 95% Approximate Gamma UCL	28.06

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (isopropanol (propanol))

General Statistics

Number of Valid Observations	8	Number of Distinct Observations	1

Warning: There is only one distinct observation value in this data set - resulting in '0' variance!
ProUCL (or any other software) should not be used on such a data set!
The data set for variable Result (1/2 DL for NDs) (isopropanol (propanol)) was not processed!

If possible, compute and collect Data Quality Objectives (DQOs) based sample size and analytical results.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Result (1/2 DL for NDs) (lead)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	3

Raw Statistics		Log-transformed Statistics	
Minimum	0.00031	Minimum of Log Data	-8.079
Maximum	0.00118	Maximum of Log Data	-6.742
Mean	0.0004205	Mean of log Data	-7.889
Median	0.00031	SD of log Data	0.44
SD	0.0002769		
Std. Error of Mean	8.756E-05		
Coefficient of Variation	0.658		
Skewness	2.808		

Warning: There are only 3 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.482	Shapiro Wilk Test Statistic	0.521
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.000581	95% H-UCL	0.0005653
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0006603
95% Adjusted-CLT UCL (Chen-1995)	0.0006476	97.5% Chebyshev (MVUE) UCL	0.0007692
95% Modified-t UCL (Johnson-1978)	0.000594	99% Chebyshev (MVUE) UCL	0.000983
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	3.228	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0001303		
MLE of Mean	0.0004205		
MLE of Standard Deviation	0.0002341		
nu star	64.56		
Approximate Chi Square Value (.05)	47.07	Nonparametric Statistics	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.0005645
Adjusted Chi Square Value	44.49	95% Jackknife UCL	0.000581
		95% Standard Bootstrap UCL	N/A
Anderson-Darling Test Statistic	2.455	95% Bootstrap-t UCL	N/A
Anderson-Darling 5% Critical Value	0.729	95% Hall's Bootstrap UCL	N/A
Kolmogorov-Smirnov Test Statistic	0.476	95% Percentile Bootstrap UCL	N/A
Kolmogorov-Smirnov 5% Critical Value	0.268	95% BCA Bootstrap UCL	N/A
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0008022
		97.5% Chebyshev(Mean, Sd) UCL	0.0009673
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.00129
95% Approximate Gamma UCL	0.0005767		
95% Adjusted Gamma UCL	0.0006102		
Potential UCL to Use		Use 95% Student's-t UCL	0.000581
		or 95% Modified-t UCL	0.000594

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (methyl tert-butyl ether (mtbe))

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	5

Raw Statistics		Log-transformed Statistics	
Minimum	0.000144	Minimum of Log Data	-8.846
Maximum	0.00387	Maximum of Log Data	-5.555
Mean	0.0012	Mean of log Data	-7.375
Median	0.00111	SD of log Data	1.332
SD	0.00122		
Std. Error of Mean	0.0003847		
Coefficient of Variation	1.016		
Skewness	1.215		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.837	Shapiro Wilk Test Statistic	0.82
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0019	95% H-UCL	0.00831
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0039
95% Adjusted-CLT UCL (Chen-1995)	0.00199	97.5% Chebyshev (MVUE) UCL	0.00501
95% Modified-t UCL (Johnson-1978)	0.00193	99% Chebyshev (MVUE) UCL	0.0072
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.698	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	0.00171		
MLE of Mean	0.0012		
MLE of Standard Deviation	0.00143		
nu star	13.97		
Approximate Chi Square Value (.05)	6.548	Nonparametric Statistics	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.00183
Adjusted Chi Square Value	5.689	95% Jackknife UCL	0.0019
		95% Standard Bootstrap UCL	0.00179
Anderson-Darling Test Statistic	0.708	95% Bootstrap-t UCL	0.00217
Anderson-Darling 5% Critical Value	0.752	95% Hall's Bootstrap UCL	0.0024
Kolmogorov-Smirnov Test Statistic	0.267	95% Percentile Bootstrap UCL	0.00179
Kolmogorov-Smirnov 5% Critical Value	0.275	95% BCA Bootstrap UCL	0.002
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.00287
		97.5% Chebyshev(Mean, Sd) UCL	0.0036
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.00503
95% Approximate Gamma UCL	0.00255		
95% Adjusted Gamma UCL	0.00294		
Potential UCL to Use		Use 95% Approximate Gamma UCL	0.00255

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (methylene chloride)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	3

Raw Statistics		Log-transformed Statistics	
Minimum	0.000152	Minimum of Log Data	-8.792
Maximum	0.001	Maximum of Log Data	-6.908
Mean	0.0004672	Mean of log Data	-8.066
Median	0.000152	SD of log Data	0.941
SD	0.0004128		
Std. Error of Mean	0.0001305		
Coefficient of Variation	0.884		
Skewness	0.575		

Warning: There are only 3 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.681	Shapiro Wilk Test Statistic	0.665
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0007065	95% H-UCL	0.00125
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00109
95% Adjusted-CLT UCL (Chen-1995)	0.0007073	97.5% Chebyshev (MVUE) UCL	0.00136
95% Modified-t UCL (Johnson-1978)	0.0007104	99% Chebyshev (MVUE) UCL	0.00189
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	1.049	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0004453		
MLE of Mean	0.0004672		
MLE of Standard Deviation	0.0004561		
nu star	20.98		
Approximate Chi Square Value (.05)	11.58	Nonparametric Statistics	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.0006819
Adjusted Chi Square Value	10.38	95% Jackknife UCL	0.0007065
		95% Standard Bootstrap UCL	N/A
Anderson-Darling Test Statistic	1.692	95% Bootstrap-t UCL	N/A
Anderson-Darling 5% Critical Value	0.741	95% Hall's Bootstrap UCL	N/A
Kolmogorov-Smirnov Test Statistic	0.394	95% Percentile Bootstrap UCL	N/A
Kolmogorov-Smirnov 5% Critical Value	0.272	95% BCA Bootstrap UCL	N/A
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.00104
		97.5% Chebyshev(Mean, Sd) UCL	0.00128
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.00177
95% Approximate Gamma UCL	0.0008467		
95% Adjusted Gamma UCL	0.000944		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.00104

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (naphthalene)

General Statistics

Number of Valid Observations	11	Number of Distinct Observations	10
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000031	Minimum of Log Data	-10.38
Maximum	0.178	Maximum of Log Data	-1.726
Mean	0.0217	Mean of log Data	-7.652
Median	0.0000842	SD of log Data	3.332
SD	0.0531		
Std. Error of Mean	0.016		
Coefficient of Variation	2.445		
Skewness	3.063		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.479	Shapiro Wilk Test Statistic	0.791
Shapiro Wilk Critical Value	0.85	Shapiro Wilk Critical Value	0.85
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0507	95% H-UCL	746.1
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.112
95% Adjusted-CLT UCL (Chen-1995)	0.0638	97.5% Chebyshev (MVUE) UCL	0.151
95% Modified-t UCL (Johnson-1978)	0.0532	99% Chebyshev (MVUE) UCL	0.227
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.201	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.108		
MLE of Mean	0.0217		
MLE of Standard Deviation	0.0483		
nu star	4.431		
Approximate Chi Square Value (.05)	0.899	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0278	95% CLT UCL	0.048
Adjusted Chi Square Value	0.673	95% Jackknife UCL	0.0507
		95% Standard Bootstrap UCL	0.0461
Anderson-Darling Test Statistic	1.274	95% Bootstrap-t UCL	0.142
Anderson-Darling 5% Critical Value	0.862	95% Hall's Bootstrap UCL	0.145
Kolmogorov-Smirnov Test Statistic	0.337	95% Percentile Bootstrap UCL	0.0514
Kolmogorov-Smirnov 5% Critical Value	0.282	95% BCA Bootstrap UCL	0.0673
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0914
		97.5% Chebyshev(Mean, Sd) UCL	0.122
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.181
95% Approximate Gamma UCL	0.107		
95% Adjusted Gamma UCL	0.143		
Potential UCL to Use		Use 95% Hall's Bootstrap UCL	0.145

In Case Bootstrap t and/or Hall's Bootstrap yields an unreasonably large UCL value, use 97.5% or 99% Chebyshev (Mean, Sd) UCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-hexane)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	5
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0000723	Minimum of Log Data	-9.535
Maximum	0.0648	Maximum of Log Data	-2.736
Mean	0.0102	Mean of log Data	-7.67
Median	0.0000723	SD of log Data	2.77
SD	0.0215		
Std. Error of Mean	0.00679		
Coefficient of Variation	2.104		
Skewness	2.307		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.567	Shapiro Wilk Test Statistic	0.71
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0226	95% H-UCL	18.12
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0345
95% Adjusted-CLT UCL (Chen-1995)	0.0267	97.5% Chebyshev (MVUE) UCL	0.0462
95% Modified-t UCL (Johnson-1978)	0.0235	99% Chebyshev (MVUE) UCL	0.0691
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.23	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0444		
MLE of Mean	0.0102		
MLE of Standard Deviation	0.0213		
nu star	4.593		
Approximate Chi Square Value (.05)	0.969	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.0214
Adjusted Chi Square Value	0.717	95% Jackknife UCL	0.0226
		95% Standard Bootstrap UCL	0.0207
Anderson-Darling Test Statistic	1.531	95% Bootstrap-t UCL	0.13
Anderson-Darling 5% Critical Value	0.841	95% Hall's Bootstrap UCL	0.161
Kolmogorov-Smirnov Test Statistic	0.354	95% Percentile Bootstrap UCL	0.0226
Kolmogorov-Smirnov 5% Critical Value	0.292	95% BCA Bootstrap UCL	0.0263
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0398
		97.5% Chebyshev(Mean, Sd) UCL	0.0526
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0778
95% Approximate Gamma UCL	0.0484		
95% Adjusted Gamma UCL	0.0654		
Potential UCL to Use		Use 99% Chebyshev (Mean, Sd) UCL	0.0778

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (nitrate)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	3

Raw Statistics		Log-transformed Statistics	
Minimum	0.031	Minimum of Log Data	-3.474
Maximum	0.0577	Maximum of Log Data	-2.852
Mean	0.0387	Mean of log Data	-3.29
Median	0.031	SD of log Data	0.288
SD	0.0121		
Std. Error of Mean	0.00493		
Coefficient of Variation	0.313		
Skewness	1.132		

Warning: There are only 3 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.697	Shapiro Wilk Test Statistic	0.688
Shapiro Wilk Critical Value	0.788	Shapiro Wilk Critical Value	0.788
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0486	95% H-UCL	0.0516
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0583
95% Adjusted-CLT UCL (Chen-1995)	0.0492	97.5% Chebyshev (MVUE) UCL	0.0669
95% Modified-t UCL (Johnson-1978)	0.049	99% Chebyshev (MVUE) UCL	0.0837
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	7.01	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00551		
MLE of Mean	0.0387		
MLE of Standard Deviation	0.0146		
nu star	84.12		
Approximate Chi Square Value (.05)	63.98	Nonparametric Statistics	
Adjusted Level of Significance	0.0122	95% CLT UCL	0.0468
Adjusted Chi Square Value	57.67	95% Jackknife UCL	0.0486
		95% Standard Bootstrap UCL	N/A
Anderson-Darling Test Statistic	1.078	95% Bootstrap-t UCL	N/A
Anderson-Darling 5% Critical Value	0.698	95% Hall's Bootstrap UCL	N/A
Kolmogorov-Smirnov Test Statistic	0.424	95% Percentile Bootstrap UCL	N/A
Kolmogorov-Smirnov 5% Critical Value	0.332	95% BCA Bootstrap UCL	N/A
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0602
		97.5% Chebyshev(Mean, Sd) UCL	0.0695
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0877
95% Approximate Gamma UCL	0.0508		
95% Adjusted Gamma UCL	0.0564		
Potential UCL to Use		Use 95% Student's-t UCL	0.0486
		or 95% Modified-t UCL	0.049

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (nitrite)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	1

Warning: There is only one distinct observation value in this data set - resulting in '0' variance!
ProUCL (or any other software) should not be used on such a data set!
The data set for variable Result (1/2 DL for NDs) (nitrite) was not processed!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQOs) based sample size and analytical results.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Result (1/2 DL for NDs) (n-propylbenzene)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	5
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000113	Minimum of Log Data	-9.088
Maximum	0.0803	Maximum of Log Data	-2.522
Mean	0.0166	Mean of log Data	-7.026
Median	0.000113	SD of log Data	2.863
SD	0.0301		
Std. Error of Mean	0.00953		
Coefficient of Variation	1.82		
Skewness	1.705		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.622	Shapiro Wilk Test Statistic	0.716
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.034	95% H-UCL	70.24
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0782
95% Adjusted-CLT UCL (Chen-1995)	0.0377	97.5% Chebyshev (MVUE) UCL	0.105
95% Modified-t UCL (Johnson-1978)	0.0349	99% Chebyshev (MVUE) UCL	0.157
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.237	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0698		
MLE of Mean	0.0166		
MLE of Standard Deviation	0.034		
nu star	4.747		
Approximate Chi Square Value (.05)	1.037	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.0322
Adjusted Chi Square Value	0.772	95% Jackknife UCL	0.034
		95% Standard Bootstrap UCL	0.0314
Anderson-Darling Test Statistic	1.405	95% Bootstrap-t UCL	0.089
Anderson-Darling 5% Critical Value	0.836	95% Hall's Bootstrap UCL	0.128
Kolmogorov-Smirnov Test Statistic	0.369	95% Percentile Bootstrap UCL	0.031
Kolmogorov-Smirnov 5% Critical Value	0.291	95% BCA Bootstrap UCL	0.0374
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0581
		97.5% Chebyshev(Mean, Sd) UCL	0.0761
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.111
95% Approximate Gamma UCL	0.0758		
95% Adjusted Gamma UCL	0.102		
Potential UCL to Use		Use 99% Chebyshev (Mean, Sd) UCL	0.111

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (oh alkalinity)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	1

Warning: There is only one distinct observation value in this data set - resulting in '0' variance!
ProUCL (or any other software) should not be used on such a data set!
The data set for variable Result (1/2 DL for NDs) (oh alkalinity) was not processed!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQOs) based sample size and analytical results.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Result (1/2 DL for NDs) (phenanthrene)

General Statistics

Number of Valid Observations	2	Number of Distinct Observations	1

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable Result (1/2 DL for NDs) (phenanthrene) was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Result (1/2 DL for NDs) (propylene glycol (1,2,-propanediol))

General Statistics

Number of Valid Observations	9	Number of Distinct Observations	1

Warning: There is only one distinct observation value in this data set - resulting in '0' variance!
ProUCL (or any other software) should not be used on such a data set!
The data set for variable Result (1/2 DL for NDs) (propylene glycol (1,2,-propanediol)) was not processed!

If possible, compute and collect Data Quality Objectives (DQOs) based sample size and analytical results.
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Result (1/2 DL for NDs) (pyrene)

General Statistics

Number of Valid Observations	2	Number of Distinct Observations	1

Warning: This data set only has 2 observations!
Data set is too small to compute reliable and meaningful statistics and estimates!
The data set for variable Result (1/2 DL for NDs) (pyrene) was not processed!

It is suggested to collect at least 8 to 10 observations before using these statistical methods!
If possible, compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Result (1/2 DL for NDs) (rro)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	4
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.15	Minimum of Log Data	-1.897
Maximum	0.278	Maximum of Log Data	-1.28
Mean	0.168	Mean of log Data	-1.801
Median	0.15	SD of log Data	0.197
SD	0.0403		
Std. Error of Mean	0.0127		
Coefficient of Variation	0.239		
Skewness	2.715		

Warning: There are only 4 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.543	Shapiro Wilk Test Statistic	0.58
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.192	95% H-UCL	0.19
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.214
95% Adjusted-CLT UCL (Chen-1995)	0.201	97.5% Chebyshev (MVUE) UCL	0.233
95% Modified-t UCL (Johnson-1978)	0.194	99% Chebyshev (MVUE) UCL	0.272
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	17.85	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00943		
MLE of Mean	0.168		
MLE of Standard Deviation	0.0399		
nu star	357.1		
Approximate Chi Square Value (.05)	314.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.189
Adjusted Chi Square Value	307.3	95% Jackknife UCL	0.192
		95% Standard Bootstrap UCL	0.188
Anderson-Darling Test Statistic	1.97	95% Bootstrap-t UCL	0.231
Anderson-Darling 5% Critical Value	0.725	95% Hall's Bootstrap UCL	0.255
Kolmogorov-Smirnov Test Statistic	0.393	95% Percentile Bootstrap UCL	0.192
Kolmogorov-Smirnov 5% Critical Value	0.266	95% BCA Bootstrap UCL	0.2
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.224
		97.5% Chebyshev(Mean, Sd) UCL	0.248
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.295
95% Approximate Gamma UCL	0.191		
95% Adjusted Gamma UCL	0.196		
Potential UCL to Use		Use 95% Student's-t UCL	0.192
		or 95% Modified-t UCL	0.194

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Appendix B
On-Site Groundwater - ProUCL Output

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (selenium)

General Statistics

Number of Valid Observations	10	Number of Distinct Observations	6
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0015	Minimum of Log Data	-6.502
Maximum	0.00218	Maximum of Log Data	-6.128
Mean	0.00174	Mean of log Data	-6.362
Median	0.00178	SD of log Data	0.134
SD	0.0002365		
Std. Error of Mean	7.479E-05		
Coefficient of Variation	0.136		
Skewness	0.449		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.872	Shapiro Wilk Test Statistic	0.867
Shapiro Wilk Critical Value	0.842	Shapiro Wilk Critical Value	0.842
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00188	95% H-UCL	0.00189
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00206
95% Adjusted-CLT UCL (Chen-1995)	0.00187	97.5% Chebyshev (MVUE) UCL	0.0022
95% Modified-t UCL (Johnson-1978)	0.00188	99% Chebyshev (MVUE) UCL	0.00248
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	43	Data appear Normal at 5% Significance Level	
Theta Star	4.046E-05		
MLE of Mean	0.00174		
MLE of Standard Deviation	0.0002653		
nu star	860		
Approximate Chi Square Value (.05)	793	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0267	95% CLT UCL	0.00186
Adjusted Chi Square Value	781.7	95% Jackknife UCL	0.00188
		95% Standard Bootstrap UCL	0.00186
Anderson-Darling Test Statistic	0.636	95% Bootstrap-t UCL	0.00189
Anderson-Darling 5% Critical Value	0.724	95% Hall's Bootstrap UCL	0.00187
Kolmogorov-Smirnov Test Statistic	0.262	95% Percentile Bootstrap UCL	0.00187
Kolmogorov-Smirnov 5% Critical Value	0.266	95% BCA Bootstrap UCL	0.00187
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.00207
		97.5% Chebyshev(Mean, Sd) UCL	0.00221
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.00248
95% Approximate Gamma UCL	0.00189		
95% Adjusted Gamma UCL	0.00191		
Potential UCL to Use		Use 95% Student's-t UCL	0.00188

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (sulfate)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	6
Raw Statistics		**Log-transformed Statistics**	
Minimum	18.8	Minimum of Log Data	2.934
Maximum	37.2	Maximum of Log Data	3.616
Mean	28.97	Mean of log Data	3.331
Median	30.6	SD of log Data	0.296
SD	7.934		
Std. Error of Mean	3.239		
Coefficient of Variation	0.274		
Skewness	-0.444		

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.88	Shapiro Wilk Test Statistic	0.858
Shapiro Wilk Critical Value	0.788	Shapiro Wilk Critical Value	0.788
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	35.49	95% H-UCL	39.21
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	44.29
95% Adjusted-CLT UCL (Chen-1995)	33.67	97.5% Chebyshev (MVUE) UCL	50.91
95% Modified-t UCL (Johnson-1978)	35.4	99% Chebyshev (MVUE) UCL	63.89
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	7.398	Data appear Normal at 5% Significance Level	
Theta Star	3.916		
MLE of Mean	28.97		
MLE of Standard Deviation	10.65		
nu star	88.77		
Approximate Chi Square Value (.05)	68.05	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0122	95% CLT UCL	34.29
Adjusted Chi Square Value	61.53	95% Jackknife UCL	35.49
		95% Standard Bootstrap UCL	33.76
Anderson-Darling Test Statistic	0.469	95% Bootstrap-t UCL	34.5
Anderson-Darling 5% Critical Value	0.698	95% Hall's Bootstrap UCL	32.6
Kolmogorov-Smirnov Test Statistic	0.224	95% Percentile Bootstrap UCL	33.78
Kolmogorov-Smirnov 5% Critical Value	0.332	95% BCA Bootstrap UCL	33.58
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	43.09
		97.5% Chebyshev(Mean, Sd) UCL	49.19
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	61.19
95% Approximate Gamma UCL	37.79		
95% Adjusted Gamma UCL	41.79		
Potential UCL to Use		Use 95% Student's-t UCL	35.49

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Note: For highly negative-skewed data, confidence limits
(e.g., Chen, Johnson, Lognormal, and Gamma) may not be
reliable. Chen's and Johnson's methods provide
adjustments for positvely skewed data sets.

Result (1/2 DL for NDs) (total kjeldahl nitrogen)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	3

Raw Statistics		Log-transformed Statistics	
Minimum	0.31	Minimum of Log Data	-1.171
Maximum	0.631	Maximum of Log Data	-0.46
Mean	0.395	Mean of log Data	-0.974
Median	0.31	SD of log Data	0.314
SD	0.138		
Std. Error of Mean	0.0562		
Coefficient of Variation	0.349		
Skewness	1.363		

Warning: There are only 3 Distinct Values in this data
There are insufficient Distinct Values to perform some GOF tests and bootstrap methods.
Those methods will return a 'N/A' value on your output display!

It is necessary to have 4 or more Distinct Values to compute bootstrap methods.
However, results obtained using 4 to 9 distinct values may not be reliable.
It is recommended to have 10-15 or more observations for accurate and meaningful bootstrap results.

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.706	Shapiro Wilk Test Statistic	0.703
Shapiro Wilk Critical Value	0.788	Shapiro Wilk Critical Value	0.788
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.508	95% H-UCL	0.544
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.613
95% Adjusted-CLT UCL (Chen-1995)	0.52	97.5% Chebyshev (MVUE) UCL	0.708
95% Modified-t UCL (Johnson-1978)	0.513	99% Chebyshev (MVUE) UCL	0.895
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	5.842	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0675		
MLE of Mean	0.395		
MLE of Standard Deviation	0.163		
nu star	70.1		
Approximate Chi Square Value (.05)	51.83	Nonparametric Statistics	
Adjusted Level of Significance	0.0122	95% CLT UCL	0.487
Adjusted Chi Square Value	46.2	95% Jackknife UCL	0.508
		95% Standard Bootstrap UCL	N/A
Anderson-Darling Test Statistic	1.02	95% Bootstrap-t UCL	N/A
Anderson-Darling 5% Critical Value	0.698	95% Hall's Bootstrap UCL	N/A
Kolmogorov-Smirnov Test Statistic	0.42	95% Percentile Bootstrap UCL	N/A
Kolmogorov-Smirnov 5% Critical Value	0.332	95% BCA Bootstrap UCL	N/A
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.64
		97.5% Chebyshev(Mean, Sd) UCL	0.746
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.954
95% Approximate Gamma UCL	0.534		
95% Adjusted Gamma UCL	0.599		
Potential UCL to Use		Use 95% Student's-t UCL	0.508
		or 95% Modified-t UCL	0.513

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (total organic carbon)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	6
Raw Statistics		**Log-transformed Statistics**	
Minimum	2.17	Minimum of Log Data	0.775
Maximum	10.3	Maximum of Log Data	2.332
Mean	4.322	Mean of log Data	1.317
Median	3.34	SD of log Data	0.549
SD	3.013		
Std. Error of Mean	1.23		
Coefficient of Variation	0.697		
Skewness	2.153		

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.718	Shapiro Wilk Test Statistic	0.874
Shapiro Wilk Critical Value	0.788	Shapiro Wilk Critical Value	0.788
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	6.8	95% H-UCL	8.529
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	8.331
95% Adjusted-CLT UCL (Chen-1995)	7.501	97.5% Chebyshev (MVUE) UCL	10.11
95% Modified-t UCL (Johnson-1978)	6.981	99% Chebyshev (MVUE) UCL	13.6
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.89	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	2.287		
MLE of Mean	4.322		
MLE of Standard Deviation	3.144		
nu star	22.68		
Approximate Chi Square Value (.05)	12.85	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0122	95% CLT UCL	6.345
Adjusted Chi Square Value	10.28	95% Jackknife UCL	6.8
		95% Standard Bootstrap UCL	6.221
Anderson-Darling Test Statistic	0.589	95% Bootstrap-t UCL	12.54
Anderson-Darling 5% Critical Value	0.701	95% Hall's Bootstrap UCL	15.46
Kolmogorov-Smirnov Test Statistic	0.284	95% Percentile Bootstrap UCL	6.573
Kolmogorov-Smirnov 5% Critical Value	0.334	95% BCA Bootstrap UCL	6.98
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	9.684
		97.5% Chebyshev(Mean, Sd) UCL	12
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	16.56
95% Approximate Gamma UCL	7.628		
95% Adjusted Gamma UCL	9.533		
Potential UCL to Use		Use 95% Approximate Gamma UCL	7.628

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (total phosphorus)

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	5

Raw Statistics		Log-transformed Statistics	
Minimum	0.0031	Minimum of Log Data	-5.776
Maximum	0.0386	Maximum of Log Data	-3.255
Mean	0.0121	Mean of log Data	-4.842
Median	0.00755	SD of log Data	0.977
SD	0.0136		
Std. Error of Mean	0.00554		
Coefficient of Variation	1.118		
Skewness	2.009		

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.737	Shapiro Wilk Test Statistic	0.909
Shapiro Wilk Critical Value	0.788	Shapiro Wilk Critical Value	0.788
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0233	95% H-UCL	0.0744
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0312
95% Adjusted-CLT UCL (Chen-1995)	0.0261	97.5% Chebyshev (MVUE) UCL	0.0398
95% Modified-t UCL (Johnson-1978)	0.024	99% Chebyshev (MVUE) UCL	0.0565
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.763	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	0.0159		
MLE of Mean	0.0121		
MLE of Standard Deviation	0.0139		
nu star	9.158		
Approximate Chi Square Value (.05)	3.422	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0122	95% CLT UCL	0.0212
Adjusted Chi Square Value	2.285	95% Jackknife UCL	0.0233
		95% Standard Bootstrap UCL	0.0203
Anderson-Darling Test Statistic	0.431	95% Bootstrap-t UCL	0.0372
Anderson-Darling 5% Critical Value	0.711	95% Hall's Bootstrap UCL	0.0554
Kolmogorov-Smirnov Test Statistic	0.216	95% Percentile Bootstrap UCL	0.0212
Kolmogorov-Smirnov 5% Critical Value	0.339	95% BCA Bootstrap UCL	0.0244
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0363
		97.5% Chebyshev(Mean, Sd) UCL	0.0467
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0672
95% Approximate Gamma UCL	0.0325		
95% Adjusted Gamma UCL	0.0486		
Potential UCL to Use		Use 95% Approximate Gamma UCL	0.0325

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	BTEX_sulf pre-process 03.27.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Result (1/2 DL for NDs) (benzene)

General Statistics

Number of Valid Observations	56	Number of Distinct Observations	31
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000113	Minimum of Log Data	-9.088
Maximum	7.14	Maximum of Log Data	1.966
Mean	0.453	Mean of log Data	-6.582
Median	0.00025	SD of log Data	3.418
SD	1.511		
Coefficient of Variation	3.333		
Skewness	3.803		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.442	Lilliefors Test Statistic	0.274
Lilliefors Critical Value	0.118	Lilliefors Critical Value	0.118
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.791	95% H-UCL	7.509
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.147
95% Adjusted-CLT UCL (Chen-1995)	0.895	97.5% Chebyshev (MVUE) UCL	1.526
95% Modified-t UCL (Johnson-1978)	0.808	99% Chebyshev (MVUE) UCL	2.272
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.139	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	3.251		
MLE of Mean	0.453		
MLE of Standard Deviation	1.214		
nu star	15.62		
Approximate Chi Square Value (.05)	7.694	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0457	95% CLT UCL	0.785
Adjusted Chi Square Value	7.547	95% Jackknife UCL	0.791
		95% Standard Bootstrap UCL	0.783
Anderson-Darling Test Statistic	10.12	95% Bootstrap-t UCL	1.17
Anderson-Darling 5% Critical Value	0.955	95% Hall's Bootstrap UCL	0.778
Kolmogorov-Smirnov Test Statistic	0.34	95% Percentile Bootstrap UCL	0.81
Kolmogorov-Smirnov 5% Critical Value	0.134	95% BCA Bootstrap UCL	0.924
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.334
		97.5% Chebyshev(Mean, Sd) UCL	1.714
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.463
95% Approximate Gamma UCL	0.92		
95% Adjusted Gamma UCL	0.938		
Potential UCL to Use		Use 97.5% Chebyshev (Mean, Sd) UCL	1.714

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (ethylbenzene)

General Statistics

Number of Valid Observations	56	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0000877	Minimum of Log Data	-9.342
Maximum	1.24	Maximum of Log Data	0.215
Mean	0.0573	Mean of log Data	-6.757
Median	0.000375	SD of log Data	2.457
SD	0.211		
Coefficient of Variation	3.687		
Skewness	4.663		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.436	Lilliefors Test Statistic	0.277
Lilliefors Critical Value	0.118	Lilliefors Critical Value	0.118
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.105	95% H-UCL	0.107
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.064
95% Adjusted-CLT UCL (Chen-1995)	0.123	97.5% Chebyshev (MVUE) UCL	0.0833
95% Modified-t UCL (Johnson-1978)	0.108	99% Chebyshev (MVUE) UCL	0.121
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.192	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.0573		
MLE of Standard Deviation	0.131		
nu star	21.5		
Approximate Chi Square Value (.05)	11.96	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0457	95% CLT UCL	0.104
Adjusted Chi Square Value	11.78	95% Jackknife UCL	0.105
		95% Standard Bootstrap UCL	0.104
Anderson-Darling Test Statistic	10.15	95% Bootstrap-t UCL	0.208
Anderson-Darling 5% Critical Value	0.916	95% Hall's Bootstrap UCL	0.275
Kolmogorov-Smirnov Test Statistic	0.364	95% Percentile Bootstrap UCL	0.108
Kolmogorov-Smirnov 5% Critical Value	0.132	95% BCA Bootstrap UCL	0.126
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.18
		97.5% Chebyshev(Mean, Sd) UCL	0.234
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.338
95% Approximate Gamma UCL	0.103		
95% Adjusted Gamma UCL	0.105		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.18

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (m,p-xylene)

General Statistics

Number of Valid Observations	56	Number of Distinct Observations	22

Raw Statistics		Log-transformed Statistics	
Minimum	0.00062	Minimum of Log Data	-7.386
Maximum	4.47	Maximum of Log Data	1.497
Mean	0.342	Mean of log Data	-5.579
Median	0.001	SD of log Data	2.892
SD	1.004		
Coefficient of Variation	2.936		
Skewness	3.244		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.434	Lilliefors Test Statistic	0.362
Lilliefors Critical Value	0.118	Lilliefors Critical Value	0.118
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.567	95% H-UCL	1.885
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.668
95% Adjusted-CLT UCL (Chen-1995)	0.625	97.5% Chebyshev (MVUE) UCL	0.88
95% Modified-t UCL (Johnson-1978)	0.576	99% Chebyshev (MVUE) UCL	1.296
Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.171	Data do not follow a Discernable Distribution (0.05)	
Theta Star	2.004		
MLE of Mean	0.342		
MLE of Standard Deviation	0.828		
nu star	19.11		
Approximate Chi Square Value (.05)	10.2	Nonparametric Statistics	
Adjusted Level of Significance	0.0457	95% CLT UCL	0.563
Adjusted Chi Square Value	10.03	95% Jackknife UCL	0.567
		95% Standard Bootstrap UCL	0.561
Anderson-Darling Test Statistic	10.93	95% Bootstrap-t UCL	0.696
Anderson-Darling 5% Critical Value	0.932	95% Hall's Bootstrap UCL	0.556
Kolmogorov-Smirnov Test Statistic	0.402	95% Percentile Bootstrap UCL	0.58
Kolmogorov-Smirnov 5% Critical Value	0.133	95% BCA Bootstrap UCL	0.641
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.927
		97.5% Chebyshev(Mean, Sd) UCL	1.18
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.678
95% Approximate Gamma UCL	0.641		
95% Adjusted Gamma UCL	0.652		
Potential UCL to Use		Use 97.5% Chebyshev (Mean, Sd) UCL	1.18

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (o-xylene)

General Statistics

Number of Valid Observations	56	Number of Distinct Observations	20
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00031	Minimum of Log Data	-8.079
Maximum	1.92	Maximum of Log Data	0.652
Mean	0.0841	Mean of log Data	-6.581
Median	0.00032	SD of log Data	2.444
SD	0.331		
Coefficient of Variation	3.941		
Skewness	4.817		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.427	Lilliefors Test Statistic	0.305
Lilliefors Critical Value	0.118	Lilliefors Critical Value	0.118
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.158	95% H-UCL	0.121
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0739
95% Adjusted-CLT UCL (Chen-1995)	0.187	97.5% Chebyshev (MVUE) UCL	0.096
95% Modified-t UCL (Johnson-1978)	0.163	99% Chebyshev (MVUE) UCL	0.139
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.184	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.457		
MLE of Mean	0.0841		
MLE of Standard Deviation	0.196		
nu star	20.62		
Approximate Chi Square Value (.05)	11.31	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0457	95% CLT UCL	0.157
Adjusted Chi Square Value	11.13	95% Jackknife UCL	0.158
		95% Standard Bootstrap UCL	0.156
Anderson-Darling Test Statistic	11.6	95% Bootstrap-t UCL	0.39
Anderson-Darling 5% Critical Value	0.922	95% Hall's Bootstrap UCL	0.458
Kolmogorov-Smirnov Test Statistic	0.378	95% Percentile Bootstrap UCL	0.164
Kolmogorov-Smirnov 5% Critical Value	0.133	95% BCA Bootstrap UCL	0.199
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.277
		97.5% Chebyshev(Mean, Sd) UCL	0.36
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.524
95% Approximate Gamma UCL	0.153		
95% Adjusted Gamma UCL	0.156		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.277

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (sulfolane)

General Statistics

Number of Valid Observations	78	Number of Distinct Observations	45

Raw Statistics		Log-transformed Statistics	
Minimum	0.0031	Minimum of Log Data	-5.776
Maximum	10.4	Maximum of Log Data	2.342
Mean	0.243	Mean of log Data	-4.031
Median	0.00513	SD of log Data	2.042
SD	1.197		
Coefficient of Variation	4.936		
Skewness	8.176		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.421	Lilliefors Test Statistic	0.241
Lilliefors Critical Value	0.1	Lilliefors Critical Value	0.1
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.468	95% H-UCL	0.322
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.339
95% Adjusted-CLT UCL (Chen-1995)	0.6	97.5% Chebyshev (MVUE) UCL	0.429
95% Modified-t UCL (Johnson-1978)	0.489	99% Chebyshev (MVUE) UCL	0.605
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.267	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.909		
MLE of Mean	0.243		
MLE of Standard Deviation	0.47		
nu star	41.62		
Approximate Chi Square Value (.05)	27.83	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0469	95% CLT UCL	0.466
Adjusted Chi Square Value	27.62	95% Jackknife UCL	0.468
		95% Standard Bootstrap UCL	0.471
Anderson-Darling Test Statistic	9.185	95% Bootstrap-t UCL	1.448
Anderson-Darling 5% Critical Value	0.879	95% Hall's Bootstrap UCL	1.211
Kolmogorov-Smirnov Test Statistic	0.241	95% Percentile Bootstrap UCL	0.495
Kolmogorov-Smirnov 5% Critical Value	0.11	95% BCA Bootstrap UCL	0.674
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.833
		97.5% Chebyshev(Mean, Sd) UCL	1.089
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.591
95% Approximate Gamma UCL	0.363		
95% Adjusted Gamma UCL	0.365		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.833

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (toluene)

General Statistics

Number of Valid Observations	56	Number of Distinct Observations	17
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.000133	Minimum of Log Data	-8.925
Maximum	12.3	Maximum of Log Data	2.51
Mean	0.342	Mean of log Data	-7.213
Median	0.00031	SD of log Data	2.148
SD	1.863		
Coefficient of Variation	5.439		
Skewness	5.764		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.531	Lilliefors Test Statistic	0.286
Lilliefors Critical Value	0.118	Lilliefors Critical Value	0.118
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.759	95% H-UCL	0.0234
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.019
95% Adjusted-CLT UCL (Chen-1995)	0.957	97.5% Chebyshev (MVUE) UCL	0.0244
95% Modified-t UCL (Johnson-1978)	0.791	99% Chebyshev (MVUE) UCL	0.035
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.133	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	2.574		
MLE of Mean	0.342		
MLE of Standard Deviation	0.939		
nu star	14.9		
Approximate Chi Square Value (.05)	7.193	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0457	95% CLT UCL	0.752
Adjusted Chi Square Value	7.051	95% Jackknife UCL	0.759
		95% Standard Bootstrap UCL	0.75
Anderson-Darling Test Statistic	17.47	95% Bootstrap-t UCL	162.9
Anderson-Darling 5% Critical Value	0.96	95% Hall's Bootstrap UCL	150.2
Kolmogorov-Smirnov Test Statistic	0.467	95% Percentile Bootstrap UCL	0.782
Kolmogorov-Smirnov 5% Critical Value	0.134	95% BCA Bootstrap UCL	1.099
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.427
		97.5% Chebyshev(Mean, Sd) UCL	1.897
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.819
95% Approximate Gamma UCL	0.709		
95% Adjusted Gamma UCL	0.724		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	1.427

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (xylenes (total))

General Statistics

Number of Valid Observations	56	Number of Distinct Observations	25

Raw Statistics		Log-transformed Statistics	
Minimum	0.000182	Minimum of Log Data	-8.612
Maximum	6.39	Maximum of Log Data	1.855
Mean	0.428	Mean of log Data	-5.496
Median	0.001	SD of log Data	2.99
SD	1.298		
Coefficient of Variation	3.036		
Skewness	3.521		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.43	Lilliefors Test Statistic	0.365
Lilliefors Critical Value	0.118	Lilliefors Critical Value	0.118
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.718	95% H-UCL	3.095
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.959
95% Adjusted-CLT UCL (Chen-1995)	0.8	97.5% Chebyshev (MVUE) UCL	1.265
95% Modified-t UCL (Johnson-1978)	0.732	99% Chebyshev (MVUE) UCL	1.868
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.167	Data do not follow a Discernable Distribution (0.05)	
Theta Star	2.568		
MLE of Mean	0.428		
MLE of Standard Deviation	1.048		
nu star	18.65		
Approximate Chi Square Value (.05)	9.862	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0457	95% CLT UCL	0.713
Adjusted Chi Square Value	9.692	95% Jackknife UCL	0.718
		95% Standard Bootstrap UCL	0.709
Anderson-Darling Test Statistic	10.3	95% Bootstrap-t UCL	0.926
Anderson-Darling 5% Critical Value	0.935	95% Hall's Bootstrap UCL	0.727
Kolmogorov-Smirnov Test Statistic	0.404	95% Percentile Bootstrap UCL	0.722
Kolmogorov-Smirnov 5% Critical Value	0.133	95% BCA Bootstrap UCL	0.831
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.184
		97.5% Chebyshev(Mean, Sd) UCL	1.511
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.154
95% Approximate Gamma UCL	0.809		
95% Adjusted Gamma UCL	0.823		
Potential UCL to Use		Use 97.5% Chebyshev (Mean, Sd) UCL	1.511

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	MB_0-2 All Transposed.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Result (1/2 DL for NDs) (1,1-dichloroethylene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.0158	Maximum of Log Data	-4.148
Mean	0.00916	Mean of log Data	-4.762
Median	0.00753	SD of log Data	0.375
SD	0.00356		
Coefficient of Variation	0.389		
Skewness	0.666		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.868	Shapiro Wilk Test Statistic	0.901
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0104	95% H-UCL	0.0105
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0121
95% Adjusted-CLT UCL (Chen-1995)	0.0104	97.5% Chebyshev (MVUE) UCL	0.0134
95% Modified-t UCL (Johnson-1978)	0.0104	99% Chebyshev (MVUE) UCL	0.016
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.556	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0014		
MLE of Mean	0.00916		
MLE of Standard Deviation	0.00358		
nu star	340.9		
Approximate Chi Square Value (.05)	299.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0103
Adjusted Chi Square Value	296.5	95% Jackknife UCL	0.0104
		95% Standard Bootstrap UCL	0.0103
Anderson-Darling Test Statistic	1.09	95% Bootstrap-t UCL	0.0105
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	0.0104
Kolmogorov-Smirnov Test Statistic	0.175	95% Percentile Bootstrap UCL	0.0103
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0104
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0122
		97.5% Chebyshev(Mean, Sd) UCL	0.0135
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0161
95% Approximate Gamma UCL	0.0104		
95% Adjusted Gamma UCL	0.0105		
Potential UCL to Use		Use 95% Student's-t UCL	0.0104
		or 95% Modified-t UCL	0.0104

**Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.**

Result (1/2 DL for NDs) (1,2,4-trimethylbenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00975	Minimum of Log Data	-4.63
Maximum	0.0315	Maximum of Log Data	-3.459
Mean	0.0184	Mean of log Data	-4.069
Median	0.0153	SD of log Data	0.389
SD	0.00724		
Coefficient of Variation	0.394		
Skewness	0.54		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.88	Shapiro Wilk Test Statistic	0.906
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0208	95% H-UCL	0.0213
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0246
95% Adjusted-CLT UCL (Chen-1995)	0.0209	97.5% Chebyshev (MVUE) UCL	0.0273
95% Modified-t UCL (Johnson-1978)	0.0208	99% Chebyshev (MVUE) UCL	0.0327
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.211	**Data Follow Appr. Gamma Distribution at 5% Significance Level**	
Theta Star	0.00296		
MLE of Mean	0.0184		
MLE of Standard Deviation	0.00738		
nu star	323		
Approximate Chi Square Value (.05)	282.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0207
Adjusted Chi Square Value	279.9	95% Jackknife UCL	0.0208
		95% Standard Bootstrap UCL	0.0207
Anderson-Darling Test Statistic	0.985	95% Bootstrap-t UCL	0.0211
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	0.0208
Kolmogorov-Smirnov Test Statistic	0.171	95% Percentile Bootstrap UCL	0.0209
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.021
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0246
		97.5% Chebyshev(Mean, Sd) UCL	0.0273
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0325
95% Approximate Gamma UCL	0.021		
95% Adjusted Gamma UCL	0.0212		
Potential UCL to Use		Use 95% Approximate Gamma UCL	0.021

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1,2-dichlorobenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.413
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.53
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.38
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.717
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1,3,5-trimethylbenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23

Raw Statistics		Log-transformed Statistics	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.0223	Maximum of Log Data	-3.803
Mean	0.0104	Mean of log Data	-4.664
Median	0.00898	SD of log Data	0.438
SD	0.00473		
Coefficient of Variation	0.456		
Skewness	0.893		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.893	Shapiro Wilk Test Statistic	0.933
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0119	95% H-UCL	0.0123
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0143
95% Adjusted-CLT UCL (Chen-1995)	0.0121	97.5% Chebyshev (MVUE) UCL	0.0161
95% Modified-t UCL (Johnson-1978)	0.012	99% Chebyshev (MVUE) UCL	0.0195

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	4.864	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	0.00213		
MLE of Mean	0.0104		
MLE of Standard Deviation	0.0047		
nu star	252.9		
Approximate Chi Square Value (.05)	217.1	Nonparametric Statistics	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0119
Adjusted Chi Square Value	214.9	95% Jackknife UCL	0.0119
		95% Standard Bootstrap UCL	0.0118
Anderson-Darling Test Statistic	0.734	95% Bootstrap-t UCL	0.0121
Anderson-Darling 5% Critical Value	0.746	95% Hall's Bootstrap UCL	0.012
Kolmogorov-Smirnov Test Statistic	0.163	95% Percentile Bootstrap UCL	0.0119
Kolmogorov-Smirnov 5% Critical Value	0.172	95% BCA Bootstrap UCL	0.012
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0144
		97.5% Chebyshev(Mean, Sd) UCL	0.0161
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0196
95% Approximate Gamma UCL	0.0121		
95% Adjusted Gamma UCL	0.0122		

Potential UCL to Use		Use 95% Approximate Gamma UCL	0.0121

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1,3-dichlorobenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21

Raw Statistics		Log-transformed Statistics	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.416
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.37
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.719
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.592
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1-methylnaphthalene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	69

Raw Statistics		Log-transformed Statistics	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	3.21	Maximum of Log Data	1.166
Mean	0.082	Mean of log Data	-5.075
Median	0.00332	SD of log Data	1.733
SD	0.374		
Coefficient of Variation	4.556		
Skewness	6.853		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.432	Lilliefors Test Statistic	0.207
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.143	95% H-UCL	0.0467
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0568
95% Adjusted-CLT UCL (Chen-1995)	0.169	97.5% Chebyshev (MVUE) UCL	0.0697
95% Modified-t UCL (Johnson-1978)	0.147	99% Chebyshev (MVUE) UCL	0.095
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.271	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.303		
MLE of Mean	0.082		
MLE of Standard Deviation	0.158		
nu star	56.32		
Approximate Chi Square Value (.05)	40.07	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.142
Adjusted Chi Square Value	39.88	95% Jackknife UCL	0.143
		95% Standard Bootstrap UCL	0.143
Anderson-Darling Test Statistic	17.91	95% Bootstrap-t UCL	0.271
Anderson-Darling 5% Critical Value	0.88	95% Hall's Bootstrap UCL	0.342
Kolmogorov-Smirnov Test Statistic	0.338	95% Percentile Bootstrap UCL	0.155
Kolmogorov-Smirnov 5% Critical Value	0.0965	95% BCA Bootstrap UCL	0.173
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.242
		97.5% Chebyshev(Mean, Sd) UCL	0.311
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.446
95% Approximate Gamma UCL	0.115		
95% Adjusted Gamma UCL	0.116		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.242

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,4,6-trichlorophenol)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.412
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.91
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.447
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.594
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,4-dichlorophenol)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.421
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.94
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.409
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.717
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,4-dimethylphenol)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21

Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.413
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.82
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.508
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.594
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,4-dinitrophenol)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.945	Minimum of Log Data	-0.0566
Maximum	40.7	Maximum of Log Data	3.706
Mean	2.551	Mean of log Data	0.163
Median	0.993	SD of log Data	0.726
SD	7.781		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.278
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	5.157	95% H-UCL	2.104
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	2.531
95% Adjusted-CLT UCL (Chen-1995)	6.691	97.5% Chebyshev (MVUE) UCL	2.971
95% Modified-t UCL (Johnson-1978)	5.412	99% Chebyshev (MVUE) UCL	3.836
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	3.602		
MLE of Mean	2.551		
MLE of Standard Deviation	3.031		
nu star	36.82		
Approximate Chi Square Value (.05)	23.93	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	5.061
Adjusted Chi Square Value	23.24	95% Jackknife UCL	5.157
		95% Standard Bootstrap UCL	5.001
Anderson-Darling Test Statistic	9.147	95% Bootstrap-t UCL	190.1
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	93.68
Kolmogorov-Smirnov Test Statistic	0.528	95% Percentile Bootstrap UCL	5.602
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	7.147
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	9.203
		97.5% Chebyshev(Mean, Sd) UCL	12.08
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	17.73
95% Approximate Gamma UCL	3.925		
95% Adjusted Gamma UCL	4.041		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	9.203

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,4-dinitrotoluene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21

Raw Statistics		Log-transformed Statistics	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.408
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.48
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.62
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.592
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		

Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,6-dinitrotoluene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.419
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.52
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.788
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.594
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2-chlorophenol)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.418
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.66
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.306
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.464
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.593
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2-methylnaphthalene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	72
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	3.66	Maximum of Log Data	1.297
Mean	0.0903	Mean of log Data	-5.072
Median	0.00377	SD of log Data	1.71
SD	0.431		
Coefficient of Variation	4.768		
Skewness	6.808		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.44	Lilliefors Test Statistic	0.204
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.16	95% H-UCL	0.0445
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0543
95% Adjusted-CLT UCL (Chen-1995)	0.19	97.5% Chebyshev (MVUE) UCL	0.0665
95% Modified-t UCL (Johnson-1978)	0.165	99% Chebyshev (MVUE) UCL	0.0904
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.263	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.344		
MLE of Mean	0.0903		
MLE of Standard Deviation	0.176		
nu star	54.64		
Approximate Chi Square Value (.05)	38.65	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.16
Adjusted Chi Square Value	38.46	95% Jackknife UCL	0.16
		95% Standard Bootstrap UCL	0.161
Anderson-Darling Test Statistic	18.85	95% Bootstrap-t UCL	0.282
Anderson-Darling 5% Critical Value	0.884	95% Hall's Bootstrap UCL	0.379
Kolmogorov-Smirnov Test Statistic	0.335	95% Percentile Bootstrap UCL	0.171
Kolmogorov-Smirnov 5% Critical Value	0.0967	95% BCA Bootstrap UCL	0.202
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.274
		97.5% Chebyshev(Mean, Sd) UCL	0.354
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.511
95% Approximate Gamma UCL	0.128		
95% Adjusted Gamma UCL	0.128		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.274

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2-methylphenol (o-cresol))

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21

Raw Statistics		Log-transformed Statistics	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.419
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.52
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.3
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.593
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (3&4-methylphenol (p&m-cresol))

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.312	Minimum of Log Data	-1.165
Maximum	13.4	Maximum of Log Data	2.595
Mean	0.841	Mean of log Data	-0.945
Median	0.328	SD of log Data	0.726
SD	2.562		
Coefficient of Variation	3.047		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.278
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.699	95% H-UCL	0.694
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.835
95% Adjusted-CLT UCL (Chen-1995)	2.204	97.5% Chebyshev (MVUE) UCL	0.98
95% Modified-t UCL (Johnson-1978)	1.783	99% Chebyshev (MVUE) UCL	1.265
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.709	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	1.185		
MLE of Mean	0.841		
MLE of Standard Deviation	0.998		
nu star	36.88		
Approximate Chi Square Value (.05)	23.98	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	1.667
Adjusted Chi Square Value	23.29	95% Jackknife UCL	1.699
		95% Standard Bootstrap UCL	1.651
Anderson-Darling Test Statistic	9.147	95% Bootstrap-t UCL	62.1
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	30.54
Kolmogorov-Smirnov Test Statistic	0.528	95% Percentile Bootstrap UCL	1.843
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	2.354
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	3.031
		97.5% Chebyshev(Mean, Sd) UCL	3.978
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	5.839
95% Approximate Gamma UCL	1.293		
95% Adjusted Gamma UCL	1.331		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	3.031

**Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.**

Result (1/2 DL for NDs) (3,3-dichlorobenzidine)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21

Raw Statistics		Log-transformed Statistics	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.415
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.82
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.41
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.593
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (4-chloroaniline)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	20

Raw Statistics		Log-transformed Statistics	
Minimum	0.151	Minimum of Log Data	-1.89
Maximum	6.5	Maximum of Log Data	1.872
Mean	0.407	Mean of log Data	-1.672
Median	0.159	SD of log Data	0.727
SD	1.243		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.824	95% H-UCL	0.336
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.404
95% Adjusted-CLT UCL (Chen-1995)	1.069	97.5% Chebyshev (MVUE) UCL	0.474
95% Modified-t UCL (Johnson-1978)	0.864	99% Chebyshev (MVUE) UCL	0.612

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.575		
MLE of Mean	0.407		
MLE of Standard Deviation	0.484		
nu star	36.8		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.808
Adjusted Chi Square Value	23.23	95% Jackknife UCL	0.824
		95% Standard Bootstrap UCL	0.809
Anderson-Darling Test Statistic	9.143	95% Bootstrap-t UCL	29.9
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	14.68
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.895
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	1.139
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.47
		97.5% Chebyshev(Mean, Sd) UCL	1.929
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.832
95% Approximate Gamma UCL	0.627		
95% Adjusted Gamma UCL	0.645		

Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	1.47

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (4-isopropyltoluene (p-cymene))

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.0182	Maximum of Log Data	-4.006
Mean	0.0097	Mean of log Data	-4.713
Median	0.00795	SD of log Data	0.4
SD	0.00394		
Coefficient of Variation	0.406		
Skewness	0.598		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.891	Shapiro Wilk Test Statistic	0.913
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.011	95% H-UCL	0.0113
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0131
95% Adjusted-CLT UCL (Chen-1995)	0.0111	97.5% Chebyshev (MVUE) UCL	0.0146
95% Modified-t UCL (Johnson-1978)	0.011	99% Chebyshev (MVUE) UCL	0.0175
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	5.878	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.00165		
MLE of Mean	0.0097		
MLE of Standard Deviation	0.004		
nu star	305.7		
Approximate Chi Square Value (.05)	266.2	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.011
Adjusted Chi Square Value	263.7	95% Jackknife UCL	0.011
		95% Standard Bootstrap UCL	0.011
Anderson-Darling Test Statistic	0.977	95% Bootstrap-t UCL	0.0111
Anderson-Darling 5% Critical Value	0.746	95% Hall's Bootstrap UCL	0.0111
Kolmogorov-Smirnov Test Statistic	0.176	95% Percentile Bootstrap UCL	0.011
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0111
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0131
		97.5% Chebyshev(Mean, Sd) UCL	0.0145
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0174
95% Approximate Gamma UCL	0.0111		
95% Adjusted Gamma UCL	0.0112		
Potential UCL to Use		Use 95% Student's-t UCL	0.011
		or 95% Modified-t UCL	0.011

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (acenaphthene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	53
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00725	Mean of log Data	-5.599
Median	0.00183	SD of log Data	1.029
SD	0.013		
Coefficient of Variation	1.796		
Skewness	4.614		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.338	Lilliefors Test Statistic	0.282
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00937	95% H-UCL	0.00788
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00956
95% Adjusted-CLT UCL (Chen-1995)	0.00997	97.5% Chebyshev (MVUE) UCL	0.011
95% Modified-t UCL (Johnson-1978)	0.00947	99% Chebyshev (MVUE) UCL	0.0138
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.854	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00849		
MLE of Mean	0.00725		
MLE of Standard Deviation	0.00785		
nu star	177.7		
Approximate Chi Square Value (.05)	147.8	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.00935
Adjusted Chi Square Value	147.5	95% Jackknife UCL	0.00937
		95% Standard Bootstrap UCL	0.00936
Anderson-Darling Test Statistic	10.15	95% Bootstrap-t UCL	0.0106
Anderson-Darling 5% Critical Value	0.789	95% Hall's Bootstrap UCL	0.0108
Kolmogorov-Smirnov Test Statistic	0.281	95% Percentile Bootstrap UCL	0.00932
Kolmogorov-Smirnov 5% Critical Value	0.0915	95% BCA Bootstrap UCL	0.01
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0128
		97.5% Chebyshev(Mean, Sd) UCL	0.0152
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.02
95% Approximate Gamma UCL	0.00872		
95% Adjusted Gamma UCL	0.00874		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0128

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (acenaphthylene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	54

Raw Statistics		Log-transformed Statistics	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00728	Mean of log Data	-5.596
Median	0.00183	SD of log Data	1.031
SD	0.013		
Coefficient of Variation	1.791		
Skewness	4.605		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.33	Lilliefors Test Statistic	0.282
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0094	95% H-UCL	0.00793
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00962
95% Adjusted-CLT UCL (Chen-1995)	0.01	97.5% Chebyshev (MVUE) UCL	0.0111
95% Modified-t UCL (Johnson-1978)	0.00949	99% Chebyshev (MVUE) UCL	0.0139
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.853	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00853		
MLE of Mean	0.00728		
MLE of Standard Deviation	0.00788		
nu star	177.5		
Approximate Chi Square Value (.05)	147.7	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.00938
Adjusted Chi Square Value	147.3	95% Jackknife UCL	0.0094
		95% Standard Bootstrap UCL	0.00935
Anderson-Darling Test Statistic	10.05	95% Bootstrap-t UCL	0.0108
Anderson-Darling 5% Critical Value	0.789	95% Hall's Bootstrap UCL	0.0108
Kolmogorov-Smirnov Test Statistic	0.281	95% Percentile Bootstrap UCL	0.0095
Kolmogorov-Smirnov 5% Critical Value	0.0915	95% BCA Bootstrap UCL	0.0102
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0128
		97.5% Chebyshev(Mean, Sd) UCL	0.0153
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.02
95% Approximate Gamma UCL	0.00875		
95% Adjusted Gamma UCL	0.00877		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0128

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (anthracene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	56

Raw Statistics		Log-transformed Statistics	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00753	Mean of log Data	-5.564
Median	0.00188	SD of log Data	1.041
SD	0.0132		
Coefficient of Variation	1.751		
Skewness	4.43		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.338	Lilliefors Test Statistic	0.271
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00968	95% H-UCL	0.0083
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0101
95% Adjusted-CLT UCL (Chen-1995)	0.0103	97.5% Chebyshev (MVUE) UCL	0.0116
95% Modified-t UCL (Johnson-1978)	0.00977	99% Chebyshev (MVUE) UCL	0.0146

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.85	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00886		
MLE of Mean	0.00753		
MLE of Standard Deviation	0.00817		
nu star	176.9		
Approximate Chi Square Value (.05)	147.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.00966
Adjusted Chi Square Value	146.7	95% Jackknife UCL	0.00968
		95% Standard Bootstrap UCL	0.00961
Anderson-Darling Test Statistic	9.585	95% Bootstrap-t UCL	0.011
Anderson-Darling 5% Critical Value	0.789	95% Hall's Bootstrap UCL	0.011
Kolmogorov-Smirnov Test Statistic	0.268	95% Percentile Bootstrap UCL	0.00981
Kolmogorov-Smirnov 5% Critical Value	0.0915	95% BCA Bootstrap UCL	0.0103
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0132
		97.5% Chebyshev(Mean, Sd) UCL	0.0156
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0204
95% Approximate Gamma UCL	0.00906		
95% Adjusted Gamma UCL	0.00908		

Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0132

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (antimony)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	26
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0524	Minimum of Log Data	-2.949
Maximum	0.227	Maximum of Log Data	-1.483
Mean	0.109	Mean of log Data	-2.29
Median	0.0958	SD of log Data	0.389
SD	0.0445		
Coefficient of Variation	0.408		
Skewness	0.949		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.908	Shapiro Wilk Test Statistic	0.963
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.124	95% H-UCL	0.126
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.146
95% Adjusted-CLT UCL (Chen-1995)	0.125	97.5% Chebyshev (MVUE) UCL	0.162
95% Modified-t UCL (Johnson-1978)	0.124	99% Chebyshev (MVUE) UCL	0.194
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.116	**Data appear Gamma Distributed at 5% Significance Level**	
Theta Star	0.0178		
MLE of Mean	0.109		
MLE of Standard Deviation	0.0441		
nu star	318		
Approximate Chi Square Value (.05)	277.7	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.123
Adjusted Chi Square Value	275.2	95% Jackknife UCL	0.124
		95% Standard Bootstrap UCL	0.123
Anderson-Darling Test Statistic	0.497	95% Bootstrap-t UCL	0.127
Anderson-Darling 5% Critical Value	0.746	95% Hall's Bootstrap UCL	0.125
Kolmogorov-Smirnov Test Statistic	0.132	95% Percentile Bootstrap UCL	0.123
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.126
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.147
		97.5% Chebyshev(Mean, Sd) UCL	0.164
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.196
95% Approximate Gamma UCL	0.125		
95% Adjusted Gamma UCL	0.126		
Potential UCL to Use		Use 95% Approximate Gamma UCL	0.125

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (arsenic)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	2.45	Minimum of Log Data	0.896
Maximum	17.6	Maximum of Log Data	2.868
Mean	6.386	Mean of log Data	1.732
Median	5.095	SD of log Data	0.49
SD	3.501		
Coefficient of Variation	0.548		
Skewness	1.54		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.85	Shapiro Wilk Test Statistic	0.954
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	7.559	95% H-UCL	7.72
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	9.104
95% Adjusted-CLT UCL (Chen-1995)	7.737	97.5% Chebyshev (MVUE) UCL	10.3
95% Modified-t UCL (Johnson-1978)	7.594	99% Chebyshev (MVUE) UCL	12.65
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	3.787	**Data appear Gamma Distributed at 5% Significance Level**	
Theta Star	1.687		
MLE of Mean	6.386		
MLE of Standard Deviation	3.282		
nu star	196.9		
Approximate Chi Square Value (.05)	165.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	7.516
Adjusted Chi Square Value	163.5	95% Jackknife UCL	7.559
		95% Standard Bootstrap UCL	7.503
Anderson-Darling Test Statistic	0.684	95% Bootstrap-t UCL	7.853
Anderson-Darling 5% Critical Value	0.747	95% Hall's Bootstrap UCL	8.163
Kolmogorov-Smirnov Test Statistic	0.154	95% Percentile Bootstrap UCL	7.548
Kolmogorov-Smirnov 5% Critical Value	0.172	95% BCA Bootstrap UCL	7.848
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	9.379
		97.5% Chebyshev(Mean, Sd) UCL	10.67
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	13.22
95% Approximate Gamma UCL	7.601		
95% Adjusted Gamma UCL	7.689		
Potential UCL to Use		Use 95% Approximate Gamma UCL	7.601

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (bap teq)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	68
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00351	Minimum of Log Data	-5.651
Maximum	0.225	Maximum of Log Data	-1.492
Mean	0.0178	Mean of log Data	-4.753
Median	0.00421	SD of log Data	1.064
SD	0.0324		
Coefficient of Variation	1.815		
Skewness	4.112		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.345	Lilliefors Test Statistic	0.287
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0231	95% H-UCL	0.0193
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0234
95% Adjusted-CLT UCL (Chen-1995)	0.0244	97.5% Chebyshev (MVUE) UCL	0.0271
95% Modified-t UCL (Johnson-1978)	0.0233	99% Chebyshev (MVUE) UCL	0.0342
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.797	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0224		
MLE of Mean	0.0178		
MLE of Standard Deviation	0.02		
nu star	165.8		
Approximate Chi Square Value (.05)	137.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0231
Adjusted Chi Square Value	136.7	95% Jackknife UCL	0.0231
		95% Standard Bootstrap UCL	0.0231
Anderson-Darling Test Statistic	10.72	95% Bootstrap-t UCL	0.0253
Anderson-Darling 5% Critical Value	0.792	95% Hall's Bootstrap UCL	0.0256
Kolmogorov-Smirnov Test Statistic	0.287	95% Percentile Bootstrap UCL	0.0234
Kolmogorov-Smirnov 5% Critical Value	0.0917	95% BCA Bootstrap UCL	0.025
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0317
		97.5% Chebyshev(Mean, Sd) UCL	0.0377
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0494
95% Approximate Gamma UCL	0.0216		
95% Adjusted Gamma UCL	0.0216		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0317

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	92
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00241	Minimum of Log Data	-6.028
Maximum	0.597	Maximum of Log Data	-0.516
Mean	0.02	Mean of log Data	-5.099
Median	0.00464	SD of log Data	1.011
SD	0.0719		
Coefficient of Variation	3.594		
Skewness	6.262		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.441	Lilliefors Test Statistic	0.243
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0317	95% H-UCL	0.0127
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0153
95% Adjusted-CLT UCL (Chen-1995)	0.0363	97.5% Chebyshev (MVUE) UCL	0.0176
95% Modified-t UCL (Johnson-1978)	0.0325	99% Chebyshev (MVUE) UCL	0.0221
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.521	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0384		
MLE of Mean	0.02		
MLE of Standard Deviation	0.0277		
nu star	108.4		
Approximate Chi Square Value (.05)	85.33	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0316
Adjusted Chi Square Value	85.05	95% Jackknife UCL	0.0317
		95% Standard Bootstrap UCL	0.0313
Anderson-Darling Test Statistic	21.86	95% Bootstrap-t UCL	0.0494
Anderson-Darling 5% Critical Value	0.816	95% Hall's Bootstrap UCL	0.036
Kolmogorov-Smirnov Test Statistic	0.391	95% Percentile Bootstrap UCL	0.0322
Kolmogorov-Smirnov 5% Critical Value	0.0933	95% BCA Bootstrap UCL	0.0376
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0508
		97.5% Chebyshev(Mean, Sd) UCL	0.0641
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0902
95% Approximate Gamma UCL	0.0254		
95% Adjusted Gamma UCL	0.0255		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0508

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(a)anthracene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	55
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00777	Mean of log Data	-5.591
Median	0.00182	SD of log Data	1.068
SD	0.0141		
Coefficient of Variation	1.816		
Skewness	4.062		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.346	Lilliefors Test Statistic	0.286
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0101	95% H-UCL	0.00839
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0102
95% Adjusted-CLT UCL (Chen-1995)	0.0106	97.5% Chebyshev (MVUE) UCL	0.0118
95% Modified-t UCL (Johnson-1978)	0.0102	99% Chebyshev (MVUE) UCL	0.0149
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.792	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00982		
MLE of Mean	0.00777		
MLE of Standard Deviation	0.00873		
nu star	164.6		
Approximate Chi Square Value (.05)	136	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.01
Adjusted Chi Square Value	135.6	95% Jackknife UCL	0.0101
		95% Standard Bootstrap UCL	0.01
Anderson-Darling Test Statistic	10.78	95% Bootstrap-t UCL	0.011
Anderson-Darling 5% Critical Value	0.792	95% Hall's Bootstrap UCL	0.011
Kolmogorov-Smirnov Test Statistic	0.287	95% Percentile Bootstrap UCL	0.0103
Kolmogorov-Smirnov 5% Critical Value	0.0917	95% BCA Bootstrap UCL	0.0107
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0138
		97.5% Chebyshev(Mean, Sd) UCL	0.0164
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0215
95% Approximate Gamma UCL	0.00941		
95% Adjusted Gamma UCL	0.00943		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0138

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(a)pyrene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	55
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00814	Mean of log Data	-5.584
Median	0.00182	SD of log Data	1.084
SD	0.0156		
Coefficient of Variation	1.919		
Skewness	4.131		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.358	Lilliefors Test Statistic	0.285
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0107	95% H-UCL	0.00863
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0105
95% Adjusted-CLT UCL (Chen-1995)	0.0113	97.5% Chebyshev (MVUE) UCL	0.0122
95% Modified-t UCL (Johnson-1978)	0.0108	99% Chebyshev (MVUE) UCL	0.0154
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.755	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0108		
MLE of Mean	0.00814		
MLE of Standard Deviation	0.00937		
nu star	157.1		
Approximate Chi Square Value (.05)	129.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0107
Adjusted Chi Square Value	128.7	95% Jackknife UCL	0.0107
		95% Standard Bootstrap UCL	0.0106
Anderson-Darling Test Statistic	11.08	95% Bootstrap-t UCL	0.0118
Anderson-Darling 5% Critical Value	0.794	95% Hall's Bootstrap UCL	0.0119
Kolmogorov-Smirnov Test Statistic	0.285	95% Percentile Bootstrap UCL	0.0108
Kolmogorov-Smirnov 5% Critical Value	0.0918	95% BCA Bootstrap UCL	0.0116
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0148
		97.5% Chebyshev(Mean, Sd) UCL	0.0177
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0234
95% Approximate Gamma UCL	0.00991		
95% Adjusted Gamma UCL	0.00994		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0148

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(b)fluoranthene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	60
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.108	Maximum of Log Data	-2.226
Mean	0.00843	Mean of log Data	-5.556
Median	0.0019	SD of log Data	1.08
SD	0.0166		
Coefficient of Variation	1.971		
Skewness	4.288		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.365	Lilliefors Test Statistic	0.254
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0111	95% H-UCL	0.00883
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0108
95% Adjusted-CLT UCL (Chen-1995)	0.0118	97.5% Chebyshev (MVUE) UCL	0.0124
95% Modified-t UCL (Johnson-1978)	0.0112	99% Chebyshev (MVUE) UCL	0.0158
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.75	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0112		
MLE of Mean	0.00843		
MLE of Standard Deviation	0.00974		
nu star	155.9		
Approximate Chi Square Value (.05)	128	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0111
Adjusted Chi Square Value	127.7	95% Jackknife UCL	0.0111
		95% Standard Bootstrap UCL	0.0111
Anderson-Darling Test Statistic	10.59	95% Bootstrap-t UCL	0.013
Anderson-Darling 5% Critical Value	0.794	95% Hall's Bootstrap UCL	0.0126
Kolmogorov-Smirnov Test Statistic	0.251	95% Percentile Bootstrap UCL	0.0113
Kolmogorov-Smirnov 5% Critical Value	0.0918	95% BCA Bootstrap UCL	0.0121
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0155
		97.5% Chebyshev(Mean, Sd) UCL	0.0186
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0246
95% Approximate Gamma UCL	0.0103		
95% Adjusted Gamma UCL	0.0103		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0155

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(g,h,i)perylene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	63

Raw Statistics		Log-transformed Statistics	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.186	Maximum of Log Data	-1.682
Mean	0.0118	Mean of log Data	-5.443
Median	0.00194	SD of log Data	1.239
SD	0.0256		
Coefficient of Variation	2.158		
Skewness	4.42		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.358	Lilliefors Test Statistic	0.248
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.016	95% H-UCL	0.0125
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0155
95% Adjusted-CLT UCL (Chen-1995)	0.0171	97.5% Chebyshev (MVUE) UCL	0.0182
95% Modified-t UCL (Johnson-1978)	0.0162	99% Chebyshev (MVUE) UCL	0.0235
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.601	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0197		
MLE of Mean	0.0118		
MLE of Standard Deviation	0.0153		
nu star	124.9		
Approximate Chi Square Value (.05)	100.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.016
Adjusted Chi Square Value	99.8	95% Jackknife UCL	0.016
		95% Standard Bootstrap UCL	0.0159
Anderson-Darling Test Statistic	10.87	95% Bootstrap-t UCL	0.0179
Anderson-Darling 5% Critical Value	0.808	95% Hall's Bootstrap UCL	0.0185
Kolmogorov-Smirnov Test Statistic	0.245	95% Percentile Bootstrap UCL	0.0162
Kolmogorov-Smirnov 5% Critical Value	0.0928	95% BCA Bootstrap UCL	0.0174
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0228
		97.5% Chebyshev(Mean, Sd) UCL	0.0275
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0368
95% Approximate Gamma UCL	0.0148		
95% Adjusted Gamma UCL	0.0148		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0228

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(k)fluoranthene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	55
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00747	Mean of log Data	-5.6
Median	0.00182	SD of log Data	1.05
SD	0.0134		
Coefficient of Variation	1.796		
Skewness	4.316		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.336	Lilliefors Test Statistic	0.287
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00966	95% H-UCL	0.0081
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00984
95% Adjusted-CLT UCL (Chen-1995)	0.0102	97.5% Chebyshev (MVUE) UCL	0.0113
95% Modified-t UCL (Johnson-1978)	0.00975	99% Chebyshev (MVUE) UCL	0.0143
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.821	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00911		
MLE of Mean	0.00747		
MLE of Standard Deviation	0.00825		
nu star	170.7		
Approximate Chi Square Value (.05)	141.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.00964
Adjusted Chi Square Value	141.1	95% Jackknife UCL	0.00966
		95% Standard Bootstrap UCL	0.00954
Anderson-Darling Test Statistic	10.54	95% Bootstrap-t UCL	0.0107
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	0.0111
Kolmogorov-Smirnov Test Statistic	0.287	95% Percentile Bootstrap UCL	0.00973
Kolmogorov-Smirnov 5% Critical Value	0.0916	95% BCA Bootstrap UCL	0.0107
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0132
		97.5% Chebyshev(Mean, Sd) UCL	0.0157
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0206
95% Approximate Gamma UCL	0.00902		
95% Adjusted Gamma UCL	0.00904		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0132

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (bis(2-chloroethyl)ether)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.409
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.47
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.403
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.593
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (bis(2-ethylhexyl)phthalate)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.42
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.81
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.624
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.592
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (chlorobenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23

Raw Statistics		Log-transformed Statistics	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.0158	Maximum of Log Data	-4.148
Mean	0.00916	Mean of log Data	-4.762
Median	0.00753	SD of log Data	0.375
SD	0.00356		
Coefficient of Variation	0.389		
Skewness	0.666		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.868	Shapiro Wilk Test Statistic	0.901
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0104	95% H-UCL	0.0105
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0121
95% Adjusted-CLT UCL (Chen-1995)	0.0104	97.5% Chebyshev (MVUE) UCL	0.0134
95% Modified-t UCL (Johnson-1978)	0.0104	99% Chebyshev (MVUE) UCL	0.016

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	6.556	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0014		
MLE of Mean	0.00916		
MLE of Standard Deviation	0.00358		
nu star	340.9		
Approximate Chi Square Value (.05)	299.1	Nonparametric Statistics	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0103
Adjusted Chi Square Value	296.5	95% Jackknife UCL	0.0104
		95% Standard Bootstrap UCL	0.0103
Anderson-Darling Test Statistic	1.09	95% Bootstrap-t UCL	0.0105
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	0.0103
Kolmogorov-Smirnov Test Statistic	0.175	95% Percentile Bootstrap UCL	0.0103
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0105
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0122
		97.5% Chebyshev(Mean, Sd) UCL	0.0135
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0161
95% Approximate Gamma UCL	0.0104		
95% Adjusted Gamma UCL	0.0105		

Potential UCL to Use		Use 95% Student's-t UCL	0.0104
		or 95% Modified-t UCL	0.0104

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (chromium (total))

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24

Raw Statistics		**Log-transformed Statistics**	
Minimum	8.83	Minimum of Log Data	2.178
Maximum	50.9	Maximum of Log Data	3.93
Mean	16.99	Mean of log Data	2.762
Median	14.9	SD of log Data	0.354
SD	8.051		
Coefficient of Variation	0.474		
Skewness	3.167		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.682	Shapiro Wilk Test Statistic	0.908
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	

Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	19.69	95% H-UCL	19.21
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	22
95% Adjusted-CLT UCL (Chen-1995)	20.63	97.5% Chebyshev (MVUE) UCL	24.25
95% Modified-t UCL (Johnson-1978)	19.85	99% Chebyshev (MVUE) UCL	28.67

Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.429	**Data Follow Appr. Gamma Distribution at 5% Significance Level**	
Theta Star	2.643		
MLE of Mean	16.99		
MLE of Standard Deviation	6.701		
nu star	334.3		
Approximate Chi Square Value (.05)	292.9	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	19.59
Adjusted Chi Square Value	290.4	95% Jackknife UCL	19.69
		95% Standard Bootstrap UCL	19.51
Anderson-Darling Test Statistic	0.986	95% Bootstrap-t UCL	21.53
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	31.31
Kolmogorov-Smirnov Test Statistic	0.148	95% Percentile Bootstrap UCL	19.75
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	20.93
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	23.87
		97.5% Chebyshev(Mean, Sd) UCL	26.85
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	32.7
95% Approximate Gamma UCL	19.39		
95% Adjusted Gamma UCL	19.56		

Potential UCL to Use		Use 95% Approximate Gamma UCL	19.39

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (chrysene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	64

Raw Statistics		Log-transformed Statistics	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.783	Maximum of Log Data	-0.245
Mean	0.0244	Mean of log Data	-5.404
Median	0.00187	SD of log Data	1.381
SD	0.0971		
Coefficient of Variation	3.983		
Skewness	6.473		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.407	Lilliefors Test Statistic	0.249
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0402	95% H-UCL	0.0166
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0206
95% Adjusted-CLT UCL (Chen-1995)	0.0465	97.5% Chebyshev (MVUE) UCL	0.0245
95% Modified-t UCL (Johnson-1978)	0.0412	99% Chebyshev (MVUE) UCL	0.0322
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.386	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0632		
MLE of Mean	0.0244		
MLE of Standard Deviation	0.0393		
nu star	80.27		
Approximate Chi Square Value (.05)	60.63	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0401
Adjusted Chi Square Value	60.39	95% Jackknife UCL	0.0402
		95% Standard Bootstrap UCL	0.0398
Anderson-Darling Test Statistic	16.25	95% Bootstrap-t UCL	0.0753
Anderson-Darling 5% Critical Value	0.845	95% Hall's Bootstrap UCL	0.0969
Kolmogorov-Smirnov Test Statistic	0.307	95% Percentile Bootstrap UCL	0.0403
Kolmogorov-Smirnov 5% Critical Value	0.0949	95% BCA Bootstrap UCL	0.0481
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0659
		97.5% Chebyshev(Mean, Sd) UCL	0.0839
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.119
95% Approximate Gamma UCL	0.0323		
95% Adjusted Gamma UCL	0.0324		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0659

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cis-1,2-dichloroethylene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.0158	Maximum of Log Data	-4.148
Mean	0.00916	Mean of log Data	-4.762
Median	0.00753	SD of log Data	0.375
SD	0.00356		
Coefficient of Variation	0.389		
Skewness	0.666		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.868	Shapiro Wilk Test Statistic	0.901
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0104	95% H-UCL	0.0105
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0121
95% Adjusted-CLT UCL (Chen-1995)	0.0104	97.5% Chebyshev (MVUE) UCL	0.0134
95% Modified-t UCL (Johnson-1978)	0.0104	99% Chebyshev (MVUE) UCL	0.016
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.556	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0014		
MLE of Mean	0.00916		
MLE of Standard Deviation	0.00358		
nu star	340.9		
Approximate Chi Square Value (.05)	299.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0103
Adjusted Chi Square Value	296.5	95% Jackknife UCL	0.0104
		95% Standard Bootstrap UCL	0.0103
Anderson-Darling Test Statistic	1.09	95% Bootstrap-t UCL	0.0104
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	0.0104
Kolmogorov-Smirnov Test Statistic	0.175	95% Percentile Bootstrap UCL	0.0103
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0104
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0122
		97.5% Chebyshev(Mean, Sd) UCL	0.0135
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0161
95% Approximate Gamma UCL	0.0104		
95% Adjusted Gamma UCL	0.0105		
Potential UCL to Use		Use 95% Student's-t UCL	0.0104
		or 95% Modified-t UCL	0.0104

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (copper)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23

Raw Statistics		Log-transformed Statistics	
Minimum	11.4	Minimum of Log Data	2.434
Maximum	37.2	Maximum of Log Data	3.616
Mean	22.27	Mean of log Data	3.059
Median	19.6	SD of log Data	0.303
SD	6.939		
Coefficient of Variation	0.312		
Skewness	0.759		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.92	Shapiro Wilk Test Statistic	0.961
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	24.59	95% H-UCL	24.89
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	28.11
95% Adjusted-CLT UCL (Chen-1995)	24.72	97.5% Chebyshev (MVUE) UCL	30.64
95% Modified-t UCL (Johnson-1978)	24.63	99% Chebyshev (MVUE) UCL	35.61

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	10.09	Data appear Normal at 5% Significance Level	
Theta Star	2.207		
MLE of Mean	22.27		
MLE of Standard Deviation	7.011		
nu star	524.6		
Approximate Chi Square Value (.05)	472.5	Nonparametric Statistics	
Adjusted Level of Significance	0.0398	95% CLT UCL	24.51
Adjusted Chi Square Value	469.2	95% Jackknife UCL	24.59
		95% Standard Bootstrap UCL	24.49
Anderson-Darling Test Statistic	0.573	95% Bootstrap-t UCL	24.8
Anderson-Darling 5% Critical Value	0.744	95% Hall's Bootstrap UCL	24.69
Kolmogorov-Smirnov Test Statistic	0.165	95% Percentile Bootstrap UCL	24.51
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	24.64
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	28.2
		97.5% Chebyshev(Mean, Sd) UCL	30.77
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	35.81
95% Approximate Gamma UCL	24.73		
95% Adjusted Gamma UCL	24.9		

Potential UCL to Use		Use 95% Student's-t UCL	24.59

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cyanide)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	12
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.03	Minimum of Log Data	-3.507
Maximum	0.15	Maximum of Log Data	-1.897
Mean	0.0496	Mean of log Data	-3.141
Median	0.03	SD of log Data	0.492
SD	0.0317		
Coefficient of Variation	0.638		
Skewness	2.059		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.683	Shapiro Wilk Test Statistic	0.767
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0602	95% H-UCL	0.0592
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0699
95% Adjusted-CLT UCL (Chen-1995)	0.0625	97.5% Chebyshev (MVUE) UCL	0.0791
95% Modified-t UCL (Johnson-1978)	0.0606	99% Chebyshev (MVUE) UCL	0.0971
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	3.388	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0146		
MLE of Mean	0.0496		
MLE of Standard Deviation	0.027		
nu star	176.2		
Approximate Chi Square Value (.05)	146.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0598
Adjusted Chi Square Value	144.7	95% Jackknife UCL	0.0602
		95% Standard Bootstrap UCL	0.0599
Anderson-Darling Test Statistic	2.598	95% Bootstrap-t UCL	0.0665
Anderson-Darling 5% Critical Value	0.748	95% Hall's Bootstrap UCL	0.0707
Kolmogorov-Smirnov Test Statistic	0.305	95% Percentile Bootstrap UCL	0.0605
Kolmogorov-Smirnov 5% Critical Value	0.172	95% BCA Bootstrap UCL	0.0636
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0767
		97.5% Chebyshev(Mean, Sd) UCL	0.0884
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.111
95% Approximate Gamma UCL	0.0597		
95% Adjusted Gamma UCL	0.0604		
Potential UCL to Use		Use 95% Student's-t UCL	0.0602
		or 95% Modified-t UCL	0.0606

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cyclohexane)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23

Raw Statistics		Log-transformed Statistics	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.1	Maximum of Log Data	-2.303
Mean	0.0139	Mean of log Data	-4.539
Median	0.0102	SD of log Data	0.585
SD	0.018		
Coefficient of Variation	1.294		
Skewness	4.726		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.386	Shapiro Wilk Test Statistic	0.81
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0199	95% H-UCL	0.0161
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0192
95% Adjusted-CLT UCL (Chen-1995)	0.0232	97.5% Chebyshev (MVUE) UCL	0.0221
95% Modified-t UCL (Johnson-1978)	0.0205	99% Chebyshev (MVUE) UCL	0.0278
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.843	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00754		
MLE of Mean	0.0139		
MLE of Standard Deviation	0.0102		
nu star	95.86		
Approximate Chi Square Value (.05)	74.28	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0197
Adjusted Chi Square Value	73.02	95% Jackknife UCL	0.0199
		95% Standard Bootstrap UCL	0.0194
Anderson-Darling Test Statistic	2.445	95% Bootstrap-t UCL	0.037
Anderson-Darling 5% Critical Value	0.757	95% Hall's Bootstrap UCL	0.0434
Kolmogorov-Smirnov Test Statistic	0.26	95% Percentile Bootstrap UCL	0.0209
Kolmogorov-Smirnov 5% Critical Value	0.173	95% BCA Bootstrap UCL	0.0244
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0293
		97.5% Chebyshev(Mean, Sd) UCL	0.0359
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.049
95% Approximate Gamma UCL	0.0179		
95% Adjusted Gamma UCL	0.0182		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0293

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (dibenzo(a,h)anthracene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	54

Raw Statistics		Log-transformed Statistics	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.0072	Mean of log Data	-5.613
Median	0.00182	SD of log Data	1.03
SD	0.013		
Coefficient of Variation	1.812		
Skewness	4.61		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.337	Lilliefors Test Statistic	0.287
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.00932	95% H-UCL	0.00778
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00943
95% Adjusted-CLT UCL (Chen-1995)	0.00992	97.5% Chebyshev (MVUE) UCL	0.0108
95% Modified-t UCL (Johnson-1978)	0.00942	99% Chebyshev (MVUE) UCL	0.0136

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.846	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.00851		
MLE of Mean	0.0072		
MLE of Standard Deviation	0.00783		
nu star	176		
Approximate Chi Square Value (.05)	146.3	Nonparametric Statistics	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0093
Adjusted Chi Square Value	146	95% Jackknife UCL	0.00932
		95% Standard Bootstrap UCL	0.00927
Anderson-Darling Test Statistic	10.43	95% Bootstrap-t UCL	0.0105
Anderson-Darling 5% Critical Value	0.79	95% Hall's Bootstrap UCL	0.0108
Kolmogorov-Smirnov Test Statistic	0.287	95% Percentile Bootstrap UCL	0.00948
Kolmogorov-Smirnov 5% Critical Value	0.0915	95% BCA Bootstrap UCL	0.0101
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0128
		97.5% Chebyshev(Mean, Sd) UCL	0.0152
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0199
95% Approximate Gamma UCL	0.00866		
95% Adjusted Gamma UCL	0.00868		

Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0128

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (dibenzofuran)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21

Raw Statistics		Log-transformed Statistics	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.415
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.52
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.519
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.593
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (dro)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	6.35	Minimum of Log Data	1.848
Maximum	869	Maximum of Log Data	6.767
Mean	63.25	Mean of log Data	2.899
Median	8.61	SD of log Data	1.317
SD	170.6		
Coefficient of Variation	2.697		
Skewness	4.568		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.364	Shapiro Wilk Test Statistic	0.791
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	120.4	95% H-UCL	93.82
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	96.19
95% Adjusted-CLT UCL (Chen-1995)	150.3	97.5% Chebyshev (MVUE) UCL	120.2
95% Modified-t UCL (Johnson-1978)	125.4	99% Chebyshev (MVUE) UCL	167.2
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.475	Data do not follow a Discernable Distribution (0.05)	
Theta Star	133.3		
MLE of Mean	63.25		
MLE of Standard Deviation	91.81		
nu star	24.68		
Approximate Chi Square Value (.05)	14.37	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	118.3
Adjusted Chi Square Value	13.85	95% Jackknife UCL	120.4
		95% Standard Bootstrap UCL	116.7
Anderson-Darling Test Statistic	3.342	95% Bootstrap-t UCL	327.5
Anderson-Darling 5% Critical Value	0.808	95% Hall's Bootstrap UCL	309.2
Kolmogorov-Smirnov Test Statistic	0.276	95% Percentile Bootstrap UCL	125.2
Kolmogorov-Smirnov 5% Critical Value	0.181	95% BCA Bootstrap UCL	164.3
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	209.1
		97.5% Chebyshev(Mean, Sd) UCL	272.2
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	396.1
95% Approximate Gamma UCL	108.7		
95% Adjusted Gamma UCL	112.7		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	209.1

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (ethylbenzene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	78
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0047	Minimum of Log Data	-5.36
Maximum	2.36	Maximum of Log Data	0.859
Mean	0.0788	Mean of log Data	-4.442
Median	0.00808	SD of log Data	1.221
SD	0.326		
Coefficient of Variation	4.136		
Skewness	5.496		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.48	Lilliefors Test Statistic	0.309
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.132	95% H-UCL	0.0332
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0409
95% Adjusted-CLT UCL (Chen-1995)	0.15	97.5% Chebyshev (MVUE) UCL	0.0479
95% Modified-t UCL (Johnson-1978)	0.135	99% Chebyshev (MVUE) UCL	0.0619
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.349	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.226		
MLE of Mean	0.0788		
MLE of Standard Deviation	0.133		
nu star	72.65		
Approximate Chi Square Value (.05)	54.02	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.131
Adjusted Chi Square Value	53.8	95% Jackknife UCL	0.132
		95% Standard Bootstrap UCL	0.131
Anderson-Darling Test Statistic	27.44	95% Bootstrap-t UCL	0.192
Anderson-Darling 5% Critical Value	0.855	95% Hall's Bootstrap UCL	0.141
Kolmogorov-Smirnov Test Statistic	0.471	95% Percentile Bootstrap UCL	0.137
Kolmogorov-Smirnov 5% Critical Value	0.0953	95% BCA Bootstrap UCL	0.148
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.218
		97.5% Chebyshev(Mean, Sd) UCL	0.279
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.397
95% Approximate Gamma UCL	0.106		
95% Adjusted Gamma UCL	0.106		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.218

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (fluoranthene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	59

Raw Statistics		Log-transformed Statistics	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.119	Maximum of Log Data	-2.129
Mean	0.00872	Mean of log Data	-5.518
Median	0.00186	SD of log Data	1.098
SD	0.0171		
Coefficient of Variation	1.963		
Skewness	4.557		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.337	Lilliefors Test Statistic	0.273
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0115	95% H-UCL	0.00941
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0115
95% Adjusted-CLT UCL (Chen-1995)	0.0123	97.5% Chebyshev (MVUE) UCL	0.0133
95% Modified-t UCL (Johnson-1978)	0.0116	99% Chebyshev (MVUE) UCL	0.0169
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.754	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0116		
MLE of Mean	0.00872		
MLE of Standard Deviation	0.01		
nu star	156.8		
Approximate Chi Square Value (.05)	128.8	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0115
Adjusted Chi Square Value	128.5	95% Jackknife UCL	0.0115
		95% Standard Bootstrap UCL	0.0115
Anderson-Darling Test Statistic	9.771	95% Bootstrap-t UCL	0.0133
Anderson-Darling 5% Critical Value	0.794	95% Hall's Bootstrap UCL	0.0138
Kolmogorov-Smirnov Test Statistic	0.268	95% Percentile Bootstrap UCL	0.0116
Kolmogorov-Smirnov 5% Critical Value	0.0918	95% BCA Bootstrap UCL	0.0123
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.016
		97.5% Chebyshev(Mean, Sd) UCL	0.0192
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0254
95% Approximate Gamma UCL	0.0106		
95% Adjusted Gamma UCL	0.0106		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.016

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (fluorene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	58
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.207	Maximum of Log Data	-1.575
Mean	0.0112	Mean of log Data	-5.478
Median	0.00188	SD of log Data	1.164
SD	0.0297		
Coefficient of Variation	2.658		
Skewness	5.634		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.373	Lilliefors Test Statistic	0.262
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.016	95% H-UCL	0.0108
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0132
95% Adjusted-CLT UCL (Chen-1995)	0.0177	97.5% Chebyshev (MVUE) UCL	0.0155
95% Modified-t UCL (Johnson-1978)	0.0163	99% Chebyshev (MVUE) UCL	0.0198
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.613	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0182		
MLE of Mean	0.0112		
MLE of Standard Deviation	0.0143		
nu star	127.4		
Approximate Chi Square Value (.05)	102.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.016
Adjusted Chi Square Value	102	95% Jackknife UCL	0.016
		95% Standard Bootstrap UCL	0.0159
Anderson-Darling Test Statistic	11.05	95% Bootstrap-t UCL	0.024
Anderson-Darling 5% Critical Value	0.807	95% Hall's Bootstrap UCL	0.0336
Kolmogorov-Smirnov Test Statistic	0.25	95% Percentile Bootstrap UCL	0.0165
Kolmogorov-Smirnov 5% Critical Value	0.0927	95% BCA Bootstrap UCL	0.0178
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0239
		97.5% Chebyshev(Mean, Sd) UCL	0.0294
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0402
95% Approximate Gamma UCL	0.0139		
95% Adjusted Gamma UCL	0.014		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0239

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (gro)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.488	Minimum of Log Data	-0.717
Maximum	5.35	Maximum of Log Data	1.677
Mean	1.162	Mean of log Data	-0.0369
Median	0.771	SD of log Data	0.563
SD	0.968		
Coefficient of Variation	0.833		
Skewness	3.468		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.609	Shapiro Wilk Test Statistic	0.889
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.486	95% H-UCL	1.418
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.69
95% Adjusted-CLT UCL (Chen-1995)	1.612	97.5% Chebyshev (MVUE) UCL	1.936
95% Modified-t UCL (Johnson-1978)	1.507	99% Chebyshev (MVUE) UCL	2.419
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	2.532	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.459		
MLE of Mean	1.162		
MLE of Standard Deviation	0.73		
nu star	131.6		
Approximate Chi Square Value (.05)	106.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	1.474
Adjusted Chi Square Value	104.6	95% Jackknife UCL	1.486
		95% Standard Bootstrap UCL	1.466
Anderson-Darling Test Statistic	1.258	95% Bootstrap-t UCL	1.779
Anderson-Darling 5% Critical Value	0.752	95% Hall's Bootstrap UCL	2.777
Kolmogorov-Smirnov Test Statistic	0.196	95% Percentile Bootstrap UCL	1.508
Kolmogorov-Smirnov 5% Critical Value	0.173	95% BCA Bootstrap UCL	1.656
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.989
		97.5% Chebyshev(Mean, Sd) UCL	2.347
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	3.05
95% Approximate Gamma UCL	1.441		
95% Adjusted Gamma UCL	1.462		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	1.989

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (hexachloro-1,3-butadiene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21

Raw Statistics		Log-transformed Statistics	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.413
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.37
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.589
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.592
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (hexachlorobenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.417
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.64
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.877
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.592
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Appendix B
Soil 2ft UCL

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (hexachlorocyclopentadiene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	19
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.201	Minimum of Log Data	-1.604
Maximum	8.65	Maximum of Log Data	2.158
Mean	0.542	Mean of log Data	-1.385
Median	0.211	SD of log Data	0.726
SD	1.654		
Coefficient of Variation	3.05		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.278
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.096	95% H-UCL	0.447
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.538
95% Adjusted-CLT UCL (Chen-1995)	1.422	97.5% Chebyshev (MVUE) UCL	0.632
95% Modified-t UCL (Johnson-1978)	1.15	99% Chebyshev (MVUE) UCL	0.816
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.765		
MLE of Mean	0.542		
MLE of Standard Deviation	0.644		
nu star	36.84		
Approximate Chi Square Value (.05)	23.94	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	1.076
Adjusted Chi Square Value	23.26	95% Jackknife UCL	1.096
		95% Standard Bootstrap UCL	1.066
Anderson-Darling Test Statistic	9.154	95% Bootstrap-t UCL	40.28
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	19.92
Kolmogorov-Smirnov Test Statistic	0.528	95% Percentile Bootstrap UCL	1.19
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	1.517
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.956
		97.5% Chebyshev(Mean, Sd) UCL	2.568
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	3.769
95% Approximate Gamma UCL	0.834		
95% Adjusted Gamma UCL	0.859		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	1.956

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (hexachloroethane)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.416
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.37
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.679
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.593
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (indeno(1,2,3-c,d)pyrene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	55
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00778	Mean of log Data	-5.593
Median	0.00182	SD of log Data	1.066
SD	0.0144		
Coefficient of Variation	1.848		
Skewness	4.104		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.347	Lilliefors Test Statistic	0.286
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0101	95% H-UCL	0.00834
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0101
95% Adjusted-CLT UCL (Chen-1995)	0.0107	97.5% Chebyshev (MVUE) UCL	0.0117
95% Modified-t UCL (Johnson-1978)	0.0102	99% Chebyshev (MVUE) UCL	0.0148
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.789	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.00986		
MLE of Mean	0.00778		
MLE of Standard Deviation	0.00876		
nu star	164		
Approximate Chi Square Value (.05)	135.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0101
Adjusted Chi Square Value	135.1	95% Jackknife UCL	0.0101
		95% Standard Bootstrap UCL	0.0101
Anderson-Darling Test Statistic	10.8	95% Bootstrap-t UCL	0.0115
Anderson-Darling 5% Critical Value	0.792	95% Hall's Bootstrap UCL	0.011
Kolmogorov-Smirnov Test Statistic	0.286	95% Percentile Bootstrap UCL	0.0102
Kolmogorov-Smirnov 5% Critical Value	0.0917	95% BCA Bootstrap UCL	0.0108
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0139
		97.5% Chebyshev(Mean, Sd) UCL	0.0166
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0218
95% Approximate Gamma UCL	0.00942		
95% Adjusted Gamma UCL	0.00945		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0139

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (iron)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	7790	Minimum of Log Data	8.961
Maximum	29000	Maximum of Log Data	10.28
Mean	15081	Mean of log Data	9.565
Median	12900	SD of log Data	0.333
SD	5471		
Coefficient of Variation	0.363		
Skewness	1.149		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.879	Shapiro Wilk Test Statistic	0.951
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	16914	95% H-UCL	17033
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	19398
95% Adjusted-CLT UCL (Chen-1995)	17104	97.5% Chebyshev (MVUE) UCL	21284
95% Modified-t UCL (Johnson-1978)	16954	99% Chebyshev (MVUE) UCL	24990
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	8.069	**Data Follow Appr. Gamma Distribution at 5% Significance Level**	
Theta Star	1869		
MLE of Mean	15081		
MLE of Standard Deviation	5309		
nu star	419.6		
Approximate Chi Square Value (.05)	373.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	16846
Adjusted Chi Square Value	370.2	95% Jackknife UCL	16914
		95% Standard Bootstrap UCL	16816
Anderson-Darling Test Statistic	0.749	95% Bootstrap-t UCL	17329
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	17053
Kolmogorov-Smirnov Test Statistic	0.166	95% Percentile Bootstrap UCL	16900
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	17282
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	19758
		97.5% Chebyshev(Mean, Sd) UCL	21781
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	25756
95% Approximate Gamma UCL	16960		
95% Adjusted Gamma UCL	17093		
Potential UCL to Use		Use 95% Approximate Gamma UCL	16960

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (isophorone)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.416
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.73
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	8.01
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.593
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (isopropylbenzene (cumene))

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0051	Minimum of Log Data	-5.279
Maximum	0.0158	Maximum of Log Data	-4.148
Mean	0.00928	Mean of log Data	-4.744
Median	0.0079	SD of log Data	0.36
SD	0.00347		
Coefficient of Variation	0.374		
Skewness	0.68		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.871	Shapiro Wilk Test Statistic	0.905
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0104	95% H-UCL	0.0106
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0122
95% Adjusted-CLT UCL (Chen-1995)	0.0105	97.5% Chebyshev (MVUE) UCL	0.0134
95% Modified-t UCL (Johnson-1978)	0.0105	99% Chebyshev (MVUE) UCL	0.0159
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	7.105	**Data Follow Appr. Gamma Distribution at 5% Significance Level**	
Theta Star	0.00131		
MLE of Mean	0.00928		
MLE of Standard Deviation	0.00348		
nu star	369.4		
Approximate Chi Square Value (.05)	325.9	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0104
Adjusted Chi Square Value	323.2	95% Jackknife UCL	0.0104
		95% Standard Bootstrap UCL	0.0104
Anderson-Darling Test Statistic	1.044	95% Bootstrap-t UCL	0.0106
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	0.0104
Kolmogorov-Smirnov Test Statistic	0.159	95% Percentile Bootstrap UCL	0.0104
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0106
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0122
		97.5% Chebyshev(Mean, Sd) UCL	0.0135
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.016
95% Approximate Gamma UCL	0.0105		
95% Adjusted Gamma UCL	0.0106		
Potential UCL to Use		Use 95% Approximate Gamma UCL	0.0105

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (m,p-xylene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	85
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00905	Minimum of Log Data	-4.705
Maximum	8.39	Maximum of Log Data	2.127
Mean	0.172	Mean of log Data	-3.756
Median	0.0159	SD of log Data	1.249
SD	0.876		
Coefficient of Variation	5.084		
Skewness	8.403		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.463	Lilliefors Test Statistic	0.291
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.315	95% H-UCL	0.069
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0851
95% Adjusted-CLT UCL (Chen-1995)	0.389	97.5% Chebyshev (MVUE) UCL	0.1
95% Modified-t UCL (Johnson-1978)	0.327	99% Chebyshev (MVUE) UCL	0.13
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.335	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.514		
MLE of Mean	0.172		
MLE of Standard Deviation	0.298		
nu star	69.7		
Approximate Chi Square Value (.05)	51.48	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.314
Adjusted Chi Square Value	51.26	95% Jackknife UCL	0.315
		95% Standard Bootstrap UCL	0.312
Anderson-Darling Test Statistic	26.84	95% Bootstrap-t UCL	0.681
Anderson-Darling 5% Critical Value	0.858	95% Hall's Bootstrap UCL	0.758
Kolmogorov-Smirnov Test Statistic	0.449	95% Percentile Bootstrap UCL	0.334
Kolmogorov-Smirnov 5% Critical Value	0.0955	95% BCA Bootstrap UCL	0.441
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.547
		97.5% Chebyshev(Mean, Sd) UCL	0.709
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.027
95% Approximate Gamma UCL	0.233		
95% Adjusted Gamma UCL	0.234		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.547

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (methyl tert-butyl ether (mtbe))

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0202	Minimum of Log Data	-3.902
Maximum	0.063	Maximum of Log Data	-2.765
Mean	0.0364	Mean of log Data	-3.382
Median	0.0299	SD of log Data	0.374
SD	0.0141		
Coefficient of Variation	0.388		
Skewness	0.669		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.868	Shapiro Wilk Test Statistic	0.901
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0411	95% H-UCL	0.0419
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0482
95% Adjusted-CLT UCL (Chen-1995)	0.0413	97.5% Chebyshev (MVUE) UCL	0.0534
95% Modified-t UCL (Johnson-1978)	0.0412	99% Chebyshev (MVUE) UCL	0.0635
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.585	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.00553		
MLE of Mean	0.0364		
MLE of Standard Deviation	0.0142		
nu star	342.4		
Approximate Chi Square Value (.05)	300.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.041
Adjusted Chi Square Value	298	95% Jackknife UCL	0.0411
		95% Standard Bootstrap UCL	0.0409
Anderson-Darling Test Statistic	1.089	95% Bootstrap-t UCL	0.0416
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	0.0412
Kolmogorov-Smirnov Test Statistic	0.176	95% Percentile Bootstrap UCL	0.0411
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0414
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0485
		97.5% Chebyshev(Mean, Sd) UCL	0.0537
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.064
95% Approximate Gamma UCL	0.0415		
95% Adjusted Gamma UCL	0.0418		
Potential UCL to Use		Use 95% Student's-t UCL	0.0411
		or 95% Modified-t UCL	0.0412

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (methylene chloride)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0202	Minimum of Log Data	-3.902
Maximum	0.063	Maximum of Log Data	-2.765
Mean	0.0381	Mean of log Data	-3.344
Median	0.0299	SD of log Data	0.398
SD	0.0152		
Coefficient of Variation	0.398		
Skewness	0.418		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.856	Shapiro Wilk Test Statistic	0.875
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0432	95% H-UCL	0.0444
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0514
95% Adjusted-CLT UCL (Chen-1995)	0.0433	97.5% Chebyshev (MVUE) UCL	0.0572
95% Modified-t UCL (Johnson-1978)	0.0432	99% Chebyshev (MVUE) UCL	0.0685
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	5.957	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0064		
MLE of Mean	0.0381		
MLE of Standard Deviation	0.0156		
nu star	309.7		
Approximate Chi Square Value (.05)	270	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.043
Adjusted Chi Square Value	267.5	95% Jackknife UCL	0.0432
		95% Standard Bootstrap UCL	0.0429
Anderson-Darling Test Statistic	1.38	95% Bootstrap-t UCL	0.0434
Anderson-Darling 5% Critical Value	0.746	95% Hall's Bootstrap UCL	0.0432
Kolmogorov-Smirnov Test Statistic	0.206	95% Percentile Bootstrap UCL	0.0432
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0431
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0511
		97.5% Chebyshev(Mean, Sd) UCL	0.0567
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0677
95% Approximate Gamma UCL	0.0437		
95% Adjusted Gamma UCL	0.0441		
Potential UCL to Use		Use 95% Student's-t UCL	0.0432
		or 95% Modified-t UCL	0.0432

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (naphthalene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	65
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.631	Maximum of Log Data	-0.46
Mean	0.0236	Mean of log Data	-5.314
Median	0.00308	SD of log Data	1.356
SD	0.0834		
Coefficient of Variation	3.538		
Skewness	5.564		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.417	Lilliefors Test Statistic	0.2
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0371	95% H-UCL	0.0174
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0215
95% Adjusted-CLT UCL (Chen-1995)	0.0418	97.5% Chebyshev (MVUE) UCL	0.0256
95% Modified-t UCL (Johnson-1978)	0.0379	99% Chebyshev (MVUE) UCL	0.0335
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.412	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0573		
MLE of Mean	0.0236		
MLE of Standard Deviation	0.0367		
nu star	85.61		
Approximate Chi Square Value (.05)	65.28	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.037
Adjusted Chi Square Value	65.04	95% Jackknife UCL	0.0371
		95% Standard Bootstrap UCL	0.0372
Anderson-Darling Test Statistic	15.07	95% Bootstrap-t UCL	0.0502
Anderson-Darling 5% Critical Value	0.839	95% Hall's Bootstrap UCL	0.0408
Kolmogorov-Smirnov Test Statistic	0.304	95% Percentile Bootstrap UCL	0.0376
Kolmogorov-Smirnov 5% Critical Value	0.0945	95% BCA Bootstrap UCL	0.0427
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0592
		97.5% Chebyshev(Mean, Sd) UCL	0.0746
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.105
95% Approximate Gamma UCL	0.0309		
95% Adjusted Gamma UCL	0.031		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0592

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-butylbenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23

Raw Statistics		Log-transformed Statistics	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.0158	Maximum of Log Data	-4.148
Mean	0.0093	Mean of log Data	-4.744
Median	0.00795	SD of log Data	0.369
SD	0.0035		
Coefficient of Variation	0.377		
Skewness	0.599		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.889	Shapiro Wilk Test Statistic	0.919
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0105	95% H-UCL	0.0107
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0123
95% Adjusted-CLT UCL (Chen-1995)	0.0105	97.5% Chebyshev (MVUE) UCL	0.0136
95% Modified-t UCL (Johnson-1978)	0.0105	99% Chebyshev (MVUE) UCL	0.0161

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	6.84	Data Follow Appr. Gamma Distribution at 5% Significance Level	
Theta Star	0.00136		
MLE of Mean	0.0093		
MLE of Standard Deviation	0.00356		
nu star	355.7		
Approximate Chi Square Value (.05)	313	Nonparametric Statistics	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0104
Adjusted Chi Square Value	310.3	95% Jackknife UCL	0.0105
		95% Standard Bootstrap UCL	0.0104
Anderson-Darling Test Statistic	0.83	95% Bootstrap-t UCL	0.0106
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	0.0105
Kolmogorov-Smirnov Test Statistic	0.156	95% Percentile Bootstrap UCL	0.0104
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0105
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0123
		97.5% Chebyshev(Mean, Sd) UCL	0.0136
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0161
95% Approximate Gamma UCL	0.0106		
95% Adjusted Gamma UCL	0.0107		

Potential UCL to Use		Use 95% Approximate Gamma UCL	0.0106

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-hexane)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.116	Maximum of Log Data	-2.154
Mean	0.0157	Mean of log Data	-4.569
Median	0.00795	SD of log Data	0.742
SD	0.0237		
Coefficient of Variation	1.507		
Skewness	3.703		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.441	Shapiro Wilk Test Statistic	0.774
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0236	95% H-UCL	0.0189
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0227
95% Adjusted-CLT UCL (Chen-1995)	0.0269	97.5% Chebyshev (MVUE) UCL	0.0268
95% Modified-t UCL (Johnson-1978)	0.0242	99% Chebyshev (MVUE) UCL	0.0346
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.218	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0129		
MLE of Mean	0.0157		
MLE of Standard Deviation	0.0142		
nu star	63.32		
Approximate Chi Square Value (.05)	46.02	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0233
Adjusted Chi Square Value	45.04	95% Jackknife UCL	0.0236
		95% Standard Bootstrap UCL	0.0233
Anderson-Darling Test Statistic	3.218	95% Bootstrap-t UCL	0.0565
Anderson-Darling 5% Critical Value	0.765	95% Hall's Bootstrap UCL	0.0635
Kolmogorov-Smirnov Test Statistic	0.282	95% Percentile Bootstrap UCL	0.024
Kolmogorov-Smirnov 5% Critical Value	0.175	95% BCA Bootstrap UCL	0.0282
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0359
		97.5% Chebyshev(Mean, Sd) UCL	0.0447
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0619
95% Approximate Gamma UCL	0.0216		
95% Adjusted Gamma UCL	0.0221		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0359

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (nickel)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23
Raw Statistics		**Log-transformed Statistics**	
Minimum	11.2	Minimum of Log Data	2.416
Maximum	28.5	Maximum of Log Data	3.35
Mean	18.63	Mean of log Data	2.893
Median	18.05	SD of log Data	0.257
SD	4.884		
Coefficient of Variation	0.262		
Skewness	0.618		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.938	Shapiro Wilk Test Statistic	0.968
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data appear Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	20.27	95% H-UCL	20.45
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	22.77
95% Adjusted-CLT UCL (Chen-1995)	20.33	97.5% Chebyshev (MVUE) UCL	24.57
95% Modified-t UCL (Johnson-1978)	20.29	99% Chebyshev (MVUE) UCL	28.09
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	13.96	**Data appear Normal at 5% Significance Level**	
Theta Star	1.335		
MLE of Mean	18.63		
MLE of Standard Deviation	4.987		
nu star	725.7		
Approximate Chi Square Value (.05)	664.2	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	20.21
Adjusted Chi Square Value	660.3	95% Jackknife UCL	20.27
		95% Standard Bootstrap UCL	20.17
Anderson-Darling Test Statistic	0.32	95% Bootstrap-t UCL	20.42
Anderson-Darling 5% Critical Value	0.744	95% Hall's Bootstrap UCL	20.33
Kolmogorov-Smirnov Test Statistic	0.0993	95% Percentile Bootstrap UCL	20.22
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	20.37
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	22.81
		97.5% Chebyshev(Mean, Sd) UCL	24.61
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	28.16
95% Approximate Gamma UCL	20.36		
95% Adjusted Gamma UCL	20.48		
Potential UCL to Use		Use 95% Student's-t UCL	20.27

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (nitrobenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.421
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.25
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.587
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.594
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-nitrosodimethylamine)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21

Raw Statistics		Log-transformed Statistics	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	Nonparametric Statistics	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.42
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.5
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.525
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.592
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		

Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-nitroso-di-n-propylamine)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21

Raw Statistics		Log-transformed Statistics	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	Nonparametric Statistics	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.418
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.69
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.668
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.594
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		

Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-nitrosodiphenylamine)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	21
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	3.38	Maximum of Log Data	1.218
Mean	0.212	Mean of log Data	-2.325
Median	0.0823	SD of log Data	0.727
SD	0.646		
Coefficient of Variation	3.051		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.279
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.428	95% H-UCL	0.175
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.21
95% Adjusted-CLT UCL (Chen-1995)	0.556	97.5% Chebyshev (MVUE) UCL	0.247
95% Modified-t UCL (Johnson-1978)	0.449	99% Chebyshev (MVUE) UCL	0.319
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.708	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.299		
MLE of Mean	0.212		
MLE of Standard Deviation	0.252		
nu star	36.81		
Approximate Chi Square Value (.05)	23.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.42
Adjusted Chi Square Value	23.24	95% Jackknife UCL	0.428
		95% Standard Bootstrap UCL	0.414
Anderson-Darling Test Statistic	9.138	95% Bootstrap-t UCL	15.23
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	7.658
Kolmogorov-Smirnov Test Statistic	0.527	95% Percentile Bootstrap UCL	0.465
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	0.592
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.764
		97.5% Chebyshev(Mean, Sd) UCL	1.003
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.473
95% Approximate Gamma UCL	0.326		
95% Adjusted Gamma UCL	0.336		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-propylbenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23

Raw Statistics		Log-transformed Statistics	
Minimum	0.0051	Minimum of Log Data	-5.279
Maximum	0.0158	Maximum of Log Data	-4.148
Mean	0.00942	Mean of log Data	-4.726
Median	0.0082	SD of log Data	0.352
SD	0.00341		
Coefficient of Variation	0.362		
Skewness	0.621		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.892	Shapiro Wilk Test Statistic	0.924
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0106	95% H-UCL	0.0107
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0123
95% Adjusted-CLT UCL (Chen-1995)	0.0106	97.5% Chebyshev (MVUE) UCL	0.0136
95% Modified-t UCL (Johnson-1978)	0.0106	99% Chebyshev (MVUE) UCL	0.016

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	7.464	Data Follow Appr. Gamma Distribution at 5% Significance Level	
Theta Star	0.00126		
MLE of Mean	0.00942		
MLE of Standard Deviation	0.00345		
nu star	388.1		
Approximate Chi Square Value (.05)	343.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0105
Adjusted Chi Square Value	340.7	95% Jackknife UCL	0.0106
		95% Standard Bootstrap UCL	0.0105
Anderson-Darling Test Statistic	0.794	95% Bootstrap-t UCL	0.0107
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	0.0106
Kolmogorov-Smirnov Test Statistic	0.141	95% Percentile Bootstrap UCL	0.0105
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0106
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0123
		97.5% Chebyshev(Mean, Sd) UCL	0.0136
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0161
95% Approximate Gamma UCL	0.0106		
95% Adjusted Gamma UCL	0.0107		

Potential UCL to Use		Use 95% Approximate Gamma UCL	0.0106

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (o-xylene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	82
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00446	Minimum of Log Data	-5.413
Maximum	2.98	Maximum of Log Data	1.092
Mean	0.0713	Mean of log Data	-4.428
Median	0.00823	SD of log Data	1.168
SD	0.349		
Coefficient of Variation	4.894		
Skewness	7.211		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.447	Lilliefors Test Statistic	0.271
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.128	95% H-UCL	0.031
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.038
95% Adjusted-CLT UCL (Chen-1995)	0.153	97.5% Chebyshev (MVUE) UCL	0.0444
95% Modified-t UCL (Johnson-1978)	0.132	99% Chebyshev (MVUE) UCL	0.0569
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.368	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.194		
MLE of Mean	0.0713		
MLE of Standard Deviation	0.118		
nu star	76.57		
Approximate Chi Square Value (.05)	57.41	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.128
Adjusted Chi Square Value	57.18	95% Jackknife UCL	0.128
		95% Standard Bootstrap UCL	0.127
Anderson-Darling Test Statistic	25.23	95% Bootstrap-t UCL	0.348
Anderson-Darling 5% Critical Value	0.85	95% Hall's Bootstrap UCL	0.371
Kolmogorov-Smirnov Test Statistic	0.431	95% Percentile Bootstrap UCL	0.137
Kolmogorov-Smirnov 5% Critical Value	0.0951	95% BCA Bootstrap UCL	0.173
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.22
		97.5% Chebyshev(Mean, Sd) UCL	0.285
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.412
95% Approximate Gamma UCL	0.0951		
95% Adjusted Gamma UCL	0.0955		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.22

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (pentachlorophenol)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	19
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.625	Minimum of Log Data	-0.47
Maximum	26.9	Maximum of Log Data	3.292
Mean	1.685	Mean of log Data	-0.253
Median	0.655	SD of log Data	0.727
SD	5.143		
Coefficient of Variation	3.053		
Skewness	5.098		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.209	Shapiro Wilk Test Statistic	0.277
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	3.408	95% H-UCL	1.389
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.671
95% Adjusted-CLT UCL (Chen-1995)	4.421	97.5% Chebyshev (MVUE) UCL	1.961
95% Modified-t UCL (Johnson-1978)	3.576	99% Chebyshev (MVUE) UCL	2.532
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.707	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	2.382		
MLE of Mean	1.685		
MLE of Standard Deviation	2.003		
nu star	36.78		
Approximate Chi Square Value (.05)	23.9	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	3.344
Adjusted Chi Square Value	23.21	95% Jackknife UCL	3.408
		95% Standard Bootstrap UCL	3.304
Anderson-Darling Test Statistic	9.164	95% Bootstrap-t UCL	125.8
Anderson-Darling 5% Critical Value	0.783	95% Hall's Bootstrap UCL	60.46
Kolmogorov-Smirnov Test Statistic	0.529	95% Percentile Bootstrap UCL	3.702
Kolmogorov-Smirnov 5% Critical Value	0.178	95% BCA Bootstrap UCL	4.72
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	6.081
		97.5% Chebyshev(Mean, Sd) UCL	7.984
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	11.72
95% Approximate Gamma UCL	2.593		
95% Adjusted Gamma UCL	2.669		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	6.081

**Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.**

Result (1/2 DL for NDs) (phenanthrene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	65

Raw Statistics		Log-transformed Statistics	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.675	Maximum of Log Data	-0.393
Mean	0.0233	Mean of log Data	-5.304
Median	0.00246	SD of log Data	1.411
SD	0.0806		
Coefficient of Variation	3.457		
Skewness	6.332		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.393	Lilliefors Test Statistic	0.245
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0365	95% H-UCL	0.0194
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.024
95% Adjusted-CLT UCL (Chen-1995)	0.0416	97.5% Chebyshev (MVUE) UCL	0.0287
95% Modified-t UCL (Johnson-1978)	0.0373	99% Chebyshev (MVUE) UCL	0.0378
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.416	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.056		
MLE of Mean	0.0233		
MLE of Standard Deviation	0.0362		
nu star	86.58		
Approximate Chi Square Value (.05)	66.13	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0363
Adjusted Chi Square Value	65.88	95% Jackknife UCL	0.0365
		95% Standard Bootstrap UCL	0.0362
Anderson-Darling Test Statistic	13.61	95% Bootstrap-t UCL	0.0534
Anderson-Darling 5% Critical Value	0.838	95% Hall's Bootstrap UCL	0.0829
Kolmogorov-Smirnov Test Statistic	0.285	95% Percentile Bootstrap UCL	0.0371
Kolmogorov-Smirnov 5% Critical Value	0.0945	95% BCA Bootstrap UCL	0.044
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0578
		97.5% Chebyshev(Mean, Sd) UCL	0.0727
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.102
95% Approximate Gamma UCL	0.0305		
95% Adjusted Gamma UCL	0.0307		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0578

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (pyrene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	60

Raw Statistics		Log-transformed Statistics	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	0.106	Maximum of Log Data	-2.244
Mean	0.00865	Mean of log Data	-5.527
Median	0.00186	SD of log Data	1.103
SD	0.0164		
Coefficient of Variation	1.897		
Skewness	4.236		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.351	Lilliefors Test Statistic	0.269
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0113	95% H-UCL	0.00938
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0115
95% Adjusted-CLT UCL (Chen-1995)	0.012	97.5% Chebyshev (MVUE) UCL	0.0133
95% Modified-t UCL (Johnson-1978)	0.0114	99% Chebyshev (MVUE) UCL	0.0169
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.752	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0115		
MLE of Mean	0.00865		
MLE of Standard Deviation	0.00997		
nu star	156.5		
Approximate Chi Square Value (.05)	128.6	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0113
Adjusted Chi Square Value	128.2	95% Jackknife UCL	0.0113
		95% Standard Bootstrap UCL	0.0112
Anderson-Darling Test Statistic	9.757	95% Bootstrap-t UCL	0.0125
Anderson-Darling 5% Critical Value	0.794	95% Hall's Bootstrap UCL	0.0132
Kolmogorov-Smirnov Test Statistic	0.266	95% Percentile Bootstrap UCL	0.0114
Kolmogorov-Smirnov 5% Critical Value	0.0918	95% BCA Bootstrap UCL	0.0122
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0157
		97.5% Chebyshev(Mean, Sd) UCL	0.0187
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0247
95% Approximate Gamma UCL	0.0105		
95% Adjusted Gamma UCL	0.0106		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0157

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (rro)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	26
Raw Statistics		**Log-transformed Statistics**	
Minimum	6.35	Minimum of Log Data	1.848
Maximum	8450	Maximum of Log Data	9.042
Mean	445.1	Mean of log Data	4.15
Median	53.75	SD of log Data	1.626
SD	1647		
Coefficient of Variation	3.701		
Skewness	4.962		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.274	Shapiro Wilk Test Statistic	0.926
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	996.9	95% H-UCL	720.6
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	589.6
95% Adjusted-CLT UCL (Chen-1995)	1312	97.5% Chebyshev (MVUE) UCL	752
95% Modified-t UCL (Johnson-1978)	1049	99% Chebyshev (MVUE) UCL	1071
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.332	**Data appear Lognormal at 5% Significance Level**	
Theta Star	1342		
MLE of Mean	445.1		
MLE of Standard Deviation	772.9		
nu star	17.24		
Approximate Chi Square Value (.05)	8.846	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	976.5
Adjusted Chi Square Value	8.45	95% Jackknife UCL	996.9
		95% Standard Bootstrap UCL	966.4
Anderson-Darling Test Statistic	3.288	95% Bootstrap-t UCL	6305
Anderson-Darling 5% Critical Value	0.842	95% Hall's Bootstrap UCL	4097
Kolmogorov-Smirnov Test Statistic	0.322	95% Percentile Bootstrap UCL	1071
Kolmogorov-Smirnov 5% Critical Value	0.185	95% BCA Bootstrap UCL	1455
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1853
		97.5% Chebyshev(Mean, Sd) UCL	2463
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	3659
95% Approximate Gamma UCL	867.6		
95% Adjusted Gamma UCL	908.3		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	1853

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (selenium)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.138	Minimum of Log Data	-1.981
Maximum	0.625	Maximum of Log Data	-0.47
Mean	0.251	Mean of log Data	-1.49
Median	0.196	SD of log Data	0.448
SD	0.131		
Coefficient of Variation	0.522		
Skewness	1.478		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.801	Shapiro Wilk Test Statistic	0.878
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.295	95% H-UCL	0.296
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.346
95% Adjusted-CLT UCL (Chen-1995)	0.301	97.5% Chebyshev (MVUE) UCL	0.389
95% Modified-t UCL (Johnson-1978)	0.296	99% Chebyshev (MVUE) UCL	0.472
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	4.337	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0578		
MLE of Mean	0.251		
MLE of Standard Deviation	0.12		
nu star	225.5		
Approximate Chi Square Value (.05)	191.7	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.293
Adjusted Chi Square Value	189.7	95% Jackknife UCL	0.295
		95% Standard Bootstrap UCL	0.293
Anderson-Darling Test Statistic	1.38	95% Bootstrap-t UCL	0.308
Anderson-Darling 5% Critical Value	0.747	95% Hall's Bootstrap UCL	0.301
Kolmogorov-Smirnov Test Statistic	0.197	95% Percentile Bootstrap UCL	0.294
Kolmogorov-Smirnov 5% Critical Value	0.172	95% BCA Bootstrap UCL	0.299
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.363
		97.5% Chebyshev(Mean, Sd) UCL	0.411
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.506
95% Approximate Gamma UCL	0.295		
95% Adjusted Gamma UCL	0.298		
Potential UCL to Use		Use 95% Student's-t UCL	0.295
		or 95% Modified-t UCL	0.296

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (sulfolane)

General Statistics

Number of Valid Observations	99	Number of Distinct Observations	49
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00313	Minimum of Log Data	-5.767
Maximum	0.0377	Maximum of Log Data	-3.278
Mean	0.00449	Mean of log Data	-5.562
Median	0.00326	SD of log Data	0.433
SD	0.00444		
Coefficient of Variation	0.99		
Skewness	5.678		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.399	Lilliefors Test Statistic	0.339
Lilliefors Critical Value	0.089	Lilliefors Critical Value	0.089
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00523	95% H-UCL	0.00457
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00505
95% Adjusted-CLT UCL (Chen-1995)	0.00549	97.5% Chebyshev (MVUE) UCL	0.00541
95% Modified-t UCL (Johnson-1978)	0.00527	99% Chebyshev (MVUE) UCL	0.00611
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	3.289	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.00136		
MLE of Mean	0.00449		
MLE of Standard Deviation	0.00247		
nu star	651.3		
Approximate Chi Square Value (.05)	593.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0476	95% CLT UCL	0.00522
Adjusted Chi Square Value	592.2	95% Jackknife UCL	0.00523
		95% Standard Bootstrap UCL	0.0052
Anderson-Darling Test Statistic	21.77	95% Bootstrap-t UCL	0.00597
Anderson-Darling 5% Critical Value	0.758	95% Hall's Bootstrap UCL	0.00829
Kolmogorov-Smirnov Test Statistic	0.376	95% Percentile Bootstrap UCL	0.0053
Kolmogorov-Smirnov 5% Critical Value	0.0904	95% BCA Bootstrap UCL	0.00564
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.00643
		97.5% Chebyshev(Mean, Sd) UCL	0.00727
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.00893
95% Approximate Gamma UCL	0.00493		
95% Adjusted Gamma UCL	0.00493		
Potential UCL to Use		Use 95% Student's-t UCL	0.00523
		or 95% Modified-t UCL	0.00527

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (tert-butylbenzene)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	23

Raw Statistics		Log-transformed Statistics	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	0.0158	Maximum of Log Data	-4.148
Mean	0.00916	Mean of log Data	-4.762
Median	0.00753	SD of log Data	0.375
SD	0.00356		
Coefficient of Variation	0.389		
Skewness	0.666		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.868	Shapiro Wilk Test Statistic	0.901
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	

Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	0.0104	95% H-UCL	0.0105
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0121
95% Adjusted-CLT UCL (Chen-1995)	0.0104	97.5% Chebyshev (MVUE) UCL	0.0134
95% Modified-t UCL (Johnson-1978)	0.0104	99% Chebyshev (MVUE) UCL	0.016

Gamma Distribution Test		Data Distribution	
k star (bias corrected)	6.556	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0014		
MLE of Mean	0.00916		
MLE of Standard Deviation	0.00358		
nu star	340.9		
Approximate Chi Square Value (.05)	299.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	0.0103
Adjusted Chi Square Value	296.5	95% Jackknife UCL	0.0104
		95% Standard Bootstrap UCL	0.0103
Anderson-Darling Test Statistic	1.09	95% Bootstrap-t UCL	0.0104
Anderson-Darling 5% Critical Value	0.745	95% Hall's Bootstrap UCL	0.0104
Kolmogorov-Smirnov Test Statistic	0.175	95% Percentile Bootstrap UCL	0.0103
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	0.0104
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0122
		97.5% Chebyshev(Mean, Sd) UCL	0.0135
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0161
95% Approximate Gamma UCL	0.0104		
95% Adjusted Gamma UCL	0.0105		

Potential UCL to Use			
		Use 95% Student's-t UCL	0.0104
		or 95% Modified-t UCL	0.0104

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (toluene)

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	90
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0047	Minimum of Log Data	-5.36
Maximum	1.04	Maximum of Log Data	0.0392
Mean	0.0318	Mean of log Data	-4.434
Median	0.0098	SD of log Data	0.904
SD	0.116		
Coefficient of Variation	3.658		
Skewness	7.328		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.445	Lilliefors Test Statistic	0.232
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0507	95% H-UCL	0.0216
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0258
95% Adjusted-CLT UCL (Chen-1995)	0.0593	97.5% Chebyshev (MVUE) UCL	0.0293
95% Modified-t UCL (Johnson-1978)	0.0521	99% Chebyshev (MVUE) UCL	0.0361
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.612	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0519		
MLE of Mean	0.0318		
MLE of Standard Deviation	0.0406		
nu star	127.3		
Approximate Chi Square Value (.05)	102.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.0505
Adjusted Chi Square Value	101.9	95% Jackknife UCL	0.0507
		95% Standard Bootstrap UCL	0.0493
Anderson-Darling Test Statistic	20.89	95% Bootstrap-t UCL	0.104
Anderson-Darling 5% Critical Value	0.807	95% Hall's Bootstrap UCL	0.118
Kolmogorov-Smirnov Test Statistic	0.377	95% Percentile Bootstrap UCL	0.053
Kolmogorov-Smirnov 5% Critical Value	0.0927	95% BCA Bootstrap UCL	0.0632
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0815
		97.5% Chebyshev(Mean, Sd) UCL	0.103
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.145
95% Approximate Gamma UCL	0.0396		
95% Adjusted Gamma UCL	0.0397		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0815

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Appendix B
Soil 2ft UCL

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (xylenes (total))

General Statistics

Number of Valid Observations	104	Number of Distinct Observations	95
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0138	Minimum of Log Data	-4.287
Maximum	10.3	Maximum of Log Data	2.332
Mean	0.244	Mean of log Data	-3.334
Median	0.024	SD of log Data	1.232
SD	1.159		
Std. Error of Mean	0.114		
Coefficient of Variation	4.757		
Skewness	7.376		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.456	Lilliefors Test Statistic	0.291
Lilliefors Critical Value	0.0869	Lilliefors Critical Value	0.0869
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.432	95% H-UCL	0.102
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.126
95% Adjusted-CLT UCL (Chen-1995)	0.518	97.5% Chebyshev (MVUE) UCL	0.148
95% Modified-t UCL (Johnson-1978)	0.446	99% Chebyshev (MVUE) UCL	0.191
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.346	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.704		
MLE of Mean	0.244		
MLE of Standard Deviation	0.414		
nu star	72		
Approximate Chi Square Value (.05)	53.46	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	0.431
Adjusted Chi Square Value	53.24	95% Jackknife UCL	0.432
		95% Standard Bootstrap UCL	0.429
Anderson-Darling Test Statistic	26.34	95% Bootstrap-t UCL	0.989
Anderson-Darling 5% Critical Value	0.855	95% Hall's Bootstrap UCL	1.106
Kolmogorov-Smirnov Test Statistic	0.448	95% Percentile Bootstrap UCL	0.447
Kolmogorov-Smirnov 5% Critical Value	0.0954	95% BCA Bootstrap UCL	0.579
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.739
		97.5% Chebyshev(Mean, Sd) UCL	0.953
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.375
95% Approximate Gamma UCL	0.328		
95% Adjusted Gamma UCL	0.33		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.739

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (zinc)

General Statistics

Number of Valid Observations	26	Number of Distinct Observations	24
Raw Statistics		**Log-transformed Statistics**	
Minimum	20.9	Minimum of Log Data	3.04
Maximum	63.8	Maximum of Log Data	4.156
Mean	40.39	Mean of log Data	3.66
Median	36.65	SD of log Data	0.282
SD	11.54		
Coefficient of Variation	0.286		
Skewness	0.573		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.928	Shapiro Wilk Test Statistic	0.956
Shapiro Wilk Critical Value	0.92	Shapiro Wilk Critical Value	0.92
Data appear Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	44.25	95% H-UCL	44.79
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	50.26
95% Adjusted-CLT UCL (Chen-1995)	44.38	97.5% Chebyshev (MVUE) UCL	54.54
95% Modified-t UCL (Johnson-1978)	44.3	99% Chebyshev (MVUE) UCL	62.94
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	11.69	**Data appear Normal at 5% Significance Level**	
Theta Star	3.456		
MLE of Mean	40.39		
MLE of Standard Deviation	11.81		
nu star	607.8		
Approximate Chi Square Value (.05)	551.6	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0398	95% CLT UCL	44.11
Adjusted Chi Square Value	548	95% Jackknife UCL	44.25
		95% Standard Bootstrap UCL	44.13
Anderson-Darling Test Statistic	0.614	95% Bootstrap-t UCL	44.72
Anderson-Darling 5% Critical Value	0.744	95% Hall's Bootstrap UCL	44.41
Kolmogorov-Smirnov Test Statistic	0.177	95% Percentile Bootstrap UCL	44.17
Kolmogorov-Smirnov 5% Critical Value	0.171	95% BCA Bootstrap UCL	44.04
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	50.25
		97.5% Chebyshev(Mean, Sd) UCL	54.52
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	62.9
95% Approximate Gamma UCL	44.5		
95% Adjusted Gamma UCL	44.79		
Potential UCL to Use		Use 95% Student's-t UCL	44.25

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

General UCL Statistics for Data Sets with Non-Detects

User Selected Options

From File	MB_0-15 All Transposed.wst
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Result (1/2 DL for NDs) (1,1-dichloroethylene)

General Statistics

Number of Valid Observations	63	Number of Distinct Observations	54
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00431	Minimum of Log Data	-5.447
Maximum	0.68	Maximum of Log Data	-0.386
Mean	0.025	Mean of log Data	-4.532
Median	0.0082	SD of log Data	0.877
SD	0.0859		
Coefficient of Variation	3.432		
Skewness	7.388		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.432	Lilliefors Test Statistic	0.22
Lilliefors Critical Value	0.112	Lilliefors Critical Value	0.112
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0431	95% H-UCL	0.0201
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0243
95% Adjusted-CLT UCL (Chen-1995)	0.0536	97.5% Chebyshev (MVUE) UCL	0.0281
95% Modified-t UCL (Johnson-1978)	0.0448	99% Chebyshev (MVUE) UCL	0.0354
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.69	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0363		
MLE of Mean	0.025		
MLE of Standard Deviation	0.0301		
nu star	86.96		
Approximate Chi Square Value (.05)	66.47	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0462	95% CLT UCL	0.0429
Adjusted Chi Square Value	66.05	95% Jackknife UCL	0.0431
		95% Standard Bootstrap UCL	0.0426
Anderson-Darling Test Statistic	10.99	95% Bootstrap-t UCL	0.109
Anderson-Darling 5% Critical Value	0.796	95% Hall's Bootstrap UCL	0.101
Kolmogorov-Smirnov Test Statistic	0.37	95% Percentile Bootstrap UCL	0.0458
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.0581
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0722
		97.5% Chebyshev(Mean, Sd) UCL	0.0927
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.133
95% Approximate Gamma UCL	0.0328		
95% Adjusted Gamma UCL	0.033		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0722

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1,2,4-trimethylbenzene)

General Statistics

Number of Valid Observations	90	Number of Distinct Observations	84
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0062	Minimum of Log Data	-5.083
Maximum	205	Maximum of Log Data	5.323
Mean	8.812	Mean of log Data	-2.376
Median	0.023	SD of log Data	2.968
SD	28.77		
Coefficient of Variation	3.265		
Skewness	4.913		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.405	Lilliefors Test Statistic	0.328
Lilliefors Critical Value	0.0934	Lilliefors Critical Value	0.0934
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	13.85	95% H-UCL	33.02
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	20.86
95% Adjusted-CLT UCL (Chen-1995)	15.48	97.5% Chebyshev (MVUE) UCL	27.28
95% Modified-t UCL (Johnson-1978)	14.11	99% Chebyshev (MVUE) UCL	39.9
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.168	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	52.41		
MLE of Mean	8.812		
MLE of Standard Deviation	21.49		
nu star	30.27		
Approximate Chi Square Value (.05)	18.7	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0473	95% CLT UCL	13.8
Adjusted Chi Square Value	18.56	95% Jackknife UCL	13.85
		95% Standard Bootstrap UCL	13.69
Anderson-Darling Test Statistic	16.66	95% Bootstrap-t UCL	18.32
Anderson-Darling 5% Critical Value	0.945	95% Hall's Bootstrap UCL	16.13
Kolmogorov-Smirnov Test Statistic	0.396	95% Percentile Bootstrap UCL	14.24
Kolmogorov-Smirnov 5% Critical Value	0.106	95% BCA Bootstrap UCL	15.94
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	22.03
		97.5% Chebyshev(Mean, Sd) UCL	27.75
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	38.99
95% Approximate Gamma UCL	14.26		
95% Adjusted Gamma UCL	14.37		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	22.03

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1,2-dichlorobenzene)

General Statistics

Number of Valid Observations	63	Number of Distinct Observations	38
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.06	Minimum of Log Data	-2.813
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.221	Mean of log Data	-2.283
Median	0.084	SD of log Data	0.753
SD	0.668		
Coefficient of Variation	3.024		
Skewness	5.411		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.426
Lilliefors Critical Value	0.112	Lilliefors Critical Value	0.112
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.362	95% H-UCL	0.165
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.197
95% Adjusted-CLT UCL (Chen-1995)	0.421	97.5% Chebyshev (MVUE) UCL	0.223
95% Modified-t UCL (Johnson-1978)	0.371	99% Chebyshev (MVUE) UCL	0.276
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.745	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.297		
MLE of Mean	0.221		
MLE of Standard Deviation	0.256		
nu star	93.9		
Approximate Chi Square Value (.05)	72.55	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0462	95% CLT UCL	0.36
Adjusted Chi Square Value	72.11	95% Jackknife UCL	0.362
		95% Standard Bootstrap UCL	0.361
Anderson-Darling Test Statistic	19.88	95% Bootstrap-t UCL	1.182
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.433
Kolmogorov-Smirnov Test Statistic	0.511	95% Percentile Bootstrap UCL	0.378
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.438
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.588
		97.5% Chebyshev(Mean, Sd) UCL	0.747
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.059
95% Approximate Gamma UCL	0.286		
95% Adjusted Gamma UCL	0.288		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.588

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1,3,5-trimethylbenzene)

General Statistics

Number of Valid Observations	89	Number of Distinct Observations	81
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00431	Minimum of Log Data	-5.447
Maximum	81.1	Maximum of Log Data	4.396
Mean	3.223	Mean of log Data	-3.116
Median	0.0122	SD of log Data	2.793
SD	11.01		
Coefficient of Variation	3.416		
Skewness	5.193		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.407	Lilliefors Test Statistic	0.323
Lilliefors Critical Value	0.0939	Lilliefors Critical Value	0.0939
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	5.163	95% H-UCL	8.205
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	5.961
95% Adjusted-CLT UCL (Chen-1995)	5.829	97.5% Chebyshev (MVUE) UCL	7.757
95% Modified-t UCL (Johnson-1978)	5.27	99% Chebyshev (MVUE) UCL	11.29
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.177	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	18.23		
MLE of Mean	3.223		
MLE of Standard Deviation	7.665		
nu star	31.47		
Approximate Chi Square Value (.05)	19.65	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0473	95% CLT UCL	5.143
Adjusted Chi Square Value	19.5	95% Jackknife UCL	5.163
		95% Standard Bootstrap UCL	5.116
Anderson-Darling Test Statistic	16.48	95% Bootstrap-t UCL	6.966
Anderson-Darling 5% Critical Value	0.936	95% Hall's Bootstrap UCL	6.805
Kolmogorov-Smirnov Test Statistic	0.401	95% Percentile Bootstrap UCL	5.404
Kolmogorov-Smirnov 5% Critical Value	0.106	95% BCA Bootstrap UCL	6.001
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	8.31
		97.5% Chebyshev(Mean, Sd) UCL	10.51
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	14.84
95% Approximate Gamma UCL	5.161		
95% Adjusted Gamma UCL	5.202		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	8.31

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1,3-dichlorobenzene)

General Statistics

Number of Valid Observations	63	Number of Distinct Observations	38
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.06	Minimum of Log Data	-2.813
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.221	Mean of log Data	-2.283
Median	0.084	SD of log Data	0.753
SD	0.668		
Coefficient of Variation	3.024		
Skewness	5.411		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.426
Lilliefors Critical Value	0.112	Lilliefors Critical Value	0.112
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.362	95% H-UCL	0.165
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.197
95% Adjusted-CLT UCL (Chen-1995)	0.421	97.5% Chebyshev (MVUE) UCL	0.223
95% Modified-t UCL (Johnson-1978)	0.371	99% Chebyshev (MVUE) UCL	0.276
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.745	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.297		
MLE of Mean	0.221		
MLE of Standard Deviation	0.256		
nu star	93.9		
Approximate Chi Square Value (.05)	72.55	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0462	95% CLT UCL	0.36
Adjusted Chi Square Value	72.11	95% Jackknife UCL	0.362
		95% Standard Bootstrap UCL	0.358
Anderson-Darling Test Statistic	19.88	95% Bootstrap-t UCL	1.139
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.435
Kolmogorov-Smirnov Test Statistic	0.511	95% Percentile Bootstrap UCL	0.371
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.45
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.588
		97.5% Chebyshev(Mean, Sd) UCL	0.747
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.059
95% Approximate Gamma UCL	0.286		
95% Adjusted Gamma UCL	0.288		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.588

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (1-methylnaphthalene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	191
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	88.5	Maximum of Log Data	4.483
Mean	2.5	Mean of log Data	-3.896
Median	0.00458	SD of log Data	3.27
SD	8.216		
Coefficient of Variation	3.287		
Skewness	5.862		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.391	Lilliefors Test Statistic	0.223
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	3.3	95% H-UCL	10.45
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	10.99
95% Adjusted-CLT UCL (Chen-1995)	3.477	97.5% Chebyshev (MVUE) UCL	14.09
95% Modified-t UCL (Johnson-1978)	3.328	99% Chebyshev (MVUE) UCL	20.19
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.159	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	15.71		
MLE of Mean	2.5		
MLE of Standard Deviation	6.266		
nu star	91.33		
Approximate Chi Square Value (.05)	70.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	3.297
Adjusted Chi Square Value	70.2	95% Jackknife UCL	3.3
		95% Standard Bootstrap UCL	3.292
Anderson-Darling Test Statistic	41.58	95% Bootstrap-t UCL	3.571
Anderson-Darling 5% Critical Value	1.022	95% Hall's Bootstrap UCL	3.683
Kolmogorov-Smirnov Test Statistic	0.312	95% Percentile Bootstrap UCL	3.363
Kolmogorov-Smirnov 5% Critical Value	0.0616	95% BCA Bootstrap UCL	3.563
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	4.614
		97.5% Chebyshev(Mean, Sd) UCL	5.528
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	7.325
95% Approximate Gamma UCL	3.248		
95% Adjusted Gamma UCL	3.252		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	4.614

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,4,6-trichlorophenol)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.363
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.165
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.458
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.387
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.456
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

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Result (1/2 DL for NDs) (2,4-dichlorophenol)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.365
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.17
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.463
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.38
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.459
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,4-dimethylphenol)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.36
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.161
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.46
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.375
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.439
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,4-dinitrophenol)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	34
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.945	Minimum of Log Data	-0.0566
Maximum	51	Maximum of Log Data	3.932
Mean	2.69	Mean of log Data	0.215
Median	1.01	SD of log Data	0.755
SD	8.092		
Coefficient of Variation	3.008		
Skewness	5.363		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.431
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	4.407	95% H-UCL	2.011
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	2.402
95% Adjusted-CLT UCL (Chen-1995)	5.129	97.5% Chebyshev (MVUE) UCL	2.732
95% Modified-t UCL (Johnson-1978)	4.523	99% Chebyshev (MVUE) UCL	3.381
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.743	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	3.619		
MLE of Mean	2.69		
MLE of Standard Deviation	3.12		
nu star	92.17		
Approximate Chi Square Value (.05)	71.04	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	4.381
Adjusted Chi Square Value	70.59	95% Jackknife UCL	4.407
		95% Standard Bootstrap UCL	4.331
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	14
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	17.6
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	4.622
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	5.258
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	7.17
		97.5% Chebyshev(Mean, Sd) UCL	9.108
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	12.92
95% Approximate Gamma UCL	3.491		
95% Adjusted Gamma UCL	3.513		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	7.17

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

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Result (1/2 DL for NDs) (2,4-dinitrotoluene)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.363
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.159
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.461
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.371
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.444
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2,6-dinitrotoluene)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37

Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.36
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.157
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.444
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.366
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.446
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2-chlorophenol)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.363
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.465
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.456
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.375
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.436
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2-methylnaphthalene)

General Statistics

Number of Valid Observations	314	Number of Distinct Observations	221
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00152	Minimum of Log Data	-6.489
Maximum	240	Maximum of Log Data	5.481
Mean	4.295	Mean of log Data	-3.531
Median	0.00763	SD of log Data	3.421
SD	17.43		
Coefficient of Variation	4.059		
Skewness	9.233		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.403	Lilliefors Test Statistic	0.207
Lilliefors Critical Value	0.05	Lilliefors Critical Value	0.05
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	5.918	95% H-UCL	25.48
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	26.55
95% Adjusted-CLT UCL (Chen-1995)	6.461	97.5% Chebyshev (MVUE) UCL	34.15
95% Modified-t UCL (Johnson-1978)	6.004	99% Chebyshev (MVUE) UCL	49.06
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.154	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	27.86		
MLE of Mean	4.295		
MLE of Standard Deviation	10.94		
nu star	96.83		
Approximate Chi Square Value (.05)	75.13	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	5.913
Adjusted Chi Square Value	75.05	95% Jackknife UCL	5.918
		95% Standard Bootstrap UCL	5.947
Anderson-Darling Test Statistic	39.86	95% Bootstrap-t UCL	6.822
Anderson-Darling 5% Critical Value	1.044	95% Hall's Bootstrap UCL	12.49
Kolmogorov-Smirnov Test Statistic	0.28	95% Percentile Bootstrap UCL	5.981
Kolmogorov-Smirnov 5% Critical Value	0.0592	95% BCA Bootstrap UCL	6.754
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	8.584
		97.5% Chebyshev(Mean, Sd) UCL	10.44
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	14.08
95% Approximate Gamma UCL	5.536		
95% Adjusted Gamma UCL	5.542		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	8.584

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (2-methylphenol (o-cresol))

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.365
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.167
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.465
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.378
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.479
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (3&4-methylphenol (p&m-cresol))

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	45
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.312	Minimum of Log Data	-1.165
Maximum	16.9	Maximum of Log Data	2.827
Mean	0.888	Mean of log Data	-0.894
Median	0.334	SD of log Data	0.756
SD	2.675		
Coefficient of Variation	3.011		
Skewness	5.37		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.432
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.456	95% H-UCL	0.663
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.793
95% Adjusted-CLT UCL (Chen-1995)	1.695	97.5% Chebyshev (MVUE) UCL	0.902
95% Modified-t UCL (Johnson-1978)	1.494	99% Chebyshev (MVUE) UCL	1.116
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.743	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	1.196		
MLE of Mean	0.888		
MLE of Standard Deviation	1.031		
nu star	92.09		
Approximate Chi Square Value (.05)	70.96	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	1.447
Adjusted Chi Square Value	70.52	95% Jackknife UCL	1.456
		95% Standard Bootstrap UCL	1.44
Anderson-Darling Test Statistic	19.75	95% Bootstrap-t UCL	4.64
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	5.84
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	1.502
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	1.749
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	2.369
		97.5% Chebyshev(Mean, Sd) UCL	3.01
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	4.268
95% Approximate Gamma UCL	1.153		
95% Adjusted Gamma UCL	1.16		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	2.369

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (3,3-dichlorobenzidine)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.362
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.161
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.464
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.364
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.443
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (4-chloroaniline)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.151	Minimum of Log Data	-1.89
Maximum	8.15	Maximum of Log Data	2.098
Mean	0.429	Mean of log Data	-1.621
Median	0.162	SD of log Data	0.755
SD	1.293		
Coefficient of Variation	3.01		
Skewness	5.364		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.432
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.704	95% H-UCL	0.321
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.383
95% Adjusted-CLT UCL (Chen-1995)	0.819	97.5% Chebyshev (MVUE) UCL	0.436
95% Modified-t UCL (Johnson-1978)	0.722	99% Chebyshev (MVUE) UCL	0.539
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.743	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.578		
MLE of Mean	0.429		
MLE of Standard Deviation	0.498		
nu star	92.12		
Approximate Chi Square Value (.05)	70.99	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.7
Adjusted Chi Square Value	70.55	95% Jackknife UCL	0.704
		95% Standard Bootstrap UCL	0.697
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	2.237
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	2.793
Kolmogorov-Smirnov Test Statistic	0.514	95% Percentile Bootstrap UCL	0.698
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.847
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.145
		97.5% Chebyshev(Mean, Sd) UCL	1.455
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.063
95% Approximate Gamma UCL	0.557		
95% Adjusted Gamma UCL	0.561		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	1.145

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (4-isopropyltoluene (p-cymene))

General Statistics

Number of Valid Observations	90	Number of Distinct Observations	80
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00431	Minimum of Log Data	-5.447
Maximum	20.2	Maximum of Log Data	3.006
Mean	0.799	Mean of log Data	-3.493
Median	0.011	SD of log Data	2.279
SD	2.669		
Coefficient of Variation	3.339		
Skewness	5.348		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.401	Lilliefors Test Statistic	0.347
Lilliefors Critical Value	0.0934	Lilliefors Critical Value	0.0934
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.267	95% H-UCL	1.01
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.012
95% Adjusted-CLT UCL (Chen-1995)	1.432	97.5% Chebyshev (MVUE) UCL	1.29
95% Modified-t UCL (Johnson-1978)	1.293	99% Chebyshev (MVUE) UCL	1.835
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.222	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	3.608		
MLE of Mean	0.799		
MLE of Standard Deviation	1.698		
nu star	39.88		
Approximate Chi Square Value (.05)	26.41	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0473	95% CLT UCL	1.262
Adjusted Chi Square Value	26.23	95% Jackknife UCL	1.267
		95% Standard Bootstrap UCL	1.262
Anderson-Darling Test Statistic	16.87	95% Bootstrap-t UCL	1.722
Anderson-Darling 5% Critical Value	0.902	95% Hall's Bootstrap UCL	1.792
Kolmogorov-Smirnov Test Statistic	0.424	95% Percentile Bootstrap UCL	1.294
Kolmogorov-Smirnov 5% Critical Value	0.104	95% BCA Bootstrap UCL	1.428
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	2.026
		97.5% Chebyshev(Mean, Sd) UCL	2.556
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	3.599
95% Approximate Gamma UCL	1.207		
95% Adjusted Gamma UCL	1.215		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	2.026

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (acenaphthene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	113
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.67	Maximum of Log Data	-0.4
Mean	0.0192	Mean of log Data	-5.479
Median	0.00178	SD of log Data	1.416
SD	0.0606		
Coefficient of Variation	3.163		
Skewness	6.693		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.385	Lilliefors Test Statistic	0.331
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0251	95% H-UCL	0.014
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.017
95% Adjusted-CLT UCL (Chen-1995)	0.0266	97.5% Chebyshev (MVUE) UCL	0.0195
95% Modified-t UCL (Johnson-1978)	0.0253	99% Chebyshev (MVUE) UCL	0.0244
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.425	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0451		
MLE of Mean	0.0192		
MLE of Standard Deviation	0.0294		
nu star	243.9		
Approximate Chi Square Value (.05)	208.8	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0251
Adjusted Chi Square Value	208.6	95% Jackknife UCL	0.0251
		95% Standard Bootstrap UCL	0.0251
Anderson-Darling Test Statistic	44.09	95% Bootstrap-t UCL	0.0272
Anderson-Darling 5% Critical Value	0.839	95% Hall's Bootstrap UCL	0.0294
Kolmogorov-Smirnov Test Statistic	0.337	95% Percentile Bootstrap UCL	0.0256
Kolmogorov-Smirnov 5% Critical Value	0.0572	95% BCA Bootstrap UCL	0.0269
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0348
		97.5% Chebyshev(Mean, Sd) UCL	0.0415
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0548
95% Approximate Gamma UCL	0.0224		
95% Adjusted Gamma UCL	0.0224		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0348

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (acenaphthylene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	114
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.67	Maximum of Log Data	-0.4
Mean	0.0192	Mean of log Data	-5.478
Median	0.00178	SD of log Data	1.416
SD	0.0606		
Coefficient of Variation	3.161		
Skewness	6.693		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.385	Lilliefors Test Statistic	0.332
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0251	95% H-UCL	0.0141
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.017
95% Adjusted-CLT UCL (Chen-1995)	0.0266	97.5% Chebyshev (MVUE) UCL	0.0195
95% Modified-t UCL (Johnson-1978)	0.0253	99% Chebyshev (MVUE) UCL	0.0244
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.425	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0451		
MLE of Mean	0.0192		
MLE of Standard Deviation	0.0294		
nu star	244		
Approximate Chi Square Value (.05)	208.8	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0251
Adjusted Chi Square Value	208.7	95% Jackknife UCL	0.0251
		95% Standard Bootstrap UCL	0.025
Anderson-Darling Test Statistic	44	95% Bootstrap-t UCL	0.0274
Anderson-Darling 5% Critical Value	0.839	95% Hall's Bootstrap UCL	0.0282
Kolmogorov-Smirnov Test Statistic	0.337	95% Percentile Bootstrap UCL	0.0253
Kolmogorov-Smirnov 5% Critical Value	0.0572	95% BCA Bootstrap UCL	0.0274
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0348
		97.5% Chebyshev(Mean, Sd) UCL	0.0415
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0548
95% Approximate Gamma UCL	0.0224		
95% Adjusted Gamma UCL	0.0224		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0348

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (anthracene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	127
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.67	Maximum of Log Data	-0.4
Mean	0.0232	Mean of log Data	-5.394
Median	0.00181	SD of log Data	1.507
SD	0.0688		
Coefficient of Variation	2.96		
Skewness	5.547		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.376	Lilliefors Test Statistic	0.322
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0299	95% H-UCL	0.0178
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0218
95% Adjusted-CLT UCL (Chen-1995)	0.0313	97.5% Chebyshev (MVUE) UCL	0.0252
95% Modified-t UCL (Johnson-1978)	0.0302	99% Chebyshev (MVUE) UCL	0.0318
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.401	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.058		
MLE of Mean	0.0232		
MLE of Standard Deviation	0.0367		
nu star	230.1		
Approximate Chi Square Value (.05)	196	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0299
Adjusted Chi Square Value	195.8	95% Jackknife UCL	0.0299
		95% Standard Bootstrap UCL	0.0298
Anderson-Darling Test Statistic	42.49	95% Bootstrap-t UCL	0.0324
Anderson-Darling 5% Critical Value	0.845	95% Hall's Bootstrap UCL	0.0321
Kolmogorov-Smirnov Test Statistic	0.328	95% Percentile Bootstrap UCL	0.0303
Kolmogorov-Smirnov 5% Critical Value	0.0574	95% BCA Bootstrap UCL	0.0319
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0409
		97.5% Chebyshev(Mean, Sd) UCL	0.0486
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0636
95% Approximate Gamma UCL	0.0273		
95% Adjusted Gamma UCL	0.0273		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0409

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (antimony)

General Statistics

Number of Valid Observations	69	Number of Distinct Observations	69
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0309	Minimum of Log Data	-3.477
Maximum	0.447	Maximum of Log Data	-0.806
Mean	0.116	Mean of log Data	-2.321
Median	0.0911	SD of log Data	0.564
SD	0.0785		
Coefficient of Variation	0.675		
Skewness	2.185		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.155	Lilliefors Test Statistic	0.0687
Lilliefors Critical Value	0.107	Lilliefors Critical Value	0.107
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.132	95% H-UCL	0.131
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.151
95% Adjusted-CLT UCL (Chen-1995)	0.134	97.5% Chebyshev (MVUE) UCL	0.167
95% Modified-t UCL (Johnson-1978)	0.132	99% Chebyshev (MVUE) UCL	0.197
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	2.994	**Data Follow Appr. Gamma Distribution at 5% Significance Level**	
Theta Star	0.0388		
MLE of Mean	0.116		
MLE of Standard Deviation	0.0672		
nu star	413.1		
Approximate Chi Square Value (.05)	367	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0465	95% CLT UCL	0.132
Adjusted Chi Square Value	366.1	95% Jackknife UCL	0.132
		95% Standard Bootstrap UCL	0.132
Anderson-Darling Test Statistic	1.078	95% Bootstrap-t UCL	0.135
Anderson-Darling 5% Critical Value	0.757	95% Hall's Bootstrap UCL	0.137
Kolmogorov-Smirnov Test Statistic	0.1	95% Percentile Bootstrap UCL	0.132
Kolmogorov-Smirnov 5% Critical Value	0.108	95% BCA Bootstrap UCL	0.135
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.157
		97.5% Chebyshev(Mean, Sd) UCL	0.175
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.21
95% Approximate Gamma UCL	0.131		
95% Adjusted Gamma UCL	0.131		
Potential UCL to Use		Use 95% Approximate Gamma UCL	0.131

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (arsenic)

General Statistics

Number of Valid Observations	69	Number of Distinct Observations	61
Raw Statistics		**Log-transformed Statistics**	
Minimum	2.16	Minimum of Log Data	0.77
Maximum	17.6	Maximum of Log Data	2.868
Mean	5.525	Mean of log Data	1.562
Median	4.18	SD of log Data	0.523
SD	3.406		
Coefficient of Variation	0.616		
Skewness	1.711		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.201	Lilliefors Test Statistic	0.109
Lilliefors Critical Value	0.107	Lilliefors Critical Value	0.107
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	6.209	95% H-UCL	6.161
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	7.039
95% Adjusted-CLT UCL (Chen-1995)	6.29	97.5% Chebyshev (MVUE) UCL	7.724
95% Modified-t UCL (Johnson-1978)	6.223	99% Chebyshev (MVUE) UCL	9.071
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	3.403	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	1.623		
MLE of Mean	5.525		
MLE of Standard Deviation	2.995		
nu star	469.7		
Approximate Chi Square Value (.05)	420.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0465	95% CLT UCL	6.2
Adjusted Chi Square Value	419.4	95% Jackknife UCL	6.209
		95% Standard Bootstrap UCL	6.226
Anderson-Darling Test Statistic	1.852	95% Bootstrap-t UCL	6.299
Anderson-Darling 5% Critical Value	0.756	95% Hall's Bootstrap UCL	6.313
Kolmogorov-Smirnov Test Statistic	0.146	95% Percentile Bootstrap UCL	6.19
Kolmogorov-Smirnov 5% Critical Value	0.108	95% BCA Bootstrap UCL	6.229
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	7.313
		97.5% Chebyshev(Mean, Sd) UCL	8.086
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	9.605
95% Approximate Gamma UCL	6.172		
95% Adjusted Gamma UCL	6.187		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	7.313

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (bap teq)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	142
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00349	Minimum of Log Data	-5.658
Maximum	0.225	Maximum of Log Data	-1.492
Mean	0.017	Mean of log Data	-4.916
Median	0.00397	SD of log Data	1.076
SD	0.0338		
Coefficient of Variation	1.985		
Skewness	3.741		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.344	Lilliefors Test Statistic	0.349
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0203	95% H-UCL	0.015
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0175
95% Adjusted-CLT UCL (Chen-1995)	0.0208	97.5% Chebyshev (MVUE) UCL	0.0195
95% Modified-t UCL (Johnson-1978)	0.0204	99% Chebyshev (MVUE) UCL	0.0233
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.71	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.024		
MLE of Mean	0.017		
MLE of Standard Deviation	0.0202		
nu star	407.4		
Approximate Chi Square Value (.05)	361.6	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0203
Adjusted Chi Square Value	361.4	95% Jackknife UCL	0.0203
		95% Standard Bootstrap UCL	0.0202
Anderson-Darling Test Statistic	44.09	95% Bootstrap-t UCL	0.021
Anderson-Darling 5% Critical Value	0.8	95% Hall's Bootstrap UCL	0.0208
Kolmogorov-Smirnov Test Statistic	0.367	95% Percentile Bootstrap UCL	0.0203
Kolmogorov-Smirnov 5% Critical Value	0.0559	95% BCA Bootstrap UCL	0.0209
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0257
		97.5% Chebyshev(Mean, Sd) UCL	0.0295
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0369
95% Approximate Gamma UCL	0.0192		
95% Adjusted Gamma UCL	0.0192		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0257

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (barium)

General Statistics

Number of Valid Observations	7	Number of Distinct Observations	7

Raw Statistics		Log-transformed Statistics	
Minimum	52	Minimum of Log Data	3.951
Maximum	103	Maximum of Log Data	4.635
Mean	70.01	Mean of log Data	4.22
Median	61.3	SD of log Data	0.253
SD	19.24		
Coefficient of Variation	0.275		
Skewness	1.215		

Warning: A sample size of 'n' = 7 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 7 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.781	Shapiro Wilk Test Statistic	0.814
Shapiro Wilk Critical Value	0.803	Shapiro Wilk Critical Value	0.803
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	84.15	95% H-UCL	87.19
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	99.07
95% Adjusted-CLT UCL (Chen-1995)	85.55	97.5% Chebyshev (MVUE) UCL	111.7
95% Modified-t UCL (Johnson-1978)	84.7	99% Chebyshev (MVUE) UCL	136.5
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	10.04	Data appear Lognormal at 5% Significance Level	
Theta Star	6.975		
MLE of Mean	70.01		
MLE of Standard Deviation	22.1		
nu star	140.5		
Approximate Chi Square Value (.05)	114.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0158	95% CLT UCL	81.98
Adjusted Chi Square Value	106.9	95% Jackknife UCL	84.15
		95% Standard Bootstrap UCL	81.11
Anderson-Darling Test Statistic	0.843	95% Bootstrap-t UCL	126.1
Anderson-Darling 5% Critical Value	0.707	95% Hall's Bootstrap UCL	239.9
Kolmogorov-Smirnov Test Statistic	0.38	95% Percentile Bootstrap UCL	81.99
Kolmogorov-Smirnov 5% Critical Value	0.312	95% BCA Bootstrap UCL	83.77
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	101.7
		97.5% Chebyshev(Mean, Sd) UCL	115.4
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	142.4
95% Approximate Gamma UCL	86.2		
95% Adjusted Gamma UCL	91.99		
Potential UCL to Use		Use 95% Student's-t UCL	84.15
		or 95% Modified-t UCL	84.7
		or 95% H-UCL	87.19

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzene)

General Statistics

Number of Valid Observations	318	Number of Distinct Observations	253
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00182	Minimum of Log Data	-6.309
Maximum	82	Maximum of Log Data	4.407
Mean	1.501	Mean of log Data	-3.895
Median	0.00585	SD of log Data	2.582
SD	6.668		
Coefficient of Variation	4.443		
Skewness	7.589		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.411	Lilliefors Test Statistic	0.286
Lilliefors Critical Value	0.0497	Lilliefors Critical Value	0.0497
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	2.118	95% H-UCL	0.981
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.222
95% Adjusted-CLT UCL (Chen-1995)	2.286	97.5% Chebyshev (MVUE) UCL	1.514
95% Modified-t UCL (Johnson-1978)	2.144	99% Chebyshev (MVUE) UCL	2.089
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.175	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	8.57		
MLE of Mean	1.501		
MLE of Standard Deviation	3.586		
nu star	111.4		
Approximate Chi Square Value (.05)	88.03	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	2.116
Adjusted Chi Square Value	87.93	95% Jackknife UCL	2.118
		95% Standard Bootstrap UCL	2.111
Anderson-Darling Test Statistic	59.16	95% Bootstrap-t UCL	2.402
Anderson-Darling 5% Critical Value	0.987	95% Hall's Bootstrap UCL	2.575
Kolmogorov-Smirnov Test Statistic	0.353	95% Percentile Bootstrap UCL	2.162
Kolmogorov-Smirnov 5% Critical Value	0.0577	95% BCA Bootstrap UCL	2.291
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	3.131
		97.5% Chebyshev(Mean, Sd) UCL	3.836
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	5.221
95% Approximate Gamma UCL	1.899		
95% Adjusted Gamma UCL	1.901		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	3.131

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(a)anthracene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	107
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.0988	Maximum of Log Data	-2.315
Mean	0.00777	Mean of log Data	-5.732
Median	0.00173	SD of log Data	1.103
SD	0.0154		
Coefficient of Variation	1.988		
Skewness	3.683		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.343	Lilliefors Test Statistic	0.352
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00927	95% H-UCL	0.00688
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00805
95% Adjusted-CLT UCL (Chen-1995)	0.00948	97.5% Chebyshev (MVUE) UCL	0.00896
95% Modified-t UCL (Johnson-1978)	0.00931	99% Chebyshev (MVUE) UCL	0.0108
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.688	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0113		
MLE of Mean	0.00777		
MLE of Standard Deviation	0.00937		
nu star	394.7		
Approximate Chi Square Value (.05)	349.6	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.00927
Adjusted Chi Square Value	349.4	95% Jackknife UCL	0.00927
		95% Standard Bootstrap UCL	0.00925
Anderson-Darling Test Statistic	43.79	95% Bootstrap-t UCL	0.00961
Anderson-Darling 5% Critical Value	0.802	95% Hall's Bootstrap UCL	0.00945
Kolmogorov-Smirnov Test Statistic	0.371	95% Percentile Bootstrap UCL	0.00927
Kolmogorov-Smirnov 5% Critical Value	0.056	95% BCA Bootstrap UCL	0.00952
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0117
		97.5% Chebyshev(Mean, Sd) UCL	0.0135
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0168
95% Approximate Gamma UCL	0.00877		
95% Adjusted Gamma UCL	0.00878		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0117

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(a)pyrene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	109
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00782	Mean of log Data	-5.741
Median	0.00172	SD of log Data	1.1
SD	0.016		
Coefficient of Variation	2.051		
Skewness	3.736		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.347	Lilliefors Test Statistic	0.349
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00938	95% H-UCL	0.0068
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00794
95% Adjusted-CLT UCL (Chen-1995)	0.0096	97.5% Chebyshev (MVUE) UCL	0.00884
95% Modified-t UCL (Johnson-1978)	0.00941	99% Chebyshev (MVUE) UCL	0.0106
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.677	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0115		
MLE of Mean	0.00782		
MLE of Standard Deviation	0.0095		
nu star	388.6		
Approximate Chi Square Value (.05)	343.9	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.00937
Adjusted Chi Square Value	343.7	95% Jackknife UCL	0.00938
		95% Standard Bootstrap UCL	0.00935
Anderson-Darling Test Statistic	44.61	95% Bootstrap-t UCL	0.00965
Anderson-Darling 5% Critical Value	0.804	95% Hall's Bootstrap UCL	0.00964
Kolmogorov-Smirnov Test Statistic	0.368	95% Percentile Bootstrap UCL	0.00951
Kolmogorov-Smirnov 5% Critical Value	0.056	95% BCA Bootstrap UCL	0.00958
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0119
		97.5% Chebyshev(Mean, Sd) UCL	0.0137
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0172
95% Approximate Gamma UCL	0.00883		
95% Adjusted Gamma UCL	0.00884		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0119

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(b)fluoranthene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	114
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.454	Maximum of Log Data	-0.79
Mean	0.0106	Mean of log Data	-5.706
Median	0.00173	SD of log Data	1.156
SD	0.0389		
Coefficient of Variation	3.664		
Skewness	9.367		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.407	Lilliefors Test Statistic	0.339
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0144	95% H-UCL	0.00758
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00892
95% Adjusted-CLT UCL (Chen-1995)	0.0158	97.5% Chebyshev (MVUE) UCL	0.00998
95% Modified-t UCL (Johnson-1978)	0.0146	99% Chebyshev (MVUE) UCL	0.0121
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.537	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0198		
MLE of Mean	0.0106		
MLE of Standard Deviation	0.0145		
nu star	308.3		
Approximate Chi Square Value (.05)	268.6	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0144
Adjusted Chi Square Value	268.4	95% Jackknife UCL	0.0144
		95% Standard Bootstrap UCL	0.0144
Anderson-Darling Test Statistic	46.41	95% Bootstrap-t UCL	0.0189
Anderson-Darling 5% Critical Value	0.818	95% Hall's Bootstrap UCL	0.0334
Kolmogorov-Smirnov Test Statistic	0.351	95% Percentile Bootstrap UCL	0.0148
Kolmogorov-Smirnov 5% Critical Value	0.0565	95% BCA Bootstrap UCL	0.0161
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0206
		97.5% Chebyshev(Mean, Sd) UCL	0.025
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0335
95% Approximate Gamma UCL	0.0122		
95% Adjusted Gamma UCL	0.0122		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0206

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (benzo(g,h,i)perylene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	121
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.186	Maximum of Log Data	-1.682
Mean	0.00918	Mean of log Data	-5.687
Median	0.00173	SD of log Data	1.173
SD	0.02		
Coefficient of Variation	2.176		
Skewness	4.5		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.35	Lilliefors Test Statistic	0.339
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0111	95% H-UCL	0.0079
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00932
95% Adjusted-CLT UCL (Chen-1995)	0.0115	97.5% Chebyshev (MVUE) UCL	0.0104
95% Modified-t UCL (Johnson-1978)	0.0112	99% Chebyshev (MVUE) UCL	0.0127
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.613	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.015		
MLE of Mean	0.00918		
MLE of Standard Deviation	0.0117		
nu star	352		
Approximate Chi Square Value (.05)	309.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0111
Adjusted Chi Square Value	309.3	95% Jackknife UCL	0.0111
		95% Standard Bootstrap UCL	0.0111
Anderson-Darling Test Statistic	44.3	95% Bootstrap-t UCL	0.0116
Anderson-Darling 5% Critical Value	0.81	95% Hall's Bootstrap UCL	0.0115
Kolmogorov-Smirnov Test Statistic	0.356	95% Percentile Bootstrap UCL	0.0112
Kolmogorov-Smirnov 5% Critical Value	0.0562	95% BCA Bootstrap UCL	0.0115
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0143
		97.5% Chebyshev(Mean, Sd) UCL	0.0166
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0209
95% Approximate Gamma UCL	0.0104		
95% Adjusted Gamma UCL	0.0105		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0143

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (benzo(k)fluoranthene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	105
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.454	Maximum of Log Data	-0.79
Mean	0.00965	Mean of log Data	-5.757
Median	0.00172	SD of log Data	1.105
SD	0.0381		
Coefficient of Variation	3.944		
Skewness	10.01		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.415	Lilliefors Test Statistic	0.347
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0134	95% H-UCL	0.00673
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00788
95% Adjusted-CLT UCL (Chen-1995)	0.0148	97.5% Chebyshev (MVUE) UCL	0.00878
95% Modified-t UCL (Johnson-1978)	0.0136	99% Chebyshev (MVUE) UCL	0.0105
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.556	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0174		
MLE of Mean	0.00965		
MLE of Standard Deviation	0.0129		
nu star	319.1		
Approximate Chi Square Value (.05)	278.7	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0133
Adjusted Chi Square Value	278.5	95% Jackknife UCL	0.0134
		95% Standard Bootstrap UCL	0.0133
Anderson-Darling Test Statistic	47.7	95% Bootstrap-t UCL	0.0195
Anderson-Darling 5% Critical Value	0.816	95% Hall's Bootstrap UCL	0.0316
Kolmogorov-Smirnov Test Statistic	0.361	95% Percentile Bootstrap UCL	0.0137
Kolmogorov-Smirnov 5% Critical Value	0.0565	95% BCA Bootstrap UCL	0.015
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0194
		97.5% Chebyshev(Mean, Sd) UCL	0.0237
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.032
95% Approximate Gamma UCL	0.011		
95% Adjusted Gamma UCL	0.0111		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0194

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (bis(2-chloroethyl)ether)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.363
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.158
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.461
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.385
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.457
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (bis(2-ethylhexyl)phthalate)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	39
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.27
Median	0.0843	SD of log Data	0.755
SD	0.673		
Coefficient of Variation	3.007		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.432
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.367	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.228
95% Modified-t UCL (Johnson-1978)	0.377	99% Chebyshev (MVUE) UCL	0.282
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.744	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.29		
Approximate Chi Square Value (.05)	71.14	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.365
Adjusted Chi Square Value	70.7	95% Jackknife UCL	0.367
		95% Standard Bootstrap UCL	0.365
Anderson-Darling Test Statistic	19.72	95% Bootstrap-t UCL	1.164
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.474
Kolmogorov-Smirnov Test Statistic	0.514	95% Percentile Bootstrap UCL	0.365
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.44
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.597
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.291		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.597

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cadmium)

General Statistics

Number of Valid Observations	7	Number of Distinct Observations	7
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0224	Minimum of Log Data	-3.801
Maximum	0.469	Maximum of Log Data	-0.757
Mean	0.207	Mean of log Data	-1.903
Median	0.219	SD of log Data	1.007
SD	0.149		
Coefficient of Variation	0.722		
Skewness	0.694		

Warning: A sample size of 'n' = 7 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 7 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.946	Shapiro Wilk Test Statistic	0.908
Shapiro Wilk Critical Value	0.803	Shapiro Wilk Critical Value	0.803
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.316	95% H-UCL	1.14
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.6
95% Adjusted-CLT UCL (Chen-1995)	0.315	97.5% Chebyshev (MVUE) UCL	0.763
95% Modified-t UCL (Johnson-1978)	0.319	99% Chebyshev (MVUE) UCL	1.081
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	1.055	Data appear Normal at 5% Significance Level	
Theta Star	0.196		
MLE of Mean	0.207		
MLE of Standard Deviation	0.201		
nu star	14.77		
Approximate Chi Square Value (.05)	7.103	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0158	95% CLT UCL	0.299
Adjusted Chi Square Value	5.577	95% Jackknife UCL	0.316
		95% Standard Bootstrap UCL	0.293
Anderson-Darling Test Statistic	0.265	95% Bootstrap-t UCL	0.341
Anderson-Darling 5% Critical Value	0.719	95% Hall's Bootstrap UCL	0.329
Kolmogorov-Smirnov Test Statistic	0.203	95% Percentile Bootstrap UCL	0.296
Kolmogorov-Smirnov 5% Critical Value	0.316	95% BCA Bootstrap UCL	0.306
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.452
		97.5% Chebyshev(Mean, Sd) UCL	0.559
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.768
95% Approximate Gamma UCL	0.43		
95% Adjusted Gamma UCL	0.547		
Potential UCL to Use		Use 95% Student's-t UCL	0.316

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (chlorobenzene)

General Statistics

Number of Valid Observations	63	Number of Distinct Observations	54
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00431	Minimum of Log Data	-5.447
Maximum	0.68	Maximum of Log Data	-0.386
Mean	0.0251	Mean of log Data	-4.531
Median	0.0082	SD of log Data	0.878
SD	0.086		
Coefficient of Variation	3.426		
Skewness	7.371		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.432	Lilliefors Test Statistic	0.22
Lilliefors Critical Value	0.112	Lilliefors Critical Value	0.112
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0432	95% H-UCL	0.0201
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0244
95% Adjusted-CLT UCL (Chen-1995)	0.0537	97.5% Chebyshev (MVUE) UCL	0.0282
95% Modified-t UCL (Johnson-1978)	0.0449	99% Chebyshev (MVUE) UCL	0.0355
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.689	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0364		
MLE of Mean	0.0251		
MLE of Standard Deviation	0.0303		
nu star	86.79		
Approximate Chi Square Value (.05)	66.31	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0462	95% CLT UCL	0.0429
Adjusted Chi Square Value	65.9	95% Jackknife UCL	0.0432
		95% Standard Bootstrap UCL	0.0427
Anderson-Darling Test Statistic	11.01	95% Bootstrap-t UCL	0.107
Anderson-Darling 5% Critical Value	0.796	95% Hall's Bootstrap UCL	0.101
Kolmogorov-Smirnov Test Statistic	0.37	95% Percentile Bootstrap UCL	0.0462
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.063
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0723
		97.5% Chebyshev(Mean, Sd) UCL	0.0928
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.133
95% Approximate Gamma UCL	0.0329		
95% Adjusted Gamma UCL	0.0331		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0723

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (chromium (total))

General Statistics

Number of Valid Observations	69	Number of Distinct Observations	56
Raw Statistics		**Log-transformed Statistics**	
Minimum	7.69	Minimum of Log Data	2.04
Maximum	50.9	Maximum of Log Data	3.93
Mean	15.84	Mean of log Data	2.686
Median	13.9	SD of log Data	0.378
SD	7.03		
Coefficient of Variation	0.444		
Skewness	2.269		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.159	Lilliefors Test Statistic	0.0736
Lilliefors Critical Value	0.107	Lilliefors Critical Value	0.107
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	17.25	95% H-UCL	17.11
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	18.96
95% Adjusted-CLT UCL (Chen-1995)	17.47	97.5% Chebyshev (MVUE) UCL	20.35
95% Modified-t UCL (Johnson-1978)	17.28	99% Chebyshev (MVUE) UCL	23.09
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.47	**Data Follow Appr. Gamma Distribution at 5% Significance Level**	
Theta Star	2.447		
MLE of Mean	15.84		
MLE of Standard Deviation	6.225		
nu star	892.9		
Approximate Chi Square Value (.05)	824.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0465	95% CLT UCL	17.23
Adjusted Chi Square Value	823.1	95% Jackknife UCL	17.25
		95% Standard Bootstrap UCL	17.22
Anderson-Darling Test Statistic	0.81	95% Bootstrap-t UCL	17.53
Anderson-Darling 5% Critical Value	0.753	95% Hall's Bootstrap UCL	17.84
Kolmogorov-Smirnov Test Statistic	0.102	95% Percentile Bootstrap UCL	17.2
Kolmogorov-Smirnov 5% Critical Value	0.107	95% BCA Bootstrap UCL	17.63
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	19.52
		97.5% Chebyshev(Mean, Sd) UCL	21.12
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	24.26
95% Approximate Gamma UCL	17.15		
95% Adjusted Gamma UCL	17.18		
Potential UCL to Use		Use 95% Approximate Gamma UCL	17.15

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (chrysene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	134
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.783	Maximum of Log Data	-0.245
Mean	0.0179	Mean of log Data	-5.55
Median	0.00175	SD of log Data	1.356
SD	0.0682		
Coefficient of Variation	3.815		
Skewness	8.109		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.405	Lilliefors Test Statistic	0.324
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0245	95% H-UCL	0.0119
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0143
95% Adjusted-CLT UCL (Chen-1995)	0.0266	97.5% Chebyshev (MVUE) UCL	0.0163
95% Modified-t UCL (Johnson-1978)	0.0249	99% Chebyshev (MVUE) UCL	0.0202
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.425	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0421		
MLE of Mean	0.0179		
MLE of Standard Deviation	0.0275		
nu star	243.7		
Approximate Chi Square Value (.05)	208.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0245
Adjusted Chi Square Value	208.4	95% Jackknife UCL	0.0245
		95% Standard Bootstrap UCL	0.0245
Anderson-Darling Test Statistic	45.82	95% Bootstrap-t UCL	0.029
Anderson-Darling 5% Critical Value	0.84	95% Hall's Bootstrap UCL	0.0277
Kolmogorov-Smirnov Test Statistic	0.335	95% Percentile Bootstrap UCL	0.0249
Kolmogorov-Smirnov 5% Critical Value	0.0572	95% BCA Bootstrap UCL	0.027
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0354
		97.5% Chebyshev(Mean, Sd) UCL	0.043
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.058
95% Approximate Gamma UCL	0.0209		
95% Adjusted Gamma UCL	0.0209		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0354

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cis-1,2-dichloroethylene)

General Statistics

Number of Valid Observations	63	Number of Distinct Observations	54
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00431	Minimum of Log Data	-5.447
Maximum	0.68	Maximum of Log Data	-0.386
Mean	0.025	Mean of log Data	-4.532
Median	0.0082	SD of log Data	0.877
SD	0.0859		
Coefficient of Variation	3.432		
Skewness	7.388		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.432	Lilliefors Test Statistic	0.22
Lilliefors Critical Value	0.112	Lilliefors Critical Value	0.112
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0431	95% H-UCL	0.0201
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0243
95% Adjusted-CLT UCL (Chen-1995)	0.0536	97.5% Chebyshev (MVUE) UCL	0.0281
95% Modified-t UCL (Johnson-1978)	0.0448	99% Chebyshev (MVUE) UCL	0.0354
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.69	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0363		
MLE of Mean	0.025		
MLE of Standard Deviation	0.0301		
nu star	86.96		
Approximate Chi Square Value (.05)	66.47	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0462	95% CLT UCL	0.0429
Adjusted Chi Square Value	66.05	95% Jackknife UCL	0.0431
		95% Standard Bootstrap UCL	0.0429
Anderson-Darling Test Statistic	10.99	95% Bootstrap-t UCL	0.105
Anderson-Darling 5% Critical Value	0.796	95% Hall's Bootstrap UCL	0.101
Kolmogorov-Smirnov Test Statistic	0.37	95% Percentile Bootstrap UCL	0.0456
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.0586
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0722
		97.5% Chebyshev(Mean, Sd) UCL	0.0927
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.133
95% Approximate Gamma UCL	0.0328		
95% Adjusted Gamma UCL	0.033		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0722

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (copper)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	55
Raw Statistics		**Log-transformed Statistics**	
Minimum	9.69	Minimum of Log Data	2.271
Maximum	52.4	Maximum of Log Data	3.959
Mean	21.15	Mean of log Data	2.974
Median	18.35	SD of log Data	0.388
SD	9.095		
Coefficient of Variation	0.43		
Skewness	1.417		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.164	Lilliefors Test Statistic	0.105
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	23.08	95% H-UCL	23.06
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	25.74
95% Adjusted-CLT UCL (Chen-1995)	23.27	97.5% Chebyshev (MVUE) UCL	27.76
95% Modified-t UCL (Johnson-1978)	23.11	99% Chebyshev (MVUE) UCL	31.73
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.258	**Data appear Lognormal at 5% Significance Level**	
Theta Star	3.379		
MLE of Mean	21.15		
MLE of Standard Deviation	8.454		
nu star	776		
Approximate Chi Square Value (.05)	712.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	23.05
Adjusted Chi Square Value	710.9	95% Jackknife UCL	23.08
		95% Standard Bootstrap UCL	23.05
Anderson-Darling Test Statistic	0.848	95% Bootstrap-t UCL	23.5
Anderson-Darling 5% Critical Value	0.753	95% Hall's Bootstrap UCL	23.32
Kolmogorov-Smirnov Test Statistic	0.129	95% Percentile Bootstrap UCL	22.95
Kolmogorov-Smirnov 5% Critical Value	0.113	95% BCA Bootstrap UCL	23.26
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	26.18
		97.5% Chebyshev(Mean, Sd) UCL	28.36
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	32.64
95% Approximate Gamma UCL	23.04		
95% Adjusted Gamma UCL	23.09		
Potential UCL to Use		Use 95% Student's-t UCL	23.08
		or 95% Modified-t UCL	23.11
		or 95% H-UCL	23.06

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cyanide)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	16
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.029	Minimum of Log Data	-3.54
Maximum	0.15	Maximum of Log Data	-1.897
Mean	0.0398	Mean of log Data	-3.314
Median	0.03	SD of log Data	0.378
SD	0.0228		
Coefficient of Variation	0.572		
Skewness	3.236		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.393	Lilliefors Test Statistic	0.42
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0447	95% H-UCL	0.0426
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0474
95% Adjusted-CLT UCL (Chen-1995)	0.0459	97.5% Chebyshev (MVUE) UCL	0.0511
95% Modified-t UCL (Johnson-1978)	0.0449	99% Chebyshev (MVUE) UCL	0.0582
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	5.378	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.00741		
MLE of Mean	0.0398		
MLE of Standard Deviation	0.0172		
nu star	666.8		
Approximate Chi Square Value (.05)	607.9	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.0446
Adjusted Chi Square Value	606.6	95% Jackknife UCL	0.0447
		95% Standard Bootstrap UCL	0.0446
Anderson-Darling Test Statistic	11.02	95% Bootstrap-t UCL	0.0471
Anderson-Darling 5% Critical Value	0.753	95% Hall's Bootstrap UCL	0.0497
Kolmogorov-Smirnov Test Statistic	0.417	95% Percentile Bootstrap UCL	0.0448
Kolmogorov-Smirnov 5% Critical Value	0.113	95% BCA Bootstrap UCL	0.0462
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0524
		97.5% Chebyshev(Mean, Sd) UCL	0.0579
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0686
95% Approximate Gamma UCL	0.0437		
95% Adjusted Gamma UCL	0.0438		
Potential UCL to Use		Use 95% Student's-t UCL	0.0447
		or 95% Modified-t UCL	0.0449

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (cyclohexane)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	57
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	44.9	Maximum of Log Data	3.804
Mean	1.834	Mean of log Data	-3.626
Median	0.0122	SD of log Data	2.332
SD	6.776		
Coefficient of Variation	3.694		
Skewness	4.992		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.472	Lilliefors Test Statistic	0.347
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	3.271	95% H-UCL	1.097
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.061
95% Adjusted-CLT UCL (Chen-1995)	3.833	97.5% Chebyshev (MVUE) UCL	1.369
95% Modified-t UCL (Johnson-1978)	3.362	99% Chebyshev (MVUE) UCL	1.974
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.179	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	10.23		
MLE of Mean	1.834		
MLE of Standard Deviation	4.331		
nu star	22.24		
Approximate Chi Square Value (.05)	12.52	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	3.25
Adjusted Chi Square Value	12.34	95% Jackknife UCL	3.271
		95% Standard Bootstrap UCL	3.234
Anderson-Darling Test Statistic	15.45	95% Bootstrap-t UCL	4.983
Anderson-Darling 5% Critical Value	0.927	95% Hall's Bootstrap UCL	6.997
Kolmogorov-Smirnov Test Statistic	0.446	95% Percentile Bootstrap UCL	3.369
Kolmogorov-Smirnov 5% Critical Value	0.126	95% BCA Bootstrap UCL	3.991
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	5.585
		97.5% Chebyshev(Mean, Sd) UCL	7.208
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	10.4
95% Approximate Gamma UCL	3.258		
95% Adjusted Gamma UCL	3.304		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	5.585

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (dibenzo(a,h)anthracene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	102
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00652	Mean of log Data	-5.801
Median	0.00171	SD of log Data	1.019
SD	0.013		
Coefficient of Variation	1.999		
Skewness	4.326		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.35	Lilliefors Test Statistic	0.355
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0078	95% H-UCL	0.00579
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00669
95% Adjusted-CLT UCL (Chen-1995)	0.008	97.5% Chebyshev (MVUE) UCL	0.0074
95% Modified-t UCL (Johnson-1978)	0.00783	99% Chebyshev (MVUE) UCL	0.00878
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.77	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.00848		
MLE of Mean	0.00652		
MLE of Standard Deviation	0.00744		
nu star	441.7		
Approximate Chi Square Value (.05)	394	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.00779
Adjusted Chi Square Value	393.8	95% Jackknife UCL	0.0078
		95% Standard Bootstrap UCL	0.00778
Anderson-Darling Test Statistic	44.27	95% Bootstrap-t UCL	0.00809
Anderson-Darling 5% Critical Value	0.796	95% Hall's Bootstrap UCL	0.00808
Kolmogorov-Smirnov Test Statistic	0.376	95% Percentile Bootstrap UCL	0.00788
Kolmogorov-Smirnov 5% Critical Value	0.0557	95% BCA Bootstrap UCL	0.00807
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.00988
		97.5% Chebyshev(Mean, Sd) UCL	0.0113
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0142
95% Approximate Gamma UCL	0.00732		
95% Adjusted Gamma UCL	0.00732		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.00988

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (dibenzofuran)

General Statistics

Number of Valid Observations	89	Number of Distinct Observations	63

Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	17.6	Maximum of Log Data	2.868
Mean	0.447	Mean of log Data	-1.982
Median	0.0895	SD of log Data	0.976
SD	1.932		
Coefficient of Variation	4.32		
Skewness	8.267		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.424	Lilliefors Test Statistic	0.282
Lilliefors Critical Value	0.0939	Lilliefors Critical Value	0.0939
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.787	95% H-UCL	0.28
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.338
95% Adjusted-CLT UCL (Chen-1995)	0.976	97.5% Chebyshev (MVUE) UCL	0.389
95% Modified-t UCL (Johnson-1978)	0.817	99% Chebyshev (MVUE) UCL	0.489
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.523	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.854		
MLE of Mean	0.447		
MLE of Standard Deviation	0.618		
nu star	93.18		
Approximate Chi Square Value (.05)	71.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0473	95% CLT UCL	0.784
Adjusted Chi Square Value	71.61	95% Jackknife UCL	0.787
		95% Standard Bootstrap UCL	0.777
Anderson-Darling Test Statistic	19.88	95% Bootstrap-t UCL	1.837
Anderson-Darling 5% Critical Value	0.815	95% Hall's Bootstrap UCL	1.792
Kolmogorov-Smirnov Test Statistic	0.393	95% Percentile Bootstrap UCL	0.821
Kolmogorov-Smirnov 5% Critical Value	0.1	95% BCA Bootstrap UCL	1.093
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.34
		97.5% Chebyshev(Mean, Sd) UCL	1.726
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.484
95% Approximate Gamma UCL	0.579		
95% Adjusted Gamma UCL	0.582		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	1.34

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (dro)

General Statistics

Number of Valid Observations	106	Number of Distinct Observations	95
Raw Statistics		**Log-transformed Statistics**	
Minimum	5.3	Minimum of Log Data	1.668
Maximum	18800	Maximum of Log Data	9.842
Mean	1061	Mean of log Data	4.416
Median	67.65	SD of log Data	2.503
SD	2482		
Coefficient of Variation	2.34		
Skewness	4.379		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.335	Lilliefors Test Statistic	0.183
Lilliefors Critical Value	0.0861	Lilliefors Critical Value	0.0861
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1461	95% H-UCL	4965
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	4841
95% Adjusted-CLT UCL (Chen-1995)	1567	97.5% Chebyshev (MVUE) UCL	6203
95% Modified-t UCL (Johnson-1978)	1478	99% Chebyshev (MVUE) UCL	8878
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.273	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	3887		
MLE of Mean	1061		
MLE of Standard Deviation	2030		
nu star	57.85		
Approximate Chi Square Value (.05)	41.36	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0477	95% CLT UCL	1457
Adjusted Chi Square Value	41.17	95% Jackknife UCL	1461
		95% Standard Bootstrap UCL	1453
Anderson-Darling Test Statistic	7.258	95% Bootstrap-t UCL	1669
Anderson-Darling 5% Critical Value	0.879	95% Hall's Bootstrap UCL	1914
Kolmogorov-Smirnov Test Statistic	0.193	95% Percentile Bootstrap UCL	1475
Kolmogorov-Smirnov 5% Critical Value	0.0959	95% BCA Bootstrap UCL	1600
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	2111
		97.5% Chebyshev(Mean, Sd) UCL	2566
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	3459
95% Approximate Gamma UCL	1483		
95% Adjusted Gamma UCL	1490		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	2111

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

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Result (1/2 DL for NDs) (ethylbenzene)

General Statistics

Number of Valid Observations	318	Number of Distinct Observations	232
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00355	Minimum of Log Data	-5.641
Maximum	111	Maximum of Log Data	4.71
Mean	4.876	Mean of log Data	-3.035
Median	0.0113	SD of log Data	2.942
SD	15.47		
Coefficient of Variation	3.173		
Skewness	4.252		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.414	Lilliefors Test Statistic	0.3
Lilliefors Critical Value	0.0497	Lilliefors Critical Value	0.0497
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	6.308	95% H-UCL	7.266
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	8.596
95% Adjusted-CLT UCL (Chen-1995)	6.525	97.5% Chebyshev (MVUE) UCL	10.84
95% Modified-t UCL (Johnson-1978)	6.342	99% Chebyshev (MVUE) UCL	15.26
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.165	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	29.6		
MLE of Mean	4.876		
MLE of Standard Deviation	12.02		
nu star	104.8		
Approximate Chi Square Value (.05)	82.14	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	6.304
Adjusted Chi Square Value	82.05	95% Jackknife UCL	6.308
		95% Standard Bootstrap UCL	6.287
Anderson-Darling Test Statistic	57.15	95% Bootstrap-t UCL	6.554
Anderson-Darling 5% Critical Value	1.016	95% Hall's Bootstrap UCL	6.498
Kolmogorov-Smirnov Test Statistic	0.354	95% Percentile Bootstrap UCL	6.293
Kolmogorov-Smirnov 5% Critical Value	0.0583	95% BCA Bootstrap UCL	6.486
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	8.659
		97.5% Chebyshev(Mean, Sd) UCL	10.3
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	13.51
95% Approximate Gamma UCL	6.219		
95% Adjusted Gamma UCL	6.226		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	8.659

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (fluoranthene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	125
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.387	Maximum of Log Data	-0.949
Mean	0.0135	Mean of log Data	-5.591
Median	0.00174	SD of log Data	1.287
SD	0.0381		
Coefficient of Variation	2.819		
Skewness	5.757		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.376	Lilliefors Test Statistic	0.326
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0172	95% H-UCL	0.0102
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0123
95% Adjusted-CLT UCL (Chen-1995)	0.018	97.5% Chebyshev (MVUE) UCL	0.0139
95% Modified-t UCL (Johnson-1978)	0.0174	99% Chebyshev (MVUE) UCL	0.0171
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.491	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0275		
MLE of Mean	0.0135		
MLE of Standard Deviation	0.0193		
nu star	282.1		
Approximate Chi Square Value (.05)	244.2	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0172
Adjusted Chi Square Value	244	95% Jackknife UCL	0.0172
		95% Standard Bootstrap UCL	0.0173
Anderson-Darling Test Statistic	44.77	95% Bootstrap-t UCL	0.0182
Anderson-Darling 5% Critical Value	0.823	95% Hall's Bootstrap UCL	0.0185
Kolmogorov-Smirnov Test Statistic	0.337	95% Percentile Bootstrap UCL	0.0176
Kolmogorov-Smirnov 5% Critical Value	0.0567	95% BCA Bootstrap UCL	0.0178
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0233
		97.5% Chebyshev(Mean, Sd) UCL	0.0276
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0359
95% Approximate Gamma UCL	0.0156		
95% Adjusted Gamma UCL	0.0156		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0233

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
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North Pole, Alaska

Result (1/2 DL for NDs) (fluorene)

General Statistics

Number of Valid Observations	314	Number of Distinct Observations	171
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	17.6	Maximum of Log Data	2.868
Mean	0.185	Mean of log Data	-4.592
Median	0.00194	SD of log Data	2.302
SD	1.037		
Coefficient of Variation	5.6		
Skewness	15.31		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.43	Lilliefors Test Statistic	0.277
Lilliefors Critical Value	0.05	Lilliefors Critical Value	0.05
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.282	95% H-UCL	0.224
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.283
95% Adjusted-CLT UCL (Chen-1995)	0.336	97.5% Chebyshev (MVUE) UCL	0.345
95% Modified-t UCL (Johnson-1978)	0.29	99% Chebyshev (MVUE) UCL	0.468
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.245	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.756		
MLE of Mean	0.185		
MLE of Standard Deviation	0.374		
nu star	153.9		
Approximate Chi Square Value (.05)	126.2	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.282
Adjusted Chi Square Value	126.1	95% Jackknife UCL	0.282
		95% Standard Bootstrap UCL	0.279
Anderson-Darling Test Statistic	37.99	95% Bootstrap-t UCL	0.469
Anderson-Darling 5% Critical Value	0.896	95% Hall's Bootstrap UCL	0.642
Kolmogorov-Smirnov Test Statistic	0.274	95% Percentile Bootstrap UCL	0.289
Kolmogorov-Smirnov 5% Critical Value	0.0561	95% BCA Bootstrap UCL	0.369
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.44
		97.5% Chebyshev(Mean, Sd) UCL	0.551
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.768
95% Approximate Gamma UCL	0.226		
95% Adjusted Gamma UCL	0.226		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.44

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (gro)

General Statistics

Number of Valid Observations	76	Number of Distinct Observations	69
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.433	Minimum of Log Data	-0.837
Maximum	7730	Maximum of Log Data	8.953
Mean	289.2	Mean of log Data	1.422
Median	1.275	SD of log Data	2.764
SD	1038		
Coefficient of Variation	3.59		
Skewness	5.727		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.395	Lilliefors Test Statistic	0.312
Lilliefors Critical Value	0.102	Lilliefors Critical Value	0.102
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	487.5	95% H-UCL	782
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	515.9
95% Adjusted-CLT UCL (Chen-1995)	568.6	97.5% Chebyshev (MVUE) UCL	673.1
95% Modified-t UCL (Johnson-1978)	500.5	99% Chebyshev (MVUE) UCL	981.9
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.178	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	1620		
MLE of Mean	289.2		
MLE of Standard Deviation	684.5		
nu star	27.13		
Approximate Chi Square Value (.05)	16.25	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0468	95% CLT UCL	485.1
Adjusted Chi Square Value	16.09	95% Jackknife UCL	487.5
		95% Standard Bootstrap UCL	490.5
Anderson-Darling Test Statistic	13.91	95% Bootstrap-t UCL	784.1
Anderson-Darling 5% Critical Value	0.931	95% Hall's Bootstrap UCL	1257
Kolmogorov-Smirnov Test Statistic	0.395	95% Percentile Bootstrap UCL	495.8
Kolmogorov-Smirnov 5% Critical Value	0.114	95% BCA Bootstrap UCL	593
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	808.3
		97.5% Chebyshev(Mean, Sd) UCL	1033
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1474
95% Approximate Gamma UCL	482.7		
95% Adjusted Gamma UCL	487.6		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	808.3

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (hexachloro-1,3-butadiene)

General Statistics

Number of Valid Observations	63	Number of Distinct Observations	38
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.222	Mean of log Data	-2.272
Median	0.084	SD of log Data	0.75
SD	0.668		
Coefficient of Variation	3.011		
Skewness	5.411		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.499	Lilliefors Test Statistic	0.416
Lilliefors Critical Value	0.112	Lilliefors Critical Value	0.112
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.362	95% H-UCL	0.166
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.198
95% Adjusted-CLT UCL (Chen-1995)	0.422	97.5% Chebyshev (MVUE) UCL	0.225
95% Modified-t UCL (Johnson-1978)	0.372	99% Chebyshev (MVUE) UCL	0.278
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.751	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.296		
MLE of Mean	0.222		
MLE of Standard Deviation	0.256		
nu star	94.59		
Approximate Chi Square Value (.05)	73.16	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0462	95% CLT UCL	0.36
Adjusted Chi Square Value	72.72	95% Jackknife UCL	0.362
		95% Standard Bootstrap UCL	0.361
Anderson-Darling Test Statistic	19.89	95% Bootstrap-t UCL	1.154
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.439
Kolmogorov-Smirnov Test Statistic	0.498	95% Percentile Bootstrap UCL	0.376
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.447
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.589
		97.5% Chebyshev(Mean, Sd) UCL	0.748
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.06
95% Approximate Gamma UCL	0.287		
95% Adjusted Gamma UCL	0.289		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.589

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (hexachlorobenzene)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.361
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.161
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.461
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.382
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.449
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (hexachlorocyclopentadiene)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	40
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.201	Minimum of Log Data	-1.604
Maximum	10.9	Maximum of Log Data	2.389
Mean	0.573	Mean of log Data	-1.333
Median	0.216	SD of log Data	0.756
SD	1.726		
Coefficient of Variation	3.011		
Skewness	5.368		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.431
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.939	95% H-UCL	0.428
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.511
95% Adjusted-CLT UCL (Chen-1995)	1.093	97.5% Chebyshev (MVUE) UCL	0.582
95% Modified-t UCL (Johnson-1978)	0.964	99% Chebyshev (MVUE) UCL	0.72
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.772		
MLE of Mean	0.573		
MLE of Standard Deviation	0.665		
nu star	92.06		
Approximate Chi Square Value (.05)	70.93	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.934
Adjusted Chi Square Value	70.49	95% Jackknife UCL	0.939
		95% Standard Bootstrap UCL	0.932
Anderson-Darling Test Statistic	19.75	95% Bootstrap-t UCL	2.977
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	3.748
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.961
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	1.142
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	1.529
		97.5% Chebyshev(Mean, Sd) UCL	1.942
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	2.754
95% Approximate Gamma UCL	0.744		
95% Adjusted Gamma UCL	0.748		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	1.529

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (hexachloroethane)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.362
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.162
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.459
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.377
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.453
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (indeno(1,2,3-c,d)pyrene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	106
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.097	Maximum of Log Data	-2.333
Mean	0.00721	Mean of log Data	-5.764
Median	0.00172	SD of log Data	1.07
SD	0.0142		
Coefficient of Variation	1.967		
Skewness	3.783		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.344	Lilliefors Test Statistic	0.357
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.00859	95% H-UCL	0.0064
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.00745
95% Adjusted-CLT UCL (Chen-1995)	0.00878	97.5% Chebyshev (MVUE) UCL	0.00827
95% Modified-t UCL (Johnson-1978)	0.00862	99% Chebyshev (MVUE) UCL	0.00989
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.719	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.01		
MLE of Mean	0.00721		
MLE of Standard Deviation	0.0085		
nu star	412.5		
Approximate Chi Square Value (.05)	366.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.00858
Adjusted Chi Square Value	366.2	95% Jackknife UCL	0.00859
		95% Standard Bootstrap UCL	0.00856
Anderson-Darling Test Statistic	44.55	95% Bootstrap-t UCL	0.00889
Anderson-Darling 5% Critical Value	0.799	95% Hall's Bootstrap UCL	0.00879
Kolmogorov-Smirnov Test Statistic	0.377	95% Percentile Bootstrap UCL	0.00854
Kolmogorov-Smirnov 5% Critical Value	0.0559	95% BCA Bootstrap UCL	0.00878
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0109
		97.5% Chebyshev(Mean, Sd) UCL	0.0124
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0155
95% Approximate Gamma UCL	0.00811		
95% Adjusted Gamma UCL	0.00812		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0109

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (iron)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	54
Raw Statistics		**Log-transformed Statistics**	
Minimum	7330	Minimum of Log Data	8.9
Maximum	29000	Maximum of Log Data	10.28
Mean	13815	Mean of log Data	9.462
Median	11450	SD of log Data	0.369
SD	5719		
Coefficient of Variation	0.414		
Skewness	1.253		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.176	Lilliefors Test Statistic	0.146
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	15029	95% H-UCL	14974
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	16635
95% Adjusted-CLT UCL (Chen-1995)	15134	97.5% Chebyshev (MVUE) UCL	17885
95% Modified-t UCL (Johnson-1978)	15048	99% Chebyshev (MVUE) UCL	20340
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.79	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	2035		
MLE of Mean	13815		
MLE of Standard Deviation	5302		
nu star	841.9		
Approximate Chi Square Value (.05)	775.6	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	15010
Adjusted Chi Square Value	774.1	95% Jackknife UCL	15029
		95% Standard Bootstrap UCL	15006
Anderson-Darling Test Statistic	1.956	95% Bootstrap-t UCL	15188
Anderson-Darling 5% Critical Value	0.752	95% Hall's Bootstrap UCL	15168
Kolmogorov-Smirnov Test Statistic	0.161	95% Percentile Bootstrap UCL	14983
Kolmogorov-Smirnov 5% Critical Value	0.113	95% BCA Bootstrap UCL	15176
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	16982
		97.5% Chebyshev(Mean, Sd) UCL	18352
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	21043
95% Approximate Gamma UCL	14997		
95% Adjusted Gamma UCL	15026		
Potential UCL to Use		Use 95% Student's-t UCL	15029
		or 95% Modified-t UCL	15048

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (isophorone)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.366
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.162
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.46
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.368
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.432
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (isopropylbenzene (cumene))

General Statistics

Number of Valid Observations	90	Number of Distinct Observations	80

Raw Statistics		Log-transformed Statistics	
Minimum	0.00431	Minimum of Log Data	-5.447
Maximum	41.6	Maximum of Log Data	3.728
Mean	1.49	Mean of log Data	-3.393
Median	0.011	SD of log Data	2.475
SD	5.375		
Coefficient of Variation	3.607		
Skewness	5.682		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.404	Lilliefors Test Statistic	0.34
Lilliefors Critical Value	0.0934	Lilliefors Critical Value	0.0934
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	2.432	95% H-UCL	2.059
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.864
95% Adjusted-CLT UCL (Chen-1995)	2.785	97.5% Chebyshev (MVUE) UCL	2.397
95% Modified-t UCL (Johnson-1978)	2.489	99% Chebyshev (MVUE) UCL	3.443
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.196	Data do not follow a Discernable Distribution (0.05)	
Theta Star	7.613		
MLE of Mean	1.49		
MLE of Standard Deviation	3.368		
nu star	35.24		
Approximate Chi Square Value (.05)	22.66	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0473	95% CLT UCL	2.422
Adjusted Chi Square Value	22.49	95% Jackknife UCL	2.432
		95% Standard Bootstrap UCL	2.427
Anderson-Darling Test Statistic	17.43	95% Bootstrap-t UCL	3.354
Anderson-Darling 5% Critical Value	0.916	95% Hall's Bootstrap UCL	3.512
Kolmogorov-Smirnov Test Statistic	0.417	95% Percentile Bootstrap UCL	2.459
Kolmogorov-Smirnov 5% Critical Value	0.105	95% BCA Bootstrap UCL	2.976
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	3.96
		97.5% Chebyshev(Mean, Sd) UCL	5.029
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	7.128
95% Approximate Gamma UCL	2.318		
95% Adjusted Gamma UCL	2.335		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	3.96

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (lead)

General Statistics

Number of Valid Observations	7	Number of Distinct Observations	7

Raw Statistics		Log-transformed Statistics	
Minimum	2.79	Minimum of Log Data	1.026
Maximum	7.48	Maximum of Log Data	2.012
Mean	4.257	Mean of log Data	1.404
Median	3.79	SD of log Data	0.308
SD	1.522		
Coefficient of Variation	0.358		
Skewness	1.95		

Warning: A sample size of 'n' = 7 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 7 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.792	Shapiro Wilk Test Statistic	0.894
Shapiro Wilk Critical Value	0.803	Shapiro Wilk Critical Value	0.803
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	5.375	95% H-UCL	5.65
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	6.398
95% Adjusted-CLT UCL (Chen-1995)	5.657	97.5% Chebyshev (MVUE) UCL	7.332
95% Modified-t UCL (Johnson-1978)	5.446	99% Chebyshev (MVUE) UCL	9.166
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.575	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	0.647		
MLE of Mean	4.257		
MLE of Standard Deviation	1.66		
nu star	92.05		
Approximate Chi Square Value (.05)	70.92	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0158	95% CLT UCL	5.204
Adjusted Chi Square Value	65.35	95% Jackknife UCL	5.375
		95% Standard Bootstrap UCL	5.131
Anderson-Darling Test Statistic	0.537	95% Bootstrap-t UCL	6.872
Anderson-Darling 5% Critical Value	0.708	95% Hall's Bootstrap UCL	10.21
Kolmogorov-Smirnov Test Statistic	0.247	95% Percentile Bootstrap UCL	5.211
Kolmogorov-Smirnov 5% Critical Value	0.312	95% BCA Bootstrap UCL	5.533
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	6.765
		97.5% Chebyshev(Mean, Sd) UCL	7.851
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	9.983
95% Approximate Gamma UCL	5.525		
95% Adjusted Gamma UCL	5.997		
Potential UCL to Use		Use 95% Approximate Gamma UCL	5.525

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (m,p-xylene)

General Statistics

Number of Valid Observations	318	Number of Distinct Observations	247
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0062	Minimum of Log Data	-5.083
Maximum	499	Maximum of Log Data	6.213
Mean	20.46	Mean of log Data	-2.123
Median	0.0218	SD of log Data	3.239
SD	67.83		
Coefficient of Variation	3.316		
Skewness	4.665		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.419	Lilliefors Test Statistic	0.303
Lilliefors Critical Value	0.0497	Lilliefors Critical Value	0.0497
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	26.73	95% H-UCL	51.81
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	57.21
95% Adjusted-CLT UCL (Chen-1995)	27.78	97.5% Chebyshev (MVUE) UCL	73.07
95% Modified-t UCL (Johnson-1978)	26.9	99% Chebyshev (MVUE) UCL	104.2
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.15	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	136.2		
MLE of Mean	20.46		
MLE of Standard Deviation	52.78		
nu star	95.55		
Approximate Chi Square Value (.05)	74	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	26.71
Adjusted Chi Square Value	73.92	95% Jackknife UCL	26.73
		95% Standard Bootstrap UCL	26.63
Anderson-Darling Test Statistic	54.8	95% Bootstrap-t UCL	28.16
Anderson-Darling 5% Critical Value	1.056	95% Hall's Bootstrap UCL	27.71
Kolmogorov-Smirnov Test Statistic	0.353	95% Percentile Bootstrap UCL	26.65
Kolmogorov-Smirnov 5% Critical Value	0.0591	95% BCA Bootstrap UCL	28.25
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	37.04
		97.5% Chebyshev(Mean, Sd) UCL	44.21
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	58.31
95% Approximate Gamma UCL	26.41		
95% Adjusted Gamma UCL	26.44		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	37.04

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (mercury)

General Statistics

Number of Valid Observations	7	Number of Distinct Observations	7
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0175	Minimum of Log Data	-4.048
Maximum	0.0208	Maximum of Log Data	-3.875
Mean	0.0188	Mean of log Data	-3.976
Median	0.0189	SD of log Data	0.0626
SD	0.00119		
Coefficient of Variation	0.0632		
Skewness	0.512		

Warning: A sample size of 'n' = 7 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 7 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.931	Shapiro Wilk Test Statistic	0.934
Shapiro Wilk Critical Value	0.803	Shapiro Wilk Critical Value	0.803
Data appear Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0197	95% H-UCL	N/A
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0207
95% Adjusted-CLT UCL (Chen-1995)	0.0196	97.5% Chebyshev (MVUE) UCL	0.0216
95% Modified-t UCL (Johnson-1978)	0.0197	99% Chebyshev (MVUE) UCL	0.0232
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	169.4	Data appear Normal at 5% Significance Level	
Theta Star	0.000111		
MLE of Mean	0.0188		
MLE of Standard Deviation	0.00144		
nu star	2371		
Approximate Chi Square Value (.05)	2259	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0158	95% CLT UCL	0.0195
Adjusted Chi Square Value	2226	95% Jackknife UCL	0.0197
		95% Standard Bootstrap UCL	0.0195
Anderson-Darling Test Statistic	0.313	95% Bootstrap-t UCL	0.0197
Anderson-Darling 5% Critical Value	0.708	95% Hall's Bootstrap UCL	0.0195
Kolmogorov-Smirnov Test Statistic	0.233	95% Percentile Bootstrap UCL	0.0195
Kolmogorov-Smirnov 5% Critical Value	0.311	95% BCA Bootstrap UCL	0.0195
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0207
		97.5% Chebyshev(Mean, Sd) UCL	0.0216
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0233
95% Approximate Gamma UCL	0.0197		
95% Adjusted Gamma UCL	0.02		
Potential UCL to Use		Use 95% Student's-t UCL	0.0197

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (methyl tert-butyl ether (mtbe))

General Statistics

Number of Valid Observations	63	Number of Distinct Observations	56
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0171	Minimum of Log Data	-4.069
Maximum	2.7	Maximum of Log Data	0.993
Mean	0.0995	Mean of log Data	-3.152
Median	0.0327	SD of log Data	0.876
SD	0.341		
Coefficient of Variation	3.43		
Skewness	7.387		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.431	Lilliefors Test Statistic	0.218
Lilliefors Critical Value	0.112	Lilliefors Critical Value	0.112
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.171	95% H-UCL	0.0799
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0967
95% Adjusted-CLT UCL (Chen-1995)	0.213	97.5% Chebyshev (MVUE) UCL	0.112
95% Modified-t UCL (Johnson-1978)	0.178	99% Chebyshev (MVUE) UCL	0.141
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.691	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.144		
MLE of Mean	0.0995		
MLE of Standard Deviation	0.12		
nu star	87.02		
Approximate Chi Square Value (.05)	66.51	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0462	95% CLT UCL	0.17
Adjusted Chi Square Value	66.09	95% Jackknife UCL	0.171
		95% Standard Bootstrap UCL	0.168
Anderson-Darling Test Statistic	10.99	95% Bootstrap-t UCL	0.429
Anderson-Darling 5% Critical Value	0.796	95% Hall's Bootstrap UCL	0.399
Kolmogorov-Smirnov Test Statistic	0.369	95% Percentile Bootstrap UCL	0.183
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.258
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.287
		97.5% Chebyshev(Mean, Sd) UCL	0.368
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.527
95% Approximate Gamma UCL	0.13		
95% Adjusted Gamma UCL	0.131		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.287

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (methylene chloride)

General Statistics

Number of Valid Observations	63	Number of Distinct Observations	58
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0171	Minimum of Log Data	-4.069
Maximum	2.7	Maximum of Log Data	0.993
Mean	0.103	Mean of log Data	-3.093
Median	0.0344	SD of log Data	0.889
SD	0.341		
Coefficient of Variation	3.307		
Skewness	7.364		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.42	Lilliefors Test Statistic	0.229
Lilliefors Critical Value	0.112	Lilliefors Critical Value	0.112
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.175	95% H-UCL	0.086
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.104
95% Adjusted-CLT UCL (Chen-1995)	0.216	97.5% Chebyshev (MVUE) UCL	0.12
95% Modified-t UCL (Johnson-1978)	0.182	99% Chebyshev (MVUE) UCL	0.152
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.707	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.146		
MLE of Mean	0.103		
MLE of Standard Deviation	0.123		
nu star	89.06		
Approximate Chi Square Value (.05)	68.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0462	95% CLT UCL	0.174
Adjusted Chi Square Value	67.87	95% Jackknife UCL	0.175
		95% Standard Bootstrap UCL	0.171
Anderson-Darling Test Statistic	9.999	95% Bootstrap-t UCL	0.429
Anderson-Darling 5% Critical Value	0.794	95% Hall's Bootstrap UCL	0.41
Kolmogorov-Smirnov Test Statistic	0.367	95% Percentile Bootstrap UCL	0.183
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.237
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.29
		97.5% Chebyshev(Mean, Sd) UCL	0.372
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.531
95% Approximate Gamma UCL	0.134		
95% Adjusted Gamma UCL	0.135		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.29

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (naphthalene)

General Statistics

Number of Valid Observations	314	Number of Distinct Observations	216
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	125	Maximum of Log Data	4.828
Mean	2.129	Mean of log Data	-3.95
Median	0.00705	SD of log Data	3.112
SD	9.112		
Coefficient of Variation	4.28		
Skewness	9.47		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.408	Lilliefors Test Statistic	0.213
Lilliefors Critical Value	0.05	Lilliefors Critical Value	0.05
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	2.978	95% H-UCL	5.274
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	6.002
95% Adjusted-CLT UCL (Chen-1995)	3.269	97.5% Chebyshev (MVUE) UCL	7.631
95% Modified-t UCL (Johnson-1978)	3.023	99% Chebyshev (MVUE) UCL	10.83
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.162	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	13.13		
MLE of Mean	2.129		
MLE of Standard Deviation	5.288		
nu star	101.8		
Approximate Chi Square Value (.05)	79.55	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	2.975
Adjusted Chi Square Value	79.46	95% Jackknife UCL	2.978
		95% Standard Bootstrap UCL	2.944
Anderson-Darling Test Statistic	46.01	95% Bootstrap-t UCL	3.645
Anderson-Darling 5% Critical Value	1.022	95% Hall's Bootstrap UCL	6.344
Kolmogorov-Smirnov Test Statistic	0.313	95% Percentile Bootstrap UCL	3.036
Kolmogorov-Smirnov 5% Critical Value	0.0587	95% BCA Bootstrap UCL	3.382
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	4.371
		97.5% Chebyshev(Mean, Sd) UCL	5.341
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	7.246
95% Approximate Gamma UCL	2.726		
95% Adjusted Gamma UCL	2.729		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	4.371

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-butylbenzene)

General Statistics

Number of Valid Observations	90	Number of Distinct Observations	80

Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00431	Minimum of Log Data	-5.447
Maximum	107	Maximum of Log Data	4.673
Mean	2.166	Mean of log Data	-3.554
Median	0.0105	SD of log Data	2.367
SD	11.88		
Coefficient of Variation	5.485		
Skewness	8.124		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.428	Lilliefors Test Statistic	0.322
Lilliefors Critical Value	0.0934	Lilliefors Critical Value	0.0934
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	4.248	95% H-UCL	1.242
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.193
95% Adjusted-CLT UCL (Chen-1995)	5.373	97.5% Chebyshev (MVUE) UCL	1.527
95% Modified-t UCL (Johnson-1978)	4.427	99% Chebyshev (MVUE) UCL	2.182
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.175	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	12.35		
MLE of Mean	2.166		
MLE of Standard Deviation	5.173		
nu star	31.57		
Approximate Chi Square Value (.05)	19.73	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0473	95% CLT UCL	4.227
Adjusted Chi Square Value	19.58	95% Jackknife UCL	4.248
		95% Standard Bootstrap UCL	4.218
Anderson-Darling Test Statistic	19.8	95% Bootstrap-t UCL	14.26
Anderson-Darling 5% Critical Value	0.937	95% Hall's Bootstrap UCL	11.54
Kolmogorov-Smirnov Test Statistic	0.405	95% Percentile Bootstrap UCL	4.481
Kolmogorov-Smirnov 5% Critical Value	0.105	95% BCA Bootstrap UCL	6.297
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	7.626
		97.5% Chebyshev(Mean, Sd) UCL	9.989
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	14.63
95% Approximate Gamma UCL	3.466		
95% Adjusted Gamma UCL	3.493		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	7.626

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-hexane)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	58

Raw Statistics		Log-transformed Statistics	
Minimum	0.00505	Minimum of Log Data	-5.288
Maximum	13	Maximum of Log Data	2.565
Mean	0.836	Mean of log Data	-3.786
Median	0.0103	SD of log Data	2.146
SD	2.77		
Coefficient of Variation	3.315		
Skewness	3.741		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.473	Lilliefors Test Statistic	0.334
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	1.423	95% H-UCL	0.553
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.574
95% Adjusted-CLT UCL (Chen-1995)	1.593	97.5% Chebyshev (MVUE) UCL	0.735
95% Modified-t UCL (Johnson-1978)	1.451	99% Chebyshev (MVUE) UCL	1.05
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.204	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	4.088		
MLE of Mean	0.836		
MLE of Standard Deviation	1.848		
nu star	25.35		
Approximate Chi Square Value (.05)	14.88	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	1.414
Adjusted Chi Square Value	14.69	95% Jackknife UCL	1.423
		95% Standard Bootstrap UCL	1.419
Anderson-Darling Test Statistic	14.67	95% Bootstrap-t UCL	1.828
Anderson-Darling 5% Critical Value	0.908	95% Hall's Bootstrap UCL	1.372
Kolmogorov-Smirnov Test Statistic	0.438	95% Percentile Bootstrap UCL	1.477
Kolmogorov-Smirnov 5% Critical Value	0.125	95% BCA Bootstrap UCL	1.713
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	2.369
		97.5% Chebyshev(Mean, Sd) UCL	3.033
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	4.336
95% Approximate Gamma UCL	1.424		
95% Adjusted Gamma UCL	1.442		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	2.369

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (nickel)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	52
Raw Statistics		**Log-transformed Statistics**	
Minimum	8.88	Minimum of Log Data	2.184
Maximum	38	Maximum of Log Data	3.638
Mean	17.58	Mean of log Data	2.807
Median	15.7	SD of log Data	0.341
SD	6.458		
Coefficient of Variation	0.367		
Skewness	1.177		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.133	Lilliefors Test Statistic	0.0788
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data appear Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	18.95	95% H-UCL	18.96
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	20.92
95% Adjusted-CLT UCL (Chen-1995)	19.06	97.5% Chebyshev (MVUE) UCL	22.39
95% Modified-t UCL (Johnson-1978)	18.97	99% Chebyshev (MVUE) UCL	25.27
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	8.181	**Data Follow Appr. Gamma Distribution at 5% Significance Level**	
Theta Star	2.149		
MLE of Mean	17.58		
MLE of Standard Deviation	6.145		
nu star	1014		
Approximate Chi Square Value (.05)	941.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	18.93
Adjusted Chi Square Value	939.8	95% Jackknife UCL	18.95
		95% Standard Bootstrap UCL	18.93
Anderson-Darling Test Statistic	0.753	95% Bootstrap-t UCL	19.11
Anderson-Darling 5% Critical Value	0.752	95% Hall's Bootstrap UCL	19.06
Kolmogorov-Smirnov Test Statistic	0.0992	95% Percentile Bootstrap UCL	18.92
Kolmogorov-Smirnov 5% Critical Value	0.113	95% BCA Bootstrap UCL	19.13
Data follow Appr. Gamma Distribution at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	21.15
		97.5% Chebyshev(Mean, Sd) UCL	22.7
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	25.74
95% Approximate Gamma UCL	18.94		
95% Adjusted Gamma UCL	18.97		
Potential UCL to Use		Use 95% Approximate Gamma UCL	18.94

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (nitrobenzene)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.363
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.162
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.461
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.39
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.448
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-nitrosodimethylamine)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.363
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.162
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.466
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.377
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.474
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-nitroso-di-n-propylamine)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.368
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.158
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.47
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.392
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.446
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (n-nitrosodiphenylamine)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	37
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0785	Minimum of Log Data	-2.545
Maximum	4.25	Maximum of Log Data	1.447
Mean	0.224	Mean of log Data	-2.274
Median	0.084	SD of log Data	0.756
SD	0.673		
Coefficient of Variation	3.012		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.43
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.366	95% H-UCL	0.167
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.2
95% Adjusted-CLT UCL (Chen-1995)	0.427	97.5% Chebyshev (MVUE) UCL	0.227
95% Modified-t UCL (Johnson-1978)	0.376	99% Chebyshev (MVUE) UCL	0.281
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.301		
MLE of Mean	0.224		
MLE of Standard Deviation	0.26		
nu star	92.03		
Approximate Chi Square Value (.05)	70.91	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	0.364
Adjusted Chi Square Value	70.47	95% Jackknife UCL	0.366
		95% Standard Bootstrap UCL	0.364
Anderson-Darling Test Statistic	19.74	95% Bootstrap-t UCL	1.21
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	1.454
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	0.37
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	0.447
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.596
		97.5% Chebyshev(Mean, Sd) UCL	0.758
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	1.075
95% Approximate Gamma UCL	0.29		
95% Adjusted Gamma UCL	0.292		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.596

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

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Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (n-propylbenzene)

General Statistics

Number of Valid Observations	90	Number of Distinct Observations	81
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00431	Minimum of Log Data	-5.447
Maximum	72.7	Maximum of Log Data	4.286
Mean	2.69	Mean of log Data	-3.231
Median	0.012	SD of log Data	2.688
SD	9.824		
Coefficient of Variation	3.652		
Skewness	5.432		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.406	Lilliefors Test Statistic	0.358
Lilliefors Critical Value	0.0934	Lilliefors Critical Value	0.0934
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	4.411	95% H-UCL	4.982
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	3.935
95% Adjusted-CLT UCL (Chen-1995)	5.026	97.5% Chebyshev (MVUE) UCL	5.101
95% Modified-t UCL (Johnson-1978)	4.51	99% Chebyshev (MVUE) UCL	7.392
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.179	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	15.02		
MLE of Mean	2.69		
MLE of Standard Deviation	6.356		
nu star	32.24		
Approximate Chi Square Value (.05)	20.26	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0473	95% CLT UCL	4.393
Adjusted Chi Square Value	20.1	95% Jackknife UCL	4.411
		95% Standard Bootstrap UCL	4.368
Anderson-Darling Test Statistic	17.54	95% Bootstrap-t UCL	6.389
Anderson-Darling 5% Critical Value	0.934	95% Hall's Bootstrap UCL	10.34
Kolmogorov-Smirnov Test Statistic	0.425	95% Percentile Bootstrap UCL	4.571
Kolmogorov-Smirnov 5% Critical Value	0.105	95% BCA Bootstrap UCL	5.14
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	7.203
		97.5% Chebyshev(Mean, Sd) UCL	9.157
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	12.99
95% Approximate Gamma UCL	4.28		
95% Adjusted Gamma UCL	4.313		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	7.203

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (o-xylene)

General Statistics

Number of Valid Observations	318	Number of Distinct Observations	237
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00355	Minimum of Log Data	-5.641
Maximum	211	Maximum of Log Data	5.352
Mean	7.245	Mean of log Data	-2.96
Median	0.0113	SD of log Data	3.06
SD	24.82		
Coefficient of Variation	3.426		
Skewness	5.219		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.417	Lilliefors Test Statistic	0.278
Lilliefors Critical Value	0.0497	Lilliefors Critical Value	0.0497
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	9.542	95% H-UCL	11.76
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	13.57
95% Adjusted-CLT UCL (Chen-1995)	9.97	97.5% Chebyshev (MVUE) UCL	17.21
95% Modified-t UCL (Johnson-1978)	9.61	99% Chebyshev (MVUE) UCL	24.36
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.155	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	46.6		
MLE of Mean	7.245		
MLE of Standard Deviation	18.37		
nu star	98.9		
Approximate Chi Square Value (.05)	76.95	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	9.535
Adjusted Chi Square Value	76.87	95% Jackknife UCL	9.542
		95% Standard Bootstrap UCL	9.449
Anderson-Darling Test Statistic	57.97	95% Bootstrap-t UCL	10.15
Anderson-Darling 5% Critical Value	1.042	95% Hall's Bootstrap UCL	10.12
Kolmogorov-Smirnov Test Statistic	0.359	95% Percentile Bootstrap UCL	9.617
Kolmogorov-Smirnov 5% Critical Value	0.0588	95% BCA Bootstrap UCL	9.984
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	13.31
		97.5% Chebyshev(Mean, Sd) UCL	15.94
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	21.09
95% Approximate Gamma UCL	9.311		
95% Adjusted Gamma UCL	9.322		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	13.31

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (pentachlorophenol)

General Statistics

Number of Valid Observations	62	Number of Distinct Observations	32
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.625	Minimum of Log Data	-0.47
Maximum	33.8	Maximum of Log Data	3.52
Mean	1.778	Mean of log Data	-0.201
Median	0.668	SD of log Data	0.756
SD	5.358		
Coefficient of Variation	3.013		
Skewness	5.366		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.506	Lilliefors Test Statistic	0.431
Lilliefors Critical Value	0.113	Lilliefors Critical Value	0.113
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	2.915	95% H-UCL	1.327
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	1.586
95% Adjusted-CLT UCL (Chen-1995)	3.393	97.5% Chebyshev (MVUE) UCL	1.804
95% Modified-t UCL (Johnson-1978)	2.992	99% Chebyshev (MVUE) UCL	2.232
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.742	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	2.397		
MLE of Mean	1.778		
MLE of Standard Deviation	2.064		
nu star	91.99		
Approximate Chi Square Value (.05)	70.87	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0461	95% CLT UCL	2.897
Adjusted Chi Square Value	70.43	95% Jackknife UCL	2.915
		95% Standard Bootstrap UCL	2.89
Anderson-Darling Test Statistic	19.76	95% Bootstrap-t UCL	9.308
Anderson-Darling 5% Critical Value	0.791	95% Hall's Bootstrap UCL	11.63
Kolmogorov-Smirnov Test Statistic	0.513	95% Percentile Bootstrap UCL	3.067
Kolmogorov-Smirnov 5% Critical Value	0.117	95% BCA Bootstrap UCL	3.67
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	4.744
		97.5% Chebyshev(Mean, Sd) UCL	6.027
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	8.548
95% Approximate Gamma UCL	2.308		
95% Adjusted Gamma UCL	2.322		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	4.744

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (phenanthrene)

General Statistics

Number of Valid Observations	314	Number of Distinct Observations	182
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	17.6	Maximum of Log Data	2.868
Mean	0.21	Mean of log Data	-4.593
Median	0.00195	SD of log Data	2.307
SD	1.115		
Coefficient of Variation	5.317		
Skewness	12.89		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.426	Lilliefors Test Statistic	0.273
Lilliefors Critical Value	0.05	Lilliefors Critical Value	0.05
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.313	95% H-UCL	0.227
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.286
95% Adjusted-CLT UCL (Chen-1995)	0.362	97.5% Chebyshev (MVUE) UCL	0.35
95% Modified-t UCL (Johnson-1978)	0.321	99% Chebyshev (MVUE) UCL	0.474
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.236	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.887		
MLE of Mean	0.21		
MLE of Standard Deviation	0.431		
nu star	148.4		
Approximate Chi Square Value (.05)	121.3	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.313
Adjusted Chi Square Value	121.2	95% Jackknife UCL	0.313
		95% Standard Bootstrap UCL	0.313
Anderson-Darling Test Statistic	39.31	95% Bootstrap-t UCL	0.45
Anderson-Darling 5% Critical Value	0.9	95% Hall's Bootstrap UCL	0.701
Kolmogorov-Smirnov Test Statistic	0.266	95% Percentile Bootstrap UCL	0.32
Kolmogorov-Smirnov 5% Critical Value	0.0562	95% BCA Bootstrap UCL	0.388
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.484
		97.5% Chebyshev(Mean, Sd) UCL	0.602
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.835
95% Approximate Gamma UCL	0.257		
95% Adjusted Gamma UCL	0.257		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.484

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (pyrene)

General Statistics

Number of Valid Observations	287	Number of Distinct Observations	123
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00151	Minimum of Log Data	-6.496
Maximum	0.387	Maximum of Log Data	-0.949
Mean	0.0129	Mean of log Data	-5.61
Median	0.00174	SD of log Data	1.269
SD	0.0369		
Coefficient of Variation	2.864		
Skewness	6.236		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.379	Lilliefors Test Statistic	0.334
Lilliefors Critical Value	0.0523	Lilliefors Critical Value	0.0523
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0165	95% H-UCL	0.0098
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0117
95% Adjusted-CLT UCL (Chen-1995)	0.0173	97.5% Chebyshev (MVUE) UCL	0.0132
95% Modified-t UCL (Johnson-1978)	0.0166	99% Chebyshev (MVUE) UCL	0.0162
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.502	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0257		
MLE of Mean	0.0129		
MLE of Standard Deviation	0.0182		
nu star	287.9		
Approximate Chi Square Value (.05)	249.6	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	0.0165
Adjusted Chi Square Value	249.4	95% Jackknife UCL	0.0165
		95% Standard Bootstrap UCL	0.0165
Anderson-Darling Test Statistic	44.81	95% Bootstrap-t UCL	0.0182
Anderson-Darling 5% Critical Value	0.821	95% Hall's Bootstrap UCL	0.0183
Kolmogorov-Smirnov Test Statistic	0.345	95% Percentile Bootstrap UCL	0.0164
Kolmogorov-Smirnov 5% Critical Value	0.0567	95% BCA Bootstrap UCL	0.0177
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.0224
		97.5% Chebyshev(Mean, Sd) UCL	0.0265
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.0345
95% Approximate Gamma UCL	0.0149		
95% Adjusted Gamma UCL	0.0149		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.0224

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

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Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (rro)

General Statistics

Number of Valid Observations	121	Number of Distinct Observations	118
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0081	Minimum of Log Data	-4.816
Maximum	64700	Maximum of Log Data	11.08
Mean	3710	Mean of log Data	3.628
Median	35.1	SD of log Data	3.949
SD	11419		
Coefficient of Variation	3.078		
Skewness	3.684		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.432	Lilliefors Test Statistic	0.153
Lilliefors Critical Value	0.0805	Lilliefors Critical Value	0.0805
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	5431	95% H-UCL	724592
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	235236
95% Adjusted-CLT UCL (Chen-1995)	5790	97.5% Chebyshev (MVUE) UCL	312717
95% Modified-t UCL (Johnson-1978)	5489	99% Chebyshev (MVUE) UCL	464915
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.166	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	22288		
MLE of Mean	3710		
MLE of Standard Deviation	9094		
nu star	40.29		
Approximate Chi Square Value (.05)	26.74	**Nonparametric Statistics**	
Adjusted Level of Significance	0.048	95% CLT UCL	5418
Adjusted Chi Square Value	26.61	95% Jackknife UCL	5431
		95% Standard Bootstrap UCL	5428
Anderson-Darling Test Statistic	8.14	95% Bootstrap-t UCL	6067
Anderson-Darling 5% Critical Value	0.956	95% Hall's Bootstrap UCL	5689
Kolmogorov-Smirnov Test Statistic	0.217	95% Percentile Bootstrap UCL	5487
Kolmogorov-Smirnov 5% Critical Value	0.0945	95% BCA Bootstrap UCL	5722
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	8236
		97.5% Chebyshev(Mean, Sd) UCL	10194
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	14040
95% Approximate Gamma UCL	5589		
95% Adjusted Gamma UCL	5617		
Potential UCL to Use		Use 99% Chebyshev (Mean, Sd) UCL	14040

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (sec-butylbenzene)

General Statistics

Number of Valid Observations	28	Number of Distinct Observations	28
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00565	Minimum of Log Data	-5.176
Maximum	25.3	Maximum of Log Data	3.231
Mean	2.228	Mean of log Data	-2.186
Median	0.0189	SD of log Data	2.847
SD	5.249		
Coefficient of Variation	2.356		
Skewness	3.613		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.49	Shapiro Wilk Test Statistic	0.822
Shapiro Wilk Critical Value	0.924	Shapiro Wilk Critical Value	0.924
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	3.917	95% H-UCL	114.8
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	15.51
95% Adjusted-CLT UCL (Chen-1995)	4.583	97.5% Chebyshev (MVUE) UCL	20.6
95% Modified-t UCL (Johnson-1978)	4.03	99% Chebyshev (MVUE) UCL	30.6
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.238	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	9.374		
MLE of Mean	2.228		
MLE of Standard Deviation	4.57		
nu star	13.31		
Approximate Chi Square Value (.05)	6.1	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0404	95% CLT UCL	3.859
Adjusted Chi Square Value	5.799	95% Jackknife UCL	3.917
		95% Standard Bootstrap UCL	3.819
Anderson-Darling Test Statistic	2.405	95% Bootstrap-t UCL	6.456
Anderson-Darling 5% Critical Value	0.88	95% Hall's Bootstrap UCL	10.26
Kolmogorov-Smirnov Test Statistic	0.311	95% Percentile Bootstrap UCL	3.979
Kolmogorov-Smirnov 5% Critical Value	0.182	95% BCA Bootstrap UCL	4.748
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	6.552
		97.5% Chebyshev(Mean, Sd) UCL	8.423
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	12.1
95% Approximate Gamma UCL	4.86		
95% Adjusted Gamma UCL	5.112		
Potential UCL to Use		Use 99% Chebyshev (Mean, Sd) UCL	12.1

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (selenium)

General Statistics

Number of Valid Observations	69	Number of Distinct Observations	55
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.138	Minimum of Log Data	-1.981
Maximum	0.635	Maximum of Log Data	-0.454
Mean	0.254	Mean of log Data	-1.488
Median	0.18	SD of log Data	0.467
SD	0.138		
Coefficient of Variation	0.543		
Skewness	1.31		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.223	Lilliefors Test Statistic	0.215
Lilliefors Critical Value	0.107	Lilliefors Critical Value	0.107
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.282	95% H-UCL	0.28
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.316
95% Adjusted-CLT UCL (Chen-1995)	0.284	97.5% Chebyshev (MVUE) UCL	0.344
95% Modified-t UCL (Johnson-1978)	0.282	99% Chebyshev (MVUE) UCL	0.398
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	4.198	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.0606		
MLE of Mean	0.254		
MLE of Standard Deviation	0.124		
nu star	579.3		
Approximate Chi Square Value (.05)	524.5	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0465	95% CLT UCL	0.282
Adjusted Chi Square Value	523.4	95% Jackknife UCL	0.282
		95% Standard Bootstrap UCL	0.281
Anderson-Darling Test Statistic	4.741	95% Bootstrap-t UCL	0.284
Anderson-Darling 5% Critical Value	0.755	95% Hall's Bootstrap UCL	0.282
Kolmogorov-Smirnov Test Statistic	0.219	95% Percentile Bootstrap UCL	0.282
Kolmogorov-Smirnov 5% Critical Value	0.108	95% BCA Bootstrap UCL	0.284
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.327
		97.5% Chebyshev(Mean, Sd) UCL	0.358
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.42
95% Approximate Gamma UCL	0.281		
95% Adjusted Gamma UCL	0.281		
Potential UCL to Use		Use 95% Student's-t UCL	0.282
		or 95% Modified-t UCL	0.282

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (silver)

General Statistics

Number of Valid Observations	7	Number of Distinct Observations	7
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0476	Minimum of Log Data	-3.045
Maximum	0.107	Maximum of Log Data	-2.235
Mean	0.0654	Mean of log Data	-2.773
Median	0.0545	SD of log Data	0.316
SD	0.0232		
Coefficient of Variation	0.354		
Skewness	1.355		

Warning: A sample size of 'n' = 7 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 7 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Shapiro Wilk Test Statistic	0.765	Shapiro Wilk Test Statistic	0.801
Shapiro Wilk Critical Value	0.803	Shapiro Wilk Critical Value	0.803
Data not Normal at 5% Significance Level		Data not Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.0825	95% H-UCL	0.0877
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0992
95% Adjusted-CLT UCL (Chen-1995)	0.0846	97.5% Chebyshev (MVUE) UCL	0.114
95% Modified-t UCL (Johnson-1978)	0.0832	99% Chebyshev (MVUE) UCL	0.143
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	6.348	Data do not follow a Discernable Distribution (0.05)	
Theta Star	0.0103		
MLE of Mean	0.0654		
MLE of Standard Deviation	0.026		
nu star	88.87		
Approximate Chi Square Value (.05)	68.14	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0158	95% CLT UCL	0.0798
Adjusted Chi Square Value	62.68	95% Jackknife UCL	0.0825
		95% Standard Bootstrap UCL	0.0791
Anderson-Darling Test Statistic	0.822	95% Bootstrap-t UCL	0.157
Anderson-Darling 5% Critical Value	0.708	95% Hall's Bootstrap UCL	0.201
Kolmogorov-Smirnov Test Statistic	0.349	95% Percentile Bootstrap UCL	0.0793
Kolmogorov-Smirnov 5% Critical Value	0.312	95% BCA Bootstrap UCL	0.0832
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.104
		97.5% Chebyshev(Mean, Sd) UCL	0.12
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.153
95% Approximate Gamma UCL	0.0853		
95% Adjusted Gamma UCL	0.0928		
Potential UCL to Use		Use 95% Student's-t UCL	0.0825
		or 95% Modified-t UCL	0.0832

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Appendix B
Soil 15 ft UCL

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (sulfolane)

General Statistics

Number of Valid Observations	277	Number of Distinct Observations	165

Raw Statistics		Log-transformed Statistics	
Minimum	0.00313	Minimum of Log Data	-5.767
Maximum	18.4	Maximum of Log Data	2.912
Mean	0.148	Mean of log Data	-4.618
Median	0.00357	SD of log Data	1.745
SD	1.167		
Std. Error of Mean	0.0701		
Coefficient of Variation	7.881		
Skewness	14.4		

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.451	Lilliefors Test Statistic	0.311
Lilliefors Critical Value	0.0532	Lilliefors Critical Value	0.0532
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.264	95% H-UCL	0.061
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.0761
95% Adjusted-CLT UCL (Chen-1995)	0.328	97.5% Chebyshev (MVUE) UCL	0.0898
95% Modified-t UCL (Johnson-1978)	0.274	99% Chebyshev (MVUE) UCL	0.117
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.26	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.569		
MLE of Mean	0.148		
MLE of Standard Deviation	0.29		
nu star	144.1		
Approximate Chi Square Value (.05)	117.4	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0491	95% CLT UCL	0.263
Adjusted Chi Square Value	117.3	95% Jackknife UCL	0.264
		95% Standard Bootstrap UCL	0.268
Anderson-Darling Test Statistic	52.34	95% Bootstrap-t UCL	0.793
Anderson-Darling 5% Critical Value	0.888	95% Hall's Bootstrap UCL	0.683
Kolmogorov-Smirnov Test Statistic	0.331	95% Percentile Bootstrap UCL	0.278
Kolmogorov-Smirnov 5% Critical Value	0.0599	95% BCA Bootstrap UCL	0.377
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.454
		97.5% Chebyshev(Mean, Sd) UCL	0.586
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.845
95% Approximate Gamma UCL	0.182		
95% Adjusted Gamma UCL	0.182		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.454

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (tert-butylbenzene)

General Statistics

Number of Valid Observations	90	Number of Distinct Observations	80
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00431	Minimum of Log Data	-5.447
Maximum	5.4	Maximum of Log Data	1.686
Mean	0.149	Mean of log Data	-4.052
Median	0.0104	SD of log Data	1.497
SD	0.646		
Coefficient of Variation	4.328		
Skewness	6.862		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.411	Lilliefors Test Statistic	0.292
Lilliefors Critical Value	0.0934	Lilliefors Critical Value	0.0934
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	0.262	95% H-UCL	0.0828
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	0.101
95% Adjusted-CLT UCL (Chen-1995)	0.314	97.5% Chebyshev (MVUE) UCL	0.123
95% Modified-t UCL (Johnson-1978)	0.271	99% Chebyshev (MVUE) UCL	0.164
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.315	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	0.474		
MLE of Mean	0.149		
MLE of Standard Deviation	0.266		
nu star	56.63		
Approximate Chi Square Value (.05)	40.33	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0473	95% CLT UCL	0.261
Adjusted Chi Square Value	40.11	95% Jackknife UCL	0.262
		95% Standard Bootstrap UCL	0.262
Anderson-Darling Test Statistic	18.14	95% Bootstrap-t UCL	0.519
Anderson-Darling 5% Critical Value	0.864	95% Hall's Bootstrap UCL	0.64
Kolmogorov-Smirnov Test Statistic	0.399	95% Percentile Bootstrap UCL	0.272
Kolmogorov-Smirnov 5% Critical Value	0.102	95% BCA Bootstrap UCL	0.339
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	0.446
		97.5% Chebyshev(Mean, Sd) UCL	0.574
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	0.827
95% Approximate Gamma UCL	0.21		
95% Adjusted Gamma UCL	0.211		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	0.446

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Appendix B
Soil 15 ft UCL

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Result (1/2 DL for NDs) (toluene)

General Statistics

Number of Valid Observations	318	Number of Distinct Observations	244
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.00355	Minimum of Log Data	-5.641
Maximum	392	Maximum of Log Data	5.971
Mean	7.684	Mean of log Data	-3.281
Median	0.0117	SD of log Data	2.639
SD	39.51		
Coefficient of Variation	5.142		
Skewness	6.735		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.459	Lilliefors Test Statistic	0.29
Lilliefors Critical Value	0.0497	Lilliefors Critical Value	0.0497
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	11.34	95% H-UCL	2.147
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	2.659
95% Adjusted-CLT UCL (Chen-1995)	12.22	97.5% Chebyshev (MVUE) UCL	3.306
95% Modified-t UCL (Johnson-1978)	11.48	99% Chebyshev (MVUE) UCL	4.576
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.146	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	52.67		
MLE of Mean	7.684		
MLE of Standard Deviation	20.12		
nu star	92.78		
Approximate Chi Square Value (.05)	71.57	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	11.33
Adjusted Chi Square Value	71.48	95% Jackknife UCL	11.34
		95% Standard Bootstrap UCL	11.4
Anderson-Darling Test Statistic	71.43	95% Bootstrap-t UCL	12.94
Anderson-Darling 5% Critical Value	1.069	95% Hall's Bootstrap UCL	12
Kolmogorov-Smirnov Test Statistic	0.38	95% Percentile Bootstrap UCL	11.72
Kolmogorov-Smirnov 5% Critical Value	0.0593	95% BCA Bootstrap UCL	12.37
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	17.34
		97.5% Chebyshev(Mean, Sd) UCL	21.52
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	29.73
95% Approximate Gamma UCL	9.961		
95% Adjusted Gamma UCL	9.973		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	17.34

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002) and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (trichlorofluoromethane (freon-11))

General Statistics

Number of Valid Observations	6	Number of Distinct Observations	6

Raw Statistics		Log-transformed Statistics	
Minimum	0.00565	Minimum of Log Data	-5.176
Maximum	22.7	Maximum of Log Data	3.122
Mean	3.874	Mean of log Data	-2.446
Median	0.0636	SD of log Data	3.227
SD	9.224		
Coefficient of Variation	2.381		
Skewness	2.448		

Warning: A sample size of 'n' = 6 may not adequate enough to compute meaningful and reliable test statistics and estimates!

It is suggested to collect at least 8 to 10 observations using these statistical methods!
If possible compute and collect Data Quality Objectives (DQO) based sample size and analytical results.

Warning: There are only 6 Values in this data
Note: It should be noted that even though bootstrap methods may be performed on this data set,
the resulting calculations may not be reliable enough to draw conclusions

The literature suggests to use bootstrap methods on data sets having more than 10-15 observations.

Relevant UCL Statistics

Normal Distribution Test		Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.509	Shapiro Wilk Test Statistic	0.866
Shapiro Wilk Critical Value	0.788	Shapiro Wilk Critical Value	0.788
Data not Normal at 5% Significance Level		Data appear Lognormal at 5% Significance Level	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	11.46	95% H-UCL	748600000
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	9.143
95% Adjusted-CLT UCL (Chen-1995)	14.09	97.5% Chebyshev (MVUE) UCL	12.3
95% Modified-t UCL (Johnson-1978)	12.09	99% Chebyshev (MVUE) UCL	18.51
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.208	Data appear Gamma Distributed at 5% Significance Level	
Theta Star	18.6		
MLE of Mean	3.874		
MLE of Standard Deviation	8.488		
nu star	2.5		
Approximate Chi Square Value (.05)	0.241	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0122	95% CLT UCL	10.07
Adjusted Chi Square Value	0.113	95% Jackknife UCL	11.46
		95% Standard Bootstrap UCL	9.652
Anderson-Darling Test Statistic	0.797	95% Bootstrap-t UCL	656.7
Anderson-Darling 5% Critical Value	0.805	95% Hall's Bootstrap UCL	340.7
Kolmogorov-Smirnov Test Statistic	0.325	95% Percentile Bootstrap UCL	11.35
Kolmogorov-Smirnov 5% Critical Value	0.364	95% BCA Bootstrap UCL	11.49
Data appear Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	20.29
		97.5% Chebyshev(Mean, Sd) UCL	27.39
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	41.34
95% Approximate Gamma UCL	40.16		
95% Adjusted Gamma UCL	85.76		
Potential UCL to Use		Use 95% Adjusted Gamma UCL	85.76

Recommended UCL exceeds the maximum observation

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

Result (1/2 DL for NDs) (xylenes (total))

General Statistics

Number of Valid Observations	318	Number of Distinct Observations	259
Raw Statistics		**Log-transformed Statistics**	
Minimum	0.0104	Minimum of Log Data	-4.566
Maximum	706	Maximum of Log Data	6.56
Mean	25.82	Mean of log Data	-1.785
Median	0.035	SD of log Data	3.132
SD	87.68		
Std. Error of Mean	4.917		
Coefficient of Variation	3.396		
Skewness	4.965		

Relevant UCL Statistics

Normal Distribution Test		**Lognormal Distribution Test**	
Lilliefors Test Statistic	0.422	Lilliefors Test Statistic	0.311
Lilliefors Critical Value	0.0497	Lilliefors Critical Value	0.0497
Data not Normal at 5% Significance Level		**Data not Lognormal at 5% Significance Level**	
Assuming Normal Distribution		**Assuming Lognormal Distribution**	
95% Student's-t UCL	33.93	95% H-UCL	49.19
95% UCLs (Adjusted for Skewness)		95% Chebyshev (MVUE) UCL	55.83
95% Adjusted-CLT UCL (Chen-1995)	35.37	97.5% Chebyshev (MVUE) UCL	71.01
95% Modified-t UCL (Johnson-1978)	34.16	99% Chebyshev (MVUE) UCL	100.8
Gamma Distribution Test		**Data Distribution**	
k star (bias corrected)	0.153	**Data do not follow a Discernable Distribution (0.05)**	
Theta Star	168.8		
MLE of Mean	25.82		
MLE of Standard Deviation	66.03		
nu star	97.26		
Approximate Chi Square Value (.05)	75.51	**Nonparametric Statistics**	
Adjusted Level of Significance	0.0492	95% CLT UCL	33.91
Adjusted Chi Square Value	75.42	95% Jackknife UCL	33.93
		95% Standard Bootstrap UCL	33.94
Anderson-Darling Test Statistic	56.29	95% Bootstrap-t UCL	36.24
Anderson-Darling 5% Critical Value	1.049	95% Hall's Bootstrap UCL	35.24
Kolmogorov-Smirnov Test Statistic	0.35	95% Percentile Bootstrap UCL	34.18
Kolmogorov-Smirnov 5% Critical Value	0.059	95% BCA Bootstrap UCL	35.27
Data not Gamma Distributed at 5% Significance Level		95% Chebyshev(Mean, Sd) UCL	47.25
		97.5% Chebyshev(Mean, Sd) UCL	56.53
Assuming Gamma Distribution		99% Chebyshev(Mean, Sd) UCL	74.74
95% Approximate Gamma UCL	33.26		
95% Adjusted Gamma UCL	33.3		
Potential UCL to Use		Use 95% Chebyshev (Mean, Sd) UCL	47.25

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). For additional insight, the user may want to consult a statistician.

ARCADIS

Appendix C

J&E Model Results for Potential Indoor Air Exposures

Input Parameters - 95% UCL

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

CALCULATE RISK-BASED GROUNDWATER CONCENTRATION (enter "X" in "YES" box)

DTSC / HERD
Vapor Intrusion Guidance
Interim Final 12/04 last update LA 01/01

YES [ ]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL GROUNDWATER CONCENTRATION (enter "X" in "YES" box and initial groundwater conc. below)

YES [X]

ENTER Chemical CAS No. (numbers only, no dashes)	**ENTER** Initial groundwater conc., C_W (μg/L)	Chemical
95636	113	1,2,4-Trimethylbenzene
108678	121	1,3,5-Trimethylbenzene
91576	35	1-Methylnaphthalene
91576	25.2	2-Methylnaphthalene
71432	1334	Benzene
110827	498	Cyclohexane
100414	180	Ethylbenzene
1634044	3.87	MTBE
91203	145	Naphthalene
110543	64.8	Hexane
103651	80.3	n-Propylbenzene
108883	1427	Toluene
106423	1184	Total Xylenes
		CAS No. not found

Input Parameters - 95% UCL

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
			Totals must add up to value of L_{WT} (cell G28)					
Average soil/ groundwater temperature, T_S (^oC)	Depth below grade to bottom of enclosed space floor, L_F (cm)	Depth below grade to water table, L_{WT} (cm)	Thickness of soil stratum A, h_A (cm)	Thickness of soil stratum B, (Enter value or 0) h_B (cm)	Thickness of soil stratum C, (Enter value or 0) h_C (cm)	Soil stratum directly above water table, (Enter A, B, or C)	SCS soil type directly above water table	Soil stratum A SCS soil type (used to estimate soil vapor permeability)
5	15	304.0	304.0	0.0		A	SC	S

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Stratum A SCS soil type Lookup Soil Parameters	Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	Stratum A soil total porosity, n^A (unitless)	Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	Stratum B SCS soil type Lookup Soil Parameters	Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	Stratum B soil total porosity, n^B (unitless)	Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	Stratum C SCS soil type Lookup Soil Parameters
S	1.66	0.38	0.054	S	1.66	0.38	0.05	

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER	ENTER		ENTER
Enclosed space floor thickness, L_{crack} (cm)	Soil-bldg. pressure differential, ΔP (g/cm-s^2)	Enclosed space floor length, L_B (cm)	Enclosed space floor width, W_B (cm)	Enclosed space height, H_B (cm)	Floor-wall seam crack width, w (cm)	Indoor air exchange rate, ER (1/h)		Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
10	40	2286	914.4	304.8	0.1	1.0		5

ENTER	ENTER	ENTER	ENTER	ENTER	ENTER
Averaging time for carcinogens, AT_C (yrs)	Averaging time for noncarcinogens, AT_{NC} (yrs)	Exposure duration, ED (yrs)	Exposure frequency, EF (days/yr)	Target risk for carcinogens, TR (unitless)	Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	25	250	1.0E-06	1

Input Parameters - 95% UCL

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Thickness of capillary zone, L_{cz} (cm)	Total porosity in capillary zone, n_{cz} (cm^3/cm^3)	Air-filled porosity in capillary zone, $\theta_{a,cz}$ (cm^3/cm^3)	Water-filled porosity in capillary zone, $\theta_{w,cz}$ (cm^3/cm^3)	Floor-wall seam perimeter, X_{crack} (cm)
7.9E+08	289	0.321	0.321	--	0.003	9.8E-08	0.998	9.8E-08	30.00	0.375	0.020	0.355	6,401

Bldg. ventilation rate, $Q_{building}$ (cm^3/s)	Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. groundwater temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. groundwater temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. groundwater temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Capillary zone effective diffusion coefficient, D^{eff}_{cz} (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
1.8E+05	2.2E+06	2.9E-04	15	11,753	1.5E-03	6.5E-02	1.7E-04	9.8E-03	0.0E+00	0.0E+00	2.9E-05	2.7E-04	289
				11,743	1.4E-03	6.2E-02		9.7E-03			3.3E-05	3.1E-04	
				16,306	7.1E-05	3.1E-03		8.4E-03			5.6E-04	3.4E-03	
				16,306	7.1E-05	3.1E-03		8.4E-03			5.6E-04	3.4E-03	
				8,172	2.1E-03	9.0E-02		1.4E-02			2.6E-05	2.5E-04	
				8,273	3.8E-02	1.7E+00		1.2E-02			2.3E-06	2.3E-05	
				10,212	2.3E-03	1.0E-01		1.2E-02			1.9E-05	1.8E-04	
				7,358	2.6E-04	1.1E-02		1.7E-02			2.1E-04	1.9E-03	
				12,964	1.0E-04	4.4E-03		9.5E-03			3.9E-04	2.8E-03	
				7,802	6.4E-01	2.8E+01		3.2E-02			3.3E-06	3.1E-05	
				11,432	2.7E-03	1.2E-01		9.7E-03			1.6E-05	1.5E-04	
				9,208	2.2E-03	9.5E-02		1.4E-02			2.2E-05	2.1E-04	
				10,306	2.2E-03	9.6E-02		1.2E-02			2.1E-05	2.0E-04	

Input Parameters - 95% UCL

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α **(unitless)**	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Infinite source bldg. conc., $C_{building}$ (mg/m^3)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	
15	7.3E+03	0.10	8.3E+01	9.8E-03	6.4E+02	5.2E+57	1.1E-05	8.2E-02	8.2E-05	NA	7.0E-03	1,2,4-Trimethylbenzene
	7.5E+03			9.7E-03		1.3E+58	1.3E-05	9.5E-02	9.5E-05	NA	6.0E-03	1,3,5-Trimethylbenzene
	1.1E+02			8.4E-03		9.9E+66	1.1E-04	1.2E-02	1.2E-05	NA	1.4E-02	1-Methylnaphthalene
	7.9E+01			8.4E-03		9.9E+66	1.1E-04	8.8E-03	8.8E-06	NA	1.4E-02	2-Methylnaphthalene
	1.2E+05			1.4E-02		5.6E+39	1.0E-05	1.2E+00	1.2E-03	2.9E-05	3.0E-02	Benzene
	8.2E+05			1.2E-02		3.9E+47	9.6E-07	7.9E-01	7.9E-04	NA	6.0E+00	Cyclohexane
	1.8E+04			1.2E-02		4.3E+46	7.5E-06	1.4E-01	1.4E-04	2.5E-06	1.0E+00	Ethylbenzene
	4.3E+01			1.7E-02		1.4E+34	6.8E-05	2.9E-03	2.9E-06	2.6E-07	3.0E+00	MTBE
	6.3E+02			9.5E-03		1.9E+59	9.4E-05	6.0E-02	6.0E-05	3.4E-05	3.0E-03	Naphthalene
	1.8E+06			3.2E-02		3.1E+17	1.3E-06	2.5E+00	2.5E-03	NA	7.0E-01	Hexane
	9.4E+03			9.7E-03		1.6E+58	6.5E-06	6.0E-02	6.0E-05	NA	1.4E-01	n-Propylbenzene
	1.4E+05			1.4E-02		1.6E+40	8.7E-06	1.2E+00	1.2E-03	NA	3.0E-01	Toluene
	1.1E+05			1.2E-02		3.0E+45	8.4E-06	9.5E-01	9.5E-04	NA	1.0E-01	Total Xylenes

Results - 95% UCL

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

RISK-BASED GROUNDWATER CONCENTRATION CALCULATIONS: INCREMENTAL RISK CALCULATIONS:

Indoor exposure groundwater conc., carcinogen (μg/L)	Indoor exposure groundwater conc., noncarcinogen (μg/L)	Risk-based indoor exposure groundwater conc., (μg/L)	Pure component water solubility, S (μg/L)	Final indoor exposure groundwater conc., (μg/L)	Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)	
NA	NA	NA	5.7E+04	NA	NA	6.7E-03	1,2,4-Trimethylbenzene
NA	NA	NA	2.0E+03	NA	NA	9.1E-03	1,3,5-Trimethylbenzene
NA	NA	NA	2.5E+04	NA	NA	5.0E-04	1-Methylnaphthalene
NA	NA	NA	2.5E+04	NA	NA	3.6E-04	2-Methylnaphthalene
NA	NA	NA	1.8E+06	NA	8.8E-06	2.4E-02	Benzene
NA	NA	NA	5.5E+04	NA	NA	7.5E-05	Cyclohexane
NA	NA	NA	1.7E+05	NA	8.3E-08	7.7E-05	Ethylbenzene
NA	NA	NA	5.1E+07	NA	1.9E-10	5.6E-07	MTBE
NA	NA	NA	3.1E+04	NA	5.0E-07	1.1E-02	Naphthalene
NA	NA	NA	1.2E+04	NA	NA	2.0E-03	Hexane
NA	NA	NA	6.0E+04	NA	NA	2.5E-04	n-Propylbenzene
NA	NA	NA	5.3E+05	NA	NA	2.2E-03	Toluene
NA	NA	NA	1.9E+05	NA	NA	5.5E-03	Total Xylenes

ARCADIS

Appendix D

Estimated Risks/Hazards Using Maximum COPC Concentrations – PPRTV Scenario and ARCADIS Comparative Scenario

Table D-1

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Indoor Worker Exposed to Indoor Air - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m^3) [a]	AF [a]	EPCia (mg/m^3) [a]		CANCER RISK Route-Specific Risk Inhalation (indoor air)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Metals											
Barium	4.8E+02							-			-
Iron	5.7E+04							-			-
Lead	2.1E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	6.1E+02	4.0E+01	1.1E-05	4.5E-04	V	-		-	1.5E-02	1.5E-02	8.0%
1,3,5-Trimethylbenzene	1.8E+02	1.1E+01	1.3E-05	1.4E-04	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	6.0E+01				V			-			-
Benzene	1.9E+04	1.7E+03	1.0E-05	1.7E-02	V	1.1E-05	1.1E-05	93%	1.3E-01	1.3E-01	71.7%
Ethylbenzene	2.8E+03	2.7E+02	7.5E-06	2.1E-03	V	4.2E-07	4.2E-07	4%	4.7E-04	4.7E-04	<1%
n-Propylbenzene	1.2E+02	1.4E+01	6.5E-06	9.2E-05	V	-		-	2.1E-05	2.1E-05	<1%
Toluene	3.0E+04	2.9E+03	8.7E-06	2.5E-02	V	-		-	1.1E-03	1.1E-03	<1%
Xylenes	1.4E+04	1.4E+03	8.4E-06	1.1E-02	V	-		-	2.6E-02	2.6E-02	14.2%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	3.1E+01	9.7E-02	1.1E-04	1.1E-05	V	-		-	-		-
PAHs											
Naphthalene	3.0E+02	1.3E+00	9.4E-05	1.2E-04	V	3.4E-07	3.4E-07	3%	9.4E-03	9.4E-03	5.2%
Miscellaneous											
Sulfolane	1.0E+04							-			-
GRO	2.1E+04							-			-
DRO	2.2E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						1E-05	1E-05		2E-01	2E-01	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Table D-1

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Indoor Worker Exposed to Indoor Air - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

CI_ATC	25550
CI_ATnc	9125
CI_ED	25
CI_EF	250
CI_ET	8

Exposure Duration CHRONIC

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-2

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]		CANCER RISK: Route-Specific Risk: Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals															
Arsenic	7.6E+00	1.3E+09	5.8E-09			4.0E-06	5.3E-07	2.0E-09	4.5E-06	97%	2.5E-02	3.3E-03	8.8E-05	2.8E-02	52.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08			-	-	-	-	-	1.3E-05	-	-	1.3E-05	<1%
Iron	1.7E+04	1.3E+09	1.3E-05			-	-	-	-	-	2.4E-02	-	-	2.4E-02	44.2%
Lead							-			-		-			-
Nickel	2.0E+01	1.3E+09	1.5E-08			-	-	3.3E-10	3.3E-10	<1%	9.9E-04	-	3.9E-05	1.0E-03	1.9%
VOCs															
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06		V	-	-	-	-	-	2.2E-06	-	-	2.2E-06	<1%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06		V	-	-	-	-	-	-	-	-	-	-
Benzene	5.1E-02	3.8E+03	1.3E-05		V	9.8E-10	-	8.5E-09	9.5E-09	<1%	1.2E-05	-	1.0E-04	1.1E-04	<1%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05		V	-	-	-	-	-	-	-	1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05		V	8.4E-10	-	7.3E-09	8.1E-09	<1%	2.1E-06	-	8.2E-06	1.0E-05	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05		V	1.6E-10	-	9.8E-10	1.1E-09	<1%	9.8E-07	-	5.8E-06	6.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04		V	-	-	-	-	-	1.9E-06	-	4.2E-05	4.4E-05	<1%
Toluene	8.2E-02	4.6E+03	1.8E-05		V	-	-	-	-	-	1.0E-06	-	8.1E-07	1.8E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04		V	-	-	-	-	-	3.6E-06	-	2.7E-04	2.7E-04	<1%
SVOCs															
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06		V	2.5E-09	-	-	2.5E-09	<1%	3.4E-06	-	-	3.4E-06	<1%
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06		V	-	-	-	-	-	6.7E-05	-	-	6.7E-05	<1%
PAHs															
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11			*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11			*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11			*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11			*	*	*	*	-	-	-	-	-	-
Chrysene	6.6E-02	1.3E+09	5.0E-11			*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11			*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11			*	*	*	*	-	-	-	-	-	-
Naphthalene	5.9E-02	5.0E+04	1.2E-06		V	-	-	3.3E-09	3.3E-09	<1%	2.9E-06	1.7E-06	9.0E-05	9.5E-05	<1%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11			8.1E-08	4.7E-08	2.2E-12	1.3E-07	3%	-	-	-	-	-
Miscellaneous															
Sulfolane	3.8E-02	1.3E+09	2.9E-11			-	-	-	-	-	3.7E-05	-	-	3.7E-05	<1%
GRO	5.4E+00	1.3E+09	4.1E-09			-	-	-	-	-	-	-	-	-	-
DRO	2.1E+02	1.3E+09	1.6E-07			-	-	-	-	-	-	-	-	-	-
RRO	1.9E+03	1.3E+09	1.4E-06			-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard						4E-06	6E-07	2E-08	5E-06		5E-02	3E-03	6E-04	5E-02	
Total Risk or Hazard Excluding Arsenic						9E-08	5E-08	2E-08	2E-07		2E-02	2E-06	6E-04	3E-02	

Table D-2
Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_EvFs	1
CIo_AF	0.2	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1316000000
CIo_EF	250	CIo_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-3a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	1.8E+01	1.0E+06	1.8E-05		6.1E-07	3.7E-08	1.5E-08	6.6E-07	69%	5.7E-03	3.5E-04	1.7E-02	2.3E-02	8.1%
Chromium, Total	5.1E+01	1.0E+06	5.1E-05		-	-	-	-	-	5.5E-05	-	-	5.5E-05	<1%
Iron	2.9E+04	1.0E+06	2.9E-02		-	-	-	-	-	6.7E-02	-	-	6.7E-02	23.8%
Nickel	3.8E+01	1.0E+06	3.8E-05		-	-	2.0E-09	2.0E-09	<1%	3.1E-03	-	6.0E-03	9.1E-03	3.2%
VOCs														
1,2,4-Trimethylbenzene	2.1E+02	8.5E+03	2.4E-02	V	-	-	-	-	-	-	-	4.9E-03	4.9E-03	1.7%
1,3,5-Trimethylbenzene	8.1E+01	7.1E+03	1.1E-02	V	-	-	-	-	-	1.3E-03	-	1.6E-02	1.8E-02	6.2%
4-Isopropyltoluene (p-cymene)	2.0E+01	9.4E+03	2.2E-03	V	-	-	-	-	-	-	-	-	-	-
Benzene	8.2E+01	3.8E+03	2.2E-02	V	1.0E-07	-	3.4E-08	1.4E-07	14%	1.3E-02	-	3.8E-03	1.7E-02	6.1%
Cyclohexane	4.5E+01	1.1E+03	4.0E-02	V	-	-	-	-	-	-	-	9.5E-05	9.5E-05	<1%
Ethylbenzene	1.1E+02	6.1E+03	1.8E-02	V	2.8E-08	-	9.3E-09	3.7E-08	4%	3.6E-03	-	2.9E-05	3.6E-03	1.3%
Isopropylbenzene (cumene)	4.2E+01	6.7E+03	6.2E-03	V	-	-	-	-	-	1.7E-04	-	9.9E-04	1.2E-03	<1%
Methylene chloride	1.9E-01	2.4E+03	8.0E-05	V	3.3E-11	-	7.6E-12	4.0E-11	<1%	5.1E-06	-	3.8E-07	5.4E-06	<1%
n-Butylbenzene	1.1E+02	8.8E+03	1.2E-02	V	-	-	-	-	-	1.7E-03	-	-	1.7E-03	<1%
n-Hexane	1.3E+01	8.9E+02	1.5E-02	V	-	-	-	-	-	7.0E-05	-	1.0E-04	1.7E-04	<1%
n-Propylbenzene	7.3E+01	7.5E+03	9.7E-03	V	-	-	-	-	-	1.2E-03	2.4E-04	1.4E-04	1.5E-03	<1%
sec-Butylbenzene	2.5E+01	8.1E+03	3.1E-03	V	-	-	-	-	-	-	-	-	-	-
Toluene	3.9E+02	4.6E+03	8.5E-02	V	-	-	-	-	-	7.9E-04	-	2.4E-04	1.0E-03	<1%
Xylenes	7.1E+02	6.3E+03	1.1E-01	V	-	-	-	-	-	2.8E-03	-	4.0E-03	6.9E-03	2.4%
SVOCs														
1-Methylnaphthalene	8.9E+01	6.3E+04	1.4E-03	V	5.9E-08	-	-	5.9E-08	6%	2.0E-03	-	-	2.0E-03	<1%
2-Methylnaphthalene	2.4E+02	6.2E+04	3.8E-03	V	-	-	-	-	-	9.7E-02	-	-	9.7E-02	34.5%
PAHs														
Benzo (a) anthracene	9.9E-02	1.0E+06	9.9E-08		*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	9.5E-02	1.0E+06	9.5E-08		*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	1.1E-01	1.0E+06	1.1E-07		*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	4.0E-02	1.0E+06	4.0E-08		*	*	*	*	-	-	-	-	-	-
Chrysene	7.8E-01	1.0E+06	7.8E-07		*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	1.8E-02	1.0E+06	1.8E-08		*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.0E+06	6.9E-08		*	*	*	*	-	-	-	-	-	-
Naphthalene	1.3E+02	5.0E+04	2.5E-03	V	-	-	1.7E-08	1.7E-08	2%	1.0E-02	2.7E-03	1.2E-02	2.5E-02	8.8%
Total Benzo(a)pyrene TEQ	2.3E-01	1.0E+06	2.3E-07		3.8E-08	1.0E-08	5.0E-11	4.8E-08	5%	-	-	-	-	-
Miscellaneous														
Sulfolane	1.8E+01	1.0E+06	1.8E-05		-	-	-	-	-	3.0E-03	-	-	3.0E-03	1.1%
GRO	7.7E+03	1.0E+06	7.7E-03		-	-	-	-	-	-	-	-	-	-
DRO	1.9E+04	1.0E+06	1.9E-02		-	-	-	-	-	-	-	-	-	-
RRO	6.5E+04	1.0E+06	6.5E-02		-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard					8E-07	5E-08	8E-08	1E-06		2E-01	3E-03	7E-02	3E-01	
Total Risk or Hazard Excluding Arsenic					2E-07	1E-08	6E-08	3E-07		2E-01	3E-03	5E-02	3E-01	

Table D-3a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI

Abbreviations:

-:	Not applicable	mg/m^3:	Milligram(s) per cubic meter
ELCR:	Excess lifetime cancer risk (unitless)	PAH:	Polycyclic aromatic hydrocarbon
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
mg/kg:	Milligram(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk
m^3/kg:	Cubic meter(s) per kilogram		

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvFs	1
CST_AF	0.3	CST_FI	1
CST_BW	70	CST_IRs	330
CST_ED	1	CST_PEF	1.00E+06
CST_EF	125	CST_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-3b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta [a] (mg/m3)		CANCER RISK Route-Specific Risk Oral	Dermal	Inhalation (trench air)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal	Inhalation (trench air)	Calculated Hazard	Percent Total HI
Metals															
Barium	4.8E-01		1.0E-06			-	-	-	-	-	1.2E-04	1.1E-03		1.2E-03	<1%
Iron	5.7E+01		1.0E-06			-	-	-	-	-	1.5E-03	8.9E-04	-	2.4E-03	<1%
Lead	2.1E-03		1.0E-07			-	-	-	-	-	-	-	-	-	-
VOCs															
1,2,4-Trimethylbenzene	6.1E-01	7.5E+00	2.6E-04	4.6E+00	V	-	-	-	-	-	-	-	9.4E-01	9.4E-01	1.9%
1,3,5-Trimethylbenzene	1.8E-01	7.6E+00	1.8E-04	1.4E+00	V	-	-	-	-	-	3.3E-05	3.7E-03	2.0E+00	2.0E+00	4.1%
4-Isopropyltoluene (p-cymene)	6.0E-02	7.2E+00	5.0E-04	4.3E-01	V	-	-	-	-	-	-	-	-	-	-
Benzene	1.9E+01	9.3E+00	2.3E-05	1.7E+02	V	2.6E-07	3.7E-06	2.7E-04	2.8E-04	92%	3.3E-02	4.7E-01	3.1E+01	3.1E+01	64.4%
Ethylbenzene	2.8E+00	8.0E+00	8.8E-05	2.2E+01	V	7.8E-09	4.1E-07	1.1E-05	1.2E-05	4%	1.0E-03	5.3E-02	3.5E-02	8.9E-02	<1%
n-Propylbenzene	1.2E-01	7.6E+00	2.8E-04	9.2E-01	V	-	-	-	-	-	2.2E-05	3.8E-03	1.3E-02	1.7E-02	<1%
Toluene	3.0E+01	8.6E+00	5.2E-05	2.6E+02	V	-	-	-	-	-	6.8E-04	2.1E-02	7.4E-01	7.6E-01	1.6%
Xylenes	1.4E+01	8.0E+00	9.5E-05	1.1E+02	V	-	-	-	-	-	6.4E-04	3.6E-02	4.0E+00	4.1E+00	8.3%
SVOCs															
1-Methylnaphthalene	3.5E-02	6.3E+00	3.3E-04	2.2E-01	V	2.6E-10	5.2E-08	-	5.2E-08	<1%	9.1E-06	1.8E-03	-	1.8E-03	<1%
2-Methylnaphthalene	3.1E-02	6.3E+00	3.2E-04	2.0E-01	V	-	-	-	-	-	1.4E-04	2.7E-02	-	2.7E-02	<1%
PAHs															
Naphthalene	3.0E-01	6.6E+00	9.7E-05	2.0E+00	V	-	-	1.4E-05	1.4E-05	5%	2.7E-04	1.6E-02	9.4E+00	9.4E+00	19.4%
Miscellaneous															
Sulfolane	1.0E+01		2.0E-07			-	-	-	-	-	1.9E-02	2.3E-03	-	2.1E-02	<1%
GRO	2.1E+01		NA			-	-	-	-	-	-	-	-	-	-
DRO	2.2E+00		NA			-	-	-	-	-	-	-	-	-	-
RRO	2.8E-01		NA			-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard						3E-07	4E-06	3E-04	3E-04		6E-02	6E-01	4.8E+01	4.9E+01	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Table D-3b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRinc_gw × EFgw × ED × CSFo) / (BW × ATc)
ELCRd = (EPCgw × DA × SAgw × EvFgw × EFgw × ED × CSFd) / (BW × ATc)
ELCRta (VOCs) = ([EPCgw × VF] × EFgw × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCgw × FIgw × IRinc_gw × EFgw × ED) / (BW × ATnc × RfDo)
HQd = (EPCgw × DA ×SAgw ×EvFgw × EFgw × ED) / (BW × ATnc × RfDa)
HQta (VOCs) = ([EPCgw × VF] × ET × EFgw × ED) / (24 × ATnc × RfC)

Table D-4

Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m³) [a]	AF [a]	EPCia (mg/m³) [a]		CANCER RISK: Route-Specific Risk Inhalation (indoor air)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals											
Barium	4.8E+02							-			-
Iron	5.7E+04							-			-
Lead	2.1E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	6.1E+02	4.0E+01	1.1E-05	4.5E-04	V	-		-	1.7E-04	1.7E-04	8.0%
1,3,5-Trimethylbenzene	1.8E+02	1.1E+01	1.3E-05	1.4E-04	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	6.0E+01				V			-			-
Benzene	1.9E+04	1.7E+03	1.0E-05	1.7E-02	V	1.6E-07	1.6E-07	93%	1.6E-03	1.6E-03	71.7%
Ethylbenzene	2.8E+03	2.7E+02	7.5E-06	2.1E-03	V	6.1E-09	6.1E-09	4%	5.7E-06	5.7E-06	<1%
n-Propylbenzene	1.2E+02	1.4E+01	6.5E-06	9.2E-05	V	-		-	2.5E-07	2.5E-07	<1%
Toluene	3.0E+04	2.9E+03	8.7E-06	2.5E-02	V	-		-	1.4E-05	1.4E-05	<1%
Xylenes	1.4E+04	1.4E+03	8.4E-06	1.1E-02	V	-		-	3.1E-04	3.1E-04	14.2%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	3.1E+01	9.7E-02	1.1E-04	1.1E-05	V	-		-	-		-
PAHs											
Naphthalene	3.0E+02	1.3E+00	9.4E-05	1.2E-04	V	5.0E-09	5.0E-09	3%	1.1E-04	1.1E-04	5.2%
Miscellaneous											
Sulfolane	1.0E+04							-			-
GRO	2.1E+04							-			-
DRO	2.2E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						2E-07	2E-07		2E-03	2E-03	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m³:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m³)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m³)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Table D-4

Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

VIS_ATC	25550
VIS_ATnc	10950
VIS_ED	30
VIS_EF	12
VIS_ET	2

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-5a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK				Percent Total ELCR	NON-CANCER HAZARD				Percent Total HI
					Route-Specific Risk			Calculated Risk		Route-Specific Hazard			Calculated Hazard	
					Oral [c]	Dermal [c]	Inhalation (ambient)			Oral [c]	Dermal [c]	Inhalation (ambient)		
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				3.9E-09	3.9E-09	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				6.3E-10	6.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			1.6E-08	1.6E-08	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			1.4E-08	1.4E-08	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			1.9E-09	1.9E-09	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			6.4E-09	6.4E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				4.2E-12	4.2E-12	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	9E-04	9E-04	

Table D-5a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATc	25550	ADUR_ET	12
ADUR_ATnc	10950	ADUR_FI	–
ADUR_AF	–	ADUR_IRs	–
ADUR_BW	70	ADUR_PEF	1316000000
ADUR_ED	30	ADUR_SA	–
ADUR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-5b

Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	1.2E+01			1.2E+01	100.0%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1.2E+01	0E+00	0E+00	1.2E+01	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-5c

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - All Offsite Wells - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	4.4E-01	1.0E+00	4.4E-01	-	-		-	3.0E-01	4.8E-01	7.9E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		3.0E-01	4.8E-01	7.9E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-6a
Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

					CANCER RISK				Percent	NON-CANCER HAZARD				Percent
					Route-Specific Risk			Calculated	Total	Route-Specific Hazard			Calculated	Total
Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	Oral [c]	Dermal [c]	Inhalation (ambient)	Risk	ELCR	Oral [c]	Dermal [c]	Inhalation (ambient)	Hazard	HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				7.9E-10	7.9E-10	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				1.3E-10	1.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			3.3E-09	3.3E-09	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			2.8E-09	2.8E-09	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			3.8E-10	3.8E-10	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			1.3E-09	1.3E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				8.4E-13	8.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	9E-09	9E-09		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	8E-09	8E-09		0E+00	0E+00	9E-04	9E-04	

Table D-6a

Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CHR_ATc	25550	CHR_ET	12
CHR_ATnc	2190	CHR_FI	–
CHR_AF	–	CHR_IRs	–
CHR_BW	15	CHR_PEF	1316000000
CHR_ED	6	CHR_SA	–
CHR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-6b
Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK: Route-Specific Risk: Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	2.8E+01			2.8E+01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2.8E+01	0E+00	0E+00	2.8E+01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-6c

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - All Offsite Wells - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	4.4E-01	1.0E+00	4.4E-01	-	-		-	1.2E+00	1.1E+00	2.3E+00	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		1E+00	1E+00	2E+00	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:
ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-7a

Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				1.3E-10	1.3E-10	9%			1.4E-04	1.4E-04	21.3%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				2.1E-11	2.1E-11	1%			6.3E-05	6.3E-05	9.4%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			1.2E-04	1.2E-04	17.3%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			5.5E-10	5.5E-10	38%			6.2E-05	6.2E-05	9.2%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			4.7E-10	4.7E-10	33%			1.5E-06	1.5E-06	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			6.4E-11	6.4E-11	4%			3.2E-06	3.2E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			2.4E-05	2.4E-05	3.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			1.1E-04	1.1E-04	16.3%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			2.1E-10	2.1E-10	15%			1.5E-04	1.5E-04	21.8%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				1.4E-13	1.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	7E-04	7E-04	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	5E-04	5E-04	

Table D-7a
Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATc	25550	INF_ET	12
INF_ATnc	365	INF_FI	–
INF_AF	–	INF_IRs	–
INF_BW	6.75	INF_PEF	1316000000
INF_ED	1	INF_SA	–
INF_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-7b
Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	6.6E+00			6.6E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		7E+00	0E+00	0E+00	7E+00	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-7c

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - All Offsite Wells - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	4.4E-01	1.0E+00	4.4E-01	-	-		-	1.9E-01	1.3E-01	3.2E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		2E-01	1E-01	3E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-8
Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	8.7E+00			8.7E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		9E+00	0E+00	0E+00	9E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-9a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				2.0E-09	2.0E-09	9%			8.8E-05	8.8E-05	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				3.3E-10	3.3E-10	1%			3.9E-05	3.9E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			8.5E-09	8.5E-09	38%			1.0E-04	1.0E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			7.3E-09	7.3E-09	33%			8.2E-06	8.2E-06	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			9.8E-10	9.8E-10	4%			5.8E-06	5.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			4.2E-05	4.2E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			8.1E-07	8.1E-07	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			2.7E-04	2.7E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			3.3E-09	3.3E-09	15%			9.0E-05	9.0E-05	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				2.2E-12	2.2E-12	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	

Table D-9a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1316000000
CIo_EF	250		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-9b

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	8.7E+00			8.7E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		9E+00	0E+00	0E+00	9E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-10

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - All Offsite Wells - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	4.4E-01		2.0E-07		-			-	-	8.0E-04			8.0E-04	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		8E-04	0E+00	0E+00	8E-04	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m^3:	Liter(s) per cubic meter		

Notes:

[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-11
Chronic Hazard Estimates for the Offsite Adult Recreator Exposed to Surface Water - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCsw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event)	CANCER RISK Route-Specific Risk Oral [c]	Dermal [d]	Inhalation [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [d]	Inhalation [d]	Calculated Hazard	Percent Total HI
Miscellaneous													
Sulfolane	1.6E-01			-			-	-	2.6E-02			2.6E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00	0E+00		3E-02	0E+00	0E+00	3E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCsw:	Exposure point concentration in surface water (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTsw) as shown for this receptor below.
[c] This exposure scenario assumes recreational contact exposures including swimming, walking, wading, and splashing.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):   Exposure Duration CHRONIC

AREC_ATC	25550	AREC_ET	1
AREC_ATnc	10950	AREC_EvFsw	–
AREC_BW	70	AREC_FIsw	1
AREC_ED	30	AREC_IRinc_sw	0.071
AREC_EFsw	60	AREC_SAsw	–
AREC_EvTsw	–		

Equations:
ELCRo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED × CSFo) / (BW × ATc)

HQo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED) / (BW × ATnc × RfDo)

Table D-12

Chronic Hazard Estimates for the Offsite Child Recreator Exposed to Surface Water - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCsw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event)	CANCER RISK Route-Specific Risk Oral [c]	Dermal [d]	Inhalation [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [d]	Inhalation [d]	Calculated Hazard	Percent Total HI
Miscellaneous													
Sulfolane	1.6E-01			-			-	-	2.1E-01			2.1E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCsw:	Exposure point concentration in surface water (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTsw) as shown for this receptor below.
[c] This exposure scenario assumes recreational contact exposures including swimming, walking, wading, and splashing.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CREC_ATC	25550	CREC_ET	1
CREC_ATnc	2190	CREC_EvFsw	–
CREC_BW	15	CREC_FIsw	1
CREC_ED	6	CREC_IRinc_sw	0.12
CREC_EFsw	60	CREC_SAsw	–
CREC_EvTsw	–		

Equations:

ELCRo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED × CSFo) / (BW × ATc)

HQo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED) / (BW × ATnc × RfDo)

Table D-13a
Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	3.9E+00			3.9E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		4E+00	0E+00	0E+00	4E+00	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-13b

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 2 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.4E-01	1.0E+00	1.4E-01	-	-		-	9.9E-02	1.6E-01	2.6E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		1E-01	2E-01	3E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-14a

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	9.2E+00			9.2E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		9E+00	0E+00	0E+00	9E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-14b

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 2 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.4E-01	1.0E+00	1.4E-01	-	-		-	4.0E-01	3.6E-01	7.5E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		4E-01	4E-01	8E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-15a
Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	2.2E+00			2.2E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E+00	0E+00	0E+00	2E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions): Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-15b

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 2 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.4E-01	1.0E+00	1.4E-01	-	-		-	6.1E-02	4.3E-02	1.0E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		6E-02	4E-02	1E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-16

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	2.8E+00			2.8E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E+00	0E+00	0E+00	3E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):   Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-17

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK: Route-Specific Risk: Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	2.8E+00			2.8E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E+00	0E+00	0E+00	3E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-18

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 2 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	1.4E-01		2.0E-07		-			-	-	2.6E-04			2.6E-04	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		3E-04	0E+00	0E+00	3E-04	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m³:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m³)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m³:	Liter(s) per cubic meter		

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

$$ELCRo = (EPCgw \times FIgw \times IRgw \times EFgw \times ED \times CSFo) / (BW \times ATc)$$

$$HQo = (EPCgw \times FIgw \times IRgw \times EFgw \times ED) / (BW \times ATnc \times RfDo)$$

Table D-19a
Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations
Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	2.2E+00			2.2E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E+00	0E+00	0E+00	2E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-19b
Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 3 - Maximum COPC Concentrations
Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	8.0E-02	1.0E+00	8.0E-02	-	-		-	5.5E-02	8.8E-02	1.4E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		5E-02	9E-02	1E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-20a

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	5.1E+00			5.1E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		5E+00	0E+00	0E+00	5E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-20b
Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 3 - Maximum COPC Concentrations
Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	8.0E-02	1.0E+00	8.0E-02	-	-		-	2.2E-01	2.0E-01	4.2E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		2E-01	2E-01	4E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:
ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-21a

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	1.2E+00			1.2E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E+00	0E+00	0E+00	1E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-21b
Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 3 - Maximum COPC Concentrations
Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK			Percent Total ELCR	NON-CANCER HAZARD			Percent Total HI
				Route-Specific Risk		Calculated Risk		Route-Specific Hazard		Calculated Hazard	
				Ingestion (fruit)	Ingestion (vegetables)			Ingestion (fruit)	Ingestion (vegetables)		
Miscellaneous											
Sulfolane	8.0E-02	1.0E+00	8.0E-02	-	-		-	3.4E-02	2.4E-02	5.8E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		3E-02	2E-02	6E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:
ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-22
Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations
Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

						CANCER RISK					NON-CANCER HAZARD				
						Route-Specific Risk					Route-Specific Hazard				
Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	1.6E+00			1.6E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E+00	0E+00	0E+00	2E+00	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm²/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m³)
EPCia:	Exposure point concentration in indoor air (mg/m³)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm²/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m³:	Milligram(s) per cubic meter
VF:	Volatilization factor (m³/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m³)
VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Exposure Duration CHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-23
Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations
Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	1.6E+00			1.6E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E+00	0E+00	0E+00	2E+00	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-24

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 3 - Maximum COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	8.0E-02		2.0E-07		-			-	-	1.5E-04			1.5E-04	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		1E-04	0E+00	0E+00	1E-04	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m³:	Liter(s) per cubic meter		

Notes:

[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-25

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Indoor Worker Exposed to Indoor Air - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m^3) [a]	AF [a]	EPCia (mg/m^3) [a]		CANCER RISK: Route-Specific Risk Inhalation (indoor air)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals											
Barium	4.8E+02							-			-
Iron	5.7E+04							-			-
Lead	2.1E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	6.1E+02	4.0E+01	1.1E-05	4.5E-04	V	-		-	1.5E-02	1.5E-02	8.0%
1,3,5-Trimethylbenzene	1.8E+02	1.1E+01	1.3E-05	1.4E-04	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	6.0E+01				V			-			-
Benzene	1.9E+04	1.7E+03	1.0E-05	1.7E-02	V	1.1E-05	1.1E-05	93%	1.3E-01	1.3E-01	71.7%
Ethylbenzene	2.8E+03	2.7E+02	7.5E-06	2.1E-03	V	4.2E-07	4.2E-07	4%	4.7E-04	4.7E-04	<1%
n-Propylbenzene	1.2E+02	1.4E+01	6.5E-06	9.2E-05	V	-		-	2.1E-05	2.1E-05	<1%
Toluene	3.0E+04	2.9E+03	8.7E-06	2.5E-02	V	-		-	1.1E-03	1.1E-03	<1%
Xylenes	1.4E+04	1.4E+03	8.4E-06	1.1E-02	V	-		-	2.6E-02	2.6E-02	14.2%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	3.1E+01	9.7E-02	1.1E-04	1.1E-05	V	-		-	-		-
PAHs											
Naphthalene	3.0E+02	1.3E+00	9.4E-05	1.2E-04	V	3.4E-07	3.4E-07	3%	9.4E-03	9.4E-03	5.2%
Miscellaneous											
Sulfolane	1.0E+04							-			-
GRO	2.1E+04							-			-
DRO	2.2E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						1E-05	1E-05		2E-01	2E-01	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Table D-25

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Indoor Worker Exposed to Indoor Air - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

CI_ATC	25550
CI_ATnc	9125
CI_ED	25
CI_EF	250
CI_ET	8

Exposure Duration CHRONIC

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-26

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09		4.0E-06	5.3E-07	2.0E-09	4.5E-06	97%	2.5E-02	3.3E-03	8.8E-05	2.8E-02	52.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08		-	-	-	-	-	1.3E-05	-	-	1.3E-05	<1%
Iron	1.7E+04	1.3E+09	1.3E-05		-	-	-	-	-	2.4E-02	-	-	2.4E-02	44.3%
Lead						-			-		-			-
Nickel	2.0E+01	1.3E+09	1.5E-08		-	-	3.3E-10	3.3E-10	<1%	9.9E-04	-	3.9E-05	1.0E-03	1.9%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V	-	-	-	-	-	2.2E-06	-	-	2.2E-06	<1%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V	-	-	-	-	-	-	-	-	-	-
Benzene	5.1E-02	3.8E+03	1.3E-05	V	9.8E-10	-	8.5E-09	9.5E-09	<1%	1.2E-05	-	1.0E-04	1.1E-04	<1%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V	-	-	-	-	-	-	-	1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V	8.4E-10	-	7.3E-09	8.1E-09	<1%	2.1E-06	-	8.2E-06	1.0E-05	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V	1.6E-10	-	9.8E-10	1.1E-09	<1%	9.8E-07	-	5.8E-06	6.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V	-	-	-	-	-	1.9E-06	-	4.2E-05	4.4E-05	<1%
Toluene	8.2E-02	4.6E+03	1.8E-05	V	-	-	-	-	-	1.0E-06	-	8.1E-07	1.8E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V	-	-	-	-	-	3.6E-06	-	2.7E-04	2.7E-04	<1%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V	2.5E-09	-	-	2.5E-09	<1%	3.4E-06	-	-	3.4E-06	<1%
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V	-	-	-	-	-	6.7E-05	-	-	6.7E-05	<1%
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11		*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11		*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11		*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11		*	*	*	*	-	-	-	-	-	-
Chrysene	6.6E-02	1.3E+09	5.0E-11		*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11		*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11		*	*	*	*	-	-	-	-	-	-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V	-	-	3.3E-09	3.3E-09	<1%	2.9E-06	1.7E-06	9.0E-05	9.5E-05	<1%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11		8.1E-08	4.7E-08	2.2E-12	1.3E-07	3%	-	-	-	-	-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11		-	-	-	-	-	3.7E-06	-	-	3.7E-06	<1%
GRO	5.4E+00	1.3E+09	4.1E-09		-	-	-	-	-	-	-	-	-	-
DRO	2.1E+02	1.3E+09	1.6E-07		-	-	-	-	-	-	-	-	-	-
RRO	1.9E+03	1.3E+09	1.4E-06		-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard					4E-06	6E-07	2E-08	5E-06		5E-02	3E-03	6E-04	5E-02	
Total Risk or Hazard Excluding Arsenic					9E-08	5E-08	2E-08	2E-07		2E-02	2E-06	6E-04	3E-02	

Table D-26

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:

[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_EvFs	1
CIo_AF	0.2	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1.316E+09
CIo_EF	250	CIo_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-27a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	1.8E+01	1.0E+06	1.8E-05		6.1E-07	3.7E-08	1.5E-08	6.6E-07	69%	5.7E-03	3.5E-04	1.7E-02	2.3E-02	8.2%
Chromium, Total	5.1E+01	1.0E+06	5.1E-05		-	-	-	-	-	5.5E-05	-	-	5.5E-05	<1%
Iron	2.9E+04	1.0E+06	2.9E-02		-	-	-	-	-	6.7E-02	-	-	6.7E-02	24.0%
Nickel	3.8E+01	1.0E+06	3.8E-05		-	-	2.0E-09	2.0E-09	<1%	3.1E-03	-	6.0E-03	9.1E-03	3.3%
VOCs														
1,2,4-Trimethylbenzene	2.1E+02	8.5E+03	2.4E-02	V	-	-	-	-	-	-	-	4.9E-03	4.9E-03	1.8%
1,3,5-Trimethylbenzene	8.1E+01	7.1E+03	1.1E-02	V	-	-	-	-	-	1.3E-03	-	1.6E-02	1.8E-02	6.3%
4-Isopropyltoluene (p-cymene)	2.0E+01	9.4E+03	2.2E-03	V	-	-	-	-	-	-	-	-	-	-
Benzene	8.2E+01	3.8E+03	2.2E-02	V	1.0E-07	-	3.4E-08	1.4E-07	14%	1.3E-02	-	3.8E-03	1.7E-02	6.1%
Cyclohexane	4.5E+01	1.1E+03	4.0E-02	V	-	-	-	-	-	-	-	9.5E-05	9.5E-05	<1%
Ethylbenzene	1.1E+02	6.1E+03	1.8E-02	V	2.8E-08	-	9.3E-09	3.7E-08	4%	3.6E-03	-	2.9E-05	3.6E-03	1.3%
Isopropylbenzene (cumene)	4.2E+01	6.7E+03	6.2E-03	V	-	-	-	-	-	1.7E-04	-	9.9E-04	1.2E-03	<1%
Methylene chloride	1.9E-01	2.4E+03	8.0E-05	V	3.3E-11	-	7.6E-12	4.0E-11	<1%	5.1E-06	-	3.8E-07	5.4E-06	<1%
n-Butylbenzene	1.1E+02	8.8E+03	1.2E-02	V	-	-	-	-	-	1.7E-03	-	-	1.7E-03	<1%
n-Hexane	1.3E+01	8.9E+02	1.5E-02	V	-	-	-	-	-	7.0E-05	-	1.0E-04	1.7E-04	<1%
n-Propylbenzene	7.3E+01	7.5E+03	9.7E-03	V	-	-	-	-	-	1.2E-03	2.4E-04	1.4E-04	1.5E-03	<1%
sec-Butylbenzene	2.5E+01	8.1E+03	3.1E-03	V	-	-	-	-	-	-	-	-	-	-
Toluene	3.9E+02	4.6E+03	8.5E-02	V	-	-	-	-	-	7.9E-04	-	2.4E-04	1.0E-03	<1%
Xylenes	7.1E+02	6.3E+03	1.1E-01	V	-	-	-	-	-	2.8E-03	-	4.0E-03	6.9E-03	2.5%
SVOCs														
1-Methylnaphthalene	8.9E+01	6.3E+04	1.4E-03	V	5.9E-08	-	-	5.9E-08	6%	2.0E-03	-	-	2.0E-03	<1%
2-Methylnaphthalene	2.4E+02	6.2E+04	3.8E-03	V	-	-	-	-	-	9.7E-02	-	-	9.7E-02	34.8%
PAHs														
Benzo (a) anthracene	9.9E-02	1.0E+06	9.9E-08		*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	9.5E-02	1.0E+06	9.5E-08		*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	1.1E-01	1.0E+06	1.1E-07		*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	4.0E-02	1.0E+06	4.0E-08		*	*	*	*	-	-	-	-	-	-
Chrysene	7.8E-01	1.0E+06	7.8E-07		*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	1.8E-02	1.0E+06	1.8E-08		*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.0E+06	6.9E-08		*	*	*	*	-	-	-	-	-	-
Naphthalene	1.3E+02	5.0E+04	2.5E-03	V	-	-	1.7E-08	1.7E-08	2%	1.0E-02	2.7E-03	1.2E-02	2.5E-02	8.9%
Total Benzo(a)pyrene TEQ	2.3E-01	1.0E+06	2.3E-07		3.8E-08	1.0E-08	5.0E-11	4.8E-08	5%	-	-	-	-	-
Miscellaneous														
Sulfolane	1.8E+01	1.0E+06	1.8E-05		-	-	-	-	-	3.0E-04	-	-	3.0E-04	<1%
GRO	7.7E+03	1.0E+06	7.7E-03		-	-	-	-	-	-	-	-	-	-
DRO	1.9E+04	1.0E+06	1.9E-02		-	-	-	-	-	-	-	-	-	-
RRO	6.5E+04	1.0E+06	6.5E-02		-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard					8E-07	5E-08	8E-08	1E-06		2E-01	3E-03	7E-02	3E-01	
Total Risk or Hazard Excluding Arsenic					2E-07	1E-08	6E-08	3E-07		2E-01	3E-03	5E-02	3E-01	

Table D-27a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/m^3:	Milligram(s) per cubic meter
ELCR:	Excess lifetime cancer risk (unitless)	PAH:	Polycyclic aromatic hydrocarbon
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
mg/kg:	Milligram(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk
m^3/kg:	Cubic meter(s) per kilogram		

Notes:

[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvFs	1
CST_AF	0.3	CST_FI	1
CST_BW	70	CST_IRs	330
CST_ED	1	CST_PEF	1.00E+06
CST_EF	125	CST_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-27b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta [a] (mg/m3)		CANCER RISK Route-Specific Risk Oral	Dermal	Inhalation (trench air)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal	Inhalation (trench air)	Calculated Hazard	Percent Total HI
Metals															
Barium	4.8E-01		1.0E-06			-	-	-	-	-	1.2E-04	1.1E-03		1.2E-03	<1%
Iron	5.7E+01		1.0E-06			-	-	-	-	-	1.5E-03	8.9E-04	-	2.4E-03	<1%
Lead	2.1E-03		1.0E-07			-	-	-	-	-	-	-	-	-	-
VOCs															
1,2,4-Trimethylbenzene	6.1E-01	7.5E+00	2.6E-04	4.6E+00	V	-	-	-	-	-	-	-	9.4E-01	9.4E-01	1.9%
1,3,5-Trimethylbenzene	1.8E-01	7.6E+00	1.8E-04	1.4E+00	V	-	-	-	-	-	3.3E-05	3.7E-03	2.0E+00	2.0E+00	4.1%
4-Isopropyltoluene (p-cymene)	6.0E-02	7.2E+00	5.0E-04	4.3E-01	V	-	-	-	-	-	-	-	-	-	-
Benzene	1.9E+01	9.3E+00	2.3E-05	1.7E+02	V	2.6E-07	3.7E-06	2.7E-04	2.8E-04	92%	3.3E-02	4.7E-01	3.1E+01	3.1E+01	64.4%
Ethylbenzene	2.8E+00	8.0E+00	8.8E-05	2.2E+01	V	7.8E-09	4.1E-07	1.1E-05	1.2E-05	4%	1.0E-03	5.3E-02	3.5E-02	8.9E-02	<1%
n-Propylbenzene	1.2E-01	7.6E+00	2.8E-04	9.2E-01	V	-	-	-	-	-	2.2E-05	3.8E-03	1.3E-02	1.7E-02	<1%
Toluene	3.0E+01	8.6E+00	5.2E-05	2.6E+02	V	-	-	-	-	-	6.8E-04	2.1E-02	7.4E-01	7.6E-01	1.6%
Xylenes	1.4E+01	8.0E+00	9.5E-05	1.1E+02	V	-	-	-	-	-	6.4E-04	3.6E-02	4.0E+00	4.1E+00	8.4%
SVOCs															
1-Methylnaphthalene	3.5E-02	6.3E+00	3.3E-04	2.2E-01	V	2.6E-10	5.2E-08	-	5.2E-08	<1%	9.1E-06	1.8E-03	-	1.8E-03	<1%
2-Methylnaphthalene	3.1E-02	6.3E+00	3.2E-04	2.0E-01	V	-	-	-	-	-	1.4E-04	2.7E-02	-	2.7E-02	<1%
PAHs															
Naphthalene	3.0E-01	6.6E+00	9.7E-05	2.0E+00	V	-	-	1.4E-05	1.4E-05	5%	2.7E-04	1.6E-02	9.4E+00	9.4E+00	19.4%
Miscellaneous															
Sulfolane	1.0E+01		2.0E-07			-	-	-	-	-	1.9E-03	2.3E-04	-	2.1E-03	<1%
GRO	2.1E+01		NA			-	-	-	-	-	-	-	-	-	-
DRO	2.2E+00		NA			-	-	-	-	-	-	-	-	-	-
RRO	2.8E-01		NA			-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard						3E-07	4E-06	3E-04	3E-04		4E-02	6E-01	4.8E+01	4.9E+01	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Table D-27b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRinc_gw × EFgw × ED × CSFo) / (BW × ATc)
ELCRd = (EPCgw × DA × SAgw × EvFgw × EFgw × ED × CSFd) / (BW × ATc)
ELCRta (VOCs) = ([EPCgw × VF] × EFgw × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCgw × FIgw × IRinc_gw × EFgw × ED) / (BW × ATnc × RfDo)
HQd = (EPCgw × DA ×SAgw ×EvFgw × EFgw × ED) / (BW × ATnc × RfDa)
HQta (VOCs) = ([EPCgw × VF] × ET × EFgw × ED) / (24 × ATnc × RfC)

Table D-28

Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m^3) [a]	AF [a]	EPCia (mg/m^3) [a]		CANCER RISK Route-Specific Risk Inhalation (indoor air)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Metals											
Barium	4.8E+02							-			-
Iron	5.7E+04							-			-
Lead	2.1E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	6.1E+02	4.0E+01	1.1E-05	4.5E-04	V	-		-	1.7E-04	1.7E-04	8.0%
1,3,5-Trimethylbenzene	1.8E+02	1.1E+01	1.3E-05	1.4E-04	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	6.0E+01				V			-			-
Benzene	1.9E+04	1.7E+03	1.0E-05	1.7E-02	V	1.6E-07	1.6E-07	93%	1.6E-03	1.6E-03	71.7%
Ethylbenzene	2.8E+03	2.7E+02	7.5E-06	2.1E-03	V	6.1E-09	6.1E-09	4%	5.7E-06	5.7E-06	<1%
n-Propylbenzene	1.2E+02	1.4E+01	6.5E-06	9.2E-05	V	-		-	2.5E-07	2.5E-07	<1%
Toluene	3.0E+04	2.9E+03	8.7E-06	2.5E-02	V	-		-	1.4E-05	1.4E-05	<1%
Xylenes	1.4E+04	1.4E+03	8.4E-06	1.1E-02	V	-		-	3.1E-04	3.1E-04	14.2%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	3.1E+01	9.7E-02	1.1E-04	1.1E-05	V	-		-	-		-
PAHs											
Naphthalene	3.0E+02	1.3E+00	9.4E-05	1.2E-04	V	5.0E-09	5.0E-09	3%	1.1E-04	1.1E-04	5.2%
Miscellaneous											
Sulfolane	1.0E+04							-			-
GRO	2.1E+04							-			-
DRO	2.2E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						2E-07	2E-07		2E-03	2E-03	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Table D-28

Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

VIS_ATC	25550
VIS_ATnc	10950
VIS_ED	30
VIS_EF	12
VIS_ET	2

Exposure Duration CHRONIC

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-29a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	CANCER RISK: Route-Specific Risk: Dermal [c]	CANCER RISK: Route-Specific Risk: Inhalation (ambient)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	NON-CANCER HAZARD: Route-Specific Hazard: Dermal [c]	NON-CANCER HAZARD: Route-Specific Hazard: Inhalation (ambient)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				3.9E-09	3.9E-09	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				6.3E-10	6.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			1.6E-08	1.6E-08	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			1.4E-08	1.4E-08	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			1.9E-09	1.9E-09	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			6.4E-09	6.4E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				4.2E-12	4.2E-12	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	9E-04	9E-04	

Table D-29a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:

[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

ADUR_ATc	25550	ADUR_ET	12
ADUR_ATnc	10950	ADUR_FI	–
ADUR_AF	–	ADUR_IRs	–
ADUR_BW	70	ADUR_PEF	1316000000
ADUR_ED	30	ADUR_SA	–
ADUR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-29b

Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	CANCER RISK Route-Specific Risk Dermal [d]	CANCER RISK Route-Specific Risk Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	NON-CANCER HAZARD Route-Specific Hazard Dermal [d]	NON-CANCER HAZARD Route-Specific Hazard Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	1.2E+00			1.2E+00	100.0%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1.2E+00	0E+00	0E+00	1.2E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-29c

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - All Offsite Wells - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	4.4E-01	1.0E+00	4.4E-01	-	-		-	3.0E-02	4.8E-02	7.9E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		3.0E-02	4.8E-02	7.9E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-30a

Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

					CANCER RISK				Percent	NON-CANCER HAZARD				Percent
					Route-Specific Risk			Calculated	Total	Route-Specific Hazard			Calculated	Total
Constituent	**EPCs (mg/kg)**	**VF *or* PEF [a] (m³/kg)**	**EPCaa (mg/m^3)**	**EPCia (mg/m^3) [b]**	**Oral [c]**	**Dermal [c]**	**Inhalation (ambient)**	**Risk**	**ELCR**	**Oral [c]**	**Dermal [c]**	**Inhalation (ambient)**	**Hazard**	**HI**
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				7.9E-10	7.9E-10	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				1.3E-10	1.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			3.3E-09	3.3E-09	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			2.8E-09	2.8E-09	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			3.8E-10	3.8E-10	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			1.3E-09	1.3E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				8.4E-13	8.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	9E-09	9E-09		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	8E-09	8E-09		0E+00	0E+00	9E-04	9E-04	

Table D-30a

Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATc	25550	CHR_ET	12
CHR_ATnc	2190	CHR_FI	–
CHR_AF	–	CHR_IRs	–
CHR_BW	15	CHR_PEF	1316000000
CHR_ED	6	CHR_SA	–
CHR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-30b
Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	2.8E+00			2.8E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2.8E+00	0E+00	0E+00	2.8E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:
ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-30c

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - All Offsite Wells - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	4.4E-01	1.0E+00	4.4E-01	-	-		-	1.2E-01	1.1E-01	2.3E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		1E-01	1E-01	2E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-31a

Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m³/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]		CANCER RISK: Route-Specific Risk: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals															
Arsenic	7.6E+00	1.3E+09	5.8E-09					1.3E-10	1.3E-10	9%			1.4E-04	1.4E-04	21.3%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08					-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05					-		-			-		-
Lead										-					-
Nickel	2.0E+01	1.3E+09	1.5E-08					2.1E-11	2.1E-11	1%			6.3E-05	6.3E-05	9.4%
VOCs															
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06		V			-		-			1.2E-04	1.2E-04	17.3%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06		V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05		V			5.5E-10	5.5E-10	38%			6.2E-05	6.2E-05	9.2%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05		V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05		V			4.7E-10	4.7E-10	33%			1.5E-06	1.5E-06	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05		V			6.4E-11	6.4E-11	4%			3.2E-06	3.2E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04		V			-		-			2.4E-05	2.4E-05	3.6%
Toluene	8.2E-02	4.6E+03	1.8E-05		V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04		V			-		-			1.1E-04	1.1E-04	16.3%
SVOCs															
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06		V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06		V			-		-			-		-
PAHs															
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11					*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11					*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11					*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11					*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11					*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11					*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11					*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06		V			2.1E-10	2.1E-10	15%			1.5E-04	1.5E-04	21.8%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11					1.4E-13	1.4E-13	<1%			-		-
Miscellaneous															
Sulfolane	3.8E-02	1.3E+09	2.9E-11					-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09					-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07					-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06					-		-			-		-
Total Risk or Hazard						0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	7E-04	7E-04	
Total Risk or Hazard Excluding Arsenic						0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	5E-04	5E-04	

Table D-31a

Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATc	25550	INF_ET	12
INF_ATnc	365	INF_FI	–
INF_AF	–	INF_IRs	–
INF_BW	6.75	INF_PEF	1316000000
INF_ED	1	INF_SA	–
INF_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-31b

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	6.6E-01			6.6E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		7E-01	0E+00	0E+00	7E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-31c

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - All Offsite Wells - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

				CANCER RISK			Percent	NON-CANCER HAZARD			Percent
				Route-Specific Risk		Calculated	Total	Route-Specific Hazard		Calculated	Total
Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	Ingestion (fruit)	Ingestion (vegetables)	Risk	ELCR	Ingestion (fruit)	Ingestion (vegetables)	Hazard	HI
Miscellaneous											
Sulfolane	4.4E-01	1.0E+00	4.4E-01	-	-		-	1.9E-02	1.3E-02	3.2E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		2E-02	1E-02	3E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-32

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	8.7E-01			8.7E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		9E-01	0E+00	0E+00	9E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-33a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

					CANCER RISK				Percent	NON-CANCER HAZARD				Percent
					Route-Specific Risk			Calculated	Total	Route-Specific Hazard			Calculated	Total
Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	Oral [c]	Dermal [c]	Inhalation (ambient)	Risk	ELCR	Oral [c]	Dermal [c]	Inhalation (ambient)	Hazard	HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				2.0E-09	2.0E-09	9%			8.8E-05	8.8E-05	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				3.3E-10	3.3E-10	1%			3.9E-05	3.9E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			8.5E-09	8.5E-09	38%			1.0E-04	1.0E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			7.3E-09	7.3E-09	33%			8.2E-06	8.2E-06	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			9.8E-10	9.8E-10	4%			5.8E-06	5.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			4.2E-05	4.2E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			8.1E-07	8.1E-07	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			2.7E-04	2.7E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			3.3E-09	3.3E-09	15%			9.0E-05	9.0E-05	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				2.2E-12	2.2E-12	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	

Table D-33a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1316000000
CIo_EF	250		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table D-33b

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - All Offsite Wells - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	4.4E-01					-			-	-	8.7E-01			8.7E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		9E-01	0E+00	0E+00	9E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-34

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - All Offsite Wells - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	4.4E-01		2.0E-07		-			-	-	8.0E-05			8.0E-05	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		8E-05	0E+00	0E+00	8E-05	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m^3:	Liter(s) per cubic meter		

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-35
Chronic Hazard Estimates for the Offsite Adult Recreator Exposed to Surface Water - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCsw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event)	CANCER RISK Route-Specific Risk Oral [c]	Dermal [d]	Inhalation [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [d]	Inhalation [d]	Calculated Hazard	Percent Total HI
Miscellaneous													
Sulfolane	1.6E-01			-			-	-	2.6E-03			2.6E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00	0E+00		3E-03	0E+00	0E+00	3E-03	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCsw:	Exposure point concentration in surface water (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTsw) as shown for this receptor below.
[c] This exposure scenario assumes recreational contact exposures including swimming, walking, wading, and splashing.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

AREC_ATC	25550	AREC_ET	1
AREC_ATnc	10950	AREC_EvFsw	–
AREC_BW	70	AREC_FIsw	1
AREC_ED	30	AREC_IRinc_sw	0.071
AREC_EFsw	60	AREC_SAsw	–
AREC_EvTsw	–		

Equations:
ELCRo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED × CSFo) / (BW × ATc)

HQo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED) / (BW × ATnc × RfDo)

Table D-36

Chronic Hazard Estimates for the Offsite Child Recreator Exposed to Surface Water - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCsw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event)	CANCER RISK Route-Specific Risk Oral [c]	Dermal [d]	Inhalation [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [d]	Inhalation [d]	Calculated Hazard	Percent Total HI
Miscellaneous													
Sulfolane	1.6E-01			-			-	-	2.1E-02			2.1E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00	0E+00		2E-02	0E+00	0E+00	2E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCsw:	Exposure point concentration in surface water (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTsw) as shown for this receptor below.
[c] This exposure scenario assumes recreational contact exposures including swimming, walking, wading, and splashing.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CREC_ATC	25550	CREC_ET	1
CREC_ATnc	2190	CREC_EvFsw	–
CREC_BW	15	CREC_FIsw	1
CREC_ED	6	CREC_IRinc_sw	0.12
CREC_EFsw	60	CREC_SAsw	–
CREC_EvTsw	–		

Equations:

ELCRo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED × CSFo) / (BW × ATc)

HQo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED) / (BW × ATnc × RfDo)

Table D-37a
Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	3.9E-01			3.9E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		4E-01	0E+00	0E+00	4E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-37b

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 2 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.4E-01	1.0E+00	1.4E-01	-	-		-	9.9E-03	1.6E-02	2.6E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		1E-02	2E-02	3E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-38a

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	9.2E-01			9.2E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		9E-01	0E+00	0E+00	9E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-38b

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 2 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.4E-01	1.0E+00	1.4E-01	-	-		-	4.0E-02	3.6E-02	7.5E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		4E-02	4E-02	8E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-39a

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	2.2E-01			2.2E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions): Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-39b

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 2 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.4E-01	1.0E+00	1.4E-01	-	-		-	6.1E-03	4.3E-03	1.0E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		6E-03	4E-03	1E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-40

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	2.8E-01			2.8E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-01	0E+00	0E+00	3E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-41

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 2 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.4E-01					-			-	-	2.8E-01			2.8E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-01	0E+00	0E+00	3E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-42

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 2 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	1.4E-01		2.0E-07		-			-	-	2.6E-05			2.6E-05	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		3E-05	0E+00	0E+00	3E-05	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m³:	Liter(s) per cubic meter		

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-43a
Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	2.2E-01			2.2E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-43b

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	8.0E-02	1.0E+00	8.0E-02	-	-		-	5.5E-03	8.8E-03	1.4E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		5E-03	9E-03	1E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-44a

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	5.1E-01			5.1E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		5E-01	0E+00	0E+00	5E-01	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m$^{3:}$	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-44b

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	8.0E-02	1.0E+00	8.0E-02	-	-		-	2.2E-02	2.0E-02	4.2E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		2E-02	2E-02	4E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-45a

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	1.2E-01			1.2E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E-01	0E+00	0E+00	1E-01	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-45b

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	8.0E-02	1.0E+00	8.0E-02	-	-		-	3.4E-03	2.4E-03	5.8E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		3E-03	2E-03	6E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table D-46

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	1.6E-01			1.6E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Exposure Duration CHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-47

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	8.0E-02					-			-	-	1.6E-01			1.6E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table D-48
Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 3 - Maximum COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK: Route-Specific Risk: Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	8.0E-02		2.0E-07		-			-	-	1.5E-05			1.5E-05	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		1E-05	0E+00	0E+00	1E-05	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m3:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m³:	Liter(s) per cubic meter		

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Appendix E

Estimated Risks/Hazards Using 95% UCL COPC Concentrations – PPRTV Scenario and ARCADIS Comparative Scenario

Table E-1

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Indoor Worker Exposed to Indoor Air - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m^3) [a]	AF [a]	EPCia (mg/m^3) [a]		CANCER RISK: Route-Specific Risk Inhalation (indoor air)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals											
Barium	2.6E+02							-			-
Iron	2.8E+04							-			-
Lead	1.2E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	1.1E+02	7.3E+00	1.1E-05	8.2E-05	V	-		-	2.7E-03	2.7E-03	14.1%
1,3,5-Trimethylbenzene	1.2E+02	7.5E+00	1.3E-05	9.5E-05	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	3.3E+01				V			-			-
Benzene	1.3E+03	1.2E+02	1.0E-05	1.2E-03	V	7.9E-07	7.9E-07	80%	9.4E-03	9.4E-03	49.7%
Ethylbenzene	1.8E+02	1.8E+01	7.5E-06	1.4E-04	V	2.8E-08	2.8E-08	3%	3.1E-05	3.1E-05	<1%
n-Propylbenzene	8.0E+01	9.4E+00	6.5E-06	6.0E-05	V	-		-	1.4E-05	1.4E-05	<1%
Toluene	1.4E+03	1.4E+02	8.7E-06	1.2E-03	V	-		-	5.4E-05	5.4E-05	<1%
Xylenes	1.2E+03	1.1E+02	8.4E-06	9.5E-04	V	-		-	2.2E-03	2.2E-03	11.5%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	2.5E+01	7.9E-02	1.1E-04	8.8E-06	V	-		-	-		-
PAHs											
Naphthalene	1.5E+02	6.3E-01	9.4E-05	6.0E-05	V	1.7E-07	1.7E-07	17%	4.6E-03	4.6E-03	24.1%
Miscellaneous											
Sulfolane	8.3E+02							-			-
GRO	2.1E+04							-			-
DRO	1.5E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						1E-06	1E-06		2E-02	2E-02	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Table E-1

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Indoor Worker Exposed to Indoor Air - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CI_ATC	25550
CI_ATnc	9125
CI_ED	25
CI_EF	250
CI_ET	8

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-2

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09		4.0E-06	5.3E-07	2.0E-09	4.5E-06	97%	2.5E-02	3.3E-03	8.8E-05	2.8E-02	52.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08		-	-	-	-	-	1.3E-05	-	-	1.3E-05	<1%
Iron	1.7E+04	1.3E+09	1.3E-05		-	-	-	-	-	2.4E-02	-	-	2.4E-02	44.2%
Lead						-			-		-			-
Nickel	2.0E+01	1.3E+09	1.5E-08		-	-	3.3E-10	3.3E-10	<1%	9.9E-04	-	3.9E-05	1.0E-03	1.9%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V	-	-	-	-	-	2.2E-06	-	-	2.2E-06	<1%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V	-	-	-	-	-	-	-	-	-	-
Benzene	5.1E-02	3.8E+03	1.3E-05	V	9.8E-10	-	8.5E-09	9.5E-09	<1%	1.2E-05	-	1.0E-04	1.1E-04	<1%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V	-	-	-	-	-	-	-	1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V	8.4E-10	-	7.3E-09	8.1E-09	<1%	2.1E-06	-	8.2E-06	1.0E-05	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V	1.6E-10	-	9.8E-10	1.1E-09	<1%	9.8E-07	-	5.8E-06	6.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V	-	-	-	-	-	1.9E-06	-	4.2E-05	4.4E-05	<1%
Toluene	8.2E-02	4.6E+03	1.8E-05	V	-	-	-	-	-	1.0E-06	-	8.1E-07	1.8E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V	-	-	-	-	-	3.6E-06	-	2.7E-04	2.7E-04	<1%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V	2.5E-09	-	-	2.5E-09	<1%	3.4E-06	-	-	3.4E-06	<1%
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V	-	-	-	-	-	6.7E-05	-	-	6.7E-05	<1%
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11		*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11		*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11		*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11		*	*	*	*	-	-	-	-	-	-
Chrysene	6.6E-02	1.3E+09	5.0E-11		*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11		*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11		*	*	*	*	-	-	-	-	-	-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V	-	-	3.3E-09	3.3E-09	<1%	2.9E-06	1.7E-06	9.0E-05	9.5E-05	<1%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11		8.1E-08	4.7E-08	2.2E-12	1.3E-07	3%	-	-	-	-	-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11		-	-	-	-	-	3.7E-05	-	-	3.7E-05	<1%
GRO	5.4E+00	1.3E+09	4.1E-09		-	-	-	-	-	-	-	-	-	-
DRO	2.1E+02	1.3E+09	1.6E-07		-	-	-	-	-	-	-	-	-	-
RRO	1.9E+03	1.3E+09	1.4E-06		-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard					4E-06	6E-07	2E-08	5E-06		5E-02	3E-03	6E-04	5E-02	
Total Risk or Hazard Excluding Arsenic					9E-08	5E-08	2E-08	2E-07		2E-02	2E-06	6E-04	3E-02	

Table E-2

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_EvFs	1
CIo_AF	0.2	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1316000000
CIo_EF	250	CIo_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-3a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.3E+00	1.0E+06	7.3E-06		2.5E-07	1.5E-08	6.4E-09	2.7E-07	94%	2.4E-03	1.4E-04	7.0E-03	9.5E-03	16.5%
Chromium, Total	1.7E+01	1.0E+06	1.7E-05		-	-	-	-	-	1.8E-05	-	-	1.8E-05	<1%
Iron	1.5E+04	1.0E+06	1.5E-02		-	-	-	-	-	3.5E-02	-	-	3.5E-02	60.4%
Nickel	1.9E+01	1.0E+06	1.9E-05		-	-	1.0E-09	1.0E-09	<1%	1.5E-03	-	3.0E-03	4.5E-03	7.9%
VOCs														
1,2,4-Trimethylbenzene	2.2E+01	8.5E+03	2.6E-03	V	-	-	-	-	-	-	-	5.3E-04	5.3E-04	<1%
1,3,5-Trimethylbenzene	8.3E+00	7.1E+03	1.2E-03	V	-	-	-	-	-	1.3E-04	-	1.7E-03	1.8E-03	3.1%
4-Isopropyltoluene (p-cymene)	2.0E+00	9.4E+03	2.2E-04	V	-	-	-	-	-	-	-	-	-	-
Benzene	3.1E+00	3.8E+03	8.2E-04	V	4.0E-09	-	1.3E-09	5.3E-09	2%	5.1E-04	-	1.5E-04	6.5E-04	1.1%
Cyclohexane	5.6E+00	1.1E+03	5.0E-03	V	-	-	-	-	-	-	-	1.2E-05	1.2E-05	<1%
Ethylbenzene	8.7E+00	6.1E+03	1.4E-03	V	2.2E-09	-	7.2E-10	2.9E-09	<1%	2.8E-04	-	2.3E-06	2.8E-04	<1%
Isopropylbenzene (cumene)	4.0E+00	6.7E+03	5.9E-04	V	-	-	-	-	-	1.6E-05	-	9.4E-05	1.1E-04	<1%
Methylene chloride	2.9E-01	2.4E+03	1.2E-04	V	5.0E-11	-	1.2E-11	6.2E-11	<1%	7.8E-06	-	5.8E-07	8.4E-06	<1%
n-Butylbenzene	7.6E+00	8.8E+03	8.7E-04	V	-	-	-	-	-	1.2E-04	-	-	1.2E-04	<1%
n-Hexane	2.4E+00	8.9E+02	2.7E-03	V	-	-	-	-	-	1.3E-05	-	1.9E-05	3.2E-05	<1%
n-Propylbenzene	7.2E+00	7.5E+03	9.6E-04	V	-	-	-	-	-	1.2E-04	2.4E-05	1.4E-05	1.5E-04	<1%
sec-Butylbenzene	6.6E+00	8.1E+03	8.1E-04	V	-	-	-	-	-	-	-	-	-	-
Toluene	1.7E+01	4.6E+03	3.8E-03	V	-	-	-	-	-	3.5E-05	-	1.1E-05	4.6E-05	<1%
Xylenes	4.7E+01	6.3E+03	7.5E-03	V	-	-	-	-	-	1.9E-04	-	2.7E-04	4.6E-04	<1%
SVOCs														
1-Methylnaphthalene	4.6E+00	6.3E+04	7.3E-05	V	3.1E-09	-	-	3.1E-09	1%	1.1E-04	-	-	1.1E-04	<1%
2-Methylnaphthalene	8.6E+00	6.2E+04	1.4E-04	V	-	-	-	-	-	3.5E-03	-	-	3.5E-03	6.0%
PAHs														
Benzo (a) anthracene	1.2E-02	1.0E+06	1.2E-08		*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	1.2E-02	1.0E+06	1.2E-08		*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	2.1E-02	1.0E+06	2.1E-08		*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	1.9E-02	1.0E+06	1.9E-08		*	*	*	*	-	-	-	-	-	-
Chrysene	3.5E-02	1.0E+06	3.5E-08		*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	9.9E-03	1.0E+06	9.9E-09		*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	1.1E-02	1.0E+06	1.1E-08		*	*	*	*	-	-	-	-	-	-
Naphthalene	4.4E+00	5.0E+04	8.8E-05	V	-	-	6.1E-10	6.1E-10	<1%	3.5E-04	9.3E-05	4.2E-04	8.6E-04	1.5%

Table E-3a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Total Benzo(a)pyrene TEQ	2.6E-02	1.0E+06	2.6E-08		4.3E-09	1.1E-09	5.8E-12	5.5E-09	2%	-	-	-	-	-
Miscellaneous														
Sulfolane	4.5E-01	1.0E+06	4.5E-07		-	-	-	-	-	7.3E-05	-	-	7.3E-05	<1%
GRO	8.1E+02	1.0E+06	8.1E-04		-	-	-	-	-	-	-	-	-	-
DRO	2.1E+03	1.0E+06	2.1E-03		-	-	-	-	-	-	-	-	-	-
RRO	8.2E+03	1.0E+06	8.2E-03		-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard					3E-07	2E-08	1E-08	3E-07		4E-02	3E-04	1E-02	6E-02	
Total Risk or Hazard Excluding Arsenic					1E-08	1E-09	4E-09	2E-08		4E-02	1E-04	6E-03	5E-02	

Abbreviations:

-:	Not applicable	mg/m^3:	Milligram(s) per cubic meter
ELCR:	Excess lifetime cancer risk (unitless)	PAH:	Polycyclic aromatic hydrocarbon
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
mg/kg:	Milligram(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk
m^3/kg:	Cubic meter(s) per kilogram		

Notes:

[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvFs	1
CST_AF	0.3	CST_FI	1
CST_BW	70	CST_IRs	330
CST_ED	1	CST_PEF	1.00E+06
CST_EF	125	CST_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-3b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta [a] (mg/m3)		CANCER RISK: Route-Specific Risk: Oral	Dermal	Inhalation (trench air)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal	Inhalation (trench air)	Calculated Hazard	Percent Total HI
Metals															
Barium	2.6E-01		1.0E-06			-	-	-	-	-	6.8E-05	5.8E-04		6.5E-04	<1%
Iron	2.8E+01		1.0E-06			-	-	-	-	-	7.3E-04	4.4E-04	-	1.2E-03	<1%
Lead	1.2E-03		1.0E-07			-	-	-	-	-	-	-	-	-	-
VOCs															
1,2,4-Trimethylbenzene	1.1E-01	7.5E+00	2.6E-04	8.5E-01	V	-	-	-	-	-	-	-	1.7E-01	1.7E-01	2.0%
1,3,5-Trimethylbenzene	1.2E-01	7.6E+00	1.8E-04	9.2E-01	V	-	-	-	-	-	2.2E-05	2.4E-03	1.3E+00	1.3E+00	15.0%
4-Isopropyltoluene (p-cymene)	3.3E-02	7.2E+00	5.0E-04	2.4E-01	V	-	-	-	-	-	-	-	-	-	-
Benzene	1.3E+00	9.3E+00	2.3E-05	1.2E+01	V	1.9E-08	2.7E-07	2.0E-05	2.0E-05	73%	2.4E-03	3.4E-02	2.2E+00	2.3E+00	25.9%
Ethylbenzene	1.8E-01	8.0E+00	8.8E-05	1.4E+00	V	5.1E-10	2.7E-08	7.4E-07	7.7E-07	3%	6.5E-05	3.4E-03	2.3E-03	5.8E-03	<1%
n-Propylbenzene	8.0E-02	7.6E+00	2.8E-04	6.1E-01	V	-	-	-	-	-	1.5E-05	2.5E-03	8.7E-03	1.1E-02	<1%
Toluene	1.4E+00	8.6E+00	5.2E-05	1.2E+01	V	-	-	-	-	-	3.2E-05	1.0E-03	3.5E-02	3.6E-02	<1%
Xylenes	1.2E+00	8.0E+00	9.5E-05	9.5E+00	V	-	-	-	-	-	5.4E-05	3.1E-03	3.4E-01	3.4E-01	3.9%
SVOCs															
1-Methylnaphthalene	3.5E-02	6.3E+00	3.3E-04	2.2E-01	V	2.6E-10	5.2E-08	-	5.2E-08	<1%	9.1E-06	1.8E-03	-	1.8E-03	<1%
2-Methylnaphthalene	2.5E-02	6.3E+00	3.2E-04	1.6E-01	V	-	-	-	-	-	1.1E-04	2.2E-02	-	2.2E-02	<1%
PAHs															
Naphthalene	1.5E-01	6.6E+00	9.7E-05	9.6E-01	V	-	-	6.6E-06	6.6E-06	24%	1.3E-04	7.7E-03	4.6E+00	4.6E+00	52.3%
Miscellaneous															
Sulfolane	8.3E-01		2.0E-07			-	-	-	-	-	1.5E-03	1.8E-04	-	1.7E-03	<1%
GRO	2.1E+01		NA			-	-	-	-	-	-	-	-	-	-
DRO	1.5E+00		NA			-	-	-	-	-	-	-	-	-	-
RRO	2.8E-01		NA			-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard						2E-08	3E-07	3E-05	3E-05		5E-03	8E-02	9E+00	9E+00	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m³:	Liter(s) per cubic meter		

Notes:

[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

Table E-3b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRinc_gw × EFgw × ED × CSFo) / (BW × ATc)
ELCRd = (EPCgw × DA × SAgw × EvFgw × EFgw × ED × CSFd) / (BW × ATc)
ELCRta (VOCs) = ([EPCgw × VF] × EFgw × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCgw × FIgw × IRinc_gw × EFgw × ED) / (BW × ATnc × RfDo)
HQd = (EPCgw × DA ×SAgw ×EvFgw × EFgw × ED) / (BW × ATnc × RfDa)
HQta (VOCs) = ([EPCgw × VF] × ET × EFgw × ED) / (24 × ATnc × RfC)

Table E-4
Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m^3) [a]	AF [a]	EPCia (mg/m^3) [a]		CANCER RISK Route-Specific Risk Inhalation (indoor air)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Metals											
Barium	2.6E+02							-			-
Iron	2.8E+04							-			-
Lead	1.2E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	1.1E+02	7.3E+00	1.1E-05	8.2E-05	V	-		-	3.2E-05	3.2E-05	14.1%
1,3,5-Trimethylbenzene	1.2E+02	7.5E+00	1.3E-05	9.5E-05	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	3.3E+01				V			-			-
Benzene	1.3E+03	1.2E+02	1.0E-05	1.2E-03	V	1.1E-08	1.1E-08	80%	1.1E-04	1.1E-04	49.7%
Ethylbenzene	1.8E+02	1.8E+01	7.5E-06	1.4E-04	V	4.0E-10	4.0E-10	3%	3.7E-07	3.7E-07	<1%
n-Propylbenzene	8.0E+01	9.4E+00	6.5E-06	6.0E-05	V	-		-	1.7E-07	1.7E-07	<1%
Toluene	1.4E+03	1.4E+02	8.7E-06	1.2E-03	V	-		-	6.5E-07	6.5E-07	<1%
Xylenes	1.2E+03	1.1E+02	8.4E-06	9.5E-04	V	-		-	2.6E-05	2.6E-05	11.5%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	2.5E+01	7.9E-02	1.1E-04	8.8E-06	V	-		-	-		-
PAHs											
Naphthalene	1.5E+02	6.3E-01	9.4E-05	6.0E-05	V	2.4E-09	2.4E-09	17%	5.5E-05	5.5E-05	24.1%
Miscellaneous											
Sulfolane	8.3E+02							-			-
GRO	2.1E+04							-			-
DRO	1.5E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						1E-08	1E-08		2E-04	2E-04	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Table E-4

Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

VIS_ATC	25550
VIS_ATnc	10950
VIS_ED	30
VIS_EF	12
VIS_ET	2

Exposure Duration CHRONIC

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-5a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				3.9E-09	3.9E-09	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				6.3E-10	6.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			1.6E-08	1.6E-08	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			1.4E-08	1.4E-08	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			1.9E-09	1.9E-09	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			6.4E-09	6.4E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				4.2E-12	4.2E-12	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	9E-04	9E-04	

Table E-5a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATc	25550	ADUR_ET	12
ADUR_ATnc	10950	ADUR_FI	–
ADUR_AF	–	ADUR_IRs	–
ADUR_BW	70	ADUR_PEF	1316000000
ADUR_ED	30	ADUR_SA	–
ADUR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-5b

Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	4.7E+00			4.7E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		5E+00	0E+00	0E+00	5E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-5c

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	1.0E+00	1.7E-01	-	-		-	1.2E-01	1.9E-01	3.0E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		1E-01	2E-01	3.0E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-6a
Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				7.9E-10	7.9E-10	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				1.3E-10	1.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			3.3E-09	3.3E-09	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			2.8E-09	2.8E-09	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			3.8E-10	3.8E-10	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			1.3E-09	1.3E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				8.4E-13	8.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	9E-09	9E-09		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	8E-09	8E-09		0E+00	0E+00	9E-04	9E-04	

Table E-6a

Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CHR_ATc	25550	CHR_ET	12
CHR_ATnc	2190	CHR_FI	–
CHR_AF	–	CHR_IRs	–
CHR_BW	15	CHR_PEF	1316000000
CHR_ED	6	CHR_SA	–
CHR_EF	270		

Equations:
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-6b

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	1.1E+01			1.1E+01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1.1E+01	0E+00	0E+00	1.1E+01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-6c

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	1.0E+00	1.7E-01	-	-		-	4.7E-01	4.2E-01	8.9E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		5E-01	4E-01	9E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-7a

Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	CANCER RISK: Route-Specific Risk: Dermal [c]	CANCER RISK: Route-Specific Risk: Inhalation (ambient)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	NON-CANCER HAZARD: Route-Specific Hazard: Dermal [c]	NON-CANCER HAZARD: Route-Specific Hazard: Inhalation (ambient)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				1.3E-10	1.3E-10	9%			1.4E-04	1.4E-04	21.3%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				2.1E-11	2.1E-11	1%			6.3E-05	6.3E-05	9.4%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			1.2E-04	1.2E-04	17.3%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			5.5E-10	5.5E-10	38%			6.2E-05	6.2E-05	9.2%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			4.7E-10	4.7E-10	33%			1.5E-06	1.5E-06	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			6.4E-11	6.4E-11	4%			3.2E-06	3.2E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			2.4E-05	2.4E-05	3.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			1.1E-04	1.1E-04	16.3%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			2.1E-10	2.1E-10	15%			1.5E-04	1.5E-04	21.8%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				1.4E-13	1.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	7E-04	7E-04	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	5E-04	5E-04	

Table E-7a

Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATc	25550	INF_ET	12
INF_ATnc	365	INF_FI	–
INF_AF	–	INF_IRs	–
INF_BW	6.75	INF_PEF	1316000000
INF_ED	1	INF_SA	–
INF_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-7b

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK: Route-Specific Risk: Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	2.5E+00			2.5E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E+00	0E+00	0E+00	3E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-7c
Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	1.0E+00	1.7E-01	-	-		-	7.2E-02	5.1E-02	1.2E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		7E-02	5E-02	1E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-8
Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm^2/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	3.3E+00			3.3E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E+00	0E+00	0E+00	3E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-9a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				2.0E-09	2.0E-09	9%			8.8E-05	8.8E-05	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				3.3E-10	3.3E-10	1%			3.9E-05	3.9E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			8.5E-09	8.5E-09	38%			1.0E-04	1.0E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			7.3E-09	7.3E-09	33%			8.2E-06	8.2E-06	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			9.8E-10	9.8E-10	4%			5.8E-06	5.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			4.2E-05	4.2E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			8.1E-07	8.1E-07	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			2.7E-04	2.7E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			3.3E-09	3.3E-09	15%			9.0E-05	9.0E-05	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				2.2E-12	2.2E-12	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	

Table E-9a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1316000000
CIo_EF	250		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-9b
Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	3.3E+00			3.3E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E+00	0E+00	0E+00	3E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-10

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	1.7E-01		2.0E-07		-			-	-	3.1E-04			3.1E-04	100.0%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		3E-04	0E+00	0E+00	3E-04	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Notes:

[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-11a

Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	1.6E+00			1.6E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E+00	0E+00	0E+00	2E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EgwF × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-11b

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	1.0E+00	5.9E-02	-	-		-	4.0E-02	6.4E-02	1.0E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		4E-02	6E-02	1E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:

[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-12a

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	3.8E+00			3.8E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		4E+00	0E+00	0E+00	4E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-12b

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	1.0E+00	5.9E-02	-	-		-	1.6E-01	1.5E-01	3.1E-01	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		2E-01	1E-01	3E-01	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-13a
Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	8.9E-01			8.9E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		9E-01	0E+00	0E+00	9E-01	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-13b

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	1.0E+00	5.9E-02	-	-		-	2.5E-02	1.8E-02	4.3E-02	100.0%
Total Risk or Hazard				0E+00	0E+00	0E+00		3E-02	2E-02	4E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-14

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	1.2E+00			1.2E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E+00	0E+00	0E+00	1E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-15
Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	1.2E+00			1.2E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E+00	0E+00	0E+00	1E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-16

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK - Route-Specific Risk: Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD - Route-Specific Hazard: Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	5.9E-02		2.0E-07		-			-	-	1.1E-04			1.1E-04	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		1E-04	0E+00	0E+00	1E-04	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m³:	Liter(s) per cubic meter		

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-17a
Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	2.8E-01			2.8E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-01	0E+00	0E+00	3E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-17b

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	1.0E+00	1.0E-02	-	-		-	7.0E-03	1.1E-02	1.8E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		7E-03	1E-02	2E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-18a

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	6.5E-01			6.5E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		7E-01	0E+00	0E+00	7E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-18b

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	1.0E+00	1.0E-02	-	-		-	2.8E-02	2.5E-02	5.3E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		3E-02	3E-02	5E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-19a
Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	1.5E-01			1.5E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-19b

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	1.0E+00	1.0E-02	-	-		-	4.3E-03	3.1E-03	7.4E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		4E-03	3E-03	7E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-20

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	2.0E-01			2.0E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-21
Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	2.0E-01			2.0E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-22
Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - PPRTV Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	1.0E-02		2.0E-07		-			-	-	1.8E-05			1.8E-05	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		2E-05	0E+00	0E+00	2E-05	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-23

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Indoor Worker Exposed to Indoor Air - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m^3) [a]	AF [a]	EPCia (mg/m^3) [a]		CANCER RISK Route-Specific Risk Inhalation (indoor air)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Metals											
Barium	2.6E+02							-			-
Iron	2.8E+04							-			-
Lead	1.2E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	1.1E+02	7.3E+00	1.1E-05	8.2E-05	V	-		-	2.7E-03	2.7E-03	14.1%
1,3,5-Trimethylbenzene	1.2E+02	7.5E+00	1.3E-05	9.5E-05	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	3.3E+01				V			-			-
Benzene	1.3E+03	1.2E+02	1.0E-05	1.2E-03	V	7.9E-07	7.9E-07	80%	9.4E-03	9.4E-03	49.7%
Ethylbenzene	1.8E+02	1.8E+01	7.5E-06	1.4E-04	V	2.8E-08	2.8E-08	3%	3.1E-05	3.1E-05	<1%
n-Propylbenzene	8.0E+01	9.4E+00	6.5E-06	6.0E-05	V	-		-	1.4E-05	1.4E-05	<1%
Toluene	1.4E+03	1.4E+02	8.7E-06	1.2E-03	V	-		-	5.4E-05	5.4E-05	<1%
Xylenes	1.2E+03	1.1E+02	8.4E-06	9.5E-04	V	-		-	2.2E-03	2.2E-03	11.5%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	2.5E+01	7.9E-02	1.1E-04	8.8E-06	V	-		-	-		-
PAHs											
Naphthalene	1.5E+02	6.3E-01	9.4E-05	6.0E-05	V	1.7E-07	1.7E-07	17%	4.6E-03	4.6E-03	24.1%
Miscellaneous											
Sulfolane	8.3E+02							-			-
GRO	2.1E+04							-			-
DRO	1.5E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						1E-06	1E-06		2E-02	2E-02	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Table E-23

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Indoor Worker Exposed to Indoor Air - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

CI_ATC	25550
CI_ATnc	9125
CI_ED	25
CI_EF	250
CI_ET	8

Exposure Duration CHRONIC

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-24

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]		CANCER RISK: Route-Specific Risk: Oral	CANCER RISK: Route-Specific Risk: Dermal	CANCER RISK: Route-Specific Risk: Inhalation (ambient)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	NON-CANCER HAZARD: Route-Specific Hazard: Dermal	NON-CANCER HAZARD: Route-Specific Hazard: Inhalation (ambient)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals															
Arsenic	7.6E+00	1.3E+09	5.8E-09			4.0E-06	5.3E-07	2.0E-09	4.5E-06	97%	2.5E-02	3.3E-03	8.8E-05	2.8E-02	52.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08			-	-	-	-	-	1.3E-05	-	-	1.3E-05	<1%
Iron	1.7E+04	1.3E+09	1.3E-05			-	-	-	-	-	2.4E-02	-	-	2.4E-02	44.3%
Lead							-			-		-			-
Nickel	2.0E+01	1.3E+09	1.5E-08			-	-	3.3E-10	3.3E-10	<1%	9.9E-04	-	3.9E-05	1.0E-03	1.9%
VOCs															
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06		V	-	-	-	-	-	2.2E-06	-	-	2.2E-06	<1%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06		V	-	-	-	-	-	-	-	-	-	-
Benzene	5.1E-02	3.8E+03	1.3E-05		V	9.8E-10	-	8.5E-09	9.5E-09	<1%	1.2E-05	-	1.0E-04	1.1E-04	<1%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05		V	-	-	-	-	-	-	-	1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05		V	8.4E-10	-	7.3E-09	8.1E-09	<1%	2.1E-06	-	8.2E-06	1.0E-05	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05		V	1.6E-10	-	9.8E-10	1.1E-09	<1%	9.8E-07	-	5.8E-06	6.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04		V	-	-	-	-	-	1.9E-06	-	4.2E-05	4.4E-05	<1%
Toluene	8.2E-02	4.6E+03	1.8E-05		V	-	-	-	-	-	1.0E-06	-	8.1E-07	1.8E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04		V	-	-	-	-	-	3.6E-06	-	2.7E-04	2.7E-04	<1%
SVOCs															
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06		V	2.5E-09	-	-	2.5E-09	<1%	3.4E-06	-	-	3.4E-06	<1%
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06		V	-	-	-	-	-	6.7E-05	-	-	6.7E-05	<1%
PAHs															
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11			*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11			*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11			*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11			*	*	*	*	-	-	-	-	-	-
Chrysene	6.6E-02	1.3E+09	5.0E-11			*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11			*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11			*	*	*	*	-	-	-	-	-	-
Naphthalene	5.9E-02	5.0E+04	1.2E-06		V	-	-	3.3E-09	3.3E-09	<1%	2.9E-06	1.7E-06	9.0E-05	9.5E-05	<1%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11			8.1E-08	4.7E-08	2.2E-12	1.3E-07	3%	-	-	-	-	-
Miscellaneous															
Sulfolane	3.8E-02	1.3E+09	2.9E-11			-	-	-	-	-	3.7E-06	-	-	3.7E-06	<1%
GRO	5.4E+00	1.3E+09	4.1E-09			-	-	-	-	-	-	-	-	-	-
DRO	2.1E+02	1.3E+09	1.6E-07			-	-	-	-	-	-	-	-	-	-
RRO	1.9E+03	1.3E+09	1.4E-06			-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard						4E-06	6E-07	2E-08	5E-06		5E-02	3E-03	6E-04	5E-02	
Total Risk or Hazard Excluding Arsenic						9E-08	5E-08	2E-08	2E-07		2E-02	2E-06	6E-04	3E-02	

Table E-24

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_EvFs	1
CIo_AF	0.2	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1316000000
CIo_EF	250	CIo_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-25a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

						CANCER RISK				Percent	NON-CANCER HAZARD				Percent
		VF *or*				Route-Specific Risk			Calculated	Total	Route-Specific Hazard			Calculated	Total
Constituent	EPCs (mg/kg)	PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]		Oral	Dermal	Inhalation (ambient)	Risk	ELCR	Oral	Dermal	Inhalation (ambient)	Hazard	HI
Metals															
Arsenic	7.3E+00	1.0E+06	7.3E-06			2.5E-07	1.5E-08	6.4E-09	2.7E-07	94%	2.4E-03	1.4E-04	7.0E-03	9.5E-03	16.5%
Chromium, Total	1.7E+01	1.0E+06	1.7E-05			-	-	-	-	-	1.8E-05	-	-	1.8E-05	<1%
Iron	1.5E+04	1.0E+06	1.5E-02			-	-	-	-	-	3.5E-02	-	-	3.5E-02	60.5%
Nickel	1.9E+01	1.0E+06	1.9E-05			-	-	1.0E-09	1.0E-09	<1%	1.5E-03	-	3.0E-03	4.5E-03	7.9%
VOCs															
1,2,4-Trimethylbenzene	2.2E+01	8.5E+03	2.6E-03		V	-	-	-	-	-	-	-	5.3E-04	5.3E-04	<1%
1,3,5-Trimethylbenzene	8.3E+00	7.1E+03	1.2E-03		V	-	-	-	-	-	1.3E-04	-	1.7E-03	1.8E-03	3.1%
4-Isopropyltoluene (p-cymene)	2.0E+00	9.4E+03	2.2E-04		V	-	-	-	-	-	-	-	-	-	-
Benzene	3.1E+00	3.8E+03	8.2E-04		V	4.0E-09	-	1.3E-09	5.3E-09	2%	5.1E-04	-	1.5E-04	6.5E-04	1.1%
Cyclohexane	5.6E+00	1.1E+03	5.0E-03		V	-	-	-	-	-	-	-	1.2E-05	1.2E-05	<1%
Ethylbenzene	8.7E+00	6.1E+03	1.4E-03		V	2.2E-09	-	7.2E-10	2.9E-09	<1%	2.8E-04	-	2.3E-06	2.8E-04	<1%
Isopropylbenzene (cumene)	4.0E+00	6.7E+03	5.9E-04		V	-	-	-	-	-	1.6E-05	-	9.4E-05	1.1E-04	<1%
Methylene chloride	2.9E-01	2.4E+03	1.2E-04		V	5.0E-11	-	1.2E-11	6.2E-11	<1%	7.8E-06	-	5.8E-07	8.4E-06	<1%
n-Butylbenzene	7.6E+00	8.8E+03	8.7E-04		V	-	-	-	-	-	1.2E-04	-	-	1.2E-04	<1%
n-Hexane	2.4E+00	8.9E+02	2.7E-03		V	-	-	-	-	-	1.3E-05	-	1.9E-05	3.2E-05	<1%
n-Propylbenzene	7.2E+00	7.5E+03	9.6E-04		V	-	-	-	-	-	1.2E-04	2.4E-05	1.4E-05	1.5E-04	<1%
sec-Butylbenzene	6.6E+00	8.1E+03	8.1E-04		V	-	-	-	-	-	-	-	-	-	-
Toluene	1.7E+01	4.6E+03	3.8E-03		V	-	-	-	-	-	3.5E-05	-	1.1E-05	4.6E-05	<1%
Xylenes	4.7E+01	6.3E+03	7.5E-03		V	-	-	-	-	-	1.9E-04	-	2.7E-04	4.6E-04	<1%
SVOCs															
1-Methylnaphthalene	4.6E+00	6.3E+04	7.3E-05		V	3.1E-09	-	-	3.1E-09	1%	1.1E-04	-	-	1.1E-04	<1%
2-Methylnaphthalene	8.6E+00	6.2E+04	1.4E-04		V	-	-	-	-	-	3.5E-03	-	-	3.5E-03	6.0%
PAHs															
Benzo (a) anthracene	1.2E-02	1.0E+06	1.2E-08			*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	1.2E-02	1.0E+06	1.2E-08			*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	2.1E-02	1.0E+06	2.1E-08			*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	1.9E-02	1.0E+06	1.9E-08			*	*	*	*	-	-	-	-	-	-
Chrysene	3.5E-02	1.0E+06	3.5E-08			*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	9.9E-03	1.0E+06	9.9E-09			*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	1.1E-02	1.0E+06	1.1E-08			*	*	*	*	-	-	-	-	-	-
Naphthalene	4.4E+00	5.0E+04	8.8E-05		V	-	-	6.1E-10	6.1E-10	<1%	3.5E-04	9.3E-05	4.2E-04	8.6E-04	1.5%

Table E-25a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Total Benzo(a)pyrene TEQ	2.6E-02	1.0E+06	2.6E-08		4.3E-09	1.1E-09	5.8E-12	5.5E-09	2%	-	-	-	-	-
Miscellaneous														
Sulfolane	4.5E-01	1.0E+06	4.5E-07		-	-	-	-	-	7.3E-06	-	-	7.3E-06	<1%
GRO	8.1E+02	1.0E+06	8.1E-04		-	-	-	-	-	-	-	-	-	-
DRO	2.1E+03	1.0E+06	2.1E-03		-	-	-	-	-	-	-	-	-	-
RRO	8.2E+03	1.0E+06	8.2E-03		-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard					3E-07	2E-08	1E-08	3E-07		4E-02	3E-04	1E-02	6E-02	
Total Risk or Hazard Excluding Arsenic					1E-08	1E-09	4E-09	2E-08		4E-02	1E-04	6E-03	5E-02	

Abbreviations:

-:	Not applicable	mg/m^3:	Milligram(s) per cubic meter
ELCR:	Excess lifetime cancer risk (unitless)	PAH:	Polycyclic aromatic hydrocarbon
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
mg/kg:	Milligram(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk
m^3/kg:	Cubic meter(s) per kilogram		

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvFs	1
CST_AF	0.3	CST_FI	1
CST_BW	70	CST_IRs	330
CST_ED	1	CST_PEF	1.00E+06
CST_EF	125	CST_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-25b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta [a] (mg/m3)		CANCER RISK: Route-Specific Risk: Oral	Dermal	Inhalation (trench air)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal	Inhalation (trench air)	Calculated Hazard	Percent Total HI
Metals															
Barium	2.6E-01		1.0E-06			-	-	-	-	-	6.8E-05	5.8E-04		6.5E-04	<1%
Iron	2.8E+01		1.0E-06			-	-	-	-	-	7.3E-04	4.4E-04	-	1.2E-03	<1%
Lead	1.2E-03		1.0E-07			-	-	-	-	-	-	-	-	-	-
VOCs															
1,2,4-Trimethylbenzene	1.1E-01	7.5E+00	2.6E-04	8.5E-01	V	-	-	-	-	-	-	-	1.7E-01	1.7E-01	2.0%
1,3,5-Trimethylbenzene	1.2E-01	7.6E+00	1.8E-04	9.2E-01	V	-	-	-	-	-	2.2E-05	2.4E-03	1.3E+00	1.3E+00	15.0%
4-Isopropyltoluene (p-cymene)	3.3E-02	7.2E+00	5.0E-04	2.4E-01	V	-	-	-	-	-	-	-	-	-	-
Benzene	1.3E+00	9.3E+00	2.3E-05	1.2E+01	V	1.9E-08	2.7E-07	2.0E-05	2.0E-05	73%	2.4E-03	3.4E-02	2.2E+00	2.3E+00	25.9%
Ethylbenzene	1.8E-01	8.0E+00	8.8E-05	1.4E+00	V	5.1E-10	2.7E-08	7.4E-07	7.7E-07	3%	6.5E-05	3.4E-03	2.3E-03	5.8E-03	<1%
n-Propylbenzene	8.0E-02	7.6E+00	2.8E-04	6.1E-01	V	-	-	-	-	-	1.5E-05	2.5E-03	8.7E-03	1.1E-02	<1%
Toluene	1.4E+00	8.6E+00	5.2E-05	1.2E+01	V	-	-	-	-	-	3.2E-05	1.0E-03	3.5E-02	3.6E-02	<1%
Xylenes	1.2E+00	8.0E+00	9.5E-05	9.5E+00	V	-	-	-	-	-	5.4E-05	3.1E-03	3.4E-01	3.4E-01	3.9%
SVOCs															
1-Methylnaphthalene	3.5E-02	6.3E+00	3.3E-04	2.2E-01	V	2.6E-10	5.2E-08	-	5.2E-08	<1%	9.1E-06	1.8E-03	-	1.8E-03	<1%
2-Methylnaphthalene	2.5E-02	6.3E+00	3.2E-04	1.6E-01	V	-	-	-	-	-	1.1E-04	2.2E-02	-	2.2E-02	<1%
PAHs															
Naphthalene	1.5E-01	6.6E+00	9.7E-05	9.6E-01	V	-	-	6.6E-06	6.6E-06	24%	1.3E-04	7.7E-03	4.6E+00	4.6E+00	52.3%
Miscellaneous															
Sulfolane	8.3E-01		2.0E-07			-	-	-	-	-	1.5E-04	1.8E-05	-	1.7E-04	<1%
GRO	2.1E+01		NA			-	-	-	-	-	-	-	-	-	-
DRO	1.5E+00		NA			-	-	-	-	-	-	-	-	-	-
RRO	2.8E-01		NA			-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard						2E-08	3E-07	3E-05	3E-05		4E-03	8E-02	9E+00	9E+00	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Notes:

[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

Table E-25b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRinc_gw × EFgw × ED × CSFo) / (BW × ATc)
ELCRd = (EPCgw × DA × SAgw × EvFgw × EFgw × ED × CSFd) / (BW × ATc)
ELCRta (VOCs) = ([EPCgw × VF] × EFgw × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCgw × FIgw × IRinc_gw × EFgw × ED) / (BW × ATnc × RfDo)
HQd = (EPCgw × DA ×SAgw ×EvFgw × EFgw × ED) / (BW × ATnc × RfDa)
HQta (VOCs) = ([EPCgw × VF] × ET × EFgw × ED) / (24 × ATnc × RfC)

Table E-26

Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m^3) [a]	AF [a]	EPCia (mg/m^3) [a]		CANCER RISK: Route-Specific Risk Inhalation (indoor air)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals											
Barium	2.6E+02							-			-
Iron	2.8E+04							-			-
Lead	1.2E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	1.1E+02	7.3E+00	1.1E-05	8.2E-05	V	-		-	3.2E-05	3.2E-05	14.1%
1,3,5-Trimethylbenzene	1.2E+02	7.5E+00	1.3E-05	9.5E-05	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	3.3E+01				V			-			-
Benzene	1.3E+03	1.2E+02	1.0E-05	1.2E-03	V	1.1E-08	1.1E-08	80%	1.1E-04	1.1E-04	49.7%
Ethylbenzene	1.8E+02	1.8E+01	7.5E-06	1.4E-04	V	4.0E-10	4.0E-10	3%	3.7E-07	3.7E-07	<1%
n-Propylbenzene	8.0E+01	9.4E+00	6.5E-06	6.0E-05	V	-		-	1.7E-07	1.7E-07	<1%
Toluene	1.4E+03	1.4E+02	8.7E-06	1.2E-03	V	-		-	6.5E-07	6.5E-07	<1%
Xylenes	1.2E+03	1.1E+02	8.4E-06	9.5E-04	V	-		-	2.6E-05	2.6E-05	11.5%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	2.5E+01	7.9E-02	1.1E-04	8.8E-06	V	-		-	-		-
PAHs											
Naphthalene	1.5E+02	6.3E-01	9.4E-05	6.0E-05	V	2.4E-09	2.4E-09	17%	5.5E-05	5.5E-05	24.1%
Miscellaneous											
Sulfolane	8.3E+02							-			-
GRO	2.1E+04							-			-
DRO	1.5E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						1E-08	1E-08		2E-04	2E-04	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Table E-26

Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

VIS_ATC	25550
VIS_ATnc	10950
VIS_ED	30
VIS_EF	12
VIS_ET	2

Exposure Duration CHRONIC

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-27a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	CANCER RISK: Route-Specific Risk: Dermal [c]	CANCER RISK: Route-Specific Risk: Inhalation (ambient)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	NON-CANCER HAZARD: Route-Specific Hazard: Dermal [c]	NON-CANCER HAZARD: Route-Specific Hazard: Inhalation (ambient)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				3.9E-09	3.9E-09	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				6.3E-10	6.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			1.6E-08	1.6E-08	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			1.4E-08	1.4E-08	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			1.9E-09	1.9E-09	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			6.4E-09	6.4E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				4.2E-12	4.2E-12	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	9E-04	9E-04	

Table E-27a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:

[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

ADUR_ATc	25550	ADUR_ET	12
ADUR_ATnc	10950	ADUR_FI	–
ADUR_AF	–	ADUR_IRs	–
ADUR_BW	70	ADUR_PEF	1316000000
ADUR_ED	30	ADUR_SA	–
ADUR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-27b

Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	4.7E-01			4.7E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		5E-01	0E+00	0E+00	5E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-27c

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	1.0E+00	1.7E-01	-	-		-	1.2E-02	1.9E-02	3.0E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		1E-02	2E-02	3.0E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions): Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-28a

Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	CANCER RISK: Route-Specific Risk: Dermal [c]	CANCER RISK: Route-Specific Risk: Inhalation (ambient)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	NON-CANCER HAZARD: Route-Specific Hazard: Dermal [c]	NON-CANCER HAZARD: Route-Specific Hazard: Inhalation (ambient)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				7.9E-10	7.9E-10	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				1.3E-10	1.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			3.3E-09	3.3E-09	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			2.8E-09	2.8E-09	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			3.8E-10	3.8E-10	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			1.3E-09	1.3E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				8.4E-13	8.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	9E-09	9E-09		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	8E-09	8E-09		0E+00	0E+00	9E-04	9E-04	

Table E-28a

Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATc	25550	CHR_ET	12
CHR_ATnc	2190	CHR_FI	–
CHR_AF	–	CHR_IRs	–
CHR_BW	15	CHR_PEF	1316000000
CHR_ED	6	CHR_SA	–
CHR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-28b

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	1.1E+00			1.1E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1.1E+00	0E+00	0E+00	1.1E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-28c

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	1.0E+00	1.7E-01	-	-		-	4.7E-02	4.2E-02	8.9E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		5E-02	4E-02	9E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-29a

Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	CANCER RISK: Route-Specific Risk: Dermal [c]	CANCER RISK: Route-Specific Risk: Inhalation (ambient)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	NON-CANCER HAZARD: Route-Specific Hazard: Dermal [c]	NON-CANCER HAZARD: Route-Specific Hazard: Inhalation (ambient)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				1.3E-10	1.3E-10	9%			1.4E-04	1.4E-04	21.3%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				2.1E-11	2.1E-11	1%			6.3E-05	6.3E-05	9.4%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			1.2E-04	1.2E-04	17.3%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			5.5E-10	5.5E-10	38%			6.2E-05	6.2E-05	9.2%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			4.7E-10	4.7E-10	33%			1.5E-06	1.5E-06	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			6.4E-11	6.4E-11	4%			3.2E-06	3.2E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			2.4E-05	2.4E-05	3.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			1.1E-04	1.1E-04	16.3%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			2.1E-10	2.1E-10	15%			1.5E-04	1.5E-04	21.8%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				1.4E-13	1.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	7E-04	7E-04	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	5E-04	5E-04	

Table E-29a

Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:

[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATc	25550	INF_ET	12
INF_ATnc	365	INF_FI	–
INF_AF	–	INF_IRs	–
INF_BW	6.75	INF_PEF	1316000000
INF_ED	1	INF_SA	–
INF_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-29b

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	2.5E-01			2.5E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-01	0E+00	0E+00	3E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-29c

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	1.0E+00	1.7E-01	-	-		-	7.2E-03	5.1E-03	1.2E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		7E-03	5E-03	1E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-30

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	3.3E-01			3.3E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-01	0E+00	0E+00	3E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Exposure Duration CHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-31a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]		CANCER RISK Route-Specific Risk Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals															
Arsenic	7.6E+00	1.3E+09	5.8E-09					2.0E-09	2.0E-09	9%			8.8E-05	8.8E-05	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08					-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05					-		-			-		-
Lead										-					-
Nickel	2.0E+01	1.3E+09	1.5E-08					3.3E-10	3.3E-10	1%			3.9E-05	3.9E-05	6.0%
VOCs															
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06		V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06		V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05		V			8.5E-09	8.5E-09	38%			1.0E-04	1.0E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05		V			-		-			1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05		V			7.3E-09	7.3E-09	33%			8.2E-06	8.2E-06	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05		V			9.8E-10	9.8E-10	4%			5.8E-06	5.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04		V			-		-			4.2E-05	4.2E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05		V			-		-			8.1E-07	8.1E-07	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04		V			-		-			2.7E-04	2.7E-04	41.7%
SVOCs															
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06		V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06		V			-		-			-		-
PAHs															
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11					*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11					*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11					*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11					*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11					*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11					*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11					*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06		V			3.3E-09	3.3E-09	15%			9.0E-05	9.0E-05	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11					2.2E-12	2.2E-12	<1%			-		-
Miscellaneous															
Sulfolane	3.8E-02	1.3E+09	2.9E-11					-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09					-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07					-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06					-		-			-		-
Total Risk or Hazard						0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	
Total Risk or Hazard Excluding Arsenic						0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	

Table E-31a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1316000000
CIo_EF	250		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table E-31b

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	3.3E-01			3.3E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-01	0E+00	0E+00	3E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-32

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 1 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	1.7E-01		2.0E-07		-			-	-	3.1E-05			3.1E-05	100.0%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		3E-05	0E+00	0E+00	3E-05	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m³:	Liter(s) per cubic meter		

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-33a

Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	1.6E-01			1.6E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EgwF × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-33b

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	1.0E+00	5.9E-02	-	-		-	4.0E-03	6.4E-03	1.0E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		4E-03	6E-03	1E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:

[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-34a

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	3.8E-01			3.8E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		4E-01	0E+00	0E+00	4E-01	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Exposure Duration CHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-34b

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	1.0E+00	5.9E-02	-	-		-	1.6E-02	1.5E-02	3.1E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		2E-02	1E-02	3E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:

[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-35a

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	8.9E-02			8.9E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		9E-02	0E+00	0E+00	9E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-35b

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	1.0E+00	5.9E-02	-	-		-	2.5E-03	1.8E-03	4.3E-03	100.0%
Total Risk or Hazard				0E+00	0E+00	0E+00		3E-03	2E-03	4E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-36

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	1.2E-01			1.2E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E-01	0E+00	0E+00	1E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-37

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	1.2E-01			1.2E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E-01	0E+00	0E+00	1E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Exposure Duration CHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-38

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 2 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK: Route-Specific Risk: Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	5.9E-02		2.0E-07		-			-	-	1.1E-05			1.1E-05	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		1E-05	0E+00	0E+00	1E-05	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Exposure Duration SUBCHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-39a

Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK				Percent Total ELCR	NON-CANCER HAZARD				Percent Total HI
						Route-Specific Risk			Calculated Risk		Route-Specific Hazard			Calculated Hazard	
						Oral	Dermal [d]	Inhalation (domestic use) [d]			Oral	Dermal [d]	Inhalation (domestic use) [d]		
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	2.8E-02			2.8E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-02	0E+00	0E+00	3E-02	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-39b

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	1.0E+00	1.0E-02	-	-		-	7.0E-04	1.1E-03	1.8E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		7E-04	1E-03	2E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	259000
ADUR_ATnc	10950	ADUR_IRPvg	413000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-40a

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	6.5E-02			6.5E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		7E-02	0E+00	0E+00	7E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-40b

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	1.0E+00	1.0E-02	-	-		-	2.8E-03	2.5E-03	5.3E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		3E-03	3E-03	5E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	223500
CHR_ATnc	2190	CHR_IRPvg	201000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-41a

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	1.5E-02			1.5E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-02	0E+00	0E+00	2E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-41b

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	1.0E+00	1.0E-02	-	-		-	4.3E-04	3.1E-04	7.4E-04	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		4E-04	3E-04	7E-04	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12a for definitions):   Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	155250
INF_ATnc	365	INF_IRPvg	109350
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table E-42

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	2.0E-02			2.0E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-02	0E+00	0E+00	2E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-43

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	2.0E-02			2.0E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-02	0E+00	0E+00	2E-02	

Abbreviations:

-: Not applicable
DA: Dermal absorption factor (L/cm^2/event)
ELCR: Excess lifetime cancer risk (unitless)
EPCdu: Exposure point concentration in air during showering (mg/m^3)
EPCia: Exposure point concentration in indoor air (mg/m^3)
EPCgw: Exposure point concentration in groundwater (mg/L)
HI: Hazard index (unitless)
HQ: Hazard quotient (unitless)
L/m³: Liter(s) per cubic meter
L/cm^2/event: Liter(s) per cubic centimeter per event
mg/L: Milligram(s) per liter
mg/m^3: Milligram(s) per cubic meter
VF: Volatilization factor (m^3/kg)
V: Indicates the constituent is a volatile compound, as defined by USEPA
VF: Volatilization factor (L/m^3)
VOCs: Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Exposure Duration CHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table E-44

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 3 - UCL COPC Concentrations - ARCADIS Comparative Scenario

Human Health Risk Assessment - ARCADIS Comparative Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	1.0E-02		2.0E-07		-			-	-	1.8E-06			1.8E-06	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		2E-06	0E+00	0E+00	2E-06	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m³:	Liter(s) per cubic meter		

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12a for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

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Appendix F

Estimated Risks/Hazards Using Maximum COPC Concentrations – ARCADIS Scenario

Table F-1a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - Maximum COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

					CANCER RISK				Percent	NON-CANCER HAZARD				Percent
					Route-Specific Risk			Calculated	Total	Route-Specific Hazard			Calculated	Total
Constituent	**EPCs (mg/kg)**	**VF *or* PEF [a] (m^3/kg)**	**EPCaa (mg/m^3)**	**EPCia (mg/m^3) [b]**	**Oral**	**Dermal**	**Inhalation (ambient)**	**Risk**	**ELCR**	**Oral**	**Dermal**	**Inhalation (ambient)**	**Hazard**	**HI**
Metals														
Arsenic	1.8E+01	1.0E+06	1.8E-05		6.1E-07	3.7E-08	1.5E-08	6.6E-07	69%	5.7E-03	3.5E-04	1.7E-02	2.3E-02	8.2%
Chromium, Total	5.1E+01	1.0E+06	5.1E-05		-	-	-	-	-	5.5E-05	-	-	5.5E-05	<1%
Iron	2.9E+04	1.0E+06	2.9E-02		-	-	-	-	-	6.7E-02	-	-	6.7E-02	24.0%
Nickel	3.8E+01	1.0E+06	3.8E-05		-	-	2.0E-09	2.0E-09	<1%	3.1E-03	-	6.0E-03	9.1E-03	3.3%
VOCs														
1,2,4-Trimethylbenzene	2.1E+02	8.5E+03	2.4E-02	V	-	-	-	-	-	-	-	4.9E-03	4.9E-03	1.8%
1,3,5-Trimethylbenzene	8.1E+01	7.1E+03	1.1E-02	V	-	-	-	-	-	1.3E-03	-	1.6E-02	1.8E-02	6.3%
4-Isopropyltoluene (p-cymene)	2.0E+01	9.4E+03	2.2E-03	V	-	-	-	-	-	-	-	-	-	-
Benzene	8.2E+01	3.8E+03	2.2E-02	V	1.0E-07	-	3.4E-08	1.4E-07	14%	1.3E-02	-	3.8E-03	1.7E-02	6.1%
Cyclohexane	4.5E+01	1.1E+03	4.0E-02	V	-	-	-	-	-	-	-	9.5E-05	9.5E-05	<1%
Ethylbenzene	1.1E+02	6.1E+03	1.8E-02	V	2.8E-08	-	9.3E-09	3.7E-08	4%	3.6E-03	-	2.9E-05	3.6E-03	1.3%
Isopropylbenzene (cumene)	4.2E+01	6.7E+03	6.2E-03	V	-	-	-	-	-	1.7E-04	-	9.9E-04	1.2E-03	<1%
Methylene chloride	1.9E-01	2.4E+03	8.0E-05	V	3.3E-11	-	7.6E-12	4.0E-11	<1%	5.1E-06	-	3.8E-07	5.4E-06	<1%
n-Butylbenzene	1.1E+02	8.8E+03	1.2E-02	V	-	-	-	-	-	1.7E-03	-	-	1.7E-03	<1%
n-Hexane	1.3E+01	8.9E+02	1.5E-02	V	-	-	-	-	-	7.0E-05	-	1.0E-04	1.7E-04	<1%
n-Propylbenzene	7.3E+01	7.5E+03	9.7E-03	V	-	-	-	-	-	1.2E-03	2.4E-04	1.4E-04	1.5E-03	<1%
sec-Butylbenzene	2.5E+01	8.1E+03	3.1E-03	V	-	-	-	-	-	-	-	-	-	-
Toluene	3.9E+02	4.6E+03	8.5E-02	V	-	-	-	-	-	7.9E-04	-	2.4E-04	1.0E-03	<1%
Xylenes	7.1E+02	6.3E+03	1.1E-01	V	-	-	-	-	-	2.8E-03	-	4.0E-03	6.9E-03	2.5%
SVOCs														
1-Methylnaphthalene	8.9E+01	6.3E+04	1.4E-03	V	5.9E-08	-	-	5.9E-08	6%	2.0E-03	-	-	2.0E-03	<1%
2-Methylnaphthalene	2.4E+02	6.2E+04	3.8E-03	V	-	-	-	-	-	9.7E-02	-	-	9.7E-02	34.8%
PAHs														
Benzo (a) anthracene	9.9E-02	1.0E+06	9.9E-08		*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	9.5E-02	1.0E+06	9.5E-08		*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	1.1E-01	1.0E+06	1.1E-07		*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	4.0E-02	1.0E+06	4.0E-08		*	*	*	*	-	-	-	-	-	-
Chrysene	7.8E-01	1.0E+06	7.8E-07		*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	1.8E-02	1.0E+06	1.8E-08		*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.0E+06	6.9E-08		*	*	*	*	-	-	-	-	-	-
Naphthalene	1.3E+02	5.0E+04	2.5E-03	V	-	-	1.7E-08	1.7E-08	2%	1.0E-02	2.7E-03	1.2E-02	2.5E-02	8.9%
Total Benzo(a)pyrene TEQ	2.3E-01	1.0E+06	2.3E-07		3.8E-08	1.0E-08	5.0E-11	4.8E-08	5%	-	-	-	-	-
Miscellaneous														
Sulfolane	1.8E+01	1.0E+06	1.8E-05		-	-	-	-	-	3.0E-04	-	-	3.0E-04	<1%
GRO	7.7E+03	1.0E+06	7.7E-03		-	-	-	-	-	-	-	-	-	-
DRO	1.9E+04	1.0E+06	1.9E-02		-	-	-	-	-	-	-	-	-	-
RRO	6.5E+04	1.0E+06	6.5E-02		-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard					8E-07	5E-08	8E-08	1E-06		2E-01	3E-03	7E-02	3E-01	
Total Risk or Hazard Excluding Arsenic					2E-07	1E-08	6E-08	3E-07		2E-01	3E-03	5E-02	3E-01	

Table F-1a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - Maximum COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/m^3:	Milligram(s) per cubic meter
ELCR:	Excess lifetime cancer risk (unitless)	PAH:	Polycyclic aromatic hydrocarbon
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
mg/kg:	Milligram(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk
m^3/kg:	Cubic meter(s) per kilogram		

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvFs	1
CST_AF	0.3	CST_FI	1
CST_BW	70	CST_IRs	330
CST_ED	1	CST_PEF	1.00E+06
CST_EF	125	CST_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table F-1b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta [a] (mg/m3)		CANCER RISK: Route-Specific Risk: Oral	Dermal	Inhalation (trench air)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal	Inhalation (trench air)	Calculated Hazard	Percent Total HI
Metals															
Barium	2.6E-01		1.0E-06			-	-	-	-	-	6.8E-05	5.8E-04		6.5E-04	<1%
Iron	2.8E+01		1.0E-06			-	-	-	-	-	7.3E-04	4.4E-04	-	1.2E-03	<1%
Lead	1.2E-03		1.0E-07			-	-	-	-	-	-	-	-	-	-
VOCs															
1,2,4-Trimethylbenzene	1.1E-01	7.5E+00	2.6E-04	8.5E-01	V	-	-	-	-	-	-	-	1.7E-01	1.7E-01	2.0%
1,3,5-Trimethylbenzene	1.2E-01	7.6E+00	1.8E-04	9.2E-01	V	-	-	-	-	-	2.2E-05	2.4E-03	1.3E+00	1.3E+00	15.0%
4-Isopropyltoluene (p-cymene	3.3E-02	7.2E+00	5.0E-04	2.4E-01	V	-	-	-	-	-	-	-	-	-	-
Benzene	1.3E+00	9.3E+00	2.3E-05	1.2E+01	V	1.9E-08	2.7E-07	2.0E-05	2.0E-05	73%	2.4E-03	3.4E-02	2.2E+00	2.3E+00	25.9%
Ethylbenzene	1.8E-01	8.0E+00	8.8E-05	1.4E+00	V	5.1E-10	2.7E-08	7.4E-07	7.7E-07	3%	6.5E-05	3.4E-03	2.3E-03	5.8E-03	<1%
n-Propylbenzene	8.0E-02	7.6E+00	2.8E-04	6.1E-01	V	-	-	-	-	-	1.5E-05	2.5E-03	8.7E-03	1.1E-02	<1%
Toluene	1.4E+00	8.6E+00	5.2E-05	1.2E+01	V	-	-	-	-	-	3.2E-05	1.0E-03	3.5E-02	3.6E-02	<1%
Xylenes	1.2E+00	8.0E+00	9.5E-05	9.5E+00	V	-	-	-	-	-	5.4E-05	3.1E-03	3.4E-01	3.4E-01	3.9%
SVOCs															
1-Methylnaphthalene	3.5E-02	6.3E+00	3.3E-04	2.2E-01	V	2.6E-10	5.2E-08	-	5.2E-08	<1%	9.1E-06	1.8E-03	-	1.8E-03	<1%
2-Methylnaphthalene	2.5E-02	6.3E+00	3.2E-04	1.6E-01	V	-	-	-	-	-	1.1E-04	2.2E-02	-	2.2E-02	<1%
PAHs															
Naphthalene	1.5E-01	6.6E+00	9.7E-05	9.6E-01	V	-	-	6.6E-06	6.6E-06	24%	1.3E-04	7.7E-03	4.6E+00	4.6E+00	52.3%
Miscellaneous															
Sulfolane	8.3E-01		2.0E-07			-	-	-	-	-	1.5E-04	1.8E-05	-	1.7E-04	<1%
GRO	2.1E+01		NA			-	-	-	-	-	-	-	-	-	-
DRO	1.5E+00		NA			-	-	-	-	-	-	-	-	-	-
RRO	2.8E-01		NA			-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard						2E-08	3E-07	3E-05	3E-05		4E-03	8E-02	8.6E+00	8.7E+00	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

Table F-1b
Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRinc_gw × EFgw × ED × CSFo) / (BW × ATc)
ELCRd = (EPCgw × DA × SAgw × EvFgw × EFgw × ED × CSFd) / (BW × ATc)
ELCRta (VOCs) = ([EPCgw × VF] × EFgw × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCgw × FIgw × IRinc_gw × EFgw × ED) / (BW × ATnc × RfDo)
HQd = (EPCgw × DA ×SAgw ×EvFgw × EFgw × ED) / (BW × ATnc × RfDa)
HQta (VOCs) = ([EPCgw × VF] × ET × EFgw × ED) / (24 × ATnc × RfC)

ARCADIS

Appendix G

Estimated Risks/Hazards Using Maximum COPC Concentrations – ARCADIS Scenario

Table G-1

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Indoor Worker Exposed to Indoor Air - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m^3) [a]	AF [a]	EPCia (mg/m^3) [a]		CANCER RISK Route-Specific Risk Inhalation (indoor air)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Metals											
Barium	2.6E+02							-			-
Iron	2.8E+04							-			-
Lead	1.2E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	1.1E+02	7.3E+00	1.1E-05	8.2E-05	V	-		-	2.7E-03	2.7E-03	14.1%
1,3,5-Trimethylbenzene	1.2E+02	7.5E+00	1.3E-05	9.5E-05	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	3.3E+01				V			-			-
Benzene	1.3E+03	1.2E+02	1.0E-05	1.2E-03	V	7.9E-07	7.9E-07	80%	9.4E-03	9.4E-03	49.7%
Ethylbenzene	1.8E+02	1.8E+01	7.5E-06	1.4E-04	V	2.8E-08	2.8E-08	3%	3.1E-05	3.1E-05	<1%
n-Propylbenzene	8.0E+01	9.4E+00	6.5E-06	6.0E-05	V	-		-	1.4E-05	1.4E-05	<1%
Toluene	1.4E+03	1.4E+02	8.7E-06	1.2E-03	V	-		-	5.4E-05	5.4E-05	<1%
Xylenes	1.2E+03	1.1E+02	8.4E-06	9.5E-04	V	-		-	2.2E-03	2.2E-03	11.5%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	2.5E+01	7.9E-02	1.1E-04	8.8E-06	V	-		-	-		-
PAHs											
Naphthalene	1.5E+02	6.3E-01	9.4E-05	6.0E-05	V	1.7E-07	1.7E-07	17%	4.6E-03	4.6E-03	24.1%
Miscellaneous											
Sulfolane	8.3E+02							-			-
GRO	2.1E+04							-			-
DRO	1.5E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						1E-06	1E-06		2E-02	2E-02	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

CI_ATC	25550
CI_ATnc	9125
CI_ED	25
CI_EF	250
CI_ET	8

Exposure Duration CHRONIC

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table G-2
Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09		4.0E-06	5.3E-07	2.0E-09	4.5E-06	97%	2.5E-02	3.3E-03	8.8E-05	2.8E-02	52.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08		-	-	-	-	-	1.3E-05	-	-	1.3E-05	<1%
Iron	1.7E+04	1.3E+09	1.3E-05		-	-	-	-	-	2.4E-02	-	-	2.4E-02	44.3%
Lead						-			-		-			-
Nickel	2.0E+01	1.3E+09	1.5E-08		-	-	3.3E-10	3.3E-10	<1%	9.9E-04	-	3.9E-05	1.0E-03	1.9%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V	-	-	-	-	-	2.2E-06	-	-	2.2E-06	<1%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V	-	-	-	-	-	-	-	-	-	-
Benzene	5.1E-02	3.8E+03	1.3E-05	V	9.8E-10	-	8.5E-09	9.5E-09	<1%	1.2E-05	-	1.0E-04	1.1E-04	<1%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V	-	-	-	-	-	-	-	1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V	8.4E-10	-	7.3E-09	8.1E-09	<1%	2.1E-06	-	8.2E-06	1.0E-05	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V	1.6E-10	-	9.8E-10	1.1E-09	<1%	9.8E-07	-	5.8E-06	6.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V	-	-	-	-	-	1.9E-06	-	4.2E-05	4.4E-05	<1%
Toluene	8.2E-02	4.6E+03	1.8E-05	V	-	-	-	-	-	1.0E-06	-	8.1E-07	1.8E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V	-	-	-	-	-	3.6E-06	-	2.7E-04	2.7E-04	<1%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V	2.5E-09	-	-	2.5E-09	<1%	3.4E-06	-	-	3.4E-06	<1%
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V	-	-	-	-	-	6.7E-05	-	-	6.7E-05	<1%
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11		*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11		*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11		*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11		*	*	*	*	-	-	-	-	-	-
Chrysene	6.6E-02	1.3E+09	5.0E-11		*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11		*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11		*	*	*	*	-	-	-	-	-	-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V	-	-	3.3E-09	3.3E-09	<1%	2.9E-06	1.7E-06	9.0E-05	9.5E-05	<1%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11		8.1E-08	4.7E-08	2.2E-12	1.3E-07	3%	-	-	-	-	-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11		-	-	-	-	-	3.7E-06	-	-	3.7E-06	<1%
GRO	5.4E+00	1.3E+09	4.1E-09		-	-	-	-	-	-	-	-	-	-
DRO	2.1E+02	1.3E+09	1.6E-07		-	-	-	-	-	-	-	-	-	-
RRO	1.9E+03	1.3E+09	1.4E-06		-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard					4E-06	6E-07	2E-08	5E-06		5E-02	3E-03	6E-04	5E-02	
Total Risk or Hazard Excluding Arsenic					9E-08	5E-08	2E-08	2E-07		2E-02	2E-06	6E-04	3E-02	

Table G-2

Chronic Risk and Hazard Estimates for the Onsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions): Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_EvFs	1
CIo_AF	0.2	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1316000000
CIo_EF	250	CIo_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table G-3a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral	Dermal	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.3E+00	1.0E+06	7.3E-06		2.5E-07	1.5E-08	6.4E-09	2.7E-07	94%	2.4E-03	1.4E-04	7.0E-03	9.5E-03	16.5%
Chromium, Total	1.7E+01	1.0E+06	1.7E-05		-	-	-	-	-	1.8E-05	-	-	1.8E-05	<1%
Iron	1.5E+04	1.0E+06	1.5E-02		-	-	-	-	-	3.5E-02	-	-	3.5E-02	60.5%
Nickel	1.9E+01	1.0E+06	1.9E-05		-	-	1.0E-09	1.0E-09	<1%	1.5E-03	-	3.0E-03	4.5E-03	7.9%
VOCs														
1,2,4-Trimethylbenzene	2.2E+01	8.5E+03	2.6E-03	V	-	-	-	-	-	-	-	5.3E-04	5.3E-04	<1%
1,3,5-Trimethylbenzene	8.3E+00	7.1E+03	1.2E-03	V	-	-	-	-	-	1.3E-04	-	1.7E-03	1.8E-03	3.1%
4-Isopropyltoluene (p-cymene)	2.0E+00	9.4E+03	2.2E-04	V	-	-	-	-	-	-	-	-	-	-
Benzene	3.1E+00	3.8E+03	8.2E-04	V	4.0E-09	-	1.3E-09	5.3E-09	2%	5.1E-04	-	1.5E-04	6.5E-04	1.1%
Cyclohexane	5.6E+00	1.1E+03	5.0E-03	V	-	-	-	-	-	-	-	1.2E-05	1.2E-05	<1%
Ethylbenzene	8.7E+00	6.1E+03	1.4E-03	V	2.2E-09	-	7.2E-10	2.9E-09	<1%	2.8E-04	-	2.3E-06	2.8E-04	<1%
Isopropylbenzene (cumene)	4.0E+00	6.7E+03	5.9E-04	V	-	-	-	-	-	1.6E-05	-	9.4E-05	1.1E-04	<1%
Methylene chloride	2.9E-01	2.4E+03	1.2E-04	V	5.0E-11	-	1.2E-11	6.2E-11	<1%	7.8E-06	-	5.8E-07	8.4E-06	<1%
n-Butylbenzene	7.6E+00	8.8E+03	8.7E-04	V	-	-	-	-	-	1.2E-04	-	-	1.2E-04	<1%
n-Hexane	2.4E+00	8.9E+02	2.7E-03	V	-	-	-	-	-	1.3E-05	-	1.9E-05	3.2E-05	<1%
n-Propylbenzene	7.2E+00	7.5E+03	9.6E-04	V	-	-	-	-	-	1.2E-04	2.4E-05	1.4E-05	1.5E-04	<1%
sec-Butylbenzene	6.6E+00	8.1E+03	8.1E-04	V	-	-	-	-	-	-	-	-	-	-
Toluene	1.7E+01	4.6E+03	3.8E-03	V	-	-	-	-	-	3.5E-05	-	1.1E-05	4.6E-05	<1%
Xylenes	4.7E+01	6.3E+03	7.5E-03	V	-	-	-	-	-	1.9E-04	-	2.7E-04	4.6E-04	<1%
SVOCs														
1-Methylnaphthalene	4.6E+00	6.3E+04	7.3E-05	V	3.1E-09	-	-	3.1E-09	1%	1.1E-04	-	-	1.1E-04	<1%
2-Methylnaphthalene	8.6E+00	6.2E+04	1.4E-04	V	-	-	-	-	-	3.5E-03	-	-	3.5E-03	6.0%
PAHs														
Benzo (a) anthracene	1.2E-02	1.0E+06	1.2E-08		*	*	*	*	-	-	-	-	-	-
Benzo (a) pyrene	1.2E-02	1.0E+06	1.2E-08		*	*	*	*	-	-	-	-	-	-
Benzo (b) fluoranthene	2.1E-02	1.0E+06	2.1E-08		*	*	*	*	-	-	-	-	-	-
Benzo (k) fluoranthene	1.9E-02	1.0E+06	1.9E-08		*	*	*	*	-	-	-	-	-	-
Chrysene	3.5E-02	1.0E+06	3.5E-08		*	*	*	*	-	-	-	-	-	-
Dibenzo (a,h) anthracene	9.9E-03	1.0E+06	9.9E-09		*	*	*	*	-	-	-	-	-	-
Indeno (1,2,3-cd) pyrene	1.1E-02	1.0E+06	1.1E-08		*	*	*	*	-	-	-	-	-	-
Naphthalene	4.4E+00	5.0E+04	8.8E-05	V	-	-	6.1E-10	6.1E-10	<1%	3.5E-04	9.3E-05	4.2E-04	8.6E-04	1.5%
Total Benzo(a)pyrene TEQ	2.6E-02	1.0E+06	2.6E-08		4.3E-09	1.1E-09	5.8E-12	5.5E-09	2%	-	-	-	-	-
Miscellaneous														
Sulfolane	4.5E-01	1.0E+06	4.5E-07		-	-	-	-	-	7.3E-06	-	-	7.3E-06	<1%
GRO	8.1E+02	1.0E+06	8.1E-04		-	-	-	-	-	-	-	-	-	-
DRO	2.1E+03	1.0E+06	2.1E-03		-	-	-	-	-	-	-	-	-	-
RRO	8.2E+03	1.0E+06	8.2E-03		-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard					3E-07	2E-08	1E-08	3E-07		4E-02	3E-04	1E-02	6E-02	
Total Risk or Hazard Excluding Arsenic					1E-08	1E-09	4E-09	2E-08		4E-02	1E-04	6E-03	5E-02	

Table G-3a

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Subsurface Soil (0 to 15 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/m^3:	Milligram(s) per cubic meter
ELCR:	Excess lifetime cancer risk (unitless)	PAH:	Polycyclic aromatic hydrocarbon
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
mg/kg:	Milligram(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk
m^3/kg:	Cubic meter(s) per kilogram		

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):   Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvFs	1
CST_AF	0.3	CST_FI	1
CST_BW	70	CST_IRs	330
CST_ED	1	CST_PEF	1.00E+06
CST_EF	125	CST_SA	2230

Equations:

ELCRo = (EPCs × FI × IRs × EF × ED × CSFo) / (1,000,000 × BW × ATc)
ELCRd = ([EPCs × AF × ABSd] × SA × EvFs × EF × ED × CSFd) / (1,000,000 × BW × ATc)
ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCs × FI × IRs × EF × ED) / (1,000,000 × BW × ATnc × RfDo)
HQd = ([EPCs × AF ×ABSd]) × SA ×EvFs × EF × ED) / (1,000,000 × BW × ATnc × RfDa)
HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table G-3b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m^3)	DA [b] L/cm2/event	EPCta [a] (mg/m3)		CANCER RISK: Route-Specific Risk: Oral	Dermal	Inhalation (trench air)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal	Inhalation (trench air)	Calculated Hazard	Percent Total HI
Metals															
Barium	2.6E-01		1.0E-06			-	-	-	-	-	6.8E-05	5.8E-04		6.5E-04	<1%
Iron	2.8E+01		1.0E-06			-	-	-	-	-	7.3E-04	4.4E-04	-	1.2E-03	<1%
Lead	1.2E-03		1.0E-07			-	-	-	-	-	-	-	-	-	-
VOCs															
1,2,4-Trimethylbenzene	1.1E-01	7.5E+00	2.6E-04	8.5E-01	V	-	-	-	-	-	-	-	1.7E-01	1.7E-01	2.0%
1,3,5-Trimethylbenzene	1.2E-01	7.6E+00	1.8E-04	9.2E-01	V	-	-	-	-	-	2.2E-05	2.4E-03	1.3E+00	1.3E+00	15.0%
4-Isopropyltoluene (p-cymene)	3.3E-02	7.2E+00	5.0E-04	2.4E-01	V	-	-	-	-	-	-	-	-	-	-
Benzene	1.3E+00	9.3E+00	2.3E-05	1.2E+01	V	1.9E-08	2.7E-07	2.0E-05	2.0E-05	73%	2.4E-03	3.4E-02	2.2E+00	2.3E+00	25.9%
Ethylbenzene	1.8E-01	8.0E+00	8.8E-05	1.4E+00	V	5.1E-10	2.7E-08	7.4E-07	7.7E-07	3%	6.5E-05	3.4E-03	2.3E-03	5.8E-03	<1%
n-Propylbenzene	8.0E-02	7.6E+00	2.8E-04	6.1E-01	V	-	-	-	-	-	1.5E-05	2.5E-03	8.7E-03	1.1E-02	<1%
Toluene	1.4E+00	8.6E+00	5.2E-05	1.2E+01	V	-	-	-	-	-	3.2E-05	1.0E-03	3.5E-02	3.6E-02	<1%
Xylenes	1.2E+00	8.0E+00	9.5E-05	9.5E+00	V	-	-	-	-	-	5.4E-05	3.1E-03	3.4E-01	3.4E-01	3.9%
SVOCs															
1-Methylnaphthalene	3.5E-02	6.3E+00	3.3E-04	2.2E-01	V	2.6E-10	5.2E-08	-	5.2E-08	<1%	9.1E-06	1.8E-03	-	1.8E-03	<1%
2-Methylnaphthalene	2.5E-02	6.3E+00	3.2E-04	1.6E-01	V	-	-	-	-	-	1.1E-04	2.2E-02	-	2.2E-02	<1%
PAHs															
Naphthalene	1.5E-01	6.6E+00	9.7E-05	9.6E-01	V	-	-	6.6E-06	6.6E-06	24%	1.3E-04	7.7E-03	4.6E+00	4.6E+00	52.3%
Miscellaneous															
Sulfolane	8.3E-01		2.0E-07			-	-	-	-	-	1.5E-04	1.8E-05	-	1.7E-04	<1%
GRO	2.1E+01		NA			-	-	-	-	-	-	-	-	-	-
DRO	1.5E+00		NA			-	-	-	-	-	-	-	-	-	-
RRO	2.8E-01		NA			-	-	-	-	-	-	-	-	-	-
Total Risk or Hazard						2E-08	3E-07	3E-05	3E-05		4E-03	8E-02	9E+00	9E+00	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m^3:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Notes:

[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

Table G-3b

Subchronic Risk and Hazard Estimates for the Onsite Construction/Trench Worker Exposed to Groundwater in a Trench - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRinc_gw × EFgw × ED × CSFo) / (BW × ATc)

ELCRd = (EPCgw × DA × SAgw × EvFgw × EFgw × ED × CSFd) / (BW × ATc)

ELCRta (VOCs) = ([EPCgw × VF] × EFgw × ED × ET × IUR × 1000) / (24 × ATc)

HQo = (EPCgw × FIgw × IRinc_gw × EFgw × ED) / (BW × ATnc × RfDo)

HQd = (EPCgw × DA ×SAgw ×EvFgw × EFgw × ED) / (BW × ATnc × RfDa)

HQta (VOCs) = ([EPCgw × VF] × ET × EFgw × ED) / (24 × ATnc × RfC)

Table G-4

Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (ug/L) [b]	EPCsg (mg/m^3) [a]	AF [a]	EPCia (mg/m^3) [a]		CANCER RISK: Route-Specific Risk Inhalation (indoor air)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard Inhalation (indoor air)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals											
Barium	2.6E+02							-			-
Iron	2.8E+04							-			-
Lead	1.2E+00							-			-
VOCs											
1,2,4-Trimethylbenzene	1.1E+02	7.3E+00	1.1E-05	8.2E-05	V	-		-	3.2E-05	3.2E-05	14.1%
1,3,5-Trimethylbenzene	1.2E+02	7.5E+00	1.3E-05	9.5E-05	V	-		-	-		-
4-Isopropyltoluene (p-cymene)	3.3E+01				V			-			-
Benzene	1.3E+03	1.2E+02	1.0E-05	1.2E-03	V	1.1E-08	1.1E-08	80%	1.1E-04	1.1E-04	49.7%
Ethylbenzene	1.8E+02	1.8E+01	7.5E-06	1.4E-04	V	4.0E-10	4.0E-10	3%	3.7E-07	3.7E-07	<1%
n-Propylbenzene	8.0E+01	9.4E+00	6.5E-06	6.0E-05	V	-		-	1.7E-07	1.7E-07	<1%
Toluene	1.4E+03	1.4E+02	8.7E-06	1.2E-03	V	-		-	6.5E-07	6.5E-07	<1%
Xylenes	1.2E+03	1.1E+02	8.4E-06	9.5E-04	V	-		-	2.6E-05	2.6E-05	11.5%
SVOCs											
1-Methylnaphthalene	3.5E+01	1.1E-01	1.1E-04	1.2E-05	V	-		-	-		-
2-Methylnaphthalene	2.5E+01	7.9E-02	1.1E-04	8.8E-06	V	-		-	-		-
PAHs											
Naphthalene	1.5E+02	6.3E-01	9.4E-05	6.0E-05	V	2.4E-09	2.4E-09	17%	5.5E-05	5.5E-05	24.1%
Miscellaneous											
Sulfolane	8.3E+02							-			-
GRO	2.1E+04							-			-
DRO	1.5E+03							-			-
RRO	2.8E+02							-			-
Total Risk or Hazard						1E-08	1E-08		2E-04	2E-04	

Abbreviations:

-:	Not applicable	ug/L:	Microgram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCgw:	Exposure point concentration in groundwater (ug/L)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	SVOCs:	Semi-volatile organic compounds
EPCsg:	Exposure point concentration in soil gas (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
AF:	Attenuation factor (unitless)		

Table G-4
Chronic Risk and Hazard Estimates for the Onsite Adult Visitor Exposed to Indoor Air - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Notes:

[a] Modeled from groundwater data using Johnson & Ettinger Soil Gas Model (USEPA, 2004). A commercial air exchange rate of 1 per hour was used. Results presented in Appendix C.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

VIS_ATC	25550
VIS_ATnc	10950
VIS_ED	30
VIS_EF	12
VIS_ET	2

Equations:

ELCRia (VOCs) = ([EPCsg × AF] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQia (VOCs) = ([EPCsg × AF] × ET × EF × ED) / (24 × ATnc × RfC)

Table G-5a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m³/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	CANCER RISK: Route-Specific Risk: Dermal [c]	CANCER RISK: Route-Specific Risk: Inhalation (ambient)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	NON-CANCER HAZARD: Route-Specific Hazard: Dermal [c]	NON-CANCER HAZARD: Route-Specific Hazard: Inhalation (ambient)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				3.9E-09	3.9E-09	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				6.3E-10	6.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			1.6E-08	1.6E-08	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			1.4E-08	1.4E-08	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			1.9E-09	1.9E-09	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			6.4E-09	6.4E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				4.2E-12	4.2E-12	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	4E-08	4E-08		0E+00	0E+00	9E-04	9E-04	

Table G-5a

Chronic Risk and Hazard Estimates for the Offsite Adult Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:

[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12b for definitions): Exposure Duration CHRONIC

ADUR_ATc	25550	ADUR_ET	12
ADUR_ATnc	10950	ADUR_FI	–
ADUR_AF	–	ADUR_IRs	–
ADUR_BW	70	ADUR_PEF	1316000000
ADUR_ED	30	ADUR_SA	–
ADUR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table G-5b

Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	4.7E-01			4.7E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		5E-01	0E+00	0E+00	5E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-5c

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK: Route-Specific Risk: Ingestion (fruit)	CANCER RISK: Route-Specific Risk: Ingestion (vegetables)	CANCER RISK: Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (fruit)	NON-CANCER HAZARD: Route-Specific Hazard: Ingestion (vegetables)	NON-CANCER HAZARD: Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	3.2E-01	5.4E-02	-	-		-	9.1E-04	2.5E-03	3.4E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		9E-04	3E-03	3E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:

[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	63000
ADUR_ATnc	10950	ADUR_IRPvg	175000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-6a

Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

					CANCER RISK					NON-CANCER HAZARD				
					Route-Specific Risk			Calculated	Percent	Route-Specific Hazard			Calculated	Percent
Constituent	**EPCs (mg/kg)**	**VF *or* PEF [a] (m^3/kg)**	**EPCaa (mg/m^3)**	**EPCia (mg/m^3) [b]**	**Oral [c]**	**Dermal [c]**	**Inhalation (ambient)**	**Risk**	**Total ELCR**	**Oral [c]**	**Dermal [c]**	**Inhalation (ambient)**	**Hazard**	**Total HI**
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				7.9E-10	7.9E-10	9%			1.4E-04	1.4E-04	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				1.3E-10	1.3E-10	1%			6.3E-05	6.3E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			3.3E-09	3.3E-09	38%			1.6E-04	1.6E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			2.8E-09	2.8E-09	33%			1.3E-05	1.3E-05	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			3.8E-10	3.8E-10	4%			9.5E-06	9.5E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			6.9E-05	6.9E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			4.4E-04	4.4E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			1.3E-09	1.3E-09	15%			1.5E-04	1.5E-04	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				8.4E-13	8.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	9E-09	9E-09		0E+00	0E+00	1E-03	1E-03	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	8E-09	8E-09		0E+00	0E+00	9E-04	9E-04	

Table G-6a

Chronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12b for definitions): Exposure Duration CHRONIC

CHR_ATc	25550	CHR_ET	12
CHR_ATnc	2190	CHR_FI	–
CHR_AF	–	CHR_IRs	–
CHR_BW	15	CHR_PEF	1316000000
CHR_ED	6	CHR_SA	–
CHR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table G-6b

Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

						CANCER RISK				Percent	NON-CANCER HAZARD				Percent
						Route-Specific Risk			Calculated	Total	Route-Specific Hazard			Calculated	Total
Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	Oral	Dermal [d]	Inhalation (domestic use) [d]	Risk	ELCR	Oral	Dermal [d]	Inhalation (domestic use) [d]	Hazard	HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	1.1E+00			1.1E+00	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E+00	0E+00	0E+00	1E+00	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-6c

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	3.2E-01	5.4E-02	-	-		-	4.6E-03	5.4E-03	1.0E-02	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		5E-03	5E-03	1E-02	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	69000
CHR_ATnc	2190	CHR_IRPvg	81000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-6d

Subchronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				7.9E-10	7.9E-10	9%			1.4E-04	1.4E-04	21.3%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				1.3E-10	1.3E-10	1%			6.3E-05	6.3E-05	9.4%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			1.2E-04	1.2E-04	17.3%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			3.3E-09	3.3E-09	38%			6.2E-05	6.2E-05	9.2%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			2.8E-09	2.8E-09	33%			1.5E-06	1.5E-06	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			3.8E-10	3.8E-10	4%			3.2E-06	3.2E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			2.4E-05	2.4E-05	3.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			1.1E-04	1.1E-04	16.3%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			1.3E-09	1.3E-09	15%			1.5E-04	1.5E-04	21.8%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				8.4E-13	8.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	9E-09	9E-09		0E+00	0E+00	7E-04	7E-04	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	8E-09	8E-09		0E+00	0E+00	5E-04	5E-04	

Table G-6d

Subchronic Risk and Hazard Estimates for the Offsite Child Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12b for definitions): Exposure Duration SUBCHRONIC

CHR_ATc	25550	CHR_ET	12
CHR_ATnc	2190	CHR_FI	–
CHR_AF	–	CHR_IRs	–
CHR_BW	15	CHR_PEF	1316000000
CHR_ED	6	CHR_SA	–
CHR_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table G-6e
Subchronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	1.1E-01			1.1E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E-01	0E+00	0E+00	1E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:
ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-6f

Subchronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	3.2E-01	5.4E-02	-	-		-	4.6E-04	5.4E-04	1.0E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		5E-04	5E-04	1E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions): Exposure Duration SUBCHRONIC

CHR_ATC	25550	CHR_IRPfr	69000
CHR_ATnc	2190	CHR_IRPvg	81000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp× EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-7a

Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m³/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK Route-Specific Risk Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				1.3E-10	1.3E-10	9%			1.4E-04	1.4E-04	21.3%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				2.1E-11	2.1E-11	1%			6.3E-05	6.3E-05	9.4%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			1.2E-04	1.2E-04	17.3%
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			5.5E-10	5.5E-10	38%			6.2E-05	6.2E-05	9.2%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.6E-06	1.6E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			4.7E-10	4.7E-10	33%			1.5E-06	1.5E-06	<1%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			6.4E-11	6.4E-11	4%			3.2E-06	3.2E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			2.4E-05	2.4E-05	3.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			1.3E-06	1.3E-06	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			1.1E-04	1.1E-04	16.3%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			2.1E-10	2.1E-10	15%			1.5E-04	1.5E-04	21.8%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				1.4E-13	1.4E-13	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	7E-04	7E-04	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	1E-09	1E-09		0E+00	0E+00	5E-04	5E-04	

Table G-7a

Subchronic Risk and Hazard Estimates for the Offsite Infant Resident Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	mg/m^3:	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:
[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

INF_ATc	25550	INF_ET	12
INF_ATnc	365	INF_FI	–
INF_AF	–	INF_IRs	–
INF_BW	6.75	INF_PEF	1316000000
INF_ED	1	INF_SA	–
INF_EF	270		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table G-7b

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	2.5E-01			2.5E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-01	0E+00	0E+00	3E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-7c

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.7E-01	3.2E-01	5.4E-02	-	-		-	6.2E-04	5.0E-04	1.1E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		6E-04	5E-04	1E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions): Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	41850
INF_ATnc	365	INF_IRPvg	33750
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-8

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	3.3E-01			3.3E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-01	0E+00	0E+00	3E-01	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm²/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m³)
EPCia:	Exposure point concentration in indoor air (mg/m³)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm²/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m³:	Milligram(s) per cubic meter
VF:	Volatilization factor (m³/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m³)
VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Exposure Duration CHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-9a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCs (mg/kg)	VF *or* PEF [a] (m^3/kg)	EPCaa (mg/m^3)	EPCia (mg/m^3) [b]	CANCER RISK: Route-Specific Risk: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral [c]	Dermal [c]	Inhalation (ambient)	Calculated Hazard	Percent Total HI
Metals														
Arsenic	7.6E+00	1.3E+09	5.8E-09				2.0E-09	2.0E-09	9%			8.8E-05	8.8E-05	13.6%
Chromium, Total	1.9E+01	1.3E+09	1.5E-08				-		-			-		-
Iron	1.7E+04	1.3E+09	1.3E-05				-		-			-		-
Lead									-					-
Nickel	2.0E+01	1.3E+09	1.5E-08				3.3E-10	3.3E-10	1%			3.9E-05	3.9E-05	6.0%
VOCs														
1,3,5-Trimethylbenzene	2.2E-02	7.1E+03	3.1E-06	V			-		-			-		-
4-Isopropyltoluene (p-cymene)	1.8E-02	9.4E+03	1.9E-06	V			-		-			-		-
Benzene	5.1E-02	3.8E+03	1.3E-05	V			8.5E-09	8.5E-09	38%			1.0E-04	1.0E-04	15.7%
Cyclohexane	2.9E-02	1.1E+03	2.6E-05	V			-		-			1.0E-06	1.0E-06	<1%
Ethylbenzene	2.2E-01	6.1E+03	3.6E-05	V			7.3E-09	7.3E-09	33%			8.2E-06	8.2E-06	1.3%
Methylene chloride	6.0E-02	2.4E+03	2.6E-05	V			9.8E-10	9.8E-10	4%			5.8E-06	5.8E-06	<1%
n-Hexane	1.2E-01	8.9E+02	1.3E-04	V			-		-			4.2E-05	4.2E-05	6.6%
Toluene	8.2E-02	4.6E+03	1.8E-05	V			-		-			8.1E-07	8.1E-07	<1%
Xylenes	7.4E-01	6.3E+03	1.2E-04	V			-		-			2.7E-04	2.7E-04	41.7%
SVOCs														
1-Methylnaphthalene	2.4E-01	6.3E+04	3.8E-06	V			-		-			-		-
2-Methylnaphthalene	2.7E-01	6.2E+04	4.4E-06	V			-		-			-		-
PAHs														
Benzo (a) anthracene	6.1E-02	1.3E+09	4.6E-11				*		-			-		-
Benzo (a) pyrene	9.2E-02	1.3E+09	7.0E-11				*		-			-		-
Benzo (b) fluoranthene	1.6E-02	1.3E+09	1.2E-11				*		-			-		-
Benzo (k) fluoranthene	4.0E-02	1.3E+09	3.1E-11				*		-			-		-
Chrysene	6.6E-02	1.3E+09	5.0E-11				*		-			-		-
Dibenzo (a,h) anthracene	1.7E-02	1.3E+09	1.3E-11				*		-			-		-
Indeno (1,2,3-cd) pyrene	6.9E-02	1.3E+09	5.2E-11				*		-			-		-
Naphthalene	5.9E-02	5.0E+04	1.2E-06	V			3.3E-09	3.3E-09	15%			9.0E-05	9.0E-05	14.0%
Total Benzo(a)pyrene TEQ	3.2E-02	1.3E+09	2.4E-11				2.2E-12	2.2E-12	<1%			-		-
Miscellaneous														
Sulfolane	3.8E-02	1.3E+09	2.9E-11				-		-			-		-
GRO	5.4E+00	1.3E+09	4.1E-09				-		-			-		-
DRO	2.1E+02	1.3E+09	1.6E-07				-		-			-		-
RRO	1.9E+03	1.3E+09	1.4E-06				-		-			-		-
Total Risk or Hazard					0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	
Total Risk or Hazard Excluding Arsenic					0E+00	0E+00	2E-08	2E-08		0E+00	0E+00	6E-04	6E-04	

Table G-9a

Chronic Risk and Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Surface Soil (0 to 2 ft below ground surface) - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Abbreviations:

-:	Not applicable	mg/kg:	Milligram(s) per kilogram
ELCR:	Excess lifetime cancer risk (unitless)	$mg/m^{3:}$	Milligram(s) per cubic meter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	PAH:	Polycyclic aromatic hydrocarbon
EPCia:	Exposure point concentration in indoor air (mg/m^3)	PEF:	Particulate emission factor (m^3/kg)
EPCs:	Exposure point concentration in soil (mg/kg)	VF:	Volatilization factor (m^3/kg)
HI:	Hazard index (unitless)	VOCs:	Volatile organic compounds
HQ:	Hazard quotient (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
m^3/kg:	Cubic meter(s) per kilogram	*	Included in Benzo(a)pyrene TEQ calculated risk

Notes:

[a] Default PEFs and VFs were obtained from USEPA (2011d).
[b] Media evaluated separately.
[c] Incomplete pathway for this receptor.

Parameters (see Table 3-12b for definitions): Exposure Duration CHRONIC

CIo_ATc	25550	CIo_ET	8
CIo_ATnc	9125	CIo_FI	1
CIo_BW	70	CIo_IRs	100
CIo_ED	25	CIo_PEF	1316000000
CIo_EF	250		

Equations:

ELCRaa = ([EPCs / (VF or PEF)] × EF × ED × ET × IUR × 1000) / (24 × ATc)

HQaa = ([EPCs / (VF or PEF)] × ET × EF × ED) / (24 × ATnc × RfC)

Table G-9b

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK: Route-Specific Risk: Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.7E-01					-			-	-	3.3E-01			3.3E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-01	0E+00	0E+00	3E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-10

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 1 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK: Route-Specific Risk: Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal [c]	Inhalation (domestic use) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	1.7E-01		2.0E-07		-			-	-	3.1E-05			3.1E-05	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		3E-05	0E+00	0E+00	3E-05	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
$mg/m^{3:}$	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Notes:

[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-11
Chronic Hazard Estimates for the Offsite Adult Recreator Exposed to Surface Water - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCsw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event)	CANCER RISK Route-Specific Risk Oral [c]	Dermal [d]	Inhalation [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [d]	Inhalation [d]	Calculated Hazard	Percent Total HI
Miscellaneous													
Sulfolane	1.6E-01			-			-	-	1.9E-04			1.9E-04	100%
Total Risk or Hazard				0E+00	0E+00	0E+00	0E+00		2E-04	0E+00	0E+00	2E-04	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCsw:	Exposure point concentration in surface water (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTsw) as shown for this receptor below.
[c] This exposure scenario assumes recreational contact exposures including swimming, walking, wading, and splashing.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions): Exposure Duration CHRONIC

AREC_ATC	25550	AREC_ET	0.5
AREC_ATnc	10950	AREC_EvFsw	–
AREC_BW	70	AREC_FIsw	1
AREC_ED	30	AREC_IRinc_sw	0.021
AREC_EFsw	30	AREC_SAsw	–
AREC_EvTsw	–		

Equations:

ELCRo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED × CSFo) / (BW × ATc)

HQo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED) / (BW × ATnc × RfDo)

Table G-12a

Chronic Hazard Estimates for the Offsite Child Recreator Exposed to Surface Water - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCsw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event)	CANCER RISK Route-Specific Risk Oral [c]	Dermal [d]	Inhalation [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral [c]	Dermal [d]	Inhalation [d]	Calculated Hazard	Percent Total HI
Miscellaneous													
Sulfolane	1.6E-01			-			-	-	2.1E-03			2.1E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00	0E+00		2E-03	0E+00	0E+00	2E-03	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCsw:	Exposure point concentration in surface water (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTsw) as shown for this receptor below.
[c] This exposure scenario assumes recreational contact exposures including swimming, walking, wading, and splashing.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions): Exposure Duration CHRONIC

CREC_ATC	25550	CREC_ET	0.5
CREC_ATnc	2190	CREC_EvFsw	–
CREC_BW	15	CREC_FIsw	1
CREC_ED	6	CREC_IRinc_sw	0.049
CREC_EFsw	30	CREC_SAsw	–
CREC_EvTsw	–		

Equations:
ELCRo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED × CSFo) / (BW × ATc)

HQo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED) / (BW × ATnc × RfDo)

Table G-12b

Subchronic Hazard Estimates for the Offsite Child Recreator Exposed to Surface Water - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCsw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event)	CANCER RISK				Percent Total ELCR	NON-CANCER HAZARD				Percent Total HI
				Route-Specific Risk			Calculated Risk		Route-Specific Hazard			Calculated Hazard	
				Oral [c]	Dermal [d]	Inhalation [d]			Oral [c]	Dermal [d]	Inhalation [d]		
Miscellaneous													
Sulfolane	1.6E-01			-			-	-	2.1E-04			2.1E-04	100%
Total Risk or Hazard				0E+00	0E+00	0E+00	0E+00		2E-04	0E+00	0E+00	2E-04	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCaa:	Exposure point concentration in ambient air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCsw:	Exposure point concentration in surface water (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTsw) as shown for this receptor below.
[c] This exposure scenario assumes recreational contact exposures including swimming, walking, wading, and splashing.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CREC_ATC	25550	CREC_ET	0.5
CREC_ATnc	2190	CREC_EvFsw	–
CREC_BW	15	CREC_FIsw	1
CREC_ED	6	CREC_IRinc_sw	0.049
CREC_EFsw	30	CREC_SAsw	–
CREC_EvTsw	–		

Equations:

ELCRo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED × CSFo) / (BW × ATc)

HQo = (EPCsw × FIsw × IRinc_sw × ET × EFsw × ED) / (BW × ATnc × RfDo)

Table G-13a
Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	1.6E-01			1.6E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-01	0E+00	0E+00	2E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EgwF × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-13b

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	3.2E-01	1.9E-02	-	-		-	3.1E-04	8.7E-04	1.2E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		3E-04	9E-04	1E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	63000
ADUR_ATnc	10950	ADUR_IRPvg	175000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-14a
Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	3.8E-01			3.8E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		4E-01	0E+00	0E+00	4E-01	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-14b

Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	3.2E-01	1.9E-02	-	-		-	1.6E-03	1.9E-03	3.5E-03	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		2E-03	2E-03	3E-03	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	69000
CHR_ATnc	2190	CHR_IRPvg	81000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-14c
Subchronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	3.8E-02			3.8E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		4E-02	0E+00	0E+00	4E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-14d

Subchronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	3.2E-01	1.9E-02	-	-		-	1.6E-04	1.9E-04	3.5E-04	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		2E-04	2E-04	3E-04	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:

[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.

[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CHR_ATC	25550	CHR_IRPfr	69000
CHR_ATnc	2190	CHR_IRPvg	81000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-15a

Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	8.9E-02			8.9E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		9E-02	0E+00	0E+00	9E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-15b

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	5.9E-02	3.2E-01	1.9E-02	-	-		-	2.2E-04	1.7E-04	3.9E-04	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		2E-04	2E-04	4E-04	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	41850
INF_ATnc	365	INF_IRPvg	33750
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-16

Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	1.2E-01			1.2E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E-01	0E+00	0E+00	1E-01	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Exposure Duration CHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-17

Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm2/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	5.9E-02					-			-	-	1.2E-01			1.2E-01	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		1E-01	0E+00	0E+00	1E-01	

Abbreviations:

-:	Not applicable
DA:	Dermal absorption factor (L/cm^2/event)
ELCR:	Excess lifetime cancer risk (unitless)
EPCdu:	Exposure point concentration in air during showering (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m³:	Liter(s) per cubic meter
L/cm^2/event:	Liter(s) per cubic centimeter per event
mg/L:	Milligram(s) per liter
mg/m$^{3:}$	Milligram(s) per cubic meter
VF:	Volatilization factor (m^3/kg)
V:	Indicates the constituent is a volatile compound, as defined by USEPA
VF:	Volatilization factor (L/m^3)
VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-18

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 2 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK Route-Specific Risk Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	5.9E-02		2.0E-07		-			-	-	1.1E-05			1.1E-05	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		1E-05	0E+00	0E+00	1E-05	

Abbreviations:

- :	Not applicable	mg/L:	Milligram(s) per liter
ELCR:	Excess lifetime cancer risk (unitless)	mg/m$^{3:}$	Milligram(s) per cubic meter
EPCta:	Exposure point concentration in trench air (mg/m^3)	V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)		
HI:	Hazard index (unitless)		
HQ:	Hazard quotient (unitless)		
L/m³:	Liter(s) per cubic meter		

Notes:
[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CST_ATC	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-19a
Chronic Hazard Estimates for the Offsite Adult Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	2.8E-02			2.8E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		3E-02	0E+00	0E+00	3E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_ETgwi	–
ADUR_ATnc	10950	ADUR_EvFgw	–
ADUR_BW	70	ADUR_FIgw	1
ADUR_ED	30	ADUR_IRgw	2
ADUR_EFgw	350	ADUR_Sagw	–
ADUR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-19b

Chronic Hazard Estimates for the Offsite Adult Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	3.2E-01	3.3E-03	-	-		-	5.4E-05	1.5E-04	2.1E-04	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		5E-05	2E-04	2E-04	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions): Exposure Duration CHRONIC

ADUR_ATC	25550	ADUR_IRPfr	63000
ADUR_ATnc	10950	ADUR_IRPvg	175000
ADUR_ED	30	ADUR_FIp	0.25
ADUR_EF	270		
ADUR_BW	70		

Equations:
ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-20a
Chronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	6.5E-02			6.5E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		7E-02	0E+00	0E+00	7E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-20b
Chronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	3.2E-01	3.3E-03	-	-		-	2.8E-04	3.3E-04	6.0E-04	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		3E-04	3E-04	6E-04	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions): Exposure Duration CHRONIC

CHR_ATC	25550	CHR_IRPfr	69000
CHR_ATnc	2190	CHR_IRPvg	81000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-20c

Subchronic Hazard Estimates for the Offsite Child Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	6.5E-03			6.5E-03	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		7E-03	0E+00	0E+00	7E-03	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	$mg/m^{3:}$	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Media evaluated separately.

[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CHR_ATC	25550	CHR_ETgwi	–
CHR_ATnc	2190	CHR_EvFgw	–
CHR_BW	15	CHR_FIgw	1
CHR_ED	6	CHR_IRgw	1
CHR_EFgw	350	CHR_Sagw	–
CHR_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-20d

Subchronic Hazard Estimates for the Offsite Child Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	CANCER RISK Route-Specific Risk Ingestion (vegetables)	CANCER RISK Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	NON-CANCER HAZARD Route-Specific Hazard Ingestion (vegetables)	NON-CANCER HAZARD Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	3.2E-01	3.3E-03	-	-		-	2.8E-05	3.3E-05	6.0E-05	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		3E-05	3E-05	6E-05	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

CHR_ATC	25550	CHR_IRPfr	69000
CHR_ATnc	2190	CHR_IRPvg	81000
CHR_ED	6	CHR_FIp	0.25
CHR_EF	270		
CHR_BW	15		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-21a
Subchronic Hazard Estimates for the Offsite Infant Resident Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	1.5E-02			1.5E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-02	0E+00	0E+00	2E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:

[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_ETgwi	–
INF_ATnc	365	INF_EvFgw	–
INF_BW	6.75	INF_FIgw	1
INF_ED	1	INF_IRgw	1.0546875
INF_EFgw	350	INF_Sagw	–
INF_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-21b

Subchronic Hazard Estimates for the Offsite Infant Resident Ingesting Homegrown Produce - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L) [b]	BCF (L/kg ww) [a]	EPCp (mg/kg ww) [a]	CANCER RISK Route-Specific Risk Ingestion (fruit)	Ingestion (vegetables)	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Ingestion (fruit)	Ingestion (vegetables)	Calculated Hazard	Percent Total HI
Miscellaneous											
Sulfolane	1.0E-02	3.2E-01	3.3E-03	-	-		-	3.7E-05	3.0E-05	6.8E-05	100%
Total Risk or Hazard				0E+00	0E+00	0E+00		4E-05	3E-05	7E-05	

Abbreviations:

-:	Not applicable	HI:	Hazard index (unitless)
ELCR:	Excess lifetime cancer risk (unitless)	L/kw ww:	Liter(s) per kilogram produce in wet weight
BCF:	Water-to-produce Bioconcentration Factor (L/kg ww)	mg/kw ww:	Milligram(s) per kilogram wet weight
EPCgw:	Exposure point concentration in groundwater (ug/L)	mg/L:	Milligram(s) per liter
EPCp:	Exposure point concentration in produce (mg/kg ww)		
HI:	Hazard index (unitless)	V:	Indicates the constituent is a volatile compound, as defined by USEPA

Notes:
[a] Modeled produce concentrations calculated from BCF derived as described in Section 3.
[b] Media evaluated separately.

Parameters (see Table 3-12b for definitions):

Exposure Duration SUBCHRONIC

INF_ATC	25550	INF_IRPfr	41850
INF_ATnc	365	INF_IRPvg	33750
INF_ED	1	INF_FIp	0.25
INF_EF	270		
INF_BW	6.75		

Equations:

ELCRp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED × CSF) / (1,000,000 × BW × ATC)

HIp = ([EPCgw × BCF] × [IRfr + IRvg] × FIp × EF × ED) / (1,000,000 × BW × ATnc × RfD)

Table G-22
Chronic Hazard Estimates for the Offsite Commercial/Industrial Indoor Worker Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] (L/cm²/event)	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	2.0E-02			2.0E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-02	0E+00	0E+00	2E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm²/event)	L/cm²/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m³)	mg/m³:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m³)	VF:	Volatilization factor (m³/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m³)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

CI_ATC	25550	CI_ETgwi	–
CI_ATnc	9125	CI_EvFgw	–
CI_BW	70	CI_FIgw	1
CI_ED	25	CI_IRgw	2
CI_EFgw	250	CI_Sagw	–
CI_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-23
Chronic Hazard Estimates for the Offsite Commercial/Industrial Outdoor Worker Exposed to Groundwater - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario
Flint Hills North Pole Refinery
North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCdu (mg/m3)	EPCia (mg/m3) [c]	CANCER RISK Route-Specific Risk Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD Route-Specific Hazard Oral	Dermal [d]	Inhalation (domestic use) [d]	Calculated Hazard	Percent Total HI
Miscellaneous															
Sulfolane	1.0E-02					-			-	-	2.0E-02			2.0E-02	100%
Total Risk or Hazard						0E+00	0E+00	0E+00	0E+00		2E-02	0E+00	0E+00	2E-02	

Abbreviations:

-:	Not applicable	L/m³:	Liter(s) per cubic meter
DA:	Dermal absorption factor (L/cm^2/event)	L/cm^2/event:	Liter(s) per cubic centimeter per event
ELCR:	Excess lifetime cancer risk (unitless)	mg/L:	Milligram(s) per liter
EPCdu:	Exposure point concentration in air during showering (mg/m^3)	mg/m^3:	Milligram(s) per cubic meter
EPCia:	Exposure point concentration in indoor air (mg/m^3)	VF:	Volatilization factor (m^3/kg)
EPCgw:	Exposure point concentration in groundwater (mg/L)	V:	Indicates the constituent is a volatile compound, as defined by USEPA
HI:	Hazard index (unitless)	VF:	Volatilization factor (L/m^3)
HQ:	Hazard quotient (unitless)	VOCs:	Volatile organic compounds

Notes:
[a] Andelman's value was used as the VF, from RAGS Part B (USEPA, 1991).
[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.
[c] Media evaluated separately.
[d] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

Exposure Duration CHRONIC

CIo_ATC	25550	CIo_ETgwi	–
CIo_ATnc	9125	CIo_EvFgw	–
CIo_BW	70	CIo_FIgw	1
CIo_ED	25	CIo_IRgw	2
CIo_EFgw	250	CIo_Sagw	–
CIo_EvTgw	–		

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

Table G-24

Subchronic Hazard Estimates for the Offsite Construction/Trench Worker Exposed to Groundwater in a Trench - Exposure Unit 3 - UCL COPC Concentrations

Human Health Risk Assessment - ARCADIS Scenario

Flint Hills North Pole Refinery

North Pole, Alaska

Constituent	EPCgw (mg/L)	VF [a] (L/m³)	DA [b] L/cm2/event	EPCta (mg/m3)	CANCER RISK: Route-Specific Risk: Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Risk	Percent Total ELCR	NON-CANCER HAZARD: Route-Specific Hazard: Oral	Dermal [c]	Inhalation (trench air) [c]	Calculated Hazard	Percent Total HI
Miscellaneous														
Sulfolane	1.0E-02		2.0E-07		-			-	-	1.8E-06			1.8E-06	100%
Total Risk or Hazard					0E+00	0E+00	0E+00	0E+00		2E-06	0E+00	0E+00	2E-06	

Abbreviations:

- :	Not applicable
ELCR:	Excess lifetime cancer risk (unitless)
EPCta:	Exposure point concentration in trench air (mg/m^3)
EPCia:	Exposure point concentration in indoor air (mg/m^3)
EPCgw:	Exposure point concentration in groundwater (mg/L)
HI:	Hazard index (unitless)
HQ:	Hazard quotient (unitless)
L/m^3:	Liter(s) per cubic meter
mg/L:	Milligram(s) per liter
mg/m^3:	Milligram(s) per cubic meter
V:	Indicates the constituent is a volatile compound, as defined by CalEPA (1994)
VF:	Volatilization factor (m^3/kg)

Notes:

[a] Calculated using default assumptions in the Virginia Department of Environmental Quality Trench Air Model for groundwater less than 15 feet.

[b] The dermal absorption factor (DA) was calculated using event time (EvTgw) as shown for this receptor below.

[c] Dermal and inhalation exposures are insignficant for sulfolane, as discussed in the RAWP (ARCADIS, 2011)

Parameters (see Table 3-12b for definitions):

CST_ATc	25550	CST_ET	1
CST_ATnc	365	CST_EvTgw	1
CST_BW	70	CST_EvFgw	1
CST_ED	1	CST_FIgw	1
CST_EFgw	125	CST_IRinc_gw	0.0037
CST_EFtr	125	CST_SAgw	2230

Exposure Duration SUBCHRONIC

Equations:

ELCRo = (EPCgw × FIgw × IRgw × EFgw × ED × CSFo) / (BW × ATc)

HQo = (EPCgw × FIgw × IRgw × EFgw × ED) / (BW × ATnc × RfDo)

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Appendix H

Toxicity Profiles for Risk/Hazard Drivers and Assessment of Dose Response Information for Sulfolane

ARSENIC

The toxicity of arsenic depends upon its chemical form along with the route, dose, and duration of exposure. In general, arsenites (As^{+3}) are potentially more toxic than arsenates, soluble arsenic compounds are potentially more toxic than insoluble compounds, and inorganic arsenic compounds are potentially more toxic than organic derivatives (USEPA 1985).

Absorption from the gastrointestinal tract is dependent upon the solubility of the specific arsenic compound and the dose. Absorption from the respiratory tract is also dependent upon the specific arsenic compound, along with particle size.

Depending upon dose and exposure route, arsenic can be an irritant of the skin, mucous membranes, and the gastrointestinal tract. Acute toxicity from the ingestion of extremely high doses of arsenic may result in vomiting, diarrhea, convulsions, a severe drop in blood pressure, and cardiovascular effects. The lethal dose for humans is reported to be 1.0 to 2.6 milligrams per kilogram-body weight (mg/kg-bw) (Vallee et al. 1960). Acute toxicity from high level inhalation exposure to arsenic adsorbed to particulate matter may result in conjunctivitis and pharyngitis. Subchronic effects from high level exposures for many years include hyperpigmentation (melanosis), multiple arsenical keratoses, sensory-motor polyneuropathy, persistent chronic headache, lethargy, gastroenteritis, and mild iron deficiency anemia. Inhaled arsenic compounds have been reported to be associated with skin lesions, cardiovascular and respiratory effects, and peripheral neuropathy (Stokinger 1981; IARC 1980). Chronic oral exposure of humans to high levels of inorganic arsenic compounds over decades has been reported to cause skin lesions, peripheral vascular disease, and peripheral neuropathy (Silver and Wainman 1952). The incidence of blackfoot disease, a peripheral circulatory disease characterized by gangrene of the extremities, has reportedly been related to the presence of arsenic in the drinking water of residents of the southwest of Taiwan (Tseng 1977). The symptoms of chronic inhalation exposure to arsenic compounds are similar to those associated with chronic oral toxicity.

Oral LD_{50} values for trivalent arsenic vary from 15 to 293 mg/kg in rats and from 10-150 mg/kg in other test species (USEPA 1984). Chronic toxicity data from high level arsenic exposure to rats for their lifetime cannot be extrapolated to man as the rat is able to store this compound bound to hemoglobin in red blood cells (Lanz et al. 1950). This binding results in extremely slow excretion by rats compared to other species (Mealey et al. 1959). For this reason, dogs have been used to obtain experimental toxicity information. Studies of the subchronic oral toxicity of diets containing high levels of sodium arsenite or sodium arsenate in dogs report that arsenite is potentially more toxic than arsenate. The NOEL (no observed effect level) was reported to be 50 mg/kg-diet for both substances (Byron et al. 1967). Schroeder and Balassa (1967) studied the chronic oral toxicity of arsenic on growth and survival in mice. Ingestion of water containing As^{+3} at 5 mg/L over two years is reported to have resulted in decreased survival and reduced median life span in male and female mice. No information regarding chronic inhalation exposure of experimental animals to arsenic could be located in the available literature. Animal studies to test the teratogenic potential of arsenic at high dose levels have been performed. Diets containing up to 100 mg-arsenite/kg-diet were reported to have had no effect on offspring (Kojima 1974). No data regarding the teratogenicity of inhaled arsenic could be found in the literature.

Nearly all results of gene mutation studies for arsenic (III) and arsenic (V) compounds have been negative. Arsenite and arsenate also have been inactive in gene-specific mutation assays in yeast and in cultured mammalian cells. In contrast, arsenic (III), arsenic (V), arsenite and arsenate have been found to result in chromosome aberrations and sister chromatid exchanges in cultured animal and human cells tested in vitro (ATSDR 1987). There is limited evidence that occupational exposure to arsenic may cause chromosome changes in humans (Beckman et al. 1977). Beckman et al. (1977) reported an increase in gaps, chromatid aberrations and chromosome aberrations from mine workers at a smelter in northern Sweden.

The majority of tests in which experimental animals were exposed orally to a variety of arsenic compounds produced negative results regarding carcinogenicity (Hueper and Payne 1962; Byron et al. 1967). A few studies have, however, reported tumorigenic effects of arsenic treatment (Schrauzer et al. 1978). Mixed results were reported in arsenic inhalation studies (Ishinishi et al. 1977; Ivankovic et al. 1979). Epidemiological studies conducted in the U.S. have failed to correlate the incidence of skin cancer with arsenic in drinking water (Morton et al. 1976; Goldsmith et al. 1972). A dose-response relationship between the occurrence of skin cancer and arsenic consumption in the drinking water of Taiwanese, however, was reported by Tseng et al. (1977). Arsenic exposure at high doses may produce a pattern of skin disorders, hyperpigmentation, and keratosis that may develop into basal or squamous cell carcinoma (USEPA 1985). Several epidemiological studies of workers occupationally exposed to high levels of arsenic over a working lifetime have reported a correlation between this exposure and mortality due to respiratory cancer (Higgins et al. 1982; Enterline and Marsh 1982; Brown and Chu 1983). Based upon epidemiological data, historically the USEPA has classified arsenic as Group A -Human Carcinogen.

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BENZENE

Benzene is a clear, volatile, highly flammable, aromatic hydrocarbon which exists naturally and is produced by volcanoes and forest fires. Benzene is also a very common industrial solvent, produced from petroleum. It is used as a solvent for fats, inks, paints, plastics, rubber, in the extraction of oils from seeds and nuts, in photogravure printing, as a chemical intermediate and in the manufacture of detergents, explosives, pharmaceuticals and dyestuffs. It is also a component of gasoline and other petroleum-based fuels. Exposure to benzene can occur via inhalation, ingestion, especially of contaminated drinking water, and dermal contact (as in contact with liquid benzene found in gasoline) (Sittig 1981; ATSDR, 1989).

Benzene is readily absorbed through ingestion, moderately absorbed through inhalation and poorly absorbed through intact skin. Once in the bloodstream, benzene is distributed throughout the body, with the concentration in any one compartment dependent on the degree of perfusion of tissues by blood. Since benzene is lipid-soluble, it accumulates in fat, but the rate of accumulation is slow since fat is poorly perfused. The metabolites of benzene are responsible for its toxic effects. These include phenol (which is either formed via an unstable benzene oxide precursor or directly from benzene), catechol, hydroquinone and conjugated phenolic compounds. The primary site of benzene metabolism is the liver via the cytochrome P450 mixed function oxidase system. Some benzene metabolism may also occur in the bone marrow via the same enzyme system. Benzene is excreted either unchanged from the lungs or as metabolites in the urine (ATSDR, 1989).

Benzene targets its effects on the hemopoietic, immune and nervous systems (ATSDR, 1989). Exposure to very high levels of benzene has produced irritation of the skin, eyes and upper respiratory tract. Acute exposure has produced central nervous system depression, headache, dizziness, nausea, convulsions, coma and death at extremely high concentrations (Sittig, 1981). Certain health effects in humans have been reported starting as low as 50 ppm via inhalation. Twenty-five ppm for six hours had no obvious effects though benzene was detected in blood (Sandmeyer, 1981). Chronic exposure to high levels of benzene can produce blood changes involving an initial increase in levels of erythrocytes, leukocytes and thrombocytes, followed by aplastic anemia indicated by anemia, leukopenia and thrombocytopenia (Sittig, 1981).

The following effects have been produced experimentally in laboratory animals, following high level exposure to benzene: decreased leukocyte and/or erythrocyte counts, reduction in cellular immunity and bone marrow depression (reduced number of granulopoietic stem cells). Animal studies do not indicate that benzene is teratogenic, but the following fetotoxic effects have been found when doses are sufficiently high: reduced fetal weight, altered fetal hematopoiesis, fetal skeletal variations and increased resorptions in pregnant exposed animals. In addition, benzene has produced histopathological changes in ovaries and testes of test animals (ATSDR 1989).

Benzene and its metabolites have been shown to be mutagenic in a number of *in vitro* and *in vivo* studies. Genotoxic effects produced experimentally include structural and numerical chromosome aberrations in humans, animals and cell cultures, and sister chromatid exchanges and micronuclei in in vivo animal studies. Benzene exposure has been found to produce an increase in the number of chromosome aberrations associated with myelotoxicity (Sittig 1981). In addition, sperm head abnormalities, inhibition of DNA and RNA synthesis, DNA binding and interference with cell cycle progression have been shown in in vitro studies (ATSDR 1989). The epidemiologic data indicate that benzene may be leukemogenic. The evidence is most convincing for acute myelogenous and acute erythroleukemia, although a correlation has also been reported for chronic leukemia. Benzene has been designated a group A human carcinogen (leukemogen) by inhalation. Although data are insufficient to validate the carcinogenicity of benzene via ingestion, it would not be unreasonable to assume that benzene is carcinogenic via this route as well if present in sufficient quantities. The carcinogenicity of benzene via dermal exposure is considered to be lower since benzene is absorbed poorly through the skin (ATSDR 1989).

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NAPHTHALENE

Naphthalene is a naturally occurring constituent of petroleum and other natural organic materials, and enters the air during the combustion of gasoline, oils, wood, coal, and other fuels. It is also released from cigarette smoke, from household products such as mothballs, and from industrial processes that use it as a reagent in the production of a variety of other chemicals and polyvinyl chloride (ATSDR 2005). Exposure to naphthalene can occur via inhalation, ingestion of drinking water, and dermal contact with materials (e.g., moth balls or materials treated with moth balls) containing naphthalene.

Naphthalene is assumed to be readily absorbed through inhalation although no human or animal studies have been located measuring the rate of absorption in either humans or animals. It is presumed that naphthalene moves across the alveolar membrane by passive diffusion through the lipophilic matrix (ATSDR 2005). From studies of polynuclear aromatic hydrocarbons including naphthalene, naphthalene is moderately to poorly absorbed into the blood stream once ingested or absorbed through intact skin, although the level of dermal absorption depends upon the nature of the soil type. Once naphthalene is absorbed, a complex metabolic pathway occurs via the P450 mixed function oxidase enzyme system, with multiple competing pathways leading to the formation of several reactive metabolites (e.g., 1,2-naphthalene oxide, 1,2-naphthoquinone, and 1,4-naphthoquinone) and an array of conjugated and nonconjugated metabolites that are excreted predominantly in the urine. (ATSDR 2005). Conjugation of the reactive metabolites is viewed as a detoxifying mechanism for the reactive metabolites. There are significant differences among different animal species following acute and chronic inhalation exposures to naphthalene (with rats more susceptible than either mice or hamsters) suggesting species differences in relevant metabolic pathways (ATSDR 2005), in addition to anatomical and physiological differences (Buckpitt 2011; Rhomberg 2010; Piccirello 2011). No studies were identified that evaluated the distribution of naphthalene following inhalation exposure. Once in the bloodstream, naphthalene is distributed throughout the body, with concentrations in any one compartment dependent upon the dose and degree of blood perfusion within that tissue. Following oral exposure, the liver is expected to be the principal site of metabolism (ATSDR 2005). No studies were located that documented excretion in humans or animals after inhalation exposure. Following oral exposures, naphthalene metabolites are primarily excreted in urine with unabsorbed naphthalene representing a minor excretion pathway (ATSDR 2005).

Although ingestion of naphthalene-containing mothballs has resulted in no ill effects in some cases (Sandmeyer 1981), hemolytic anemia and cataracts have been observed in humans following accidental or intentional ingestion and inhalation of extremely high doses of naphthalene (acute exposure). However, information is not available regarding dose-response relationships for these effects in humans with acute, subchronic, or chronic exposure by any route (USEPA 2012). The hemolytic anemia subsequent to extremely high level exposure is associated with decreased hemoglobin, hematocrit and erythrocyte values, increased reticulocyte counts, presence of Heinz bodies, and increased serum bilirubin levels, and preferentially among individuals having a congenital deficiency of erythrocyte glucose-6-phosphate dehydrogenase. Other reported effects from acute exposure to high levels of naphthalene include gastrointestinal disorders (nausea, vomiting, abdominal pain, and diarrhea); renal effects; neurological effects (confusion, listlessness, lethargy, vertigo, muscle twitching, convulsions, decreased responses to painful stimuli, cerebral edema, and coma); hepatic effects (jaundice, hepatomegaly, and elevated serum enzyme levels); and ocular effects (restricted visual fields, optic atrophy, and bilateral cataracts). Hemolytic anemia has also been noted in infants born to pregnant women who ingested high levels of naphthalene during the last trimester of pregnancy as mothballs intentional "sniffing" of mothballs (Anziulewicz et al. 1959; Zinkham and Childs 1958; as cited in RAIS (ORNL 2012)).

Among animal studies in which the test species are exposed to high concentrations in a laboratory setting via inhalation, rats exposed to 78 ppm naphthalene for 4 hours exhibited no clinical signs of toxicity during or 14 days after exposure (Fait and Nachreiner 1985; as cited in RAIS (ORNL 2012)). Animal inhalation studies are restricted to three studies of mice: a 2-year study (National Toxicology Program [NTP] 1992), a 6-month study (Adkins et al. 1986), and a 4-hour study (Buckpitt 1982) (as cited in USEPA 2012). Results from the chronic study, supported by the subchronic and acute studies, identify nasal and pulmonary injuries as critical effects from chronic inhalation exposure to naphthalene; effects in other organs or tissues were not found. Incidence data for male and female mice with hyperplasia of the nasal respiratory epithelium, metaplasia of the nasal olfactory epithelium, and chronic pulmonary inflammation clearly show that the nose is more sensitive than the lung to chronic inhalation exposure to high levels of naphthalene.

There are no adequate studies or reports on the carcinogenicity of naphthalene in humans following oral, dermal or inhalation exposures (USEPA 2012).

The potential for naphthalene to induce carcinogenic effects in laboratory animals was tested by the NTP in two-year inhalation studies in B6C3F1 mice (NTP 1992) and F344/N rats (NTP 2000). Increased incidences of lung tumors (primarily alveolar/bronchiolar adenomas) in female mice and nasal tumors (primarily olfactory epithelial neuroblastomas and respiratory epithelial adenomas) in male and female rats were observed during these studies. These naphthalene-induced neoplastic lesions found in mice (lung adenomas) and rats (nose respiratory epithelial adenomas and olfactory epithelial neuroblastomas) are not caused by a genotoxic mode of action. Results from genotoxicity tests for naphthalene have been predominately negative.

Based on these results, the International Agency for Research on Cancer (IARC) classified naphthalene as a 2B carcinogen (“possibly carcinogenic to humans”) (IARC 2002); NTP listed naphthalene as “reasonably anticipated to be a human carcinogen” (NTP 2004); and California Environmental Protection Agency (CalEPA) developed an inhalation Unit Risk Factor (URF) for use in human health risk assessments for waste sites under state control (CalEPA 2009).

In an unpublished preliminary assessment, the USEPA proposed an inhalation unit risk (IUR) of 0.1 $(mg/m^3)^{-1}$ (USEPA 2004) based on the results of the NTP study in which naphthalene exposure corresponded to increases in the incidence of olfactory epithelial neuroblastomas and respiratory epithelial adenomas in male rats (NTP 2000). USEPA also proposed an IUR of 0.054 $(mg/m^3)^{-1}$ based on olfactory epithelial neuroblastomas in female rats. USEPA later withdrew both IURs. Naphthalene is currently being re-evaluated for USEPA's Integrated Risk Information System ([IRIS] 2012).

Using the same NTP study, California's Office of Environmental Health Hazard Assessment (OEHHA) has derived an IUR value for estimating the cancer risk associated with inhalation exposures to naphthalene under the state Air Toxics Hot Spots and TAC programs (OEHHA 2007). OEHHA derived the IUR value for naphthalene from incidence data of nasal respiratory epithelial adenoma and nasal olfactory epithelial neuroblastoma in male rats in the NTP study (NTP 2000). Naphthalene is not mutagenic in animals and the observed carcinogenicity is due to a non-genotoxic mechanism (USEPA 2012). The evidence of carcinogenicity from the NTP study is only in one species (rats with no unusual degree of tumors) and not from multiple species.

Current scientific research demonstrates that the URF derived by OHEEA based on the NTP rodent studies is not relevant to human health risk assessment. Since the listing of naphthalene as a *possible or reasonably anticipated* carcinogen by IARC and NTP, numerous investigators have raised strong concerns regarding the relevance of the rodent inhalation cancer data to humans.

One set of concerns revolves around the well-documented anatomical and physiological differences between the upper airways of rodents and humans and evidence that suggests that human are less, not more, sensitive than rodents to health effects from inhaled naphthalene. Considerable recent research has been dedicated to elucidating the mode of action (MoA) by which naphthalene could potentially cause cancer in humans, based on comparisons with metabolic and genetic processes in rodents and non-human primates.

While not reviewed comprehensively here, much of that research demonstrates a lack of species concordance between rodents and humans with respect to a MoA for naphthalene. For example, with recent research, Buckpitt et al. (2011) found 10- to 50-fold lower target tissue metabolism of naphthalene in monkey compared to rat olfactory epithelium, and weight-of-evidence reviews by Rhomberg et al. (2010) and Piccirillo et al. (2011) found no clear indications that any currently hypothesized MoA for naphthalene in rodents is relevant to humans.

Another set of concerns revolves around the high doses of naphthalene employed in the NTP rodent studies. An expert panel at the Naphthalene State-of-the-Science Symposium (NS^3) charged with reviewing naphthalene metabolism in relation to tissues with elevated tumor incidence in the NTP rodent studies concluded that linear extrapolation from tumor induction rates in rodents chronically exposed to high, cytotoxic naphthalene concentrations did not meaningfully predict tumor induction rates from environmental, non-cytotoxic concentrations (Bogen et al. 2008).

Another expert panel concluded from signs of inflammation indicating extensive cytotoxicity that the maximum tolerated dose (MTD) was exceeded in both doses in both sexes in the NTP (2000) rat bioassay (North et al. 2008). According to the National Research Council (1993), studies executed at doses that exceed the MTD are inappropriate for cancer risk assessment.

Thus, the NTP rodent studies are not appropriate to use as a basis for any cancer risk assessment activities.

In addition, the USEPA's Office of Prevention, Pesticides and Toxic Substances reviewed these same data when considering the re-registration of naphthalene mothballs and concluded that there was inadequate evidence to evaluate naphthalene as a human carcinogen (USEPA 2008).

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SULFOLANE

Introduction

Sulfolane, tetrahydrothiophene-1,1-dioxide, is a man-made industrial solvent commonly used in gas production and oil refining (Alaska Department of Health and Social Services [ADHSS] 2012). The sulfur-oxygen double bond is highly polar, which makes it very water soluble. The presence of the four-carbon ring allows for some non-polar stability. These properties make sulfolane miscible in both water and hydrocarbons, which gives it desirable properties as a solvent for purifying hydrocarbon mixtures (ADHSS 2012).

Sulfolane is absorbed via the oral route. However, is not readily absorbed via the dermal and inhalation routes. Animal studies have shown that sulfolane is not readily absorbed through human skin because of its low permeability (Brown et al. 1966) and is not expected to pose a significant risk via an inhalation exposure route due to its low volatility (Andersen et al. 1977). Brown et al. (1966) studied the skin and eye irritant and skin sensitizing properties of acute exposures to sulfolane on two animal species. It was concluded that sulfolane did not irritate or sensitize the skins of guinea pigs or rabbits and, undiluted, was only very mildly irritating on the eyes of rabbits. Andersen et al. (1977) conducted acute and subacute investigations of the inhalation toxicity of sulfolane on four animal species including monkey, dog, guinea pig and rat. A no observed adverse effect level (NOAEL) of 20 mg sulfolane per cubic meter (m^3) was reported. The authors also concluded that airborne concentrations of sulfolane as high as those investigated are unlikely to be encountered on any but an emergency basis. They reported that sulfolane has a relatively low vapor pressure of about 0.13 millimeters mercury at 32^o Celsius and that only unusual conditions would produce extensive release of aerosolized sulfolane. They further noted that if it is handled at room temperature in an area with proper ventilation, sulfolane should not be regarded as posing any unusual hazard.

There are three laboratory animal studies that have been used by various parties to derive toxicological reference values for sulfolane. Zhu et al. (1987) was a six-page report published in a Chinese journal entitled Huaxi yike daxue xuebao, (Journal of West China University of Medical Sciences). In this study, a series of experiments were performed. Acute, subchronic (90-day), and chronic (6-month) toxicity testing was performed via the oral route of exposure in mice, white rats, and guinea pigs. Zhu et al. (1987) also performed a developmental toxicity study in mice and several genotoxicity tests. Huntingdon Life Sciences (2001) was a GLP-compliant study in which sulfolane was administered to CD rats (10/sex/group) in drinking water at concentrations of 0, 25, 100, 400, or 1600 mg/L for 13 weeks. All animals were examined for individual signs of general health, body weights, food and water consumption, ophthalmoscopy, functional observation battery, hematology, blood chemistry, organ weights, macropathology, and hisopathology. The Ministry of Health and Welfare Japan (MHWJ, 1999) was a 50-day oral gavage study in Crj:CD(S-D) rats as summarized in Organization for Economic Co-operation and Development ([OECD] 2004). These studies are evaluated below in the context of evaluating existing Reference Doses (RfDs) and similar toxicological reference criteria and deriving the alternative scientifically defensible RfDs from the scientific literature.

These studies have been evaluated in various efforts to set toxicologic criteria by U.S and Canadian entities and by ATSDR and form the basis for the EPA's PPRTV. They are also considered in the attached Assessment of Dose Response for Sufolane by Dr. Brian Magee of Arcadis.

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1,3,5-TRIMETHYLBENZENE

1,3,5-Trimethylbenzene,or mesitylene, is a colorless liquid with a peculiar odor used in the manufacturing of dyes, as an ultraviolet oxidation stabilizer of plastics, and as a gasoline additive.

There is no information regarding the toxic effects in humans following oral exposure. A no observed adverse effect level (NOAEL) of 200 mg 1,3-5-trimethylbenzene per kilogram body weight per day (mg/kg-d) was used as the basis of a chronic oral screening value and a subchronic oral screening value (USEPA 2009). USEPA notes that although the single laboratory study was comprehensive for systemic toxicity, only one species was tested (rats), and studies evaluating oral neurotoxicity, developmental and reproductive toxicity are lacking. The observed effects in the oral rat studies include decreased body weight, blood chemistry changes (including changes in cholesterol levels), and increases in relative liver weight.

From a limited occupational study in which workers were exposed to workplace air containing a high concentration of a mixture of trimethylbenzene isomers (reported to include more than 30% 1,3,5-trimethylbenzene and more than 50% 1,2,4-trimethylbenzene), workers reported CNS symptoms (vertigo, headaches, and drowsiness) which were reversible, chronic asthma-like bronchitis, hyperchromic anemia, and alterations in blood clotting (Batting 1958; as cited in PPRTV documentation). In another health effects study in healthy humans, no CNS effects or eye, nose or airway irritations were reported following acute inhalation exposures to 1,3,5-trimethylbenznene (Jamberg 1996). This study indicated a high respiratory uptake (>60% at 25 ppm) and moderately rapid elimination (~1 L/hr-kg). A large volume of distribution (~39 L/kg) and long terminal half-life in blood (120 hours) implied extensive accumulation of 1,3,5-trimethylbenzene in adipose tissue. The primary metabolite reported in urine was 3,5-dimethylbenzoic acid (USEPA 2009).

Potential effects reported in several animal studies where 1,3,5-trimenthylbenzene was present in air at high levels either alone or as a mixture of trimethylbenzene isomers include CNS alterations (including impaired learning and memory), decreased body weight, hematological effects, and fatty changes in the liver and kidneys.

The data from limited developmental toxicity studies in laboratory animals exposed to high levels of 1,3,5-trimethylbenzene in air indicate reductions in maternal and fetal body-weight (Saillenfait, 2005).

Limited genotoxicity data suggest that 1,3,5-trimethylbenzene is not mutagenic but may be clastogenic. 1,3,5-Trimethylbenzene did not induce reverse mutations in *in vitro* assays (Janik-Spiechowicz et al. 1998; Nohmi et al. 1985; as cited in PPRTV documentation) and was negative in an *in vivo* assay and weakly positive at the middle and high dose levels in sister-chromatid exchange. In accordance with USEPA cancer guidelines (USEPA 2005), the available data for 1,3,5-trimethylbenzene are characterized as “Inadequate Information to Assess Carcinogenic Potential (USEPA 2009).

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XYLENES

A xylenes mixture is a colorless liquid with a sweet odor and a high degree of lipid solubility. There are three isomers of xylenes: meta, ortho- and para-xylene (m-, o-, and p-xylenes, respectively). The term “total xylenes” is used in reference to a mixture of the three possible isomers in any proportions, although USEPA notes that m-xylene is generally the predominant isomer in commercial mixtures (USEPA 2012).   Xylenes are commonly used as industrial solvents, as components of paints, varnishes, cleaners, degreasers, and gasoline, and as chemical intermediates in the manufacture of other chemicals, plastics, and synthetic fibers. Xylenes are volatile molecules and therefore evaporate quickly. They are also flammable and may pose a fire hazard if improperly handled (ATSDR 2007).

Xylenes are absorbed following oral, dermal, or inhalation exposures. They can be stored in adipose tissue and areeliminated in the urine. The biotransformation of xylene in humans proceeds primarily by the oxidation of a side-chain methyl group by microsomal enzymes (mixed function oxidases) in the liver to yield toluic acids. Toluic acids conjugate with glycine to form conjugated toluic acids that are excreted into the urine (Astrand et al. 1978; Norstrom et al. 1989; Ogata et al. 1970, 1979; Riihimaki et al. 1979a; Sedivec and Flek 1976b; Senczuk and Orlowski 1978 as cited in ATSDR, 2007). This metabolic pathway accounts for almost all of the absorbed dose of xylenes, regardless of the isomers, route of administration, administered dose, or duration of exposure.

High levels of exposure to xylenes for short or long periods can cause headaches, lack of muscle coordination, dizziness, confusion, and changes in the sense of balance. Exposure of people to high levels of xylenes for short periods can also cause irritation of the skin, eyes, nose, and throat; difficulty in breathing; problems with the lungs; delayed reaction time; memory difficulties; stomach discomfort; and possibly changes in the liver and kidneys. It can cause unconsciousness and even death at very high levels.

Human exposure to xylenes vapor by the inhalation route may cause eye (Carpenter et al. 1975), nose, and throat (ATSDR 2007) irritation, and contact with liquid may result in dermatitis (Sittig, 1985). Chronic occupational exposure to xylenes has been associated with headaches, chest pain, electrocardiographic abnormalities, dyspnea, cyanosis of hands, fever, leukopenia, malaise, impaired lung function, and confusion (Hipolito 1980). Reversible symptoms of neurological impairment and irritation of the eyes and throat are well-known health hazards from acute inhalation exposure to xylenes. In general, these acute effects are expected to involve reversible molecular interactions of the solvent itself (not metabolites) with membranes of the affected tissues, including neuronal membranes, and are most pronounced at high exposure levels in excess of 1,000 ppm. At lower concentrations, more subtle effects may occur. Human volunteers exposed under controlled conditions to xylenes concentrations in the range of 200-400 ppm for short time periods (15 minutes to 4 hours) have reported symptoms of irritation (e.g., watering eyes and sore throat) or neurological impairment (e.g., mild nausea, headache) (Carpenter et al. 1975; Gamberale et al. 1978; as cited in Integrated Risk Information System (IRIS); USEPA 2012).

Long-term gavage studies with mixed xylenes in laboratory animals resulted in decreased body weight gain in male rats given 500 mg/kg/day and hyperactivity in male and female mice given 1,000 mg/kg/day (NTP 1986). A chronic oral reference dose (RfD) of 0.2 mg/kg/day for mixed xylenes was calculated from a no-observed-adverse-effect level (NOAEL) of 250 mg/kg/day derived from a chronic gavage study with rats (USEPA 2012). The critical effects were decreased body weight and increased mortality (males).

A chronic reference concentration (RfC) of 0.1 mg/m^3 was derived from a NOAEL of 2 mg/m^3 from a male rat inhalation study where m-xylene isomer was administered separately and in a mixture with toluene over 6 hours per day 5 days per week over a 3-month period. The critical effects were impaired motor coordination (Korsak et al. 1994; as cited in IRIS). The animal inhalation exposure database contains no chronic toxicity studies, but there are a number of subchronic toxicity studies (of which several focused on neurological endpoints), a one-generation reproduction study in rats, and several developmental toxicity studies, some of which evaluated offspring for performance in neurobehavioral tests. Subchronic toxicity assays in animals have not found consistent evidence for other noncancer effects, such as changes in body weight or in hepatic, hematologic, or renal toxicity endpoints, following exposure to concentrations of xylenes as high as 800-1,000 ppm for 6 hours per day, 5 days per week (e.g., Carpenter et al. 1975; Jenkins et al. 1970; Korsak et al. 1992, 1994; as cited in IRIS, USEPA 2012).

Data are inadequate for an assessment of the carcinogenic potential of xylenes. Adequate human data on the carcinogenicity of xylenes are not available, and the available animal data are inconclusive as to the ability of xylenes to cause a carcinogenic response. Evaluations of the genotoxic effects of xylenes have consistently given negative results.

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B0081981.0029

Subject:
ASSESSMENT OF DOSE RESPONSE INFORMATION FOR SULFOLANE

There are three laboratory animal studies that have been used by various parties to derive toxicological reference values for sulfolane. Zhu et al. (1987) was a six-page report published in a Chinese journal entitled Huaxi yike daxue xuebao, (Journal of West China University of Medical Sciences). In this study, a series of experiments were performed. Acute, subchronic (90-day), and chronic (6-month) toxicity testing was performed via the oral route of exposure in mice, white rats, and guinea pigs. Zhu et al. (1987) also performed a developmental toxicity study in mice and several genotoxicity tests. Huntingdon Life Sciences (2001) was a GLP-compliant study in which sulfolane was administered to CD rats (10/sex/group) in drinking water at concentrations of 0, 25, 100, 400, or 1600 mg/L for 13 weeks. All animals were examined for individual signs of general health, body weights, food and water consumption, ophthalmoscopy, functional observation battery, hematology, blood chemistry, organ weights, macropathology, and hisopathology. The Ministry of Health and Welfare Japan (MHWJ, 1999) was a 50-day oral gavage study in Crj:CD(S-D) rats as summarized in Organization for Economic Co-operation and Development ([OECD] 2004). These studies are evaluated below in the context of evaluating existing Reference Doses (RfDs) and similar toxicological reference criteria and deriving the alternative scientifically defensible RfDs from the scientific literature.

Summary of Alternative Scientifically Defensible Reference Doses

ARCADIS, U.S., Inc. (ARCADIS) scientifically evaluated the existing RfDs and equivalent toxicological reference values and found that all existing values had issues that did not allow ARCADIS to endorse any of them. Accordingly, ARCADIS derived chronic and subchronic RfDs in accordance with the best available science and United States Environmental Protection Agency (USEPA) guidance for evaluation of primary toxicology studies and the derivation of RfDs. The alternative scientifically defensible RfDs are as follows:

Chronic RfD 0.01 mg/kg-day

Subchronic RfD 0.1 mg/kg-day

According to the USEPA, a chronic RfD is: “An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure for a chronic duration (up to a lifetime) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, lowest observed adverse effects level (LOAEL), or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's noncancer health assessments” (USEPA 2011).

Similarly, according to USEPA, a subchronic RfD is: “An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure for a subchronic duration (up to 10% of average lifespan) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's noncancer health assessments” (USEPA, 2011).

Accordingly, a subchronic RfD is applicable for human health risk assessments involving exposure durations of up to 7 years, which is 10% of an average human lifetime of 70 years. A chronic RfD is applicable for risk assessments involving exposures that exceed 7 years in duration.

USEPA and certain regulatory agencies derive RfDs, not the Agency for Toxic Substances and Disease Registry (ATSDR). Instead, ATSDR derived “public health action levels” for sulfolane using similar procedures as USEPA uses to derive RfDs. The difference between USEPA and ATSDR actions is that USEPA RfDs and State regulatory agency RfDs are toxicological reference values that have regulatory standing and must be used to assess human health risks when performing site specific risk assessments. ATSDR’s public action levels no not have regulatory standing as noted in ATSDR documents.

“The public health action level is a non-regulatory level set to identify if human exposure to that water needs to be evaluated further (a/k/a, a screening level). If exposure is occurring, then consideration should be given to reducing that exposure.” (ATSDR 2010)

“The public health action level is a non-regulatory level set to identify whether human exposure needs further evaluation.” (ATSDR 2011)

“A public health action level is a recommended, but not required (i.e., non-regulatory), level above which a public health intervention might be needed. Public health interventions are actions taken to reduce further chemical exposure, such as switching to another drinking water source. An action level can be used as a screening tool, because water concentrations of a chemical (contaminant) below that amount do not pose a public health concern.” (ADHSS 2012)

“The ATSDR action level is a screening level, and not a clear line between safe and unsafe. It is used as a first step to identify potential contaminants of public health importance for further detailed evaluation, and is therefore set approximately 1,000 times lower than levels that caused health effects in animals. (ADHSS 2012)

The evaluation of existing RfDs, ATSDR toxicological reference values, and the derivation of the alternative scientifically defensible RfDs are described below.

Brief Summary of Existing Screening Values for Sulfolane

Three animal studies are available for consideration in deriving toxicological screening values for sulfolane. Huntingdon Life Sciences (HLS 2001) was a fully documented 90-day oral drinking water study in CD rats that was performed in accordance with Good Laboratory Practices (GLP) with detailed information on each animal. Ministry of Health and Welfare Japan (MHWJ 1999) was a 50-day oral gavage study in Crj:CD(S-D) rats as summarized in OECD (2004). Zhu, et al. (1987) was a 180-day unspecified oral study in unspecified guinea pigs. The results of Zhu, et al. (1987) were published in Chinese in a non peer-reviewed journal with little documentation.

The Canadian Council of Ministers of the Environment (CCME 2006) rejected the Zhu, et al. (1987) study on the basis of study quality and derived a screening value of 0.01 mg/kg-day based on the NOAEL for decreases in white blood cells in rats in the HLS (2001) study, which was 2.9 mg/kg/day, as the Point of Departure. CCME (2006) used a composite Uncertainty Factor of 300 (*i.e.,* Interspecies-10; intraspecies-10; 3 to account for possible teratogenic response at very high doses, subchronic to chronic exposures, and an adequate, but not extensive dataset).

Despite issues of quality, the ATSDR chose the Zhu, et al. (1987) study in its *Health Consultation* for sulfolane as the critical study because it gave a lower Point of Departure than the HLS (2001) study (ATSDR 2011). The ATSDR (2011) derived a screening value of 0.002 mg/kg-day. The Point of Departure was 1.5 mg/kg-day based on benchmark dose modeling of shrinkage of spleen white pulp in guinea pigs as the critical endpoint. The ATSDR (2011) used a composite Uncertainty Factor of 1,000 (*i.e.,* Interspecies-10; intraspecies-10; subchronic-chronic exposure duration-10). Note that the ATSDR (2010) concluded that the Zhu, et al. (1987) six-month duration study (180 day) was a *longer term* duration study that required no subchronic to chronic uncertainty factor, but in 2011, the ATSDR decided, instead, that this 180-day duration study was a *subchronic* duration study that required a subchronic to chronic uncertainty factor. This decision does not conform to ATSDR's definition of subchronic animal studies, which are studies performed in animals for 30-90 days (ATSDR 2005).

In an update to its March 9, 2011 toxicity factor documentation for sulfolane, the Texas Commission on Environmental Quality (TCEQ 2011a) reviewed screening values presented by ToxStrategies, Inc. (ToxStrategies) and URS Corporation (URS) in a September 6, 2011 document and adopted a screening value of 0.01 mg/kg-day based on a Point of Departure defined as the lower confidence limit on the benchmark dose (BMDL) of 16.1 mg/kg-day based on decreases in white blood cell counts in rats in HLS (2001). The Point of Departure of 16.1 mg/kg-day in rats was first converted to a Human Equivalent Dose (HED) of 3.9 mg/kg-day per USEPA (2011) and TCEQ (2011b). TCEQ (2011a) then used a composite Uncertainty Factor of 300 (*i.e.*, Intraspecies- 10; subchronic to chronic exposures-10; database uncertainty- 3).

In its *Provisional Peer-Reviewed Toxicity Values for Sulfolane (CASRN 126-33-0)*, USEPA (2012a) rejected the Zhu, et al (1987) study on the basis of study quality and derived a Provisional Peer-Reviewed Toxicity Value (PPRTV) of 0.001 mg/kg-day based on the NOAEL for decreases in white blood cells in rats in HLS (2001), which was 2.9 mg/kg/day. They used a composite Uncertainty Factor of 3,000 (*i.e.,* Interspecies-10; intraspecies-10; subchronic to chronic exposures-10; database uncertainty- 3). EPA (2012a) did not use benchmark dose modeling or calculate a HED.

Scientific Critique of Existing Screening Values for Sulfolane

ARCADIS reviewed the existing screening values for sulfolane and determine which value was the most scientifically defensible. ARCADIS finds that the Zhu, et al. (1987) study fails to meet the criteria for an acceptable study established by USEPA, other governmental and nongovernmental bodies, and the Federal Information Quality Act (IQA).

Zhu et al. (1987) was a six-page report published in a Chinese journal entitled Huaxi yike daxue xuebao, (Journal of West China University of Medical Sciences). This journal no longer exists and was subsumed in 2000 by the Journal of Sichuan University (Medical Science Edition). According to OriProbe Information Sciences (2012), the main object of this journal was to present medical and health work performed by students and teachers of the university. There is no evidence on the University's website that this journal is peer-reviewed. Regardless of its peer review status, the report presents an abstract level report of a study with no supporting details.

For instance, the source and purity of the test compound and the analysis of the dosing media were not revealed. The source and strain of animals was not presented. The mode of dosing was not presented, such as drinking water, diet or gavage. It is presumed by ATSDR that the doses were given by gavage, but this most critical of information is not presented in the document. Body weights and water and food consumption were not reported, and no methods for any tests were identified. Most importantly, no individual animal data were presented, and no statistical tests were performed on the white blood cell critical endpoints.

The Zhu et al. (1987) study clearly did not meet the criteria set forth by the USEPA for study selection when deriving RfDs. USEPA's (1994) *Criteria For Assessing The Quality Of Individual Laboratory Animal Toxicity Studies* provides criteria that define the minimum information that must be reported in a study chosen as a critical study for a RfD.

In addition, the Zhu, et al (1987) study does not adhere to the standards of the IQA(Public Law 106-554; H.R. 5658), which requires the Office of Management and Budget (OMB) to issue federal agency-wide guidelines that "provide policy and procedural guidance to Federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by Federal agencies" (Federal Register, Vol. 67, No. 38, February 22, 2002). OMB issued guidelines directing federal agencies, among other things, to: "Issue guidelines ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by the agency, …."

In response, the USEPA developed *Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by the Environmental Protection Agency* (EPA 2002b). In these guidelines, the USEPA expresses a preference for peer-reviewed scientific information as the basis for human health risk assessment, but the USEPA concedes that not all information available for decision making is peer-reviewed. In that case, the USEPA states that the data must be performed in accordance with an accepted test protocols and Good Laboratory Practices (GLP) so that USEPA scientists can ensure that the study was properly conducted. Zhu, et al. (1987) was not peer reviewed, was not performed in accordance with a standard test guideline, was not performed GLP, nor does it contain sufficient detailed information for any reviewer to ensure that the data are valid.

In 2003, the USEPA also issued *A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information* (USEPA 2003). This document also clearly demonstrates that the USEPA does not rely on studies that have insufficient information for independent review and validation.

Accordingly, the ATSDR (2011) screening criterion cannot be considered to be scientifically defensible, because it is based on the inadequately documented study by Zhu, et al. (1987), which does not conform to USEPA regulations and the IQA. In addition, the USEPA rejected the Zhu, et al. (1987) study as a critical study when deriving PPRTVs (USEPA 2012a).

The screening criteria derived by CCME (2006), TCEQ (2011a) and USEPA (2012a) are all based on the HLS (2001) study. The HLS (2001) study was performed in accordance with GLP criteria. In addition, the HLS (2001) report was a thorough and comprehensive 600 page report with a detailed protocol, a certificate of analysis of the test article, a formulation chemistry report, individual animal signs, body weights, food consumption, and water consumption, individual animal values for ophthalmoscopy, functional observation battery, hematology, blood chemistry, organ weights, macropathology observations and hisopathology observations. The USEPA also sanctioned a peer review of the HLS study, using an independent panel. The screening criteria derived from the HLS (2001) study, thus, deserve due consideration. ARCADIS finds, however, that the values from all three sources (CCME (2006), TCEQ (2011a) and EPA (2012a)), have scientific limitations that do not allow any one of the values to be endorsed.

The CCME (2006) value was based on a simple NOAEL and does not take full advantage of the benchmark dose modeling approach now favored in the United States for derivation of toxicological reference values for human health risk assessment (USEPA 2000).

The TCEQ (2011a) value was based on a value derived by ToxStrategies (2010) with an error corrected in the standard deviation of the white blood cell counts in the female highest dose group. ARCADIS performed benchmark dose modeling and confirmed that the corrected BMDL from the linear model for this endpoint is, indeed, 16.1 mg/kg-day and not 15.1 mg/kg-day as initially stated by ToxStrategies (2010). ToxStrategies (2010) found acceptable and identical model fits for four models (*i.e.,* Exponential M2, exponential M4, linear and power) and chose the results of the linear model, stating that this model was simpler than the other models, citing a USEPA precedent for reliance on the most “parsimonious” model.

ATDSR (2011), however, criticized this decision and stated that when logarithmic dose transformation is performed, the linear and exponential models are equally “parsimonious.” ATSDR (2011) further stated: “When the BMDLs are within a factor of three, the lowest AIC [Akaike's Information Criterion] is chosen. Or, if multiple values have the same AIC, then an average is recommended (USEPA 2000).” ARCADIS confirmed that the USEPA’s guidance (USEPA 2000) *does* state that it is recommended that the average of BMDL values be taken when multiple models adequately fit the experimental data and multiple BMDLs are within a factor of 3. On the other hand, USEPA (2000) further states that for models “that have met the default statistical criteria for adequacy and visually fit the data, any of them theoretically could be used for determining the BMDL.” Thus, ToxStrategies (2010) was not deviating from USEPA (2000) guidance by choosing the linear model over the exponential models. However, the recommendation in USEPA’s (2000) guidance is that BMDLs from multiple models with adequate fits can be averaged. Furthermore, a more recent presentation from USEPA stated that BMDLs *can be averaged* in such circumstances, which indicates that EPA is not explictly requiring an averaging approach.

ARCADIS notes that ATSDR (2011) has made several errors when it stated in Tables B-4, B-5, B-6, and B-7 that a particular model was the “best fitting model.” In fact, all of the listed models have adequate fits to the experimental data, and in most cases the model fits are *identical.* For instance, the white blood cell data using historical controls provided BMDLs ranging from 5.54 to 16.12 mg/kg-day, and all five models (exponential M2, exponential M4, linear, power and polynomial) gave identical homogeneity variance p-values, goodness of fit p-values, and AIC values. Further, even though all four models met the scaled residual criterion of absolute value <2, the scaled residuals for the linear, power, and polynomial models showed a slightly better fit to the data than the two exponential models (M2 and M4).

ToxStrategies (2010) based its screening value on the white blood cell decrements as a critical endpoint. ARCADIS confirmed that benchmark dose modeling of decrements in lymphocytes yields slightly higher BMDLs. ARCADIS verified the white blood cell benchmark dose modeling of ToxStrategies (2011), specifically, the female rat BMDL values for the white blood cell decrements using the historical control variance are 8.78, 5.55, 16.12 and 16.12 mg/kg-day, for each of 4 BMD model types, with an average BMDL of 11.64 mg/kg-day. All models are acceptable fits to the experimental data, and the AIC values for the four models are identical. Thus, the USEPA’s default averaging approach is appropriate for setting a Point of Departure.

The female rat BMDL values for the lymphocyte decrements using the historical control variance are 7.94, 4.37, 15.95, 15.95 and 15.95 mg/kg-day, for each of 5 BMD model types, with an average BMDL of 12.03 mg/kg-day. All five models (including the polynomial model) are acceptable fits to the experimental data. The AIC values for the five models are 102.5, 102.5, 102.6, 102.6, and 102.6. According to USEPA’s Benchmark Dose Software manual (EPA 2012b), one model is preferred over another only if “the AIC value is substantially smaller for one model.” Clearly, 102.5 is not “substantially smaller” than 102.6, so these AICs are virtually identical. Thus, USEPA’s default averaging approach is appropriate for setting a Point of Departure. To summarize, the four model average Point of Departure based on white blood cell decrements is 11.64 mg/kg-day and the five model average Point of Departure based on lymphocyte decrements is 12.03 mg/kg-day.

The USEPA (2012a) value was based on a simple NOAEL and does not take full advantage of the benchmark dose modeling approach now favored in the United States (USEPA 2000) for derivation of toxicological reference values for human health risk assessment. The USEPA (2012a) performed some initial benchmark dose modeling without log transforming the data as did ToxStrategies (2011) and ATSDR (2011). Without log transforming the data, acceptable model fits were not attained. This outcome was already reported by others, and it is unclear why the USEPA presented the unsuccessful benchmark dose modeling efforts and then did not proceed to log transform the data as did others.

ARCADIS investigated the scientific appropriateness of log transforming data during benchmark dose modeling. Log transformation of the data is explicitly allowed by USEPA guidance (USEPA 1995; 2000; 2012a,b,c). For instance, USEPA (1995) states: "…it may be necessary to transform continuous data in some cases so that they better satisfy the assumptions of a normal distribution. A log-transform is often used for this purpose." Similarly, when discussing acceptable adjustments to the data in the Benchmark Dose (BMD) Methodology Software Tutorial, USEPA (2012c) states: "In certain cases, the typical models for a standard study design cannot be used with the observed data as, for example, when the data are not monotonic, or when the response rises abruptly after some lower doses that give only the background response. In these cases, adjustments to the data (e.g., a log-transformation of dose) or the model (e.g., adjustments for unrelated deaths) may be necessary."

More importantly, the USEPA itself has log transformed data sets when performing benchmark dose modeling. In the IRIS profile for benzene for instance, USEPA (2012d) states: "Most of the data were supralinear (i.e., the magnitude of the reductions in lymphocyte count decreased with increasing unit dose), and it was necessary to transform the dose data according to the formula d' = ln(d+1) in order to fit the available models." This regulatory precedent for log dose transformation concerns a data set that matches the data set for sulfolane. In both cases, the critical effect was decreased white blood cell counts, and in both cases simple log transformation of the raw data provided acceptable model fits.

In addition, ARCADIS reviewed the USEPA's database of Provisional Peer-Reviewed Toxicity Values (PPRTVs) and found that USEPA has derived a total of 44 chronic oral RfDs and 33 chronic reference concentrations. Of the 77 total noncancer toxicity values, 26 are based on benchmark dose modeled values (~33%) with 9 of the 26 (35%) based on a lognormal transformation of the dose-response data from the critical study.

Lastly, log dose transformation is performed in peer-reviewed scientific studies in which reference doses and reference concentrations were derived by benchmark dose modeling of data of critical effects (TERA 2005; Budtz-Jorgensen et al., 2000; Grandjean et al. 1997; Suwazono et al. 2006, 2011; Gaylor et al. 1998; Clewell et al. 2003).

Derivation of Alternative Reference Doses

Based on the above logic, a scientifically defensible approach to deriving chronic and subchronic RfDs for sulfolane is as follows:

1. Based on a quality assessment, the HLS (2001) is defined as the critical study (USEPA, 1994, 2002a, 2002b, 2003, 2012a; Klimisch et al. 1997).

2. The HLS (2001) data are subjected to benchmark dose modeling to define the $BMDL_{10}$ per USEPA guidance (USEPA, 1995, 2000, 2002, 2012a,b).

3. Benchmark dose modeling is performed using log transformed doses per USEPA guidance (USEPA, 1995, 2000, 2012a,b,c;) and in accordance with USEPA's RfC for benzene (USEPA, 2012d). The appropriateness of log transformation of doses is supported by peer-reviewed literature citations (TERA, 2005; Budtz-Jorgensen et al. 2000; Grandjean et al., 1997; Suwazono et al., 2006, 2011; Gaylor et al., 1998; Clewell et al., 2003).

4. Benchmark dose modeling is performed using historical control variances per USEPA guidance (USEPA 1994; 2000 2012b).

5. White blood cell reduction is defined as the critical endpoint instead of lymphocyte reduction because benchmark dose modeling of white blood cell data results in slightly lower BMDLs. USEPA (2012a), TCEQ (2011a), and CCME (2006) all based their screening criteria on decreases in white blood cells in rats as reported by HLS (2001).

6. Because the exponential M2, exponential M4, linear, and power models all provide acceptable fits to the experimental data and because no model has a "substantially lower" AIC value, EPA's default approach of averaging the BMDLs and designating the four model average BMDL as the Point of Departure is used (EPA 2000).

7. The four model average BMDL is 11.64 mg/kg-day for white blood cells (12.03 mg/kg-day for lymphocytes). Thus, the Point of Departure is defined as 11.64 mg/kg-day.

8. The chronic RfD is derived from the Point of Departure using a standard composite Uncertainty Factor of 1,000 (Interspecies-10; intraspecies-10; subchronic to chronic exposures-10).

The interspecies UF of 10 is a standard UF unless one converts the animal dose to a Human Equivalent Dose (HED). In that case, the HED conversion is considered by EPA to comprise the pharmacokinetic portion of the interspecies UF, and only the pharmacodynamic portion of that UF is used (1-3). In this case, the standard UF of 10 is used to be consistent with the approaches taken by EPA (2012a), ATSDR

(2011), and CCME (2006). If the HED were calculated and then the maximum pharmacodynamic UF of 3 applied, the total effect would be to reduce the chronic RfD from 0.012 to 0.01 and the subchronic RfD from 0.12 to 0.1 mg/kg-day. TCEQ (2011a) used an interspecies UF of 1 after converting the animal dose to an HED.

The intraspecies UF of 10 is a standard UF used by USEPA (2012a), ATSDR (2011), CCME (2006) and TCEQ (2011a).

The subchronic to chronic UF of 10 is a standard UF used by USEPA (2012a), ATSDR (2011), CCME (2006) and TCEQ (2011a).

Because the database is adequate for setting RfDs, a database uncertainty factor of 1 was used.

The composite UF of 1,000 is the same composite UF as used by ATSDR (2011). It is higher than the composite UFs of TCEQ (2011a) and CCME (2006), which were both 300. Lastly, is it slightly lower than the composite UF used by USEPA (2012a). Thus, the composite UF is within the range of UFs used by others.

9. The subchronic RfD is derived from the Point of Departure using a standard composite Uncertainty Factor of 100 (Interspecies-10; intraspecies-10). The subchronic RfD is 0.12 mg/kg-day, rounded to 0.1 mg/kg-day. The UFs are as noted above with the omission of the subchronic to chronic UF, which is unnecessary for subchronic exposures.

10. The chronic RfD is 0.012 mg/kg-day, rounded to 0.01 mg/kg-day.

11. The chronic RfD is virtually identical to the TCEQ (2011a) value (0.013 mg/kg-day) and the CCME (2006) value (0.010 mg/kg-day), although the values are derived using different approaches.

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Appendix I

Adult Lead Model Spreadsheet – Calculations of Blood Lead Concentrations

Appendix I
North Pole Refinery, North Pole, Alaska
Onsite Construction/Excavation Worker
Calculations of Blood Lead Concentrations (PbBs)
U.S. EPA Technical Review Workgroup for Lead, Adult Lead Committee

Version date 6/21/09

EDIT RED CELLS

Variable	Description of Variable	Units	GSDi and PbBo from Analysis of NHANES 1999-2004	GSDi and PbBo from Analysis of NHANES III (Phases 1&2)
PbW	Water lead concentration	µg/L or ppb	2.05	2.05
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4	0.4
GSD_i	Geometric standard deviation PbB	--	1.8	1.8
PbB_0	Baseline PbB	µg/dL	1.0	1.0
IR_W	Water ingestion rate	L/day	1.0	0.0037
$AF_{S, D}$	Absorption fraction (water)	--	0.20	0.20
$EF_{S, D}$	Exposure frequency (water)	days/yr	250	125
$AT_{S, D}$	Averaging time (water)	days/yr	365	365
PbB_{adult}	PbB of adult worker, geometric mean	µg/dL	1.1	1.0
$PbB_{fetal, 0.95}$	95th percentile PbB among fetuses of adult workers	µg/dL	2.6	2.4
PbB_t	Target PbB level of concern (e.g., 10 µg/dL)	µg/dL	10.0	10.0
$P(PbB_{fetal} > PbB_t)$	Probability that fetal PbB > PbB_t, assuming lognormal distribution	%	0.005%	0.002%

Source: U.S. EPA (1996). Recommendations of the Technical Review Workgroup for Lead for an Interim Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil

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Appendix J

Site-Specific Alternative Cleanup Levels for Risk/Hazard Drivers

Table J-1
Derivation of Alternative Cleanup Levels -- Onsite Contruction/Trench Worker

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

	CAS # / Constituent	71432 71-43-2 Benzene				91203 91-20-3 Naphthalene			
Exposure Parameters and units		**Exposure Pathways: Onsite Construction/Trench Worker**				**Exposure Pathways: Onsite Construction/Trench Worker**			
		Ingestion	**Dermal Contact**	**Inhalation Trench Air**	**ACL**	**Ingestion**	**Dermal Contact**	**Inhalation Trench Air**	**ACL**
Target ELCR	unitless	1.00E-05	1.00E-05	1.00E-05		1.00E-05	1.00E-05	1.00E-05	
Target HI	unitless	1	1	1		1	1	1	
DA	mg/cm^2-event	--	2.34192E-05	--		--	9.72126E-05	--	
VFgw	m3/L	--	--	9.3		--	--	6.6	
BW	kg	70	70	--		70	70	--	
ATc	days	25550	25550	25550		25550	25550	25550	
ATnc	days	365	365	365		365	365	365	
FIgw	unitless	1	--	--		1	--	--	
IRgw	L/day	0.0037	--	--		0.0037	--	--	
SAgw	cm^2/event	--	2230	--		--	2230	--	
EF	days/year	125	125	125		125	125	125	
EFtr	days/year	--	--	125		--	--	125	
ED	years	1	1	1		1	1	1	
EvFgw	days/year	--	1	--		--	1	--	
ET	hr/day	--	--	1		--	--	1	
CSFo	$(mg/kg\text{-}day)^{-1}$	5.50E-02	5.50E-02	--		--	--	--	
IUR	$(\mu g/m3)^{-1}$	--	--	7.80E-06		--	--	3.40E-05	
Subchronic RfDo	mg-kg-day	1.00E-02	1.00E-02	--		2.00E-02	2.00E-02	--	
Subchronic RfC	mg/m^3	--	--	8.00E-02		--	--	3.00E-03	
		Benzene				**Naphthalene**			
		Ingestion	**Dermal Contact**	**Inhalation Trench Air**	**ACL (all pathways)**	**Ingestion**	**Dermal Contact**	**Inhalation Trench Air**	**ACL (all pathways)**
ACL - Cancer	mg/m^3	7.03E+02	4.98E+01	6.73E-01	6.63E-01	--	--	2.18E-01	2.18E-01
ACL - Noncancer	mg/m^3	5.52E+02	3.91E+01	6.00E-01	5.90E-01	1.10E+03	1.89E+01	3.18E-02	3.18E-02
	Final ACLgw (mg/L)				**5.90E-01**				**3.18E-02**

Table J-1
Derivation of Alternative Cleanup Levels -- Onsite Contruction/Trench Worker

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

			1330207				**108678**		
CAS #			**1330-20-7**				**108-67-8**		
Constituent			**Xylenes**				**1,3,5-Trimethylbenzene**		
Exposure Parameters and units		**Exposure Pathways: Onsite Construction/Trench Worker**				**Exposure Pathways: Onsite Construction/Trench Worker**			
		Ingestion	**Dermal Contact**	**Inhalation Trench Air**	**ACL**	**Ingestion**	**Dermal Contact**	**Inhalation Trench Air**	**ACL**
Target ELCR	unitless	1.00E-05	1.00E-05	1.00E-05		1.00E-05	1.00E-05	1.00E-05	
Target HI	unitless	1	1	1		1	1	1	
DA	mg/cm^2-event	--	9.49361E-05	--		--	0.00018264	--	
VFgw	m3/L	--	--	8.0		--	--	7.6	
BW	kg	70	70	--		70	70	--	
ATc	days	25550	25550	25550		25550	25550	25550	
ATnc	days	365	365	365		365	365	365	
FIgw	unitless	1	--	--		1	--	--	
IRgw	L/day	0.0037	--	--		0.0037	--	--	
SAgw	cm^2/event	--	2230	--		--	2230	--	
EF	days/year	125	125	125		125	125	125	
EFtr	days/year	--	--	125		--	--	125	
ED	years	1	1	1		1	1	1	
EvFgw	days/year	--	1	--		--	1	--	
ET	hr/day	--	--	1		--	--	1	
CSFo	$(mg/kg\text{-}day)^{-1}$	--	--	--		--	--	--	
IUR	$(\mu g/m3)^{-1}$	--	--	--		--	--	--	
Subchronic RfDo	mg-kg-day	4.00E-01	4.00E-01	--		1.00E-01	1.00E-01	--	
Subchronic RfC	mg/m^3	--	--	4.00E-01		--	--	1.00E-02	
			Xylenes				**1,3,5-Trimethylbenzene**		
		Ingestion	**Dermal Contact**	**Inhalation Trench Air**	**ACL (all pathways)**	**Ingestion**	**Dermal Contact**	**Inhalation Trench Air**	**ACL (all pathways)**
ACL - Cancer	mg/m^3	--	--	--	--	--	--	--	--
ACL - Noncancer	mg/m^3	2.21E+04	3.86E+02	3.50E+00	3.47E+00	5.52E+03	5.02E+01	9.26E-02	9.24E-02
Final ACLgw (mg/L)					**3.47E+00**				**9.24E-02**

Table J-1
Derivation of Alternative Cleanup Levels -- Onsite Contruction/Trench Worker

Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

Equations:

Ingestion	ELCR = (EPCgw*FIgw*IRgw*EF*ED*CSFo)/(BW*ATc)	H I= (EPCgw*FIgw*IRgw*EF*ED)/(BW*ATnc*RfDo)
Dermal Contact	ELCR = (EPCgw*DA*Sagw*EvFgw*EF*ED*CSFo)/(BW*ATc)	H I= (EPCgw*DA*Sagw*EvFgw*EF*ED)/(BW*ATnc*RfDo)
Inhalation Trench Air	ELCR = (EPCgw*VFgw)*EFtr*ED*ET*IUR*1000)/(ATc*24)	H I= (EPCgw*VFgw)*EFtr*ED*ET)/(ATnc*24*RfC)
Ingestion SL	EPCgw = (ELCR*BW*ATc)/(FIgw*IRgw*EF*ED*CSFo)	EPCgw = (HI*BW*ATnc*RfDo)/(FIgw*IRgw*EF*ED)
Dermal Contact SL	EPCgw = (ELCR*BW*ATc)/(DA*SAgw*EvFgw*EF*ED*CSFo)	EPCgw = (HI*BW*ATnc*RfDo)/(DA*SAgw*EvFgw*EF*ED)
Inhalation Trench Air SL	EPCgw = (ELCR*ATc*24)/(VFgw*EFtr*ED*ET*IUR*1000)	EPCgw = (HI*ATnc*24*RfC)/(VFgw*EFtr*ED*ET)

Notes:

µg = microgram(s)
ACL = alternative cleanup level
ACLgw = alternative cleanup level (groundwater)
ATc = averaging time (cancer)
ATnc = averaging time (noncancer)
BW = body weight
cm = centimeter(s)
CSFo = oral cancer slope factor
DA = dermal absorption factor
ED = exposure duration
EF = exposure frequency
EFtr = exposure frequency (trench)
ELCR = excess lifetime cancer risk (unitless)
EPCgw = Exposure point concentration (groundwater)
ET = exposure time
EvFgw = event frequency (groundwater)
FIgw = fraction ingested (groundwater)
HI = hazard index
HLC = Henry's Law constant
hr = hour(s)
IRgw = ingestion rate (groundwater)
IUR = inhalation unit risk
kg = kilogram
L = liter
m = meter(s)
mg = milligram(s)
RfC = reference concentration
RfDo = oral reference dose
SAgw = surface area (groundwater)
VFgw = volatilization factor (groundwater)

Table J-2
Derivation of Alternative Cleanup Levels -- Offsite Resident: Infant, Child and Adult - Groundwater -- PPRTV Scenario
Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

CAS # **126-33-0**
Constituent **Sulfolane**

Exposure Parameters and units		**Relevant Exposure Pathways**						
		Groundwater Ingestion ACL[a]			**Produce Ingestion ACL[b]**			
		Infant (0-1 yr)	**Child (1-6 yrs)**	**Adult**	**Infant (0-1 yr)**	**Child (1-6 yrs)**	**Adult**	**Comment**
Target HI	unitless	1	1	1	1	1	1	
BW	kg	6.75	15	70	6.75	15	70	
ATnc	days	365	2190	10950	365	2190	10950	
FI	unitless	1	1	1	0.25	0.25	0.25	ADEC assumption
IRgw	L/day	1.05	1	2				
IRPfr	mg/day	--	--	--	155250	223500	259000	95%ile intake, all fruit
IRPvg	mg/day	--	--	--	109350	201000	413000	95%ile intake, all vegetables
BCF		--	--	--	1	1	1	ADEC assumption
EFgw	days/year	350	350	350	--	--	--	
EF	days/year	--	--	--	270	270	270	
ED	years	1	6	30	1	6	30	
Chronic RfDo	mg-kg-day	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	PPRTV
Subchronic RfDo	mg-kg-day	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	PPRTV

Groundwater Ingestion ACL[a]		**Groundwater Ingestion ACL[a]**			**Produce Ingestion ACL[b]**			**ACL (all pathways)[c]**		
		Infant	**Child**	**Adult**	**Infant**	**Child**	**Adult**	**Infant**	**Child**	**Adult**
	RfD selected									
ACL - Noncancer endpoint (mg/L)	PPRTV Chronic	--	1.56E-02	3.65E-02	--	1.91E-01	5.63E-01	**--**	**1.45E-02**	**3.43E-02**
ACL - Noncancer endpoint (mg/L)	PPRTV SubChronic	6.67E-02	--	--	1.38E+00	--	--	**6.37E-02**	**--**	**--**

Exposure Pathway

[a] Groundwater Ingestion
[b] Groundwater to Produce Ingestion
[c] Groundwater ACL (all pathways) ACL =1/SUM(1/ACLing,1/ACLprod)

ACL Equations for Noncancer endpoints

ACLing-nc = (HI*BW*ATnc*RfDo)/(FIgw*IRgw*EFgw*ED)
ACLpro-nc = (HI*BW*ATnc*1000000*RfDo)/(BCF*[IRPfr + IRPvg]*FI*EF*ED)

Notes:
µg = microgram(s)
ACL = alternative cleanup level
ATnc = averaging time (noncancer)
BCF = bioconcentration factor
BW = body weight
ED = exposure duration
EF = exposure frequency
EFgw = exposure frequency (groundwater)
ELCR = excess lifetime cancer risk (unitless)
FI = fraction ingested
HI = hazard index
IRgw = ingestion rate (groundwater)
IRPfr = ingestion rate of produce (fruit)
IRPvg = ingestion rate of produce (vegetable)
kg = kilogram
L = liter(s)
m = meter(s)
mg = milligram(s)
NA = Not Applicable
NC = Not Carcinogenic
PPRTV = Provisional Peer Reviewed Toxicity Value
RfD = reference dose
RfDo = oral reference dose
yrs = years

Table J-3
Derivation of Alternative Cleanup Levels -- Offsite Resident: Infant, Child and Adult - Groundwater -- ARCADIS Comparative* Scenario
Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

	CAS #	**126-33-0**						
	Constituent	**Sulfolane**						
Exposure Parameters and units		**Relevant Exposure Pathways**						
		Groundwater Ingestion ACL[a]			**Produce Ingestion ACL[b]**			
		Infant (0-1 yr)	**Child (1-6 yrs)**	**Adult**	**Infant (0-1 yr)**	**Child (1-6 yrs)**	**Adult**	**Comment**
Target HI	unitless	1	1	1	1	1	1	
BW	kg	6.75	15	70	6.75	15	70	
ATnc	days	365	2190	10950	365	2190	10950	
FI	unitless	1	1	1	0.25	0.25	0.25	ADEC assumption
IRgw	L/day	1.05	1	2				
IRPfr	mg/day	--	--	--	155250	223500	259000	95%ile intake, all fruit
IRPvg	mg/day	--	--	--	109350	201000	413000	95%ile intake, all vegetables
BCF		--	--	--	1	1	1	ADEC assumption
EFgw	days/year	350	350	350	--	--	--	
EF	days/year	--	--	--	270	270	270	
ED	years	1	6	30	1	6	30	
Chronic RfDo	mg-kg-day	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	Literature Derived RfD
Subchronic RfDo	mg-kg-day	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	Literature Derived RfD

Groundwater Ingestion ACL[a]		**Groundwater Ingestion ACL[a]**			**Produce Ingestion ACL[b]**			**ACL (all pathways)[c]**		
		Infant	**Child**	**Adult**	**Infant**	**Child**	**Adult**	**Infant**	**Child**	**Adult**
	RfD selected									
ACL - Noncancer endpoint (mg/L)	PPRTV Chronic	--	1.56E-01	3.65E-01	--	1.91E+00	5.63E+00	**--**	**1.45E-01**	**3.43E-01**
ACL - Noncancer endpoint (mg/L)	PPRTV SubChronic	6.67E-01	--	--	1.38E+01	--	--	**6.37E-01**	**--**	**--**

Exposure Pathway

[a] Groundwater Ingestion
[b] Groundwater to Produce Ingestion
[c] Groundwater ACL (all pathways) ACL =1/SUM(1/ACLing,1/ACLprod)

ACL Equations for Noncancer endpoints

ACLing-nc = (HI*BW*ATnc*RfDo)/(FIgw*IRgw*EFgw*ED)
ACLpro-nc = (HI*BW*ATnc*1000000*RfDo)/(BCF*[IRPfr + IRPvg]*FI*EF*ED)

Notes:

µg = microgram(s)
ACL = alternative cleanup level
ATnc = averaging time (noncancer)
BCF = bioconcentration factor
BW = body weight
ED = exposure duration
EF = exposure frequency
EFgw = exposure frequency (groundwater)
ELCR = excess lifetime cancer risk (unitless)
FI = fraction ingested
HI = hazard index
IRgw = ingestion rate (groundwater)
IRPfr = ingestion rate of produce (fruit)
IRPvg = ingestion rate of produce (vegetable)
kg = kilogram
L = liter(s)
m = meter(s)
mg = milligram(s)
NA = Not Applicable
NC = Not Carcinogenic
PPRTV = Provisional Peer Reviewed Toxicity Value
RfD = reference dose
RfDo = oral reference dose
yrs = years

* ARCADIS Comparative Scenario assumes ARCADIS RfD plus ADEC-approved exposure assumptions

Table J-4
Derivation of Alternative Cleanup Levels -- Offsite Resident: Infant, Child and Adult -- Groundwater -- ARCADIS Scenario*
Human Health Risk Assessment
Flint Hills North Pole Refinery
North Pole, Alaska

	CAS #	126-33-0						
	Constituent	**Sulfolane**						
Exposure Parameters and units		**Relevant Exposure Pathways**						
		Groundwater Ingestion ACL[a]			**Produce Ingestion ACL[b]**			
		Infant (0-1 yr)	**Child (1-6 yrs)**	**Adult**	**Infant (0-1 yr)**	**Child (1-6 yrs)**	**Adult**	**Comment**
Target HI	unitless	1	1	1	1	1	1	
BW	kg	6.75	15	70	6.75	15	70	
ATnc	days	365	2190	10950	365	2190	10950	
FI	unitless	1	1	1	0.25	0.25	0.25	ARCADIS rec
IRgw	L/day	1.05	1	2				
IRPfr	mg/day	--	--	--	41850	69000	63000	mean intake, all fruit
IRPvg	mg/day	--	--	--	33750	81000	175000	mean intake, all vegetables
BCF		--	--	--	0.32	0.32	0.32	ARCADIS rec
EFgw	days/year	350	350	350	--	--	--	
EF	days/year	--	--	--	270	270	270	
ED	years	1	6	30	1	6	30	
Chronic RfDo	mg-kg-day	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	Literature Derived RfD
Subchronic RfDo	mg-kg-day	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	Literature Derived RfD

Groundwater Ingestion ACL[a]		**Groundwater Ingestion ACL[a]**			**Produce Ingestion ACL[b]**			**ACL (all pathways)[c]**		
		Infant	**Child**	**Adult**	**Infant**	**Child**	**Adult**	**Infant**	**Child**	**Adult**
	RfD selected									
ACL - Noncancer endpoint (mg/L)	PPRTV Chronic	--	1.56E-01	3.65E-01	--	1.69E+01	4.97E+01	**--**	**1.55E-01**	**3.62E-01**
ACL - Noncancer endpoint (mg/L)	PPRTV SubChronic	6.67E-01	1.56E+00	--	1.51E+02	1.69E+02	--	**6.64E-01**	**1.55E+00**	**--**

Exposure Pathway

[a] Groundwater Ingestion
[b] Groundwater to Produce Ingestion
[c] Groundwater ACL (all pathways) ACL =1/SUM(1/ACLing,1/ACLprod)

ACL Equations for Noncancer endpoints

ACLing-nc = (HI*BW*ATnc*RfDo)/(FIgw*IRgw*EFgw*ED)
ACLpro-nc = (HI*BW*ATnc*1000000*RfDo)/(BCF*[IRPfr + IRPvg]*FI*EF*ED)

Notes:
µg = microgram(s)
ACL = alternative cleanup level
ATc = averaging time (cancer)
BCF = bioconcentration factor
BW = body weight
ED = exposure duration
EF = exposure frequency
EFgw = exposure frequency (groundwater)
ELCR = excess lifetime cancer risk (unitless)
FI = fraction ingested
HI = hazard index
IRgw = ingestion rate (groundwater)
* ARCADIS Scenario assumes ARCADIS RfD plus ARCADIS exposure assumptions

IRPfr = ingestion rate of produce (fruit)
IRPvg = ingestion rate of produce (vegetable)
kg = kilogram
L = liter(s)
m = meter(s)
mg = milligram(s)
NA = Not Applicable
NC = Not Carcinogenic
PPRTV = Provisional Peer Reviewed Toxicity Value
RfD = reference dose
RfDo = oral reference dose
yrs = years

ARCADIS

Appendix K

Sulfolane Hazard Characterization - Considerations

Sulfolane Hazard Characterization – Considerations

William H. Farland, Ph.D., ATS

April 5, 2012

Introduction

This set of considerations on the hazard characterization of sulfolane is being prepared at the request of Flint Hills Resources. It is based on an independent assessment of the toxicological data available for sulfolane as well as the various efforts that have been made by others to put these data and observations into a risk assessment context. These considerations rely heavily on the previous efforts but provide a more holistic view in order to assure that decision-makers in Alaska have the information needed to make reasonable, public health-protective judgments regarding potential exposure to sulfolane.

These perspectives represent my collective expertise and experience over more than thirty years as a scientist, toxicologist and risk assessment practitioner. I am currently the Vice President for Research at Colorado State University in Fort Collins, CO. I am also a Professor in the Department of Environmental and Radiological Health Sciences, School of Veterinary Medicine and Biomedical Sciences at that institution. I hold a Ph.D. (1976) from UCLA in Cell Biology and Biochemistry. In 2006, I completed 27 years of Federal service in research and development with the U.S. Environmental Protection Agency, leaving as the Deputy Assistant Administrator for Science. I have served on a number of executive-level committees and advisory boards within the Federal government and in the private sector. I served as Chair of an External Advisory Group for the National Institute of Environmental Health Sciences (NIEHS) on the future of the Superfund Basic Research Program. I currently serve as Chair of a standing committee on emerging science for environmental health decisions of the National Research Council (NRC) of the National Academy of Sciences and a member of an NRC Committee to Develop a Research Strategy for Environmental, Health, and Safety Aspects of Engineered Nanomaterials. In 2002, I was recognized by the Society for Risk Analysis with the "Outstanding Risk Practitioner Award," and in 2005 was appointed as a Fellow of the Society. In 2006, I received a Presidential Rank Award for my service as a federal senior executive. In 2007, I was elected as a Fellow, Academy of Toxicological Sciences. I continue to teach and publish and have been a member of the Editorial Board and reviewer for Risk Analysis, Environmental Health Perspectives and Chemosphere.

Executive Summary

The database on sulfolane has been evolving over the last three decades. Relatively speaking, compared to other industrial chemicals encountered in the environment, the available data and details of their generation are quite robust. A picture emerges of sulfolane, as a minimally toxic chemical at low levels in a variety of animal test systems. The effects seen a low doses represent subtle changes which are generally considered to be of unclear toxicological significance and may represent reversible, "adaptive" responses rather than precursors to toxicity. The recent assessments have illustrated the differences in opinion and policy judgments that can arise when subtle effects with questionable toxicological significance lead to identification of points of departure (POD's) for risk assessment purposes. This lack of consensus on which study to use as the "critical study" and the lack of a consistent method of assessment supports the argument that the observations in these studies provide an uncertain basis for health risk assessment and provide "screening-level values" at best. The assessment activities discussed above have produced a provisional health guidance value (ATSDR) and provisional peer-reviewed toxicity values including a provisional RfD (EPA). It is important to remember that these RfD-equivalent values are not boundaries between safety and risk. A variety of uncertainties are present when extrapolating from such effects in animals to human populations and from partial lifetime studies in animals to longer term potential exposures in humans. Many of these uncertainties are inherent in the policy choices available to risk assessors and are compounded when multiple policy choices are chosen in a given assessment like that for Sulfolane. Calculation of a "safe" drinking water level based on such policy choices would result in a level that is thousands of times below the level where the subtlest potential adverse effects were NOT seen in the animal studies and about 11,000 times below the level where these subtle effects of unknown toxicologic significance were seen. This suggests that at these drinking water levels of sulfolane there would likely be no appreciable risk to exposed human populations.

Toxicity Data Base for Sulfolane

Relatively speaking, compared to many chemicals encountered in the environment, sulfolane has been well studied. The details of these studies and their use in a risk assessment context has been presented previously by the British Columbia Ministry of Water, Land and Air Protection (BCMWLA, 2001); Canadian Council of Ministers of the Environment (CCME, 2006); Alaska Department of Environmental Conservation (ADEC, 2006); ToxStrategies (2009, 2010, 2011); Texas Commission on Environmental Quality (TCEQ, 2011); Agency for Toxic Substances and Disease Registry (ATSDR, 2010, 2011); and US Environmental Protection Agency (USEPA, 2012a). These assessments have considered a historical data base developed over two decades from the mid-1970's to the early 2000's.

Although sulfolane has not been the subject of many studies in the peer-reviewed, published scientific literature, several well conducted studies have been reported and subsequently peer reviewed. The majority of these reports contain sufficient information to judge the details and the quality of the work presented. In the case of the studies by Zhu et al (1987), follow-up evaluations have pointed out the lack of detail in the reporting of these studies and their shortcomings for use in up-to-date risk assessment. Although no lifetime studies are available, the data base is robust with acute, subchronic and developmental/reproductive screening data. One study was a study of six-month duration, which is twice as long as a typical subchronic study. In these studies, multiple species were examined and in several studies, comprehensive pathology evaluation was performed. Acute toxicity data are available from several studies in multiple species by multiple routes. Results suggest an LD 50 value around 2 g/kg/day. To put this dose in perspective, it is equivalent to the "limit test" dose of 2 g/kg/day for acute toxicity that is used nationally and internationally to test chemicals to determine that they have a minimal degree of toxicity.

Aside from frank effects seen in acute studies within an order of magnitude (factor of ten) of the very high doses causing lethality, other manifestations of toxicity are lacking in longer term, lower dose studies. The partial lifetime (subchronic) studies in particular suggest toxicological investigations without appreciable low dose toxicological effects. Carcinogenicity does not appear to be of concern since genotoxicity studies have been mostly negative and a lifetime cancer study in animals of a similar compound (sulfolene) raised no concerns. The focus of attention at low doses in subchronic studies has been on the observation of subtle changes which are generally considered to be of unclear toxicological significance.

An example of the effects that are currently the focus of the assessment process includes the subtle effects seen in the well conducted Huntington Life Sciences study (HLS, 2001). In this study, investigators reported statistically significant decreases in white blood cell (WBC), lymphocyte, monocyte, and large unstained cell counts in female rats given 100 mg/l (10.6 mg/kg/day) or more sulfolane. To put these observations in context, the HLS study investigators concluded that the toxicological significance of the effects on WBC counts was unclear due to the lack of evidence of any chronic inflammatory change or compromised immune function in female rats, even though these decreases were statistically significant relative to the concurrent control animals. In addition, these investigators failed to detect any effects on bone marrow, thymus or spleen that might provide a biological basis for reduced numbers of white blood cells. Despite the fact that the three highest doses produced a statistically significant reduction on WBC counts compared to concurrent controls, the questionable significance of these effects as an indication of toxicity is supported further when the effects are compared to historical control female counts. Using this larger population of control animal values, ToxStrategies (as reported in ToxStrategies' Sulfolane White Paper Update, 2010), demonstrated that the "reduced values" seen in the HLS study were within the range of historical controls. Similarly, the Zhu et al. (1987) study found subtle changes in the liver (fatty deposits) and WBC counts in another test species, the guinea pig. These endpoints, which have been the focus of some risk assessment and health screening values, are considered "non-specific." They are not associated with a particular toxicity or disease and are, in fact, quite common manifestations of adaptive rather than adverse responses. They do not easily project into specific health concerns for exposure to sulfolane.

Differentiation between an adverse effect and an adaptive response is central to toxicology and is a critical determination in the context of toxicity testing approaches. In a recent publication, Keller et al (2012) discuss the importance of this distinction to toxicity testing and risk assessment. The identification of an adverse outcome after xenobiotic exposure has been a mainstay for assessing risk to inform risk management decisions. Adverse effects used for these decisions tend to be apical outcomes such as tumors, permanent changes in the target tissue, or specific transient changes in the target tissue directly associated with the ultimate outcome of concern. This manuscript defines adverse and adaptive responses as follows:

Adverse Effect: A change in morphology, physiology, growth, development, reproduction, or life span of a cell or organism, system, or (sub)population that results in an impairment of functional capacity, an impairment of the capacity to compensate for additional stress, or an increase in susceptibility to other influences.

Adaptive Response: In the context of toxicology, the process whereby a cell or organism responds to a xenobiotic so that the cell or organism will survive in the new environment that contains the xenobiotic without impairment of function.

In the absence of the linkage of observations like those described above with potential human disease outcomes, the distinction between adverse and adaptive becomes blurred and use of these endpoints for other than screening purposes becomes problematic.

Lack of Scientific Consensus on the Selection and Use of a Particular "Critical Study"

The most recent assessments from governmental bodies (ATSDR, 2010, 2011; EPA, 2012a) have illustrated the differences in opinion that can arise when subtle effects with questionable toxicological significance lead to identification of points of departure (POD's) for risk assessment purposes. ATSDR's decision as to what study to rely on as the critical study hinged on whether the study had been published in the open literature (the Zhu et al. studies). ATSDR chose to use the Zhu studies to set an "action level" despite the fact that the publications are in an obscure, local Chinese journal, lacked experimental and statistical detail and presented decisions on the level of no observed adverse effect levels (NOAELS) that are unsupported by a statistical analysis of the data. Additional arguments made by ATSDR for use of these studies include an assessment that they report data from a more "sensitive" species, guinea pigs, when compared to observations in rats in the HLS study. EPA in its final PPRTV document does not rely on the Zhu et al. studies despite the fact that several EPA toxicologists participated in the ATSDR document review. EPA states that "This report appears to be an extended abstract of the original study with very little useful information for risk assessment purposes. There is, for example, no clear indication of histopathological examination of any tissues in any test described, save for the spleen and liver in the 6-month study. This lack of results precludes assigning any effect levels at least to the 90-day test reports." In a recent Research Concept document (NTP, 2011), citing similar concerns, NTP opined that evidence that the guinea pig may be more sensitive than rats is "suggestive" at best. In its most recent assessment, ATSDR chose to use a benchmark dose (BMD) approach to determine a POD. Use of a BMD approach is consistent with more modern approaches to risk assessment and moves away from the NOAEL approach that was used in its previous assessment (ATSDR, 2010).

EPA (2012), on the other hand, chose to rely on the HLS (2001) study as its critical study. EPA explains this decision by saying "The methods in the Huntingdon Life Sciences study are well documented, and the study adheres to GLP guidelines. Additionally, the study authors conducted the drinking water study at a lower dose range and examined a wider array of endpoints than the other available studies, and thus, the study was able to detect more sensitive effects of sulfolane." The EPA concluded that confidence in the HLS study was "high." However, despite a variety of available approaches to BMD analysis with precedence in other EPA assessments, including log transformation of the experimental doses, EPA chose to rely on a NOAEL approach to evaluating the HLS data (2001). EPA also chose to use the maximum recommended uncertainty factor for its chronic PPRTV value. EPA's confidence in this value is considered "medium" despite its "high" confidence in the HLS study data.

This lack of consensus on which study to use as the "critical study" and the lack of a consistent method of assessment supports the argument that the observations in these studies provide an uncertain basis for health risk assessment and provide "screening-level values" at best.

Uncertainty in the RfD-Equivalent Value

EPA, in its Integrated Risk Information System glossary, defines a reference dose (RfD) as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark dose, with uncertainty factors generally applied to reflect limitations of the data used. The RfD is the approach generally used in EPA's noncancer health assessments. Durations include acute, short-term, subchronic, and chronic and are defined individually in the glossary. Other Agencies, including ATSDR and State Agencies, have adopted similar approaches. As defined, an RfD-equivalent value contains inherent uncertainty of perhaps an order of magnitude and is not a precise value. This uncertainty is considered to extend to approximately a factor of three on either side of the stated value. While operationally, a POD represents a single number, it should be remembered that the POD also contains inherent uncertainty dependent on the dose spacing in the critical study supporting the assessment or on the BMD model used to set the POD.

The assessment activities discussed above have produced a provisional health guidance value (ATSDR) and provisional peer-reviewed toxicity values including provisional chronic and subchronic RfDs (EPA). ATSDR's guidance value has led to their development of an action level for drinking water exposures to sulfolane. In describing its action level, ATSDR says "Simply put, an action level is intended to serve only as a screening tool to help decide whether to evaluate more closely exposures to a substance found at a site (ATSDR 2005). Exceeding the recommended action level supports the need for additional assessment of site conditions." Exceeding the action level should not be construed as representing a true health risk given the uncertainty in the number and the conservative approaches used in its derivation. ATSDR chose to use the 1.5 mg/kg/day Benchmark Dose Low (BMDL) on the dispersion of the spleen's white pulp from the Zhu et al. study. In 2011, ATSDR recommended a total uncertainty factor of 1000 (10 for animal to human extrapolation, 10 for variability in human sensitivity, and 10 for extrapolation of an intermediate dose to a chronic dose), resulting in a sulfolane guidance level of 0.002 mg/kg/day. Despite the fact that the 2011 evaluation was based on the same Zhu et al. results as were used in 2010, the 2011 evaluation incorporated an additional uncertainty factor for intermediate to chronic exposure, as compared with ATSDR's 2010 Health Consultation. The reason given for adding an additional factor of 10 was to account for "the longer duration of exposure apparently occurring at this site." It is unclear why this perspective should be new compared to the 2010 assessment. So, despite the use of a modeling approach which increased the estimate of a POD level likely to be without appreciable risk from 0.25 mg/kg/day to 1.5 mg/kg/day, ATSDR did not significantly change its action level estimates. In essence, this increases the margin of exposure associated with observed subtle effects to well over 1000.

As mentioned above, EPA chose the study by Huntingdon Life Sciences (2001) as the critical study for derivation of the p-RfD (provisional RfD). The critical endpoint is decreased total and differential WBC count in female rats. BMD modeling of total WBC count in female rats was attempted consistent with EPA's BMD technical guidance (USEPA, 2000a). According to EPA (2012), the BMD analysis resulted in significant lack of fit. Because these data were not amenable to BMD modeling according to EPA, a NOAEL/LOAEL approach was employed to identify the point of departure (POD). EPA indicates that the leukocyte data provide a consistently observed effect, and identifies a NOAEL of 2.9 mg/kg-day in females that can be established as a POD for deriving the oral subchronic and chronic RfDs. The LOAEL for this same effect in females is 10.6 mg/kg-day. EPA applies a total uncertainty factor of 300 and 3,000 for the subchronic and chronic p-RfDs respectively. Each contains uncertainty factors to account for interspecies differences (10X), intraspecies sensitivity (10X), and database sufficiency (3X). The chronic p-RfD contains an extra factor (10X) to account for use of a subchronic study to predict chronic exposure. A composite uncertainty of 3,000 is the maximum recommended composite uncertainty value according to EPA guidance. This is because it is recognized by risk assessment practitioners that individual uncertainty factors are not fully independent and overlap exists among these factors. Use of multiple factors increases the potential for over estimation of relative uncertainty. If the composite uncertainty factor exceeds 3,000, then the database generally does not support development of an RfD (USEPA, 2002), although some early assessments used a composite uncertainty factor of 10,000. A “safe” drinking water level selected using this chronic p-RfD would be 3,000 times below a NOAEL, chosen from a dose in the study that was determined to be without even a subtle effect. Therefore, the drinking water level would be thousands of times below the level where the subtlest potential adverse effects were NOT seen in the animal studies and about 11,000 times below the level where these subtle effects of unknown toxicological significance were seen.

It is important to remember that these RfD-equivalent values are not boundaries between safety and risk. The ATSDR consultation is clear on this point. Human risk is more likely as one approaches the doses producing effects in other animals. If composite uncertainty factors are low, as is the case when human data are available, the probability of effects increases quickly as the Hazard Index exceeds 1. If composite uncertainty factors are large, as in this case, choice of an exposure even an order of magnitude (factor of 10) above the RfD-equivalent screening value likely carries little to no probability of risk of adverse health implications. The use of an animal study to predict effects in humans in the absence of human data is not driven purely by science but is a science policy decision. The selection of specific UFs when developing an RfD-equivalent value also involves science policy. In any risk assessment, a number of decision points occur where risk to humans can only be inferred from the available evidence and science policy decisions are required to bridge this gap. Both scientific judgments and policy choices may be involved in selecting from among several possible inferences when conducting a risk assessment. It is important that these choices are understood and factored into decision-making regarding protection of human health. Simply compounding numerous “conservative” policy choices in the derivation process, in the absence of good scientific reason, can result in decisions which provide no more protection for human health but alarm the public, require unnecessary controls, and have social implications for the community in terms of property values, tax revenues, population growth, etc.

Coupling of Exposure Scenarios to the USEPA PPRTV or Other RfD-like Values

A variety of approaches have been taken to couple exposure scenarios to RfD-like values when setting safe drinking water levels. These range from the use of the chronic RfD-like value (in mg/kg/day) converted to the equivalent of ppb in water, assuming consumption of 2 liters of water per day by a 70 kg human to set a drinking water equivalent level (DWEL), to the application of shorter (acute or subchronic) duration RfD-like values coupled with lower body weights and lower water consumption values to represent exposure scenarios for infants or children for a portion of their lifespan. The DWEL assumes that some fraction of the exposure will be coming through the drinking water route.

The use of an adult body weight and water consumption level has its basis in USEPA Drinking Water Standards and Health Advisories (USEPA, 2011). In this document a "Lifetime Health Advisory" is defined as "the concentration of a chemical in drinking water that is not expected to cause any adverse non-carcinogenic effects for a lifetime of exposure. The Lifetime HA is based on exposure of a 70-kg adult consuming 2 liters of water per day." One day or ten day health advisories use different assumptions regarding acute responses and a body weight of 10 kg and 1 liter a day consumption to protect infants for short durations of exposure when their body weight and consumption patterns could result in higher relative exposures. However, the assumption is that these short duration, higher exposure concerns are adequately accounted for by use of chronic RfD-like values for longer term (lifetime) exposures. Studies of "community water" consumption support these default values of 2 liters for lifetime exposure and 1 liter for infants' and children's exposure as representing the 80-90th percentile of the population values with mean consumption values being closer to half these values. It is considered fully protective of health to combine a chronic RfD-like value, which by definition is protective against appreciable risk for a lifetime of exposure for the population, including sensitive subpopulations and life-stages, with exposure values that represent the greatest part of a lifetime exposure. In other words, it is appropriately health protective to assess chronic exposure scenarios for a chemical like sulfolane by using an RfD-like value with an adult body weight and ingestion rate.

An alternative approach has been chosen by the EPA Superfund program. The EPA Superfund program has developed a consensus approach to the calculation of screening levels (SLs) which are developed using EPA risk assessment guidance and can be used for Superfund sites. A discussion of SLs can be found at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm (USEPA, 2012b). The SLs are described as "risk-based concentrations derived from standardized equations combining exposure information assumptions with EPA toxicity data. SLs are considered by the Agency to be protective for humans (including sensitive groups) over a lifetime." In the case of drinking water exposure, SLs include an assumption that the use of a chronic RfD-like value, coupled with an assumption of exposure parameters of 1 liter per day consumption for a 15 kg child, will generate a drinking water SL that is protective for the population with a lifetime of exposure. While the SL takes a more conservative approach, the HA value and the SL differ only by a factor of 2.3 times (70kg/2liters/day divided by 15kg/1liter/day). This difference is well within the inherent uncertainty of the RfD-like estimate itself and can be contrasted with the magnitude of the composite uncertainty factor which renders the estimate of the RfD-like value to be 1-10,000 times below observed subtle effects in animals. USEPA is clear to point out that SLs are generic screening values, not *de facto* cleanup standards. The SL approach is used to assess acceptable levels of both carcinogenic and non-carcinogenic effects and accounts for the possibility of shorter-term, age-specific exposures leading to toxicity. The available toxicity data base for sulfolane supports neither a concern for irreversible effects of early exposures nor age-specific sensitivity of children. Site-specific decisions determine how the SLs will impact remediation goals.

States have developed their own guidance for deriving screening or clean-up levels. For instance, Alaska's Department of Environmental Conservation has issued an updated draft of its Risk Assessment Procedures Manual (ADEC, 2011). In this manual, the use of RfD-like values in deriving acceptable drinking water concentrations is discussed. The use of the adult weight (70 kg) and water consumption value (2 liters/day) is presented in the example. Similarly, the uncertainty in the estimates is discussed as a critical part of a site-specific human health risk assessment.

While some groups, such as ATSDR, have coupled subchronic and chronic RfD-like values with lower body weights (10 kg) and consumption levels (1 liter/day) to set action levels that are purported to be "protective" for infants, given the results of the sulfolane studies and the approach used to derive the RfD-like values, there is no reason to believe that this step is necessary to protect public health. Infants remain at these average body weights for a short period of time and, unless acute responses are predicted or infants are expected to be unusually susceptible to an observed effect, there is no reason to believe that the approaches described above will not be protective of the entire population, including infants, for a full lifetime of exposure. Neither of these reasons is applicable given what is known about sulfolane.

Use of Defaults in Risk Assessment

Throughout the history of risk assessment, practitioners have embraced the use of default values to limit the number of inference options to be considered, to replace missing or inadequate chemical-specific information, and to allow a risk assessment to continue. In 1983, the authors of the National Research Council's (NRC) report, *Risk Assessment in the Federal Government: Managing the Process* (NRC, 1983) described a default as the inference option "chosen on the basis of risk assessment policy that appears to be the best choice in the absence of data to the contrary." Much debate has surrounded the use of default values in the conduct of risk assessment. In its 1994 report, *Science and Judgment in Risk Assessment*, the NRC discusses the key defaults used by EPA and suggests that they are based on relatively strong scientific foundations, despite the fact that none can be demonstrated to be "correct" for every chemical or situation (NRC, 1994). They represent science policy choices which must be examined in light of available chemical- or site-specific information. This perspective has led to the practice of substance-specific departures from defaults and to discussions around what information, and how much, is needed to reasonably select alternative inferences in individual risk assessments. Over the last decade, EPA's risk assessment guidance has moved toward the examination of all relevant and available data first before making a conscious choice to invoke defaults or standard values (USEPA 2000b, 2004, 2005). This is a different approach from choosing defaults first and then using data to depart from them. This shift in guidance, while well founded, is not without its own controversy. In its 2009 report, *Science and Decisions, Advancing Risk Assessment*, the NRC discussed the importance of continuing to examine the evolving science underlying defaults to ensure their consistency and to define the evidentiary standards for the use of alternative inferences; and suggests the importance of the development of specific criteria for judging alternatives. (NRC, 2009). The heart of this decades' long discussion is that application of default values or standardized assumptions should always be accompanied by the evaluation of their consistency with available data and information. Risk assessments that carefully evaluate available information and rely on scientific judgment, applied to the chemical constituent and its site-specific exposure characteristics, are typically preferred over risk assessments that make significant use of default positions.

Assessment of Margins-of-Exposure (M-O-E)

Risk assessors and decision-makers have often found it informative to compare margins-of-exposure (MOEs) for available PODs as way to put the toxicity data analysis in perspective. MOEs compare the POD divided by anticipated or desired environmental concentrations. With the multiple studies that have been published on sulfolane, a variety of subtle low dose effects have been analyzed as potential PODs. These have included effects on blood cells, male rat kidney, reproductive and developmental effects and spleen and liver effects. Depending on the effect and the approach used for analysis (observed level in a particular study e.g. NOAEL or benchmark dose assessment); different PODs might have been chosen. In the case of blood cell effects from the HLS study, PODs are in the 10's of thousands parts per billion (ppb) drinking water equivalent concentration. For kidney effects in the rats from the MHWJ studies (MHWJ, 1999), which are generally considered to be species-specific effects based on mechanisms seen only in male rats and for the reproductive and developmental effects seen in the same studies and in the Zhu study (Zhu, 1987), PODs are in the 100's of thousands ppb drinking water equivalent concentration. If spleen or liver effects were used as a POD, results from individual studies could range from just over a thousand to a million ppb drinking water equivalent concentration. As illustrated in Figure 1, at concentrations approaching the level of detection (6 ppb) or at levels representing the recent ARCADIS best estimate for a “protective” level in drinking water, MOEs are generally 2-3 orders of magnitude (hundreds to thousands) below where no subtle effect was seen or modeled in several studies. Depending on the study and dose spacing in the protocol, the actual level where these effects were seen could be an order of magnitude greater. This figure illustrates that, using the subtlest of effects seen in the various toxicity studies that have been the focus of risk assessment efforts and a variety of approaches representing best thinking among a variety of risk assessors, the MOE for sulfolane in drinking water is likely to be adequate to protect public health for populations exposed up to the current best estimate of a “protective” level coming out of the ARCADIS assessment.

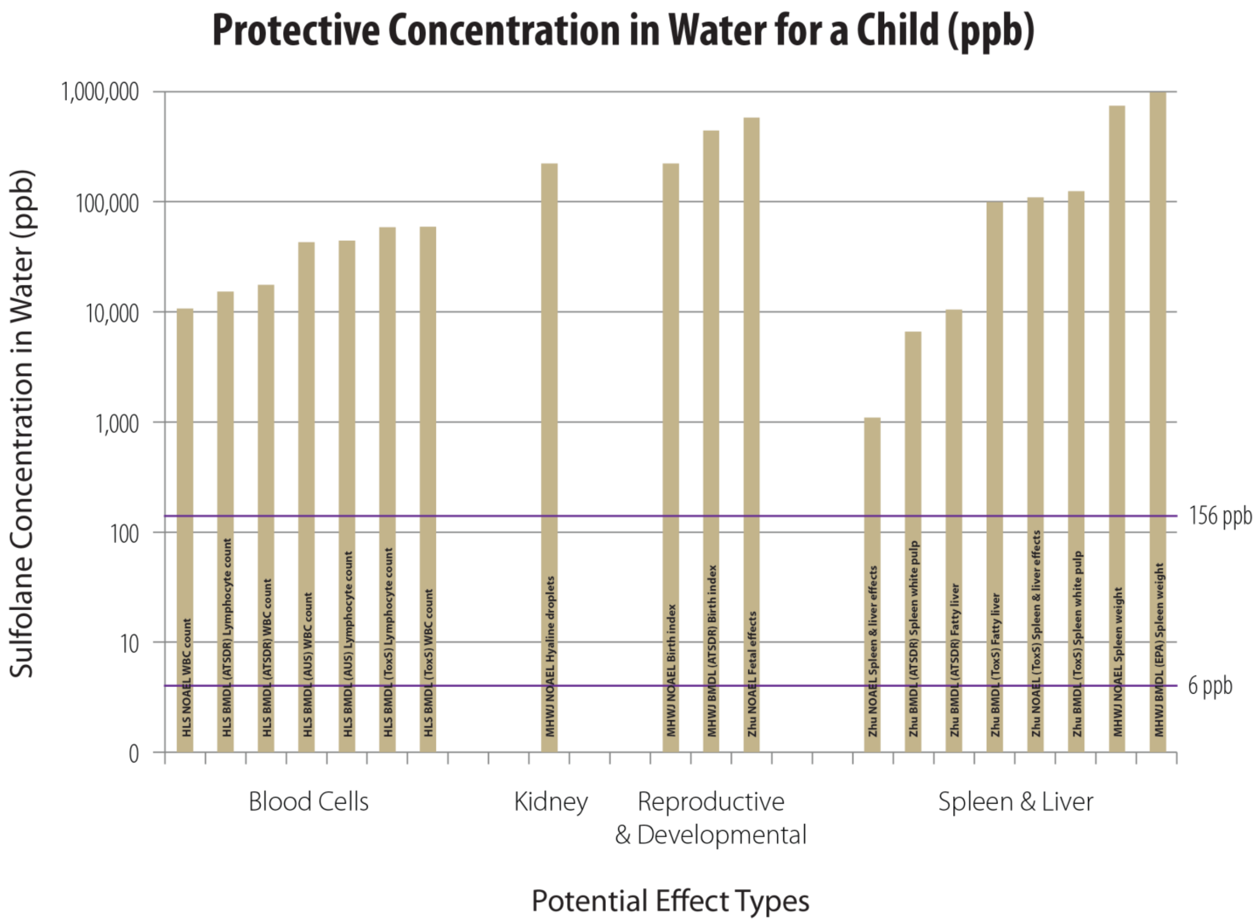

Figure1. Margins of Exposure (MOEs) based on alternative points of departure and drinking water concentrations (figure courtesy of ARCADIS)

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