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Baseline Human Health and Ecological Risk Assessment - Operable Unit E

Former Georgia-Pacific Wood Products Facility
Fort Bragg, California

July 2015

ARCADIS

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Baseline Human Health and Ecological Risk Assessment - Operable Unit E

Former Georgia-Pacific Wood Products Facility

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Acronyms and Abbreviations

ABSd	dermal absorption factor
ADD	average daily dose
ADEC	average daily exposure concentration
AE	assessment endpoint
ALM	Adult Lead Model
AOC	Area of Concern
AOI	area of interest
ARCADIS	ARCADIS U.S., Inc.
ARRF	applied relative response factor
As	arsenic
AsFeOOH	arsenic-iron oxides
AST	aboveground storage tank
B(a)P	benzo(a)pyrene
BAF	bioaccumulation factor
BBL	Blasland, Bouck & Lee, Inc.
bgs	below ground surface
BHHRA	Baseline Human Health Risk Assessment
bss	below sediment surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CalEPA	California Environmental Protection Agency
CCA	chromated copper arsenate
CCC	California Coastal Commission
City	City of Fort Bragg
cm/hr	centimeters per hour
cm^2	square centimeters

COI	constituent of interest
COPC	chemical of potential concern
CSF	cancer slope factor
CSM	conceptual site model
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
dioxin	polychlorinated dibenzo-p-dioxin
DTSC	California Environmental Protection Agency, Department of Toxic Substances Control
EF	exposure factor
ELCR	excess lifetime cancer risk
EMPA	electron microprobe analysis
EPC	exposure point concentration
ERA	ecological risk assessment
ESB	equilibrium partitioning sediment benchmark
ESHA	environmentally sensitive habitat area
ESTCP	Environmental Security Technical Certification Program
EqP	equiibrium partitioning
FCV	final chronic values
FeOOH	iron oxides
FeSO4	iron sulfates
FOD	frequency of detection
ft	feet or foot
furan	polychlorinated dibenzofuran
Georgia-Pacific	Georgia-Pacific LLC

HERD	Human and Ecological Risk Division
HERO	Human and Ecological Risk Office
HHRA	Human Health Risk Assessment
HI	hazard index
HMW	high molecular weight
HQ	hazard quotient
IRIS	Integrated Risk Information System
IRM	Interim Remedial Measure
kg	kilogram
L/cm^2-event	liters per square centimeter per event
L/day	liters per day
LADD	lifetime average daily dose
LADEC	lifetime average daily exposure concentrations
LMW	low molecular weight
LOAEL	lowest observed adverse effect level
m^3/kg	cubic meters per kilogram
MADEP	Massachusetts Department of Environmental Protection
ME	measurement endpoint
mg/cm^2-day	milligrams per square centimeter per day
mg/cm^2-event	milligrams per square centimeter per event
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilogram per day
mg/L	milligrams per liter
mg/L-day	milligrams per liter per day
mg/m^3	milligrams per cubic meter

NOAA	National Oceanic and Atmospheric Administration
NOAEL	no adverse effect level
OU-A	Operable Unit A
OU-C	Operable Unit C
OU-D	Operable Unit D
OU-C/OU-D RI	*Remedial Investigation Report for Operable Units C and D*
OU-E	Operable Unit E
OU-E BHHERA	*Baseline Human Health and Ecological Risk Assessment Report for Operable Unit E*
OU-E BHHERA Work Plan	*Baseline Human Health and Ecological Risk Assessment Work Plan – Operable Unit E*
OU-E RI	Final Remedial Investigation Report Operable Unit E
OEHHA	Office of Environmental Health and Hazard Assessment
Order	Site Investigation and Remediation Order, Docket No. HSA-RAO 06-07-150
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEC	probable effects concentration
PEF	particulate emission factor
PPE	personal protective equipment
PSL	primary screening level
RAWP	Risk Assessment Work Plan
RBA	relative bioavailability
RBTL	risk based target level
RfC	reference concentration
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure

SCV	secondary chronic value
site	Former Georgia-Pacific Wood Products Facility located at 90 West Redwood Avenue in Fort Bragg, Mendocino County, California
Site-Wide RAWP	Site-Wide Risk Assessment Work Plan
SPME	solid-phase micro-extraction
SUF	site use factor
SVOC	semivolatile organic compound
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TEC	threshold effects concentration
TEF	toxicity equivalency factor
TEQ	toxic equivalent
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
TPHd	total petroleum hydrocarbons as diesel
TPHg	total petroleum hydrocarbons as gasoline
TPHmo	total petroleum hydrocarbons as motor oil
TRC	TRC Companies, Inc.
TRV	toxicity reference value
UCL	upper confidence limit
µg/dL	microgram per deciliter
µg/L	micrograms per liter
USEPA	U.S. Environmental Protection Agency
ve	viable epidermis
VOC	volatile organic compound
waters/wetlands	waters, including wetlands

Executive Summary

On behalf of Georgia-Pacific LLC, ARCADIS U.S., Inc. (ARCADIS) prepared this *Baseline Human Health and Ecological Risk Assessment Report* for Operable Unit E (OU-E BHHERA) for the former Georgia-Pacific Wood Products Facility (site) located in Fort Bragg, Mendocino County, California. This BHHERA was prepared under oversight by the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) in accordance with Site Investigation and Remediation Order, Docket No. HAS-RAO 06-07-150.

Operable Unit E (OU-E) consists of approximately 27 terrestrial acres and 12 aquatic acres of seasonal wetlands and man-made ponds (i.e., Ponds 1 through 9 and the North Pond). Additionally, DTSC requested that this BHHERA also consider an additional 18 acres in Operable Unit C and Operable Unit D (OU-C/OU-D) known as the Riparian Area of Interest (AOI), Interim Remedial Measure (IRM), and West of IRM AOIs.

The *Final Remedial Investigation – Operable Unit E* (OU-E RI; ARCADIS 2013a), identified one area of concern (AOC) for the terrestrial area, known as the OU-E Lowland AOC, which encompasses the Water Treatment and Truck Dump AOI, Sawmill #1 AOI, Compressor House and Lath Building AOI, and Powerhouse and Fuel Barn AOI. The OU-E RI also identified seven AOCs for the aquatic areas: the Southern Ponds, Pond 5, Pond 6, Pond 7, Pond 8, Pond 9, and North Pond. Figure ES-1 shows locations of these AOCs evaluated in this OU-E BHHERA.

This OU-E BHHERA relies on data presented in the OU-E RI and additional data collected in April 2013, as outlined in the *Baseline Human Health and Ecological Risk Assessment Work Plan – Operable Unit-E* (OU-E BHHERA Work Plan) (ARCADIS 2013b). This OU-E BHHERA describes the analytical data for OU-E, identifies chemicals of potential concern (COPCs) in OU-E environmental media, provides toxicity values for COPCs and scenario-specific exposure point concentrations (EPCs), and quantifies potential risk and hazard for human and ecological receptors in accordance with methods presented in the *Site-Wide Risk Assessment Work Plan* (Site-Wide RAWP; ARCADIS BBL 2008a), the OU-E BHHERA Work Plan, and additional scenarios based on input from DTSC. Additional scenarios in the HHRA and the ERA evaluate the Ponds collectively as one exposure area and each pond AOC individually as an exposure area.

DTSC also requested a hot spot analysis to assess the contribution of specific COPCs to the risks and hazards identified in the BHHERA (DTSC 2014). DTSC asked for hot spot identification based on a comparison of soil data within the OU-E Lowland AOC to not-to-exceed soil values for benzo(a)pyrene (B(a)P) equivalents, dioxin toxicity equivalency factor (TEF), and lead. These not-to-exceed soil values are: 0.90 mg/kg for B(a)P equivalents; 160 pg/kg or parts per trillion (ppt) for dioxin TEQs; and 320 mg/kg for lead. In addition to the DTSC recommended RBTL-based hot spot identification approach, ARCADIS also used quantile-quantile plots prepared using ProUCL Version 4.1.00 (USEPA 2011b) to identify statistical

outliers in the 0 to 6 foot soil dataset (Appendix L). These statistical outliers were also identified as hot spots. As noted in Appendix L, the samples identified as statistical outliers were also greater than the DTSC recommended RBTLs.

Residual B(a)P equivalents, dioxin TEQ, and lead EPCs (i.e., the 95% upper confidence limit (95% UCL) on the arithmetic mean) were calculated excluding the identified hot spot concentrations to assess residual risks and hazards assuming hot spot removal. Results of the BHHERA and hot-spot/residual risk and hazard analyses are summarized below.

Human Health Risk Assessment

Potential OU-E future receptors were identified based on reasonable likely future land use in accordance with State and Federal guidance and stakeholder input. Sources of stakeholder input on reasonable likely future land use include the City of Fort Bragg Mill Site Specific Plan (City of Fort Bragg 2015), City of Fort Bragg Draft Municipal Service Review (City of Fort Bragg 2013), and the California Coastal Commission's (CCC) California Coastal Act (2014).

The City of Fort Bragg Mill Site Specific Plan (City of Fort Bragg 2015) identifies the northern portion of OU-E as the "Mill Pond and Open Space District" (Figure 2-6). The "Mill Pond and Open Space District" extends southward to include the Riparian AOI and portions of the IRM and West of IRM AOIs formerly included in OU-C/D and now included in OU-E. The southern portion of OU-E is surrounded by area designated as "Mill Site Urban Reserve" and "Mill Site Industrial".

All ponds in OU-E and approximately 1.7 acres of the OU-E Lowland AOC delineated as wetlands, are designated as ESHAs in the Environmentally Sensitive Habitat Areas Delineation Report (ARCADIS 2011b). Furthermore, as discussed in Section 6.1.1, in accordance with the California Coastal Act (CCC 2014), ESHAs are "protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas" (Section 30240). As such, the aquatic portions of OU-E will be protected as ESHAs in accordance with the California Coastal Act (CCC 2014), restricting significant disruption of habitat values and preventing visitors from entering these areas (e.g., by placement of boardwalks/trails outside of sensitive habitat areas, fencing, and/or signage).

Likely and reasonably anticipated current and future human receptors in terrestrial areas evaluated in OU-E include construction workers, maintenance/utility workers, recreational visitors, and commercial/industrial workers, while recreational visitors were the human receptors for the aquatic areas. Based on the information presented in DTSC approved documents for OU-E and City of Fort Bragg planning documents, ESHA designations of OU-E ponds and wetlands, state and federal regulations and guidance, it is appropriate to conclude that residential receptors are not an appropriate assessment endpoint for OU-E under current or reasonable future land uses.

Exposure pathways for human receptors in the terrestrial and aquatic exposure areas were evaluated in accordance with the conceptual site models (CSMs) presented in the DTSC-approved OU-E BHHERA Work Plan (ARCADIS 2013b). Exposure pathways for human receptors in the terrestrial exposure area included: incidental soil ingestion, dermal contact with soil, inhalation of particulates, and contact with groundwater (construction and utility workers only). Exposure pathways for the passive recreator receptor in the aquatic area included: incidental sediment ingestion, dermal contact with sediment, and contact with surface water.

Human receptors evaluated in the terrestrial exposure area of OU-E included construction workers, maintenance/utility workers, passive (occasional) child and adult recreational visitors, frequent adult recreational visitors, and commercial/industrial workers. Human receptors in the aquatic exposure areas of OU-E included passive child and adult recreational visitors. The results of the BHHRA are presented in Table 6-12. Results indicate that baseline terrestrial excess lifetime cancer risks (ELCRs) range from less than one in a million (1×10^{-6}) to 4×10^{-5}, depending on the exposure scenario evaluated, with the highest risk for the commercial worker. Baseline terrestrial Hazard Indices (HIs) range from less than one to five, depending on the exposure scenario evaluated, with the highest HI for the construction worker. Dioxin TEQ concentrations in soil in the terrestrial OU-E lowland AOC represent the largest contributor to potential cancer risk and non-cancer hazard. Aquatic ELCRs for the passive recreational visitor range from less than 1×10^{-6} to 2×10^{-5} at Pond 7. The HIs at all ponds are less than one. As noted below, terrestrial ELCRs and HIs are below 10^{-6} and 1, respectively, when soil hot spots are removed from the terrestrial dataset.

BHHRA scenarios with HIs greater than 1 in the terrestrial exposure area (Table 6-12, Appendix G) include:

- Construction worker HIs in each of the four exposure intervals (HIs range from 2 to 5 for the 0 to 0.5 feet below ground surface [ft bgs], 0 to 2 ft bgs, 0 to 6 ft bgs, and 0 to 10 ft bgs exposure intervals). Potential exposure to dioxin TEQ from incidental soil ingestion in the terrestrial AOC is the primary contributor to the HIs.

BHHRA scenarios with risk estimates greater than 10^{-6} in the terrestrial exposure area (Table 6-12, Appendix G) include:

- Construction worker ELCRs for the 0 to 2 ft bgs, 0 to 6 ft bgs and 0 to 10 ft bgs exposure intervals (5×10^{-6}, 4×10^{-6}, 3×10^{-6}, respectively). Potential exposure to dioxin TEQ is the primary contributor to the ELCRs. Baseline dioxin TEQ EPCs are 691 pg/g, 395 pg/g, and 326 pg/g in the 0 to 2 ft bgs, 0 to 6 ft bgs and 0 to 10 ft bgs exposure intervals, respectively.

- Utility worker ELCRs in the 0 to 2 ft bgs and 0 to 6 ft bgs exposure interval (ELCRs are 3×10^{-6} and 2×10^{-6}, respectively). Potential exposure to dioxin TEQ in soil is the primary contributor to the ELCRs. Baseline dioxin TEQ EPCs are 691 pg/g and 395 pg/g in the 0 to 2 ft bgs and 0 to 6 ft bgs exposure intervals, respectively.

- Terrestrial passive child and adult recreational visitor ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure interval are 2 x 10^{-6} and 6 x 10^{-6}, respectively. Potential exposure to arsenic in soil in the 0-0.5 ft bgs exposure interval and to dioxin TEQ in the 0-2 ft bgs exposure interval are the primary contributors to the ELCRs. Arsenic EPCs are less than the site-specific background concentration (10 mg/kg). Baseline soil dioxin TEQ EPCs are 132 pg/g and 691 pg/g in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals, respectively.

- Terrestrial adult frequent recreational visitor ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure interval are 4 x 10^{-6} and 2 x 10^{-5}, respectively. Potential exposure to arsenic and dioxin TEQ in the 0-0.5 ft bgs interval, and to dioxin TEQ in the 0-2 ft bgs exposure interval are the primary contributors to the ELCRs. Arsenic EPCs are less than the site-specific background concentration (10 mg/kg). Baseline soil dioxin TEQ EPCs are 132 pg/g and 691 pg/g in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals, respectively.

- Commercial/industrial worker ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure interval are 1 x 10^{-5} and 4 × 10^{-5}. Potential exposure to arsenic and dioxin TEQ in the 0-0.5 ft bgs exposure interval, and to dioxin TEQ in the 0-2 ft bgs exposure interval are the primary contributors to the ELCRs. Arsenic EPCs are less than the site-specific background concentration (10 mg/kg). Baseline soil dioxin TEQ EPCs are 132 pg/g and 691 pg/g in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals, respectively.

The hot spot analysis identified hot spot sample locations in the terrestrial exposure area based on the requested DTSC approach (DTSC 2014). The following table lists soil hot spot areas within the OU-E Lowland AOC that are greater than the not-to-exceed soil values for B(a)P equivalents (0.90 mg/kg), dioxin TEQ (160 ppt), and lead (320 mg/kg). The table also includes residual EPCs (i.e., the 95% UCL) that were calculated excluding hot spot concentrations. To assess residual risks and hazards assuming hot spot removal, these residual EPCs were compared to human health risk-based target levels identified by DTSC (DTSC 2014).

Constituent	Human Health RBTL	Residual EPCs and Depth Interval*				Hot Spot Areas (depth in ft bgs)
		0-0.5 ft bgs	0-2 ft bgs	0-6 ft bgs	0-10 ft bgs	
B(a)P TEQ (mg/kg)	0.3	0.04	0.08	0.06	0.06	**Powerhouse and fuel barn AOI:** HSA-4.3 (2-2.5); **Sawmill #1 AOI:** OUE-DP-073 (2-3), OUE-DP-074 (2-3), OUE-DP-075 (2-3), OUE-DP-026 (2-3.5); **Waste treatment and truck dump AOI:** OUE-DP-099 (0.5-1), OUE-DP-100 (2.5-3.5)
Dioxin TEQ (pg/g)	53	6.3	4.9	7.2	8.5	**Powerhouse and fuel barn AOI:** OUE-DP-052 (0.5-1.5 & 0-0.5)

Constituent	Human Health RBTL	Residual EPCs and Depth Interval*				Hot Spot Areas (depth in ft bgs)
		0-0.5 ft bgs	0-2 ft bgs	0-6 ft bgs	0-10 ft bgs	
Lead (mg/kg)	320	49.5	39.5	48.7	44.9	**Sawmill #1 AOI:** OUE-DP-070 (3-4), DP-05.57 (0.5-1); **Powerhouse and fuel barn AOI:** OUE-DP-094 (5.5-6), OUE-DP-090 (5.5-6)

Notes:
ft bgs = feet below ground surface
mg/kg = milligrams per kilogram
pg/g = picograms per gram
*Residual soil EPCs are the 95% UCL on the mean for the dataset after removal of the identified hot spot samples, with the exception of lead and B(a)P TEQ in the 0-0.5 ft bgs interval, which are the baseline EPCs. Maximum lead and B(a)P TEQ concentrations in the 0-0.5 ft bgs interval are below the not-to-exceed levels.

The hot spot analysis for the terrestrial AOC indicates the following:

- Removal of the dioxin TEQ hot spot identified as the area in the vicinity of sample location DP-052 in Powerhouse and fuel barn AOI decreases the dioxin TEQ EPC to less than the site-specific RBTL of 53 pg/g. In turn, the change in the dioxin TEQ EPC reduces the HIs to below 1 and ECLR to below 1×10^{-6} in the terrestrial AOC.

- Although baseline EPCs for lead and B(a)P TEQ were below their respective site-specific RBTLs, four locations were identified as hot spots for lead and seven locations were identified as hot spots for B(a)P TEQ. Residual EPCs are also below the site-specific RBTLs.

Separate evaluations were performed for occasional adult/child recreators in the aquatic exposure area (consisting of all Pond AOCs) assuming 50 days and 12 days of exposure per year. Results of these evaluations (Table 6-12, Appendix G) indicate the following:

- ELCRs and HIs for the occasional recreator are below the target thresholds for potential cancer and noncancer effects for a 12-day exposure frequency.

- HIs for the occasional recreator are below the target thresholds for potential noncancer effects for a 50-day exposure frequency. ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals are 5×10^{-6} and 6×10^{-6}. Sediment ingestion exposures to dioxin TEQ comprise the greatest proportion of the ELCR.

- All aquatic exposure scenarios ELCRs are within the risk management range of 1×10^{-4} to 1×10^{-6} established in the National Contingency Plan (NCP; 40 CFR 300.430; 2014) and by CalEPA (1996a).

In addition to the combined aquatic AOC, individual ponds in OU-E were evaluated as separate aquatic exposure areas (Table 6-12; Appendix G). Each pond was evaluated using a conservative exposure frequency of 50 days per year for the adult and child occasional recreator. A lower exposure frequency would be expected in Ponds 1 through 4 because proposed uses in this portion of the site are “industrial” and “urban reserve”; therefore, an alternate scenario is also presented in this BHHERA for Ponds 1 through 4 assuming potential exposures of 12 days per year. Results of these evaluations indicate the following:

- For Ponds 1 through 4, HIs are below one. ELCRs for exposure frequency of 50 days per year in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals are 8×10^{-6} and 7×10^{-6}, Potential exposure to arsenic and dioxin TEQ from sediment ingestion in Ponds 1 through 4 are primary contributors to the ELCRs with the COPC-specific ELCRs for arsenic and dioxin TEQ greater than 1×10^{-6}.

  ELCRs for exposure frequency of 12 days per year in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals are both 2×10^{-6}. Potential exposure to arsenic and dioxin TEQ from sediment ingestion in Ponds 1 through 4 are primary contributors to the ELCRs and the COPC-specific ELCRs for arsenic and dioxin TEQ both equal 1×10^{-6}.

- HIs for the remaining ponds (i.e., Pond 6, Pond 7, Pond 8 and North Pond), assuming an exposure frequency of 50 days per year are less than 1. The following bullets summarize the ELCRs in Pond 6, Pond 7, Pond 8 and North Pond, assuming an exposure frequency of 50 days.

  - Pond 6 ELCRs are 4×10^{-6} (0 to 0.5 ft bgs) and 3×10^{-6} (0 to 2 ft bgs), Pond 7 ELCRs are 2×10^{-5} (0 to 0.5 ft bgs and 0 to 2 ft bgs), and North Pond ELCRs are 2×10^{-6} (0 to 0.5 ft bgs and 0 to 2 ft bgs). Potential exposure to arsenic and dioxin TEQ from sediment ingestion in Pond 6 and Pond 7 are the primary contributors to the ELCRs. Arsenic is the primary risk contributor in North Pond.

  - Pond 8 ELCRs are 2×10^{-6} (0 to 0.5 ft bgs and 0 to 2 ft bgs). Potential exposures to arsenic and dioxin TEQ from sediment ingestion in Pond 8 are primary contributors to the ELCRs, but this result is mitigated by the following factors. From a practical standpoint, exposure to the sediments in Pond 8 for any duration is remote due to site-specific factors that discourage access such as dense vegetation, steep banks, and cold surface water and air temperatures for much of the year. From a risk analysis standpoint, arsenic concentrations in Pond 8 are comparable to background, so arsenic ECLRs are not associated with site conditions for the Pond 8 AOC. When the Pond 8 occasional recreator is evaluated without considering background arsenic exposures, the resulting cumulative ELCR in Pond 8 is 1×10^{-6}.

Ecological Risk Assessment

This OU-E ERA estimates exposure and characterizes potential ecological risk in accordance with the CSM presented in this OU-E BHHERA and methods described in the Site-Wide RAWP (ARCADIS BBL 2008a) and the OU-E BHHERA Work Plan. Results of the ERA for the terrestrial exposure area indicate that potential unacceptable risk for populations of plants, soil invertebrates, birds, and mammals is unlikely. Tables 7-6, 7-14 and 7-16 present hazard quotients estimated in the terrestrial ERA, and Section 7.3.1 presents detailed risk characterization using a weight of evidence approach. Section 7.4.2.1 presents an alternative exposure scenario conservatively assuming 100 percent bioaccessibility of COCs in soil.

Hot spot analysis for the terrestrial exposure area in the ERA assumed removal of the hot spots identified in the analysis for HHRA. The following table compares the residual EPCs in each terrestrial exposure interval to the RBTL assuming removal of the hot spots identified in the HHRA. EPCs in the ERA are 95% UCL of the data or the maximum detected value if a 95% UCL could not be calculated (in the case of lead and dioxin, the EPC is the 95% UCL). ERA RBTL values are back-calculated soil concentrations that are conservatively protective of ecological receptors.

Terrestrial Residual EPCs and ERA RBTLs: Dioxin TEQ and Lead

Constituent	ERA RBTL	Residual EPCs and Depth Interval*			Hot Spot Areas (depth in ft bgs)
		0-0.5 ft bgs	0-2 ft bgs	0-6 ft bgs	
Dioxin TEQ, Mammal (pg/g)	1,920	6.3	4.9	7.2	**Powerhouse and fuel barn AOI:** OUE-DP-052 (0.5-1.5 & 0-0.5)
Lead (mg/kg)	127	49.5*	39.5	48.7	**Sawmill #1 AOI:** OUE-DP-070 (3-4), DP-05.57 (0.5-1); **Powerhouse and fuel barn AOI:** OUE-DP-094 (5.5-6), OUE-DP-090 (5.5-6)

Notes:
mg/kg = milligrams per kilogram
pg/g = picograms per gram
* The lead residual EPCs in the 0 to 0.5 ft bgs depth interval is equal to the baseline EPCs. Maximum lead concentrations in this interval are below the not-to-exceed level (320 mg/kg).

As shown above, assuming hot spots removal, the residual EPCs for each depth interval are less than the site-specific RBTL developed for ecological receptors. Dioxin TEQ and lead were not identified in the ERA as potential risk drivers for plants, soil invertebrates, and upper trophic level receptors, because the removal of hot spots further reduces the EPCs. Therefore, potential risk is not identified for ecological receptors exposed to Dioxin TEQ and lead (Section 7.3.1.5).

Results of the ERA for aquatic exposure areas indicate that unacceptable risk is not likely for populations of plants, benthic organisms, birds, mammals and amphibians exposed to site sediment and surface water. Tables 7-7 through 7-12, 7-15, and 7-14 present hazard quotients estimated in the ERA for all aquatic areas as a single exposure unit. Tables 7-18 through 7-34 present hazard quotients estimated in the ERA for each pond AOC as a single exposure unit. Section 7.3.2 presents detailed risk characterization using a weight of evidence approach. Section 7.4.2.2 and 7.2.2.3 present alternative exposure scenarios conservatively each Pond AOC as a separate exposure unit and assuming 100 percent bioaccessibility of COCs in sediment. ERA results for ponds evaluated individually indicate potential risk is not likely, with the exception of barium partitioning to porewater in Pond 7 sediment, which may pose a potential risk to benthic organisms based on comparison of porewater concentrations at locations Pond 7-01 (1570 µg/L), Pond 7-01 (1935 µg/L), and DP-4.13 (1780 µg/L) to the selected screening level of 1,000 µg/L provided by the Regional Water Quality Control Board (2013).

1 Introduction

On behalf of Georgia-Pacific, LLC (Georgia-Pacific), ARCADIS U.S., Inc. (ARCADIS) prepared this *Baseline Human Health and Ecological Risk Assessment Report for Operable Unit E* (OU-E BHHERA) for the Former Georgia-Pacific Wood Products Facility located at 90 West Redwood Avenue in Fort Bragg, Mendocino County, California (site; Figure 1-1).

The 415-acre site is located west of Highway 1 along the Pacific Ocean coastline and is bounded by Noyo Bay to the south, the City of Fort Bragg (City) to the east and north, and the Pacific Ocean to the west. Union Lumber Company began sawmill operations at the site in 1885. Georgia-Pacific acquired the site in 1973. Sawmill operations at the site included lumber production and power generation by burning residual bark and wood. Georgia-Pacific ceased operations on August 8, 2002. Much of the equipment and structures associated with the sawmill operations have been removed. The site is fenced and locked to restrict trespassers.

This OU-E BHHERA evaluates potential risks to human and ecological receptors in Operable Unit E (OU-E), as required by the Site Investigation and Remediation Order for the site (Docket No. HAS-RAO 06-07-150; Order). OU-E is one of five operable units on the site, and consists of approximately 27 terrestrial acres[1] and 12 acres of seasonal wetland and man-made ponds (i.e., Ponds 1 through 9 and the North Pond) (Figure 1-2).

1.1 Objectives

This OU-E BHHERA provides a baseline risk assessment using historical data presented in the *Final Remedial Investigation Report Operable Unit E* (OU-E RI; ARCADIS 2013a), and recently collected data discussed in Section 4. This OU-E BHHERA follows relevant U.S. Environmental Protection Agency (USEPA) and California Environmental Protection Agency (CalEPA) guidance. Methodologies are also consistent with those presented in the site documents listed below and are further discussed in the following sections:

- *Site-Wide Risk Assessment Work Plan* (Site-Wide RAWP), Former Georgia-Pacific Wood Products Facility, Fort Bragg, California (ARCADIS BBL 2008a).

[1] Approximately 11.1 acres of lowland terrestrial habitat (i.e., the OU-E Lowland area of concern) was evaluated in the terrestrial BHHERA for potential soil exposure (See Section 3.1.1).

- *Final Operable Unit A (OU-A) Remedial Action Plan and Feasibility Study*, Former Georgia-Pacific Wood Products Facility, Fort Bragg, California (ARCADIS BBL 2008b).
- *Technical Memorandum – Risk Assessment Approach for Operable Unit E* (ARCADIS 2010).
- *Remedial Investigation Report, Operable Units C and D* (OU-C/OU-D RI), Former Georgia-Pacific Wood Products Facility, Fort Bragg California (ARCADIS 2011a).
- *Baseline Human Health and Ecological Risk Assessment Work Plan – Operable Unit E Addendum* (OU-E BHHERA Work Plan; ARCADIS 2013b).

1.2 Report Organization

The remainder of this OU-E BHHERA is organized as follows:

- **Section 2 - Physical Characteristics and Land Use:** This section summarizes land use, ecology, climate, geology, hydrogeology, and surface water hydrology in OU-E.
- **Section 3 - Site History:** This section describes the operational history and previous environmental investigations conducted at the site.
- **Section 4 - Baseline Human Health and Ecological Risk Assessment Investigation:** This section describes the approach and the results of the field data collection effort presented in the OU-E BHHERA Work Plan (ARCADIS 2013b).
- **Section 5 - Datasets Used for the Risk Assessments:** This section describes methods to evaluate data used to estimate exposures for the human health and ecological risk assessments.
- **Section 6 - Human Health Risk Assessment:** This section provides an assessment of potential human health risks associated with OU-E.
- **Section 7 - Ecological Risk Assessment:** This section provides an assessment of potential ecological risks associated with OU-E.
- **Section 8 - Portions of Operable Units C and D Deferred to OU-E BHHERA:** This section provides a summary of updated potential human health and ecological risks in the following areas of interest (AOI) within Operable Unit C and Operable Unit D (OU-C/OU-D).
- **Section 9 - Conclusions:** This section provides a summary of findings and conclusions.
- **Section 10 - References:** This section lists sources of information cited in this OU-E BHHERA.

2 Physical Characteristics and Land Use

Figure 2-1 presents the location of the OU-E terrestrial and aquatic areas of concern (AOCs) and OU-C/OU-D IRM, West of IRM, and Riparian Area AOIs. As shown on Figure 2-1, much of the terrestrial portion of OU-E is situated in an area of lower elevation north of Pond 8, just east of Soldier Bay. This terrestrial portion of OU-E is approximately 20 to 40 feet (ft) lower in elevation than the remainder of the site and is identified as the OU-E Lowland AOC. As shown on Figure 2-2, industrial development in OU-E occurred in the OU-E Lowland AOC. Predominant industrial features in this area supported power production, milling of timber, water treatment, management of fly ash, and fuel storage. Additional features included water cooling towers at the southwestern tip of Pond 8, which were present prior to the 1970s; cooling towers just north of Pond 8 that replaced the original cooling towers; and the pump house along the southern shore of Pond 8.

Within OU-E, identified wetlands and waters include ponds and ditches used in former sawmill operations and storm-water management, seasonal wetlands[2], and wetland seeps[3]. Figures 2-3 to 2-5 show the locations of waters and wetlands in OU-E. Additional details regarding climate, geology, hydrogeology, and surface water hydrology are presented in the OU-E RI (ARCADIS 2013a).

The terrestrial portion of OU-E has been subdivided into five AOIs based on historical uses and data derived from previous investigations. The terrestrial AOIs, listed below, and related features are shown on Figure 2-2.

- Water Treatment and Truck Dump AOI.
- Sawmill #1 AOI
- Compressor House and Lath Building AOI
- Powerhouse and Fuel Barn AOI
- Pond 8 Fill Area AOI

[2] Seasonal wetland plant communities occur in depressions inundated during the rainy season for sufficient duration to support vegetation adapted to wetland conditions.

[3] Freshwater seep plant communities are wetlands containing perennial and annual herbs, including sedges and grasses, which occur in areas that receive perennial or semi-perennial hydrological input as a result of subsurface flow of water.

Industrial features within OU-E have been removed with some former building foundations remaining in areas investigated during the OU-E RI. OU-E is generally vacant and used to support ongoing environmental support activities, as well as storm-water management. While foundations of former buildings remain in certain portions of this area, there has been extensive investigation of these areas.

Portions of the terrestrial area north of Pond 8 were capped following foundation removal activities, as shown on Figure 2-2. These caps remain in place and were installed to restrict exposure to impacted soil that remained after foundation removal.

The Mill Site Coordinating Committee (2012) has considered alternatives for future development of OU-E. Figure 2-6 shows the layout prepared by the Mill Site Coordinating Committee for future development in OU-E. This figure shows the majority of OU-E, including the terrestrial area and Pond 8, designated as open space. Ponds 1 through 4 span areas designated as urban reserve and industrial use. The area around Pond 5 is designated as mixed use, and the area around Pond 9 is designated as residential. Environmentally sensitive habitat areas (ESHAs[4]) comprise approximately one-fifth of the OU-E lowland (Figure 2-4) and approximately one-third of the flat potentially developable area. The configuration of these ESHAs limits the area of contiguous land available for development.

The AOCs evaluated in this OU-E BHHERA are consistent with the OU-E BHHERA Work Plan (ARCADIS 2013b) and are based on the use of appropriate habitat (i.e., aquatic or terrestrial) in OU-E. This OU-E BHHERA assumes an area of 11.1 acres of terrestrial habitat (i.e., OU-E Lowland AOC) as the terrestrial exposure area. Seven aquatic AOCs (Ponds 1 through 4, Pond 5, Pond 6, Pond 7, the North Pond, Pond 8 and Pond 9) comprise a total of 11.7 acres of aquatic habitat. Two exposure scenarios are included in the BHHERA, one with exposure areas defined as individual aquatic AOCs and a second using a combined AOC aquatic exposure area. AOCs are depicted on Figure 2-1.

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[4] ESHAs are referred to as "environmentally sensitive habitat area[s]" in Section 30107.5 of the California Coastal Act, and are defined as "any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments". ESHAs in OUE include wetland and open water habitats. Regulatory protection of ESHAs in the California Coastal Zone ultimately falls under the jurisdiction of the California Coastal Commission (CCC). The City of Fort Bragg administers CCC Coastal Act jurisdiction for the site under their Local Coastal Program.

As noted above, although the area around Pond 9 is designated as residential, this is outside of the OU-E boundary and therefore, the human health risk assessment was not based on residential land use for Pond 9.

The IRM, West of IRM, and Riparian AOIs have been moved from OU-C/OU-D to be further assessed in the OU-E feasibility study. The Remedial Investigation and HHERA were already completed for the IRM and West of IRM AOIs as part of the OU-C/OU-D RI (ARCADIS 2011a). Since additional work was completed for the Riparian AOI as part of the OU-E BHHERA using recently collected sediment and porewater data, the ERA for the Riparian AOI was updated based on this new information and these updates are summarized in Section 8.1. The IRM and West of IRM were evaluated in the OU-C/OU-D RI (ARCADIS 2011a) and are not discussed further in this BHHERA.

3 Site History

This section summarizes the operational history of the terrestrial area and ponds within OU-E, including descriptions of historical use of each AOC and AOI, focusing on areas where industrial activities occurred.

3.1 Operational History

A summary of the terrestrial area and ponds within OU-E is provided in the OU-E RI (ARCADIS 2013a). AOIs are briefly discussed below.

3.1.1 Terrestrial Area

The following five AOIs were evaluated as terrestrial area within the OU-E Lowland AOC as part of the BHHERA. As mentioned in Section 1, approximately 11.1 acres of lowland terrestrial habitat (i.e., the OU-E Lowland area of concern) was evaluated in the BHHERA for soil exposure. Additional details regarding each area can be found in the OU-E RI (ARCADIS 2013a).

- *Water Treatment and Truck Dump AOI:* Figure 2-2 shows the location of this 4.8-acre AOI in the northwest section of OU-E. Former features in the AOI include the Alum Tank, Water Treatment Plant, Sewage Pump Station, Water Supply Switch Building, Water Valve Shed, Water Tower, Powerhouse Fuel Storage Shed, Chipper Building, Truck Dump, Truck Dump Hydraulic Unit Building, and the Bunker Fuel Aboveground Storage Tank (AST) Area.

- *Compressor House AOI:* Figure 2-2 shows the location of this 2.19-acre AOI. Former features in this AOI included two small buildings (Compressor House 1 and Compressor House 2), Electrical Shop, Compressor House Shed, Lath Building, and a secondary containment structure.

- *Sawmill #1 AOI:* Figure 2-2 shows the location of this 3.05-acre AOI as an "L" shaped area north of the eastern half of Pond 8. Former features in this AOI include the Sawmill #1 Building, Press Building, Green Chain (and Elevated Roadway), Lath and Shake Mill, Refuse Wood for Fuel Area, Engine House Area, Number 5 Shingle Mill Area, and AST.

- *Powerhouse and Fuel Barn AOI:* Figure 2-2 shows the location of this 6.05-acre AOI directly north of Pond 8. Former features in this AOI include the Dewatering Slabs, Equipment Fueling Area, Steam Dry Kilns, Former South Pond, Fuel Barn, Powerhouse Building, Transformer Pad, Oil Storage Shed, Chemical Storage Tank, Poly Tanks/Small Transformer Pad to the south, Paint Storage Shed, Fly Ash Reinjection System, Open Refuse Fire Area, and Cooling Towers (including the Poly Tank/Transformer Pad and the Cooling Towers Storage Shed), Concrete Lined Tank, and Process Water Pumping Station.

- *Pond 8 Fill AOI:* Figure 2-2 shows the location of this 5.01-acre AOI along the eastern, southern, and western perimeters of Pond 8. Pond 8 originally extended further west. The western portion of Pond 8 appears to have been filled prior to 1973 (TRC Companies, Inc. [TRC] 2004).

3.1.2 Aquatic Areas

Ten ponds -1 through 9 and the North Pond – were investigated as AOCs in OU-E. These ponds range in size from 0.06 acre (North Pond) to 7.29 acres (Pond 8) and served operational purposes, including management of wastewater from site operations, a source of water for fire-fighting, stormwater management, and as a log pond. Historical use of the ponds is described in the *Preliminary Site Investigation Work Plan Operable Unit E – Onsite Ponds* (ARCADIS BBL 2007a). A schematic illustrating the flow between the ponds is provided on Figure 3-1. The ponds AOCs described below collectively comprise the aquatic exposure area. Additionally, each individual pond AOC is evaluated separately for potential ecological risk in the uncertainty evaluation (Section 7.4.2) of the BHHERA.

- *Ponds 1 through 4 (South Ponds):* Ponds 1 through 4 (a total of 2.8 acres), together with Pond 7 (0.1 acre), provided a series of treatment ponds related to the operation of the former Powerhouse. Pond 7 received effluent from the wet scrubbers operating in the power plant. From approximately the mid-1970s up until 1996, fly ash emissions from the boilers were controlled by multi-cyclone collectors, followed by wet scrubbers. Scrubber water from the boilers contained fly ash and was piped to two dewatering slabs where, after drying the residual, fly ash was placed in a dump hopper for removal and placement at an offsite location. Water on the dewatering slabs that did not evaporate was conveyed to Pond 7, and then pumped to Ponds 1 through 4 (Settling Ponds) for further treatment. Pond 7 also received water from the dewatering slabs and wash water from the Powerhouse as well as groundwater and surface water runoff from the Powerhouse area. The South Ponds discharge to the southwest end of Pond 8 through a culvert system.

- *Pond 5:* Pond 5 (0.6 acre) was man-made for facility purposes. Pond 5 received water from Pudding Creek as well as runoff from the main office area (Operable Unit B) and offsite runoff from Highway 1.

- *North Pond:* The North Pond (0.06 acre) was formerly used as a settling basin for water used during the operation of the hydraulic debarker. Water from surface runoff from the surrounding uplands to the north currently enters the North Pond via a culvert on its east side and discharges to Pond 6 via a culvert.

- *Pond 6:* Pond 6 (0.17 acre) collects storm-water runoff during winter storm events and also receives discharge from the North Pond and drainage water from Parcel 2. When the plant was operational, water from Pond 6 (when full) would be pumped to Pond 7 and subsequently to Ponds 1 through 4 when full. There is also an overflow culvert in Pond 6 that allows discharge of stormwater to Soldier Bay.

- *Pond 8:* Pond 8 (7.3 acres), also known as the Log Pond, was created in the late 1800s by the damming of Alder Creek. Pond 8 receives storm-water runoff as well as overflow from Pond 5. Approximately 50% to 60% of the stormwater runoff entering Pond 8 comes from the City, depending on storm magnitude (ARCADIS 2012). Water from Pond 8 discharges over the dam spillway to the beach adjacent to Soldier Bay. The total contributing watershed to Pond 8 is approximately 417 acres, consisting of 190 acres (including the pond) within the Mill Site property and 227 acres outside the Mill Site property. Total direct rainfall to the surface of the pond is less than 2% of the total inflow to the pond.

- *Pond 9:* Pond 9 (0.71 acres) is a man-made reservoir supplied by surface water pumped from Pudding Creek. Water from this pond was pumped to hydrants for firefighting. Water is not currently pumped to Pond 9 from Pudding Creek.

3.1.2.1 *Riparian AOI*

The Riparian AOI was moved from OU-C/OU-D to be further assessed in the OU-E feasibility study. This AOI consists of undeveloped, wooded land along the eastern boundary of Parcel 7 (Figure 2-1). A riparian wetland and perennial surface drainage are present in the northern end of the AOI, and a seasonal wetland ditch runs along the western perimeter of the AOI. Shallow, unpaved drainage ditches run from the Former Log Storage and Sediment Stockpile AOI into the ditch in the Riparian AOI. Three existing groundwater wells (FB-1 through FB-3) were identified in the wooded area along the east side of Parcel 7 during previous investigations. The locations of these wells are not known, and they are, therefore, not presented on figures in this RI Report. Remnants of a corrugated metal drainage pipe have been observed in the stream bed approximately midway in the north-south section of the drainage. A water supply well on the western edge of this AOI contained a pump connected to an aboveground plastic pipeline used to transmit water to the nursery in Parcel 9 (TRC 2004). Sanitary sewer lines run through the north end of this AOI. No other historical uses of this AOI have been identified.

3.2 Results of the Remedial Investigation

Historical and OU-E RI data (ARCADIS 2013a) characterize the nature and extent of impacts in OU-E. A screening level analyses for unrestricted use, including potential residential receptors, was conducted in the approved OU-E RI report and exceedances of the unrestricted residential screening levels were identified in the OU-E RI Section 4 Tables. In addition, Figures 4-15b, 4-17, 4-18b of the approved OU-E RI present comparison of lead, B(a)P TEQ, and dioxin TEQ in soil with human health PSLs, respectively. Figures 4-20 and 4-24 of the approved RI present a comparison of arsenic and dioxin TEQ in Ponds 6, 7, 8, and North Pond with human health PSLs, and Figures 4-25 and 4-29a of the approved OU-E RI present a comparison of arsenic and dioxin TEQ in the southern ponds with human health PSLs, respectively.

Conclusions from the OU-E RI report are summarized below for terrestrial AOC and aquatic pond AOCs listed in Section 3.1. These include constituents detected at concentrations greater than human health and/or ecological preliminary screening levels (PSLs) appropriate for unrestricted land use.

- OU-E Lowland AOC:
  - Water Treatment and Truck Dump AOI: Metals (antimony, arsenic, barium, chromium, copper, lead, mercury, molybdenum, and zinc), and polycyclic aromatic hydrocarbon (PAHs) were detected at concentrations greater than PSLs.
  - Sawmill #1 AOI: Total petroleum hydrocarbons as diesel (TPHd) (leaching to groundwater only), PAHs, and metals (arsenic, antimony, barium, copper, chromium, lead, mercury, molybdenum, nickel, vanadium, and zinc) concentrations were detected at concentrations greater than PSLs.
  - Compressor House and Lath Building AOI: TPHd and PAHs were detected at concentrations greater than PSLs.
  - Powerhouse and Fuel Barn AOI: Metals (antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, vanadium, and zinc), dioxins/polychlorinated dibenzofuran (furans), and PAHs were detected at concentrations greater than PSLs.
  - Pond 8 Fill Area AOI: One soil sample exceeded the ecological PSL for zinc; however, metals concentrations in all remaining samples collected were below PSLs.
- Aquatic Area AOCs:
  - Ponds 1, 2, 3, and 4 AOC: Metals (arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc), PAHs, volatile organic compounds (VOCs), dioxins, and TPH were found at concentrations greater than PSLs.
  - Pond 5 AOC: Metals (arsenic, copper, lead, molybdenum, nickel, and zinc), PAHs, VOCs, dioxins, polychlorinated biphenyls (PCBs), and TPH were found at concentrations greater than PSLs.
  - Pond 6 AOC: Metals (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc), PAHs, VOCs, and dioxins were found at concentrations greater than PSLs.
  - Pond 7 AOC: Metals (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc), PAHs, dioxins, and TPH were found at concentrations greater than PSLs.

- Pond 8 AOC: Metals (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc), PAHs, VOCs, dioxins, PCBs, TPH and pesticides were found at concentrations greater than PSLs.

- Pond 9 AOC: Metals (arsenic, copper, lead, molybdenum, nickel, and zinc), VOCs, and dioxins were found at concentrations greater than PSLs.

- North Pond AOC: Metals (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc), PAHs, and dioxins were found at concentrations greater than PSLs.

- Groundwater: Metals (arsenic, barium, cobalt, copper, lead, molybdenum, nickel, thallium, and vanadium), PAHs, VOCs, dioxins, PCBs, and TPH were found at concentrations greater than PSLs.

4 Baseline Human Health and Ecological Risk Assessment Investigation

Additional sampling activities completed since submittal of the OU-E RI (ARCADIS 2013a) followed methods presented in the OU-E BHHERA Work Plan (ARCADIS 2013b). The purpose of the OU-E BHHERA sampling activities was to address two questions.

1) What is the bioaccessible fraction of arsenic in OU-E sediment for potential human health receptors?

2) Do metals and PAHs in OU-E and Riparian AOI sediment partition to porewater at sufficient concentrations to result in potentially unacceptable risk to sediment invertebrates?

Data collection activities included the following, which are further summarized in Section 4.1.

- Surface sediment samples (i.e., 0 to 0.5 ft below sediment surface [bss]) were collected and analyzed for arsenic speciation and total arsenic, alkylated PAHs (bulk sediment and porewater), total organic carbon (TOC), black carbon, and pH.

- Porewater samples were collected and analyzed for metals, major cations and anions, and alkalinity.

Sample locations for the OU-E BHHERA investigation are presented on Figures 4-1 through 4-4. Field notes and photographs (Appendix A), laboratory reports and validation (Appendix B), and analytical results (Appendix C) are included as appendices to this OU-E BHHERA.

4.1 Deviations from the Work Plan Addendum

Data collection activities associated with the OU-E BHHERA investigation were consistent with methods outlined in the approved OU-E BHHERA Work Plan (ARCADIS 2013b), with the exceptions outlined below.

4.1.1 Sampling

- Two sediment samples were collected from Pond 8-05 and analyzed for designated constituents; one sample on April 8, 2013 and one sample on April 11, 2013.

- The *in-situ* dialysis membrane porewater samplers were deployed for a maximum of 16 days instead of 14 days, as presented in the OU-E BHHERA Work Plan. Reference literature regarding acetate cellulose membranes, which were used *in-situ* dialysis membrane porewater samplers, indicate these membranes maintain integrity for at least 16 days.

- The in-situ dialysis membrane porewater sampler could not be retrieved from sample location Pond 5-02 and porewater analyses were not performed.

4.1.2 Analyses

- Porewater PAHs analyzed using the solid-phase micro-extraction (SPME) method could not be measured for OUD-HA-SED-048 due to insufficient porewater volume recovery.

- Electron microprobe analysis (EMPA) for arsenic speciation was not performed on the following samples because arsenic concentrations below method analytical limits (i.e., 50 parts per million arsenic) may not produce representative results (Drexler 2013):

  - Pond 1-01, Pond 2-01, Pond 2-02, Pond 3-04, Pond 3-06, Pond 6-01, Pond 6-02, Pond 8-04, and Pond 8-05.

4.2 Data Quality

Data quality was maintained during sediment and porewater sample collection by following the standard operating procedures outlined in the OU-E BHHERA Work Plan (ARCADIS 2013b). Integrity of *in-situ* dialysis membrane porewater samplers for the sampling interval of 0-0.5 ft bss was evaluated during retrieval by comparing deployment and retrieval depth measurements. Field personnel confirmed sampler deployment depths through observation of distinct sediment-water interface lines (Photographs 17 and 19, Appendix A). Fine-grained sediment was also observed coating dialysis membranes demonstrating contact between the membrane and the sediment matrix (Photograph 22, Appendix A).

Quality of analytical results used in the OU-E BHHERA is discussed in Section 5.2.

5 Datasets Used for the Risk Assessments

Datasets were developed for soil, sediment, groundwater, and surface water for use in the Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA) as discussed in the following sections. The OU-E-specific approach to the OU-E BHHERA follows the Site-Wide RAWP (ARCADIS BBL 2008a), with exceptions described in the sections below. This approach evaluates a single terrestrial exposure unit (i.e., OU-E Lowland AOC), and a single aquatic exposure unit (i.e., combined Pond AOCs)[5]. While OU-E was divided into AOIs for the purpose of investigation based on operational history, the investigation approach was not limited to specific COCs within each AOI. Variability within the results was limited, with relatively few outliers. As described in the hot spot evaluation in section 5.1.1, and quantile-quantile plots, those locations with significant variability have been selected for additional evaluation and potential remedial action. Therefore, a single terrestrial exposure unit is used for the evaluation of risk in the OU-E lowland. The HHRA and the ERA also present additional exposure scenarios for the aquatic habitat in which each Pond is considered a unique exposure unit (Sections 6.4.2.4 and 7.3.4). The specific exposure unit, along with the steps used to define the OU-E BHHERA datasets, are described in Section 5.1 and are shown on Figure 2-1. The OU-E BHHERA is based on a conceptual site model (CSM) for constituent sources, exposure pathways, and human and ecological receptors. CSM illustrations showing potential sources and transport pathways are shown on Figure 5-1 (terrestrial) and Figure 5-2 (aquatic). Datasets were developed to assess potential exposure pathways for each receptor identified in the CSMs based on how likely a receptor is to contact a particular depth interval (e.g., 0 to 0.5 ft below ground surface [bgs] and 0 to 2 ft bgs) for the applicable media (i.e., soil, sediment, groundwater, or surface water). The CSMs are further discussed in Sections 6 (human health) and 7 (ecological).

In addition to the OU-E Lowland AOC and combined Pond AOCs, the Riparian AOI was evaluated using sediment and porewater data collected as part of the OU-E BHHERA Work Plan (ARCADIS 2013b). Porewater data were used in the ERA to assess potential risk to benthic invertebrates exposed to metals partitioning from sediment to porewater, and sediment data were used to evaluate potential risk to benthic organisms from exposure to PAHs in sediment. Results are discussed in Section 8.1.

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[5] The IRM and West of IRM AOCs are not included in this OU-E BHHERA report, because they are quantitatively addressed in the OU-C and D RI (ARCADIS 2011a). The IRM and West of IRM AOIs will be carried forward into the OU-E feasibility study.

5.1 Exposure Units and Dataset Development

The dataset development approach used in this OU-E BHHERA follows the Site-Wide RAWP (ARCADIS BBL 2008a) as amended by the OU-E BHHERA Work Plan (ARCADIS 2013b). The boundaries of the terrestrial AOC and aquatic AOCs are depicted on Figure 2-1. Locations within AOC boundaries were considered for potential exposure regardless of current site conditions, barriers or constraints. For example, areas that were capped following foundation removal activities north of Pond 8 were considered to be potentially accessible for potential future exposures despite the current cap presence.

Terrestrial Areas

As discussed in Section 3.1.1, the OU-E Lowland AOC is terrestrial habitat and consists of the following AOIs (Figure 2-1):

- Water Treatment and Truck Dump AOI
- Sawmill #1 AOI
- Compressor House and Lath Building AOI
- Powerhouse and Fuel Barn AOI
- Pond 8 (also known as the Log Pond or Mill Pond) Fill Area AOI.

Sample locations from the five AOIs included in the OU-E Lowland terrestrial AOC are presented on Figures 5-3 through 5-5. In response to Department of Toxic Substances Control (DTSC) comments on the BHHERA work plan, and due to the absence of COPCs above relevant screening levels, the Pond 8 Fill Area AOI was not included as part of the BHHERA dataset. The specific datasets used in the OU-E BHHERA are discussed in Sections 5.1.1 through 5.1.6.

Aquatic Areas

As discussed in Section 3.1.2, the aquatic portion of OU-E consists of the following seasonal wetlands and man-made ponds. Seven aquatic AOCs were evaluated as separate exposure areas. Additionally, all ponds were evaluated as one exposure area. The seven aquatic exposure areas are listed below:

- Ponds 1, 2, 3, and 4 combined (Southern Ponds)
- Pond 5

- Pond 6
- Pond 7
- North Pond
- Pond 8
- Pond 9

Sample locations included in the OU-E BHHERA aquatic datasets are presented on Figures 5-6 through 5-8. The specific datasets used in the OU-E BHHERA are discussed in the following sections.

5.1.1 Soil and Sediment Datasets

Soil and sediment data were subdivided into two exposure units: soils within the OU-E Lowland AOC and sediment within the aquatic exposure unit. Potential aquatic exposures were evaluated in two ways: collectively for the 10 ponds as one exposure unit, and separately with each pond as an exposure unit.

Soil and sediment data used to assess potential human health and ecological risks consist of data representative of the environmental media to which a receptor can realistically be exposed. Consistent with methods from the Site-Wide RAWP (ARCADIS BBL 2008a) and OU-E BHHERA Work Plan (ARCADIS 2013b), soils from 0 to 10 ft bgs represent potential exposure depths in terrestrial habitat, and sediments from 0 to 2 ft bss represent potential exposure depths within aquatic habitat. These exposure depth intervals align with the terrestrial and aquatic CSMs presented in the OU-E BHHERA Work Plan (ARCADIS 2013b).

The exposure intervals for receptor scenarios in the OU-E BHHERA are as follows:

- *0 to 0.5 ft bgs:* This depth range applies to all human receptors and specific to human receptors not engaged in subsurface activities (e.g., commercial/industrial workers and recreators), as well as ecological receptors in terrestrial and aquatic areas.
- *0 to 2 ft bgs:* The depth range applies to all human receptors (e.g., commercial/industrial workers, construction workers in aquatic areas, and recreators), as well as burrowing receptors in aquatic areas that may dig into sediment to forage (e.g., raccoon). Terrestrial plants and invertebrates may also be exposed to this depth interval.
- *0 to 6 ft bgs:* This depth range applies to human receptors who may be engaged in subsurface activities (e.g., utility/trench workers), as well as potential exposures associated with burrowing ecological receptors in terrestrial areas (e.g., ornate shrew). Plants were not evaluated for this exposure interval based on shallow depth to groundwater and the lack of deep rooting plants observed at the site.

- *0 to 10 ft bgs:* This depth range applies to human receptors who may be engaged in subsurface activities in terrestrial areas (e.g., construction workers) and also accounts for a scenario where grading of the soil during restoration or redevelopment activities brings subsurface soil to the surface.

Soils greater than ten feet are not quantitatively evaluated in the BHHERA. Potential changes in soil depth due to grading or potential future construction will be addressed in a soil management plan (SMP) that addresses all soil depths such that site conditions during and following the work are acceptable for the planned use.

Sample intervals with overlap of an exposure interval were included in the dataset for that exposure interval. For example, a sample collected from 1.5 to 2.5 ft bgs would be included in the 0 to 2 ft depth interval.

Analytical results from duplicate samples collected from the same sampling location during the same sampling event were considered usable for the OU-E BHHERA. When a constituent was detected in both the original sample and the duplicate sample, the results were averaged. When one sample result showed no detectable concentration and a duplicate sample showed a detected concentration, the detected concentration was included in the dataset. If a constituent was not detected in either the original sample or the duplicate sample, the maximum reporting limit from the two samples was used as the reporting limit for that sample.

For the ERA, based on the foraging habits of the identified receptors, the 0 to 0.5 ft depth profile applies to all non-burrowing receptors evaluated. However, consistent with the Human and Ecological Risk Division (HERD) ERA Note 1 (DTSC 1998), the maximum site-wide exposure point concentration (EPC) of the 0 to 0.5 ft and 0 to 2 ft depth interval was used to evaluate potential risk to upper trophic ecological receptors in the OU-E Lowland AOC for each constituent. For burrowing ecological receptors (i.e., ornate shrew), the maximum site-wide EPC for the intervals between 0 to 0.5 ft bgs, 0 to 2 ft bgs, and 0 to 6 ft bgs was evaluated in the terrestrial AOC.

A summary of the complete soil and sediment datasets considered in the OU-E BHHERA for each exposure area is provided in Appendix D. Statistics (i.e., frequency of detection, minimum and maximum concentrations) are provided in Tables 5-1 through 5-17. Tables 5-1 through 5-6 present the terrestrial and aquatic exposure units, and pond-specific statistics for sediment are presented in Tables 5-7 through 5-17. Sediment datasets for aquatic AOCs for the HHRA are further discussed in Section 6.1.3 and sediment datasets for aquatic AOCs for the ERA are further discussed in Section 7.3.4. Datasets for the soil hot spot analysis conducted for the terrestrial Lowland AOC is presented in Section 5.1.1.1.

5.1.1.1 *Hot Spot Analysis (Terrestrial Lowland AOC)*

There is no general approach currently recommended by the DTSC for hot spot analysis. However, in an *Identification of Presumptive Remedy Areas on Operable Unit E* memorandum provided by the DTSC on June 25, 2014, DTSC recommended site-specific soil risk-based target levels (RBTLs) for B(a)P TEQ, Dioxin TEQ, and lead for use in the terrestrial Lowland AOC hot spot analysis. In a subsequent email from DTSC dated July 18, 2014, the DTSC determined that hot spot identification should be based on a comparison of soil data within the OU-E Lowland AOC to not-to-exceed soil values for benzo(a) pyrene (B(a)P) equivalents, dioxin toxicity equivalency factor (TEF), and lead. These not-to-exceed soil values are: 0.90 mg/kg for B(a)P equivalents; 160 pg/kg or parts per trillion (ppt) for dioxin TEQs; and 320 mg/kg for lead.

The recommended site-specific soil RBTLs and not-to-exceed soil concentrations for B(a)P TEQ, dioxin TEQ, and lead are summarized in the following table.

Site-Specific soil RBTLs and Not to Exceed Concentrations

Constituent	Human Health RBTL	Ecological RBTL	Selected RBTL	Not-To-Exceed Value
B(a)P TEQ	0.3 mg/kg	Not applicable[6]	0.3 mg/kg	0.9 mg/kg
Dioxin TEQ	53 pg/g	1,920 pg/g	53 pg/g	160 pg/g
Lead	320 mg/kg	127 mg/kg	127 mg/kg	320 mg/kg

Note:
mg/kg = milligrams per kilogram
pg/g = picograms per gram

The site-specific RBTLs were developed by DTSC according to the following methods:

- B(a)P TEQ: For the protection of human health, 0.3 mg/kg equates to the current Regional Screening Level (RSL) for protection of the commercial/industrial worker (USEPA 2015).
- Dioxin TEQ: For the protection of human health, 53 pg/g equates to a soil concentration based on the OU-E BHHERA occasional recreator. Table 6-2 presents the exposure parameters assumed for the occasional recreator in the terrestrial exposure area. For the protection of

[6] B(a)P TEQ is not considered in the ecological evaluation; B(a)P toxicity to ecological receptors is evaluated as the high molecular weight PAH COPC. Therefore, a B(a)P TEQ RBTL is not calculated for ecological receptors.

ecological receptors, 1,920 pg/g is the back-calculated soil concentration using the mammalian LOAEL (i.e., 1.0 x 10^{-5} mg/kg-day), assuming 100 percent bioaccessibility, and using a site-specific bioaccumulation regression to estimate uptake into soil invertebrates for the ornate shrew (Tables 7-2 and 7-3). Appendix F of the OU-A RI presents the site-specific regression equation (ARCADIS BBL 2008c).

- Lead: For the protection of human health, 320 mg/kg is the concentration recommended for the commercial/industrial worker in the DTSC Human and Ecological Risk Office (HERO) HHRA Note Number 3 (DTSC/HERO 2013). For the protection of ecological receptors, 127 is the back-calculated soil concentration for the ornate shrew which uses the mammalian LOAEL (i.e., 8.9 mg/kg-day), 100 percent bioaccessibility, and the literature-based ecological soil screening level bioaccumulation factor (USEPA 2007a) to estimate uptake into soil invertebrates (Tables 7-2 and 7-3).

In addition to the DTSC recommended RBTL-based hot spot identification approach, ARCADIS also used quantile-quantile plots prepared using ProUCL Version 4.1.00 (USEPA 2011b) to identify statistical outliers in the 0 to 6 foot soil dataset (Appendix L). These statistical outliers were also identified as hot spots. As noted in Appendix L, the samples identified as statistical outliers were also greater than three times the DTSC recommended RBTLs.

Soil hot spot areas are summarized in the following table and are depicted on Figures 5-9 (B(a)P TEQ), 5-10 (dioxin TEQ) and 5-11 (lead). To calculate residual (post-remedy) soil EPCs, these hot spot samples were removed from the baseline soil dataset. Residual EPCs are presented below and are also presented in Appendix L. Lead and B(a)P TEQ hot soil spots were not identified in the 0 to 0.5 ft bgs depth interval since maximum concentrations are less than the respective not-to-exceed value. As such, residual EPCs were not calculated for lead and B(a)P in the 0 to 0.5 ft bgs depth interval.

Residual Soil EPCs

Constituent	Depth Interval				Sample Removed (depth in feet bgs)
	0-0.5 ft bgs	0-2 ft bgs	0-6 ft bgs	0-10 ft bgs	
B(a)P TEQ (mg/kg)	0.0397*	0.0801	0.0618	0.0559	**Powerhouse and fuel barn AOI:** HSA-4.3 (2-2.5); **Sawmill #1 AOI:** OUE-DP-073 (2-3), OUE-DP-074 (2-3), OUE-DP-075 (2-3), OUE-DP-026 (2-3.5); **Waste treatment and truck dump AOI:** OUE-DP-099 (0.5-1), OUE-DP-100 (2.5-3.5)
Dioxin TEQ (pg/g)	6.311	4.85	7.152	8.522	**Powerhouse and fuel barn AOI:** OUE-DP-052 (0.5-1.5 & 0-0.5)

Constituent	Depth Interval				Sample Removed (depth in feet bgs)
	0-0.5 ft bgs	0-2 ft bgs	0-6 ft bgs	0-10 ft bgs	
Lead (mg/kg)	49.5*	39.54	48.65	44.97	**Sawmill #1 AOI:** OUE-DP-070 (3-4), DP-05.57 (0.5-1); **Powerhouse and fuel barn AOI:** OUE-DP-094 (5.5-6), OUE-DP-090 (5.5-6)

Note:
mg/kg = milligrams per kilogram
pg/g = picograms per gram
* Residual soil EPCs are the 95% UCL on the mean for the dataset after removal of the hot spot samples, with the exception of lead and B(a)P TEQ in the 0-0.5 ft bgs interval, which is the baseline EPC. Maximum concentrations are less than three times the RBTL value resulting in no identified lead or B(a)P TEQ hot spots in this depth interval.

Refer to Section 6.4.1 (HHRA) and 7.3.1 (ERA) for an evaluation of human and ecological receptors considering the removal of the identified hot spot locations (Figures 5-9 through 5-11).

5.1.2 Groundwater and Surface Water Datasets

Groundwater and surface water data were each compiled as exposure areas for the OU-E BHHERA. Consistent with sediment, surface water was also evaluated for the BHHERA for individual pond AOCs, as described in Section 5.1. Groundwater grab sample data were not used in the risk evaluation, as analytical data from groundwater grab samples tend to be less accurate than results from monitoring wells due to the presence of higher levels of particulates, which potentially results in biased sample results (USEPA 2005a). Monitoring well data from the first quarter of 2010 through first quarter of 2013 were included in the dataset. Exposures to groundwater (ingestion and dermal contact) within the terrestrial exposure area are only anticipated during future construction or trench work. Groundwater at the site is not a source of drinking water and residential or commercial developments are not consistent within the proposed future scenarios presented for OU-E. As such, the domestic use of groundwater for drinking water is not a complete exposure pathway and was not considered in this BHHERA. Ecological receptors are not likely to encounter groundwater. Therefore, groundwater is not considered in the ERA. Surface water data from 2006 and 2011 were included in the risk assessment dataset.

A summary of groundwater and surface water datasets is provided in Appendix D. Statistics (i.e., frequency of detection, minimum and maximum concentrations) for groundwater and surface water data used to estimate EPCs for aquatic areas as one collective exposure unit are provided in Tables 5-18 and 5-19, respectively. Pond-specific statistics for surface water are presented in Tables 5-20 through 5-26.

5.1.3 Porewater

Porewater data were collected from the ponds and Riparian AOI, consistent with methods in the OU-E BHHERA Work Plan (ARCADIS 2013b). Data are summarized in Appendix C. Porewater data were used in the ERA to assess potential risk to benthic invertebrates exposed to metals partitioning from sediment to porewater. Porewater data were not considered in the HHRA.

5.1.4 Test Method Hierarchy

In some cases, a naphthalene concentration was reported for multiple analytical methods in the same sample. Analytical data from USEPA Method 8270C-SIM were selected, followed by (in order of preference) USEPA Methods 8310, 8270C, and 8260.

5.1.5 Data Management Methods used for Summed COPCs

Based on similarity in toxicity or availability of toxicity values, summed or toxic equivalent (TEQ) values were used for the following chemicals in the risk evaluations:

- Dichlorodiphenyltrichloroethane (DDT) isomer concentrations (i.e., DDT, dichlorodiphenyldichloroethylene [DDE], and dichlorodiphenyldichloroethane [DDD]) were summed to obtain a total DDT value per analyzed sample.
- Chlordane isomer concentrations (i.e., alpha- and gamma-chlordane) were summed to obtain a total chlordane value per analyzed sample.
- PCBs were reported as either congeners or Aroclors. If a sample concentration was reported by both methods, then congener results were used. Total PCB concentrations were calculated as follows:
    - Aroclor concentrations were summed together per analyzed sample.
    - PCB congener concentrations were summed and multiplied by 2 per analyzed sample (National Oceanic and Atmospheric Administration [NOAA] 2000).
- Dioxins/furans were evaluated by estimating the 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) TEQ. The detected dioxin/furan congener concentrations were multiplied by their corresponding toxic equivalency factor (TEF) (Van den Berg et al. 2006), and the results were summed to develop a 2,3,7,8-TCDD TEQ concentration per analyzed sample.
    - For the HHRA, the mammal TEFs were applied for the human/mammal TEQ.

  - For the ERA, the mammal TEFs were applied for the mammal TEQ, and the avian TEFs were applied for the avian TEQ.

- For the ERA, PAHs were grouped into low molecular weight (LMW) and high molecular weight (HMW) PAHs. LMW PAHs consist of 1-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, and phenanthrene. HMW PAHs consist of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, and pyrene. Non-detected concentrations were assumed to contribute zero to the overall LMW or HMW PAH calculated result.

5.1.6 Use of Proxy Values

Proxy values are a substituted value for the analytical result dependent on the constituent, as presented in Table 5-27. Proxy values were only used to substitute for non-detected results for individual constituents summed for the risk assessment (i.e., sum chlordane, sum DDT, total PCBs, HMW PAHs, LMW PAHs, and 2,3,7,8-TCDD TEQ). Proxy values are not necessary for intervals where all values were detected (as for 2,3,7,8-TCDD TEQ in the 0-0.5 foot depth interval). The minimum detected value for the summed constituent in the applicable AOC and depth interval was used as the proxy value. This was necessary for certain exposure intervals as presented in Table 5-9. For the dioxin hot spot analysis, proxy values did not change based on the removed locations. Proxy values were not used for individual constituents contributing to the summed result.

5.2 Data Quality and Usability Evaluation

Data review was performed according to the following guidelines:

- *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, USEPA SW-846, 6th Edition*, November 2004, as amended and updated (USEPA 2004a)

- *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (USEPA 1999)

- *Contract Laboratory Program National Functional Guidelines for Inorganics Data Review* (USEPA 2004b)

- *Quality Assurance Project Plan*, Former Georgia-Pacific Wood Products Facility, Fort Bragg, California (ARCADIS BBL 2007b)

The available data (summarized in Sections 4 and 5 and provided in Appendix D) were evaluated and subsequently grouped into terrestrial and aquatic exposure areas. These data were found to be of sufficient quality for use in the OU-E BHHERA.

5.3 Chemicals of Potential Concern

Chemicals of potential concern (COPCs) were identified after data were evaluated and compiled into datasets using the steps described above. Generally, constituents were selected as COPCs if they were detected at concentrations exceeding background levels. COPC selection methods varied for the HHRA and ERA components, as noted below.

The following list summarizes the general selection criteria:

- *Frequency of Detection (FOD):* For the HHRA, with the exception of known human (Class A, B, or C) carcinogens, constituents were eliminated as COPCs if the FOD was below 5%, consistent with USEPA guidelines (USEPA 1989). Known human carcinogens (Class A, B or C) were not subject to this COPC screening criterion. For the ERA, FOD was not used to eliminate constituents as COPCs.

- *Laboratory Contaminants:* For both the HHRA and ERA, constituents typically considered common laboratory contaminants (e.g., acetone, 2-butanone, methylene chloride, isopropyl alcohol, and ethanol) were excluded as COPCs if this classification was supported following review of the analytical laboratory data and information regarding potential constituents of interest (COIs) (USEPA 1989).

- *Background Comparison:* Metals concentrations in soil (HHRA and ERA) were compared to site-specific background concentrations provided in the Background Metals Report (ARCADIS BBL 2007c). A metal was eliminated as a COPC if the maximum detected concentration was below the upper-bound background concentration. Tables 5-1 through 5-17 present metal concentrations compared to background concentrations as part of the COPC identification process.

COIs not eliminated by these criteria were selected as COPCs for evaluation in the HHRA and ERA. Soil, sediment, groundwater, and surface water COPCs under current conditions are presented in Tables 5-1 through 5-17 (soil and sediment), Table 5-18 (groundwater), and Tables 5-19 through 5-26 (surface water).

5.4 Exposure Point Concentration Calculations for the HHRA and ERA

The EPC is the concentration of a COPC in an environmental medium to which a potential receptor might be exposed. If sufficient data were available, a conservatively based 95% upper confidence limit (UCL) on the arithmetic mean concentration was estimated using USEPA's ProUCL 4.1 software (USEPA 2011b) and was used to represent the EPC for each COPC in each exposure area (USEPA 1989, CalEPA 1992). Maximum concentrations were used as EPCs if insufficient data were available to calculate a 95% UCL.

Methods used to estimate EPCs for the HHRA and the ERA follow the Site-Wide RAWP (ARCADIS BBL 2008a), with the exception that the ProUCL recommended UCL value, even if based on a confidence level greater than 95%, was selected as the EPC used in the risk assessment. If ProUCL recommends more than one value, the Decision Matrix Table (Table 19 of user's guide; USEPA 2011b) was used to select the appropriate EPC for use in the risk assessment.

As discussed in Section 5.1.1.1, residual EPCs for B(a)P TEQ, Dioxin TEQ, and lead were calculated based on the removal of the data points identified as hot spots in each exposure interval. Residual EPCs were not used to calculate exposure, because risk characterization presented in this BHHERA represents baseline conditions. Residual EPCs were compared to the DTSC provided screening values to evaluate protectiveness of removal of the identified hot spots. Consistent methods were used in estimating residual EPCs associated with the hot spot analysis.

The ProUCL 4.1 output tables for COPCs and media, are provided in Appendix E. Tables 5-28 through 5-31 present EPCs for HHRA COPCs in soil, sediment, groundwater, and surface water. Section 5.1.1.1 presents the residual soil EPCs for B(a)P TEQ, Dioxin TEQ, and lead associated with the hot spot analysis.

5.4.1 Total Petroleum Hydrocarbon EPCs

TPH was quantified for the OU-E BHHERA according to a method defined in a memorandum submitted to DTSC in November 2010 and revised in January 2011 in response to comments from DTSC, consistent with the OU-C/OU-D RI (ARCADIS 2011a). EPCs for the total petroleum hydrocarbons as gasoline (TPHg) and TPHd carbon ranges were developed through a three-step process for each exposure area and depth interval where TPHg and/or TPHd are COPCs:

1) Datasets for TPHg C7-C12 and TPHd C10-C24 were developed by summing the concentrations reported for the individual carbon ranges in each sample in the more recent data, and the UCL or maximum concentration was selected for each dataset by processing with ProUCL 4.1. This applied to the following datasets that have carbon ranges for each sample:

   - Sediment (all depth intervals and ponds)
   - Groundwater
   - TPH was not analyzed in surface water.

2) Individual sample data reported as carbon ranges were used to calculate carbon range proportions in each exposure unit and depth interval. This applied to datasets that have a mix of samples analyzed for only TPHg C_7-C_{12} and TPHd C_{10}-C_{24}, and samples analyzed for three TPHd ranges and two TPHg ranges:

    - Soil (0 to 0.5 ft bgs, 0 to 2 ft bgs, 0 to 6 ft bgs, and 0 to 10 ft bgs)

3) The proportions were applied to the UCL or maximum selected in the first step to calculate EPCs for the individual TPHg and TPHd carbon ranges in each exposure area and depth interval (see Appendix F).

Twenty-five percent of each carbon range was apportioned as aromatic and 75 percent was apportioned as aliphatic for the purpose of evaluating TPH toxicity in the human health risk assessment (Section 6.2.2).

5.4.2 Lead EPCs

Consistent with USEPA (2007b), the arithmetic mean for lead in soil was used to evaluate lead exposures in the HHRA for baseline conditions as well as comparing residual concentrations to screening values after removal of the hot spots (Section 5.1.1.1). Lead EPCs were compared against health-based, receptor-specific screening levels consistent with CalEPA (2009a) regulatory guidance and methods used in the OU-C/OU-D RI (ARCADIS 2011a).

As an added measure of conservatism, lead was also evaluated using estimated UCLs, or maximum detected concentrations when data were insufficient to estimate a UCL.

6 Human Health Risk Assessment

This section presents the methods used to conduct the baseline human health risk assessment (BHHRA) for OU-E and summarizes the results of the assessment. In addition, a hot spot analysis was conducted (Section 5.1.1.1) for the terrestrial Lowland AOC and residual soil EPCs were calculated for B(a)P TEQ, Dioxin TEQ, and lead. The residual soil EPCs were compared to risk-based concentrations (DTSC 2014) to evaluate potential risks in the terrestrial Lowland AOC following hot spot removal.

The purpose of the BHHRA is to evaluate potential risks to human health associated with current and foreseeable future exposure to site-related constituents (i.e., COPCs) within OU-E. The conclusions reached in the BHHRA, along with information from the ERA (Section 7), will inform a risk management strategy for OU-E.

6.1 Exposure Assessment

The human health exposure evaluation was completed for the terrestrial and aquatic portions of OU-E based on both federal and state risk assessment guidance and includes direct input from DTSC, as outlined in the OU-E BHHERA Work Plan (ARCADIS 2013b). Figures 5-1 and 5-2 present CSMs for the terrestrial exposure unit and aquatic exposure unit (i.e., ponds) of OU-E, respectively. The CSMs illustrate potential human receptors and exposure pathways. The following subsections summarize each of the human health components of the OU-E CSM.

6.1.1 Exposure Scenarios for Human Receptors

The OU-E BHHERA was conducted in accordance with the DTSC-approved Site-Wide RAWP (ARCADIS BBL 2008a) and the subsequent OU-E BHHERA Work Plan (ARCADIS 2013b). The scope of the BHHERA was established in the work plans considering current and reasonably anticipated future land use in coordination with the DTSC and with input from stakeholders. The selected exposure scenarios are in compliance with State and Federal regulations and guidance. Specifically, the BHHERA scope complies with Federal regulations (National Oil and Hazardous Substances Pollution Contingency Plan [NCP 55 Fed. Reg. at 8710]), which state, “The assumption of residential land use is not a requirement of the program but rather is an assumption that may be made, based on conservative but realistic exposures, to ensure that remedies that are ultimately selected for the site will be protective. An assumption of future residential land use may not be justifiable if the probability that the site will support residential use in the future is small.” Consistent with Federal guidance (USEPA 2010, OSWER Directive 9355.7-19), engagement regarding reasonably anticipated future land use began early in the process as documented in the approved Site-Wide RAWP and confirmed in the OU-E BHHERA Work Plan.

The scope of the OU-E BHHERA is also consistent with State guidance. State regulations (California Health and Safety Code Section 25350-25359.7) include the following requirement "The exposure assessment for any risk assessment prepared in conjunction with a response action taken or approved pursuant to this chapter shall include the development of reasonable maximum estimates of exposure for both current land use conditions and reasonably foreseeable future land use conditions at the site." DTSC relies on the Federal risk assessment guidance for Superfund (USEPA 1989) and associated federal guidance for the execution of baseline risk assessment which states "Because residential land use is most often associated with the greatest exposures, it is generally the most conservative choice to make when deciding what type of alternate land use may occur in the future. However, an assumption of future residential land use may not be justifiable if the probability that the site will support residential use in the future is exceedingly small." As such, the BHHERA provides proper consideration of current and potential risks, to a conservative selection of receptors, on which to base risk management decisions.

As outlined in the OU-E BHHERA Work Plan (ARCADIS 2013b), the following hypothetical human receptors were identified and evaluated in the terrestrial exposure unit based on current and reasonably anticipated future land use.

- *Construction Worker* – This adult receptor would perform construction activities in the terrestrial portions of OU-E during site restoration or reconfiguration and would be onsite for one year, with a frequency of 5 days per week for 50 weeks.

- *Utility/Trench Worker* – This adult receptor would conduct short-term maintenance and emergency repair activities on underground utilities at the terrestrial portions of OU-E and/or conduct site restoration activities.

- *Recreational Visitors (Passive/Occasional and Frequent)* - Consistent with the approved OU-E BHHERA Work Plan (ARCADIS 2013b), two separate recreational visitor scenarios were evaluated: an occasional visitor and a frequent visitor (such as a jogger) living near the site. The occasional visitor was evaluated as both a child and an adult and was assumed to engage in mainly passive recreational activities (e.g., walking) at a frequency of 50 days per year. The frequent recreational visitor in the terrestrial exposure areas was assumed to visit the terrestrial portions of the site at a frequency of 200 days per year. Young children are not expected to run or walk long distances frequently for exercise; for this reason the frequent visitor was evaluated only as an adult receptor.

- *Commercial/Industrial Worker* - This adult receptor was evaluated in the terrestrial portions of OU-E to assess hypothetical future commercial or industrial uses occurring in OU-E.

Consistent with the OU-E BHHERA Work Plan (ARCADIS 2013b), occasional visitors (i.e., adult and child passive recreators) were evaluated as potential receptors in aquatic areas of OU-E. Human receptors are unlikely to enter the aquatic portions of OU-E and these areas are not easily accessed due to dense vegetation and/or steep gradients. As discussed in Section 2, all ponds in OU-E and delineated wetlands in the Lowland AOC are designated as ESHAs in the Environmentally Sensitive Habitat Areas Delineation Report (ARCADIS 2011b). The California Coastal Act (California Coastal Commission [CCC] 2014) places strict controls on development in ESHAs and stipulates that these areas be protected against any "significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas" (Section 30240). The Coastal Act also indicates that "development in areas adjacent to ESHAs areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas" (Section 30240). As such, the aquatic portions of OU-E will be protected as ESHAs, restricting visitors from entering these areas (e.g., by placement of boardwalks/trails outside of sensitive habitat areas, fencing, and/or signage). Nonetheless, for the aquatic exposure unit, the passive recreational visitor scenario was conservatively evaluated assuming such persons may ignore such provisions and occasionally enter the ponds at a frequency of 50 days per year, resulting in potential exposure to sediment and surface water. This scenario assumes the passive recreator receptors will be exposed to the aquatic portions of OU-E at the same frequency as the passive recreator in the terrestrial portions of OU-E. Alternate pond exposure scenarios are also presented for the adult and child passive recreator receptors assuming potential exposures of 12 days per year.

A potential secondary exposure scenario could include the family dog entering the ponds of OU-E, becoming covered with material (sediment/water), returning to the family, and family members contacting the dog. As noted in Table 6-2, the occasional recreator ingestion rate is based on a 24-hour period and the dermal absorption values (ABSd) presented in Table 6-3 are based on experimental studies that assume 24 hours of exposure. Therefore, secondary exposures that include exposure for longer periods than the time of direct human contact with the subject media are addressed in these factors and a separate evaluation is not presented in this BHHERA to specifically address this potential exposure route.

As noted in Section 5.1.2, individual ponds were also evaluated as separate aquatic exposure areas. The occasional adult and child visitor in individual ponds was conservatively evaluated using an exposure frequency of 50 days per year. Since a lower exposure frequency would be expected in Ponds 1 through 4 because proposed uses in this portion of the site are "industrial" and "urban reserve", an alternate scenario is also presented for the hypothetical adult and child occasional visitor in Ponds 1 through 4 assuming potential exposures of 12 days per year.

6.1.2 Potential Exposure Pathways

Potentially complete and significant exposure pathways for human receptors are presented on Figures 5-1 and 5-2. Based on the assumed activities of the receptors selected for OU-E, the following complete and significant exposure pathways were quantified.

- *Incidental Soil/Sediment Ingestion* - The intake of COPCs from incidental soil/sediment ingestion is directly related to the amount of soil/sediment ingested. Receptors at OU-E may ingest surface soil/sediment particles attached to food, cigarettes, or their hands. This exposure pathway was considered potentially complete for all human receptors and was evaluated quantitatively in the BHHRA. In the terrestrial exposure area, commercial workers and recreators could be exposed to surface soils located in the 0 to 0.5 ft bgs or the 0 to 2 ft bgs interval. During future intrusive work, utility workers and construction workers could come into contact with subsurface soils located in the 0 to 6 ft bgs and 0 to 10 ft bgs interval, respectively. For the aquatic exposure unit, recreators are assumed to have potential exposure to surface sediments located in the 0 to 0.5 ft bgs or the 0 to 2 ft bgs interval of the ponds.

- *Dermal Contact with Soil/Sediment* - Receptors at OU-E may come into direct dermal contact with COPCs in soil/sediment. This exposure pathway was considered potentially complete for all human receptors and was evaluated quantitatively in the BHHRA. In the terrestrial exposure unit, commercial workers and recreators could be exposed to surface soils located in the 0 to 0.5 ft bgs or the 0 to 2 ft bgs interval. During future intrusive work, utility workers and construction workers could come into contact with subsurface soils located in the 0 to 6 ft bgs and 0 to 10 ft bgs interval, respectively. For the aquatic exposure unit, recreators are assumed to have potential exposure to surface sediments located in the 0 to 0.5 ft bgs or the 0 to 2 ft bgs interval of the ponds.

- *Inhalation of Particulates from Soil* - Receptors within the terrestrial portions of OU-E may be exposed to COPCs adhered to airborne surface soil particles. This exposure pathway was considered to be potentially complete for all human receptors in the terrestrial exposure area.

- *Inhalation of Ambient Air* - Considering the prevalence of high wind conditions in the coastal region, exposure to VOCs in ambient air would be minimal. In addition, based on infrequent detections of VOCs at low concentrations across OU-E, inhalation exposure to volatile emissions is considered negligible. Because this is assumed to be an insignificant pathway, inhalation of VOCs in ambient air was not evaluated quantitatively in this BHHRA.

- *Surface Water*- and Groundwater-Related Exposure Pathways - Exposures to groundwater (ingestion and dermal contact) within the terrestrial exposure area are only anticipated during future construction or trench work. As discussed above, exposure to surface waters within the aquatic exposure area is unlikely. However, a wading scenario was conservatively evaluated for the occasional recreational receptor scenario to assess hypothetical exposures to surface water. Groundwater at the site is not a source of drinking water and residential or commercial developments are not consistent within the proposed future scenarios presented for OU-E. As such, the domestic use of groundwater for drinking water is not a complete exposure pathway and was not considered in this BHHRA.

6.1.3 Exposure Point Concentrations

An EPC is an estimate of a COPC concentration to which a hypothetical receptor may be exposed. As noted in Section 5, EPCs related to contact with soil, sediment, groundwater and surface water were estimated using USEPA's ProUCL software program (USEPA 2010); the output files are presented in Appendix E. Residual EPCs and associated results for B(a)P TEQ, Dioxin TEQ, and lead in the terrestrial Lowland AOC are presented in Section 6.4.1. For the terrestrial particulate inhalation pathway evaluation, EPCs of COPCs adsorbed to soil particles and released to air from wind erosion or during invasive soil activities were estimated using agency-developed default particulate emission factors (PEFs) for construction and utility/trench worker activities (DTSC 2005) and non-construction exposure activities (USEPA 2004c). The PEFs are presented in Table 6-1.

6.1.4 Dose (Intake) Estimates

Dose is an estimated daily intake that accounts for receptor-specific information such as exposure duration and exposure frequency. When evaluating exposure to noncarcinogens via the oral and dermal pathways, doses are estimated as average daily doses (ADDs), calculated as the average exposure over the time the receptor is assumed to be exposed to the COPC. When evaluating exposure to potential carcinogens, lifetime average daily doses (LADDs) are calculated by averaging exposure over a 70-year timeframe.

Consistent with Risk Assessment Guidance for Superfund Part F (USEPA 2009a), inhalation exposures were evaluated in a different manner. Instead of doses, an average daily exposure concentration (ADEC) and a lifetime average daily exposure concentration (LADEC) were estimated for noncarcinogens and carcinogens, respectively. Exposures were quantified using the equations recommended by USEPA (1989, 2004c, 2010) for the potentially complete exposure pathways identified previously in Section 6.1.2.

Soil, groundwater, sediment, and surface water EPCs were mathematically combined with applicable receptor-specific exposure parameters to estimate exposures for each related exposure pathway. Exposure parameters to estimate potential exposure to constituents in terrestrial and aquatic exposure areas are consistent with the OU-E BHHERA Work Plan (ARCADIS 2013b). Table 6-2 presents exposure parameters selected for each human receptor.

The equations used to estimate pathway-specific doses are presented below.

6.1.4.1 *Incidental Ingestion of Soil and Sediment*

The doses of constituents associated with incidental ingestion of soil/sediment were calculated as follows:

$$Dose = \frac{C_S * IR_S * CF * FI * EF * ED}{BW * AT}$$

Where:

Dose	=	ADD or LADD (milligrams per kilogram per day [mg/kg-day])
C_S	=	COPC concentration in soil/sediment (mg/kg; equivalent to the exposure point concentration)
IR_S	=	soil/sediment ingestion rate (milligrams per day [mg/day])
CF	=	conversion factor (1×10^{-6} mg/kg)
FI	=	fraction ingested from contaminated source (unitless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kilogram [kg])
AT	=	averaging time (days)

6.1.4.2 *Dermal Contact with Soil and Sediment*

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

$$Dose = \frac{C_S * CF * SA * AF * ABS_d * EF * ED}{BW * AT}$$

Where:

Dose	=	ADD or LADD (mg/kg-day)
C_S	=	COPC concentration in soil/sediment (mg/kg; equivalent to the exposure point concentration)
CF	=	conversion factor (1×10^{-6} mg/kg)
SA	=	skin surface area available for contact (square centimeters [cm^2])
AF	=	soil-to-skin adherence factor (milligrams per square centimeter per day [mg/cm^2-day])
ABS_d	=	dermal absorption factor (unitless) (Table 6-3)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

Consistent with USEPA guidance (2004c), organic COPCs in soil were assigned a dermal absorption factor (ABS_d) value of 0.1 in the absence of chemical-specific values. The dermal absorption factor for VOCs is assumed to be zero, based on the assumption that VOCs will volatilize from soil on skin (USEPA 2004c, DTSC 2011).

6.1.4.3 *Incidental Ingestion of Groundwater and Surface Water*

The doses of constituents associated with ingestion of surface water and groundwater were calculated as follows:

$$Dose = \frac{C_{GW} * IR_{GW} * EF * ED}{BW * AT}$$

Where:

Dose	=	ADD or LADD (milligrams per liter per day [mg/L-day])
C_{GW}	=	COPC concentration in groundwater/surface water (mg/L; equivalent to the exposure point concentration)
IR_{GW}	=	incidental ingestion rate (liters per day [L/day])
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

6.1.4.4 *Dermal Contact with Groundwater and Surface Water*

Absorbed doses of constituents associated with dermal contact to surface water within OU-E or a construction or utility/trench worker contacting groundwater were calculated as follows:

$$Dose = \frac{DA_{event} * SSA * EF * ED * EV}{BW * AT}$$

Where:

Dose	=	ADD or LADD (mg/kg-day)
DA_{event}	=	dermal absorption factor per event (liters per square centimeter per event [L/cm^2-event])
SSA	=	exposed skin surface area (cm^2)
EF	=	exposure frequency (days/year)
EV	=	events per day (event/day)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (days)

The DA_{event} for organic compounds is calculated as follows:

$$If\ t_{event} > t^*,\ then:\ DA_{event} = FA \times K_p \times C_w \left[\frac{t_{event}}{1+B} + 2\ \tau_{event}\left(\frac{1+3\ B+3\ B^2}{(1+B)^2}\right)\right]$$

$$If\ t_{event} \leq t^{*},\ then:\ DA_{event} = 2\ FA \times K_p \times C_w \sqrt{\frac{6\ \tau_{event} \times t_{event}}{\pi}}$$

Where:

t_{event}	=	Event duration (hour/event)
t *	=	Time to reach steady state (hour) = 2.4 τevent
DA_{event}	=	Absorbed dose per event (milligrams per square centimeter per event [mg/cm^2-event])
FA	=	Fraction absorbed water (dimensionless)
K_p	=	Dermal permeability coefficient of compound in water (centimeters per hour [cm/hr])
C_w	=	Concentration in groundwater/surface water (multiplied by conversion factor of 0.001; mg/L)
B	=	Dimensionless ratio of the permeability coefficient across the viable epidermis (ve) (dimensionless)

The DA_{event} for inorganic or highly ionized organic chemicals is calculated as follows:

$$DA_{event} = K_p \times C_w \times t_{event}$$

Where:

DA_{event}	=	Absorbed dose per event (mg/cm^2-event)
K_p	=	Dermal permeability coefficient of compound in water (cm/hr; Table 6-4)
C_w	=	Concentration in groundwater (multiplied by conversion factor of 0.001; mg/L)
T_{event}	=	Event duration (hour/event)

Exposure parameters are presented in Table 6-4.

6.1.4.5 *Inhalation of Fugitive Dust Particulates*

Exposure concentrations (ADECs or LADECs) associated with the inhalation fugitive dust particles from ambient air within the terrestrial exposure area were calculated as follows:

$$ExposureConcentration = \frac{C_a * ET * EF * ED}{AT * CF}$$

and:

$$C_a = C_S * PEF^{-1}$$

Where:

Exposure Concentration	=	ADEC or LADEC (milligrams per cubic meter [mg/m^3])
C_a	=	COPC concentration in air (mg/m^3)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
AT	=	averaging time (days)
CF	=	Conversion factor (24 hours/day)
C_S	=	COPC concentration in soil (mg/kg; equivalent to the exposure point concentration)
PEF	=	particulate emission factor for dust particles (cubic meters per kilogram [m^3/kg])

6.2 Toxicity Assessment

The toxicity values used in this BHHRA for assessing potential carcinogenic risk and noncarcinogenic hazards were derived using the methodologies described in the Site-Wide RAWP (ARCADIS BBL 2008a) and are presented in Tables 6-5 through 6-8.

6.2.1 Treatment of Lead

USEPA recommends the potential hazard associated with lead exposure be evaluated by comparing blood-lead concentrations (using models such as the USEPA Adult Lead Model [ALM]) to the Centers for Disease Control (CDC 1991) target blood-lead concentration of 10 micrograms per deciliter (µg/dL) of whole blood, based on potentially adverse neurological effects in children (CDC 1991). Recent CalEPA guidance (CalEPA 2009a; DTSC 2010e) recommends evaluation of lead using a threshold of an increase in blood-lead levels of 1 µg/dL from baseline conditions. Lead effects were evaluated by comparing EPCs with site-specific, health-based screening values developed using the CalEPA (2009a) LeadSpread model for children and a modified version of the USEPA (2003b, 2007b) ALM model for adults and the DTSC (2007). Specific methods used in the BHHRA to evaluate lead hazards consistent with this new guidance are discussed in Section 6.3.1.

6.2.2 Toxicity Assessment for TPH

To address the lack of chemical-specific criteria for components of petroleum hydrocarbon mixtures, TPH can be generally evaluated through the use of surrogate chemicals. DTSC recommends the use of the following six groups of hydrocarbons for which chemical surrogates for toxicity have been selected:

- C_5-C_8 (aliphatics)
- C_6-C_8 (aromatics)
- C_9-C_{18} (aliphatics)
- C_9-C_{16} (aromatics)
- C_{19+} (aliphatics)
- C_{17+} (aromatics)

These six groups and surrogates, as presented in Table 6-9, were chosen based in part on the TPH work performed by the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG 1997a,b, 1998a,b, 1999) and regulatory agencies such as the Massachusetts Department of Environmental Protection (MADEP 2002 and 2003).

The analytical method used during the site investigations (USEPA Method 8015M with and without carbon ranges) did not provide speciation of TPH into aromatic and aliphatic components. Based on the evaluation previously presented in the *revised Approach for Evaluating Human Health Hazard from Total Petroleum Hydrocarbons* memorandum (ARCADIS 2011c), detected concentrations in each carbon range were apportioned as 75% aliphatic and 25% aromatic. The primary toxic (and aromatic) constituents of TPH (benzene, toluene, ethylbenzene, and xylenes [BTEX] in gasoline and PAHs in diesel) detected in areas of petroleum releases are evaluated individually in the BHHRA. Assuming significant aromatic constituents are present in TPH and evaluating their toxicity using a surrogate chemical counts these constituents twice in the hazard evaluation.

As noted in Section 5, there are two types of TPHg and TPHd data from the historical site investigations. TPHg and TPHd data collected prior to 2005 were not reported according to carbon ranges, but were reported as TPHg C_7-C_{12} and TPHd C_{10}-C_{24}. In 2005, the quantitation and reporting was changed to report TPHg as two carbon ranges (C_6-C_8 and C_8-C_{10}) and TPHd as three carbon ranges (C_{10}-C_{12}, C_{12}-C_{16}, and C_{16}-C_{24}). Reference doses (RfDs) and reference concentrations (RfCs) recommended in the rescinded DTSC guidance (2009c) were applied in the BHHRA as shown in Table 6-9, which provides selected surrogates for chemicals lacking toxicity values. The carbon ranges quantified in site samples do not exactly match the carbon ranges defined in the guidance. Based on the selection of surrogate carbon ranges as shown in Table 6-9, RfDs and RfCs are shown in Tables 6-7 and 6-8, respectively. TPHg C_6-C_8 was not selected as a COPC in site media, and is not discussed further in this section. The RfDs and RfCs selected as surrogates are presented in the following table.

RfDs and RfCs used for TPH Carbon Ranges

OU-E BHHERA Carbon Range	Surrogate Carbon Range	RfD (mg/kg/day)	RfC (mg/m³)
Aliphatic			
TPHg C8-C10	C9-C18	0.1	0.3
TPHd C10-C12	C9-C18	0.1	0.3
TPHd C12-C16	C9-C18	0.1	0.3
TPHd C16-C24	C19-C32	2	*
TPHmo C24-C36	C19-C32	2	*
Aromatic			
TPHg C8-C10	C9-C16	0.03	0.05
TPHd C10-C12	C9-C16	0.03	0.05
TPHd C12-C16	C9-C16	0.03	0.05
TPHd C16-C24	C17-C32	0.03	*
TPHmo C24-C36	C17-C32	0.03	*

*Not developed due to low volatility of the COPCs in this hydrocarbon range. Although exposure via inhalation may occur via C17-C32 TPH in dust, the HERD recommends that a quantitative evaluation of inhalation exposure for C17-C32 not be performed due to the significant uncertainty involved (ARCADIS 2008b).

TPHmo = total petroleum hydrocarbons as motor oil

6.2.3 Treatment of Chlordane and DDT

Alpha and gamma chlordane were detected at OU-E, but there are no toxicity values developed for them. As a result, the concentrations for these two isomers were summed together and toxicity values developed for technical chlordane (includes a mixture of alpha and gamma chlordane) were used in the BHHRA.

DDT, DDD, and DDE are related chemicals and were detected in OU-E. DDT and DDE have identical toxicity values, and DDD is considered the least potentially toxic of the three compounds. As a conservative measure, the concentrations of the three congeners were summed together and evaluated using the toxicity values developed for DDT and DDE.

6.2.4 Treatment of PCBs

For PCBs, DTSC recommends cancer slope factors (CSFs) from the USEPA Integrated Risk Information System (USEPA 2009b), as follows: 2 mg/kg-day^{-1} for high-persistence PCBs such as Aroclors 1260, 1254, and 1248 and 0.4 mg/kg-day^{-1} for low-persistence PCBs such as Aroclor 1242. However, because a total PCB value was estimated (sum of Aroclors or two times the sum of congeners) rather than individual Aroclors, the CSF of 2 mg/kg-day^{-1} was used to develop a conservative estimate of potential risk.

Dioxins and furans were evaluated as aryl hydrocarbon receptor mediated toxicants; however, 12 dioxin-like PCBs were not evaluated as aryl hydrocarbon receptor mediated toxicants. PCBs were evaluated in the BHHRA as a total PCBs which does not consider the contribution of the non-ortho substituted and mono-ortho substituted PCBs to the total dioxin/furan/PCB TEQ. Most of the 12 World Health Organization (WHO) PCB TEFs are small (0.0001 to 0.0003), but the PCB 126 TEF is 0.1 and PCB 169 TEF is 0.03. Therefore, if significant concentrations of these two congeners (PCB 126 and PCB 169) are present within OU-E, the dioxin TEQ risk in this BHHERA could underestimate potential effects of aryl hydrocarbon receptor mediated toxicants. To address this potential uncertainty, available data for PCB 126 and PCB 169 were reviewed. As summarized in Table 4-25 of the OU-E RI, PCB 126 was only detected at one soil location (OUE-HA-030 at 0.00021 (J) mg/kg) out of 45 soil samples collected in the OU-E Lowland area, while no detects were reported for PCB 169 in soil. As summarized in Table 4-32 of the OU-E RI, PCB 126 was not detected in sediment within OU-E. Concentrations of PCB 169 were only detected at two locations in Pond 8 (Pond 8-07 and Pond 8-08) ranging from 0.00044 (J) to 0.00095 mg/kg. Since concentrations of these congeners are low and infrequently detected, the alternate evaluation of PCBs as aryl hydrocarbon receptor mediated toxicants will not impact the conclusions of this BHHERA.

6.2.5 Treatment of Dioxins/Furans

Consistent with USEPA (2009a) and CalEPA (1992) guidelines, dioxin and furan congeners were evaluated using TEFs (Van den Berg et al., 2006). Each dioxin or furan congener was multiplied by the appropriate TEF, resulting in a dioxin TEQ EPC, which was used in the BHHRA. Although source classification evaluation (Appendix G) indicates dioxin/furan concentrations in several samples are consistent with ambient/mixture sources, dioxins/furans were quantitatively evaluated in the human health and ecological RAs.

6.2.6 Arsenic Relative Bioavailability

The relative bioavailability (RBA) of arsenic refers to the difference in the absorption of arsenic by the gastrointestinal system when incidentally ingested in either soil or sediment compared to the absorption of arsenic ingested in water. An RBA factor of 60% was applied directly to quantitative human health ingestion risk assessment for both carcinogenic and non-carcinogenic endpoints (Appendix G). The USEPA (USEPA

2012) published guidance states the default RBA factor for arsenic is 0.6 (60%). The bioavailability of arsenic in soil and sediments is closely related to the site-specific speciation of arsenic in the soil or sediment matrix and geochemistry.

As discussed in Section 4, sediment samples were collected in April 2013 to characterize the speciation of arsenic in sediment at the OU-E Ponds in support of the application of the default 60% RBA for arsenic. Consistent with the OU-E BHHERA Work Plan (ARCADIS 2013b), 13 sediment samples were collected from the OU-E ponds in April 2013 for speciation analysis. Sample locations were biased to select locations with elevated arsenic concentrations, as well as those likely areas for human contact. The purpose of the bias was to provide quality data (total arsenic approaching or greater than 50 mg/kg) for the analyses of the site-specific RBA of arsenic rather than evaluate the extent or distribution of arsenic in the environment.

Sediment samples were sent to Dr. John Drexler of Laboratory for Environmental and Geological Studies at the University of Colorado, Boulder for speciation analyses. As noted in Section 4, speciation analysis was performed using EMPA. The EMPA analysis examines randomly selected particles within a sample population; therefore, sediment samples with higher concentrations of arsenic typically produce more reliable results. Of the 13 sediment samples collected, those with concentrations of total arsenic approaching or greater than 50 mg/kg were selected for EMPA analysis. Specifically, the following four sediment samples were selected for EMPA analysis: Pond 1-02 (45.2 mg/kg arsenic [As]), Pond 3-07 (55.4 mg/kg As), Pond 7-01 (103 mg/kg As), and Pond 7-02 (85.4 mg/kg As).

Analysis of sediment samples by EMPA provide frequencies and relative masses for different arsenic species of particles analyzed using the electron microprobe (Appendix C). The frequencies refer to the number of particles out of the entire population assessed with arsenic of a particular species phase. The relative mass refers to the fraction of the total mass of arsenic in a sample that is related to each species phase identified. A total of seven different arsenic species phases were identified in the four sediment samples collected from the OU-E ponds including: arsenic-iron oxides (AsFeOOH), iron oxides (FeOOH), iron sulfates ($FeSO_4$), clay, pyrite, chalcopyrite, and chromated copper arsenate (CCA). The frequencies of detection for each of these phases are summarized in the following table below.

Table 6-13 Frequency of Particles for Individual Arsenic Species Phases

Arsenic Species Phases	Pond 1-02	Pond 3-07	Pond 7-01	Pond 7 -02
AsFeOOH			1.82%	
FeOOH	82.54%	82.4%	61.36%	76.17%
$FeSO_4$	2.54%			
Clay	14.93%	12.4%	27.86%	21.32%
Pyrite		2.8%		
Chalcopyrite		2.4%	4.48%	
CCA			4.48%	2.51%

FeOOH represents the highest percentage of arsenic-bearing particles in sediment at the OU-E Ponds followed by arsenic adsorbed to clay particles. The relative mass of arsenic is calculated from the particle frequencies based on the specific gravity of each species phase. A summary of the relative mass for each of the arsenic species phases is presented in the following table.

Table 6-14 Relative Mass of Arsenic Species Phases

Arsenic Species Phases	Pond 1-02	Pond 3-07	Pond 7-01	Pond 7 -02
AsFeOOH			42.81%	
FeOOH	94.54%	93.11%	36.15%	76.04%
$FeSO_4$	3.8%			
Clay	1.66%	1.82%	1.57%	3.52%
Pyrite		2.38%		
Chalcopyrite		2.69%	2.95%	
CCA			16.52%	20.44%

The mass of arsenic in sediment at the OU-E Ponds are almost exclusively FeOOH-phase in sediment from Pond 1 and Pond 3, while the principal arsenic species-phase for Pond 7 is either FeOOH or AsFeOOH.

The evaluation of arsenic RBA at the OU-E Ponds was completed by comparing the predominant species of arsenic in site-specific sediments to published data for in vivo RBA results for soils and sediments with similar characteristics. The results of the EMPA analysis indicate that in vivo RBA studies using soil or sediment with arsenic speciation indicating high mass fractions of FeOOH would be most appropriate for evaluating the potential RBA for arsenic in sediment at the OU-E Ponds. Compilation of in vivo RBA studies of arsenic in soil and sediment were completed by the USEPA (2012) and Environmental Security Technology Certification Program (ESTCP; Griffin and Lowney 2012). Results for multiple in vivo studies of arsenic RBA in soil/sediment samples were identified with arsenic speciation dominated by iron oxides. The soil sample sources, relative mass of FeOOH arsenic species phase, and in vivo RBA are summarized in the following table.

Table 6-15 Arsenic Relative Bioavailability for Soils with High Relative Mass of Arsenic-Iron Oxide Species

Soil Sample Source	Relative Mass FeOOH	RBA
Aberjona River TM1	69 %	38 %
NIST 2710	64 %	44 %
NYPS1	66 %	20 %
NYPS2	100 %-	19 %
NYPS3	99 %	28 %
MTSS	70 %	13 %

Source: ESTCP 2012 (Griffin and Lowney 2012)

The in vivo testing results for soils with high relative arsenic mass of FeOOH indicate these soils have relatively moderate arsenic RBA ranging from 13 to 38%. As such, the RfD and CSF values considered in the arsenic ingestion evaluations have been adjusted (refer to Appendix G) using the default arsenic RBA of 60% published by USEPA (2012). Based on the site-specific speciation data for arsenic in sediment, the default 60 percent RBA for arsenic is a conservative estimate of for exposure and risk calculations.

6.2.7 Chemicals Lacking Toxicity Values

Quantitative analyses were not performed on COPCs that lack toxicity values or for which a reasonable toxicity surrogate could not be identified. COPCs lacking values for which surrogates were selected are presented in Table 6-9.

6.3 Risk Characterization

Risk characterization integrates the exposure assessment and toxicity information. The cancer risk and/or noncancer hazard was calculated for each COPC and for each medium and potentially complete exposure pathway. An excess lifetime cancer risk (ELCR) is calculated for compounds identified by CalEPA or USEPA as probable human carcinogens. The cancer risk is defined by DTSC (1994) as “the risk, or theoretical probability of developing cancer from that chemical upon exposure to that medium." Excess cancer risk was estimated by multiplying the LADD by the chemical-specific CSF as shown in the following equation:

$$CSF \times LADD = \text{Excess Lifetime Cancer Risk}$$

The total excess cancer risk at OU-E was calculated by summing the risk for each carcinogen over the exposure media and exposure pathways. As discussed above, the soil/sediment pathway cancer risk estimates for dioxin were not divided by 10 to account for the minimal contribution of soil and dust to the dioxin human body burden.

A hazard quotient (HQ) is calculated for the COPCs. The HQ is the ratio of the estimated dose from exposure to a COPC in a particular medium to the dose that is not expected to result in adverse health effects, other than cancer.

$$HQ = \frac{ADD}{RfD}$$

If the HQ exceeds a value of one, the possibility exists for noncarcinogenic hazard. The HQ is not a mathematical prediction of the severity or incidence of the effects, but rather is an indication that a hazard may exist. DTSC (1994) and USEPA (1989) recommend that the total HI (i.e., the sum of the HQs for all chemicals) not exceed a value of one. As discussed above, the soil/sediment pathway HQ estimates for dioxin were not divided by 10 to account for the minimal contribution of soil and dust to the dioxin human body burden.

Consistent with DTSC (1994) guidance, the BHHRA assumed that ELCRs of greater than 1×10^{-6} or a noncancer HI of greater than one suggest that exposure to COPCs may pose a potential threat to human health. There may be exceptions to these criteria, including elevated background concentrations, other applicable criteria, or specific site circumstances that allow for "a risk management decision to elevate the acceptable screening levels" (DTSC 1994). USEPA (2003c) recommends a range of risks of 1×10^{-4} to 1×10^{-6} (one in ten thousand to one in one million).

6.3.1 Methods Used to Evaluate Lead Hazards

The potential hazard associated with lead exposure was evaluated by comparing lead EPCs to health-based screening levels developed for OU-E, as stated in Section 6.2.1. Based on discussions with DTSC (2010a), lead hazards were evaluated by comparing EPCs (for each exposure area where the maximum detected lead concentration exceeded the site-specific background concentration) to RBTLs developed using modified versions of the USEPA ALM (USEPA 2003a and 2007b) for adults and DTSC's LeadSpread model for children (DTSC 2007 and 2010a; CalEPA 2009b) as follows:

- 385 mg/kg for the commercial/industrial worker (terrestrial only)
- 182 mg/kg for the construction worker and the utility/trench worker (terrestrial only)

- 1,112 mg/kg (child) and 3,212 mg/kg (adult) passive recreational visitor (terrestrial and aquatic assuming 50-day exposure frequency)
- 1,112 mg/kg (child) and 13,282 mg/kg (adult) passive recreational visitor (aquatic assuming 12-day exposure frequency)
- 822 mg/kg for the frequent recreational visitor (terrestrial only).

These RBTLs reflect a 90th percentile value that would result in an incremental 1 microgram per deciliter (µg/dL) increase in blood lead over the background concentrations in soil (22 mg/kg) consistent with recent changes to DTSC lead guidance (CalEPA 2009b; DTSC 2010a).

A detailed description of the models used to evaluate lead and develop the RBTLs is presented in Appendix G. A summary of the lead hazard evaluation for soil and sediment are presented in Section 6.4.1 (soil) and Section 6.4.2 (sediment), and the lead screening is summarized in Tables 6-10 and 6-11. The results based on residual lead soil EPCs after removal of the data points identified as hot spots (Section 5.1.1.1) are discussed in Section 6.4.1.1.

6.4 BHHRA Results

This section summarizes the results for the terrestrial and aquatic exposure units in OU-E and includes an uncertainty analysis. An evaluation of residual EPCs for B(a)P TEQ, Dioxin TEQ, and lead after removal of potential hot spots is also discussed. ELCRs and HIs were estimated to account for the COPCs and impacted media. Human health dose and ELCR and HI estimate tables are provided in Appendix G.

6.4.1 Terrestrial Exposure Area

As described in Section 6.2, potential cancer risk and noncancer hazard were evaluated for commercial/industrial workers, construction workers, utility workers, frequent recreators, and passive (occasional) recreators in the terrestrial exposure unit. In Table 6-12, ELCRs and HIs are shown by soil depth interval for each receptor evaluated in the terrestrial exposure unit. For each value greater than 1×10^{-6} in Table 6-12, a note explains the medium and COPCs that make up the greatest proportion of the risk or hazard.

No background concentrations, RSLs or USEPA ecological soil screening levels (Eco-SSLs) are available for TPH in soil. Site-specific risk-based screening concentrations for TPH for direct contact and indoor air, and site-specific TPH screening levels for the leaching to groundwater pathway were used for the TPH evaluation in the OU-E RI (ARCADIS 2013a). TPHd (leaching to groundwater only) in the Sawmill #1 AOI, TPHd at the Compressor House and Lath Building AOI was found at concentrations greater than PSLs. TPH human health risks do not significantly contribute to the human health risks presented in Appendix G for each receptor.

ELCRs and HIs for receptors in the terrestrial unit are below the target thresholds for potential cancer and noncancer effects, with the exception of the following:

- Construction worker HIs in each of the four exposure intervals (HIs range from 2 to 5 for the 0 to 0.5 ft bgs, 0 to 2 ft bgs, 0 to 6 ft bgs, and 0 to 10 ft bgs exposure intervals), and ELCRs in three of the exposure intervals (ELCRs range from 4 x 10^{-6} to 5 x 10^{-6} in the 0 to 2 ft bgs, 0 to 6 ft bgs and 0 to 10 ft bgs).

- Utility worker ELCRs in the 0 to 2 ft bgs and 0 to 6 ft bgs exposure intervals (ELCRs are 3 x 10^{-6} and 2 x 10^{-6}, respectively).

- Terrestrial recreational visitor (passive) ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals (ELCRs are 2 x 10^{-6} and 6 x 10^{-6}, respectively).

- Terrestrial recreational visitor (frequent) ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals (ELCRs are 4 x 10^{-6} and 2 x 10^{-5}, respectively).

- Commercial/industrial worker ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals (ELCRs = 1 x 10^{-5} and 4 x 10^{-5}).

Dioxin TEQ concentrations in soils in the terrestrial OU-E Lowland AOC represent the largest contributor to potential cancer risk and non-cancer hazard. As shown in Table 5-28, baseline dioxin TEQ soil EPCs are 132 pg/g, 691 pg/g, 395 pg/g, and 326 pg/g in the 0 to 0.5 ft bgs, 0 to 2 ft bgs, 0 to 6 ft bgs, and 0 to 10 ft bgs exposure intervals, respectively. As discussed further below in Section 6.4.1.1, a soil hot spot analysis was conducted to further evaluate these results in accordance with DTSC requests (2014). As further discussed below, dioxin TEQ concentrations in soil samples collected from location DP-052 were identified as the principal contributor to potential risk and hazard. If the dioxin TEQ hot spot soil concentrations are removed, the residual dioxin TEQ EPC decreases to below the site-specific risk-based target level (RBTL) for 2,3,7,8 TCDD-TEQ of 53 pg/g. In turn, assuming this hot spot removal, OU-E non-cancer hazards and cancer risks in the terrestrial Lowland AOC reduce to below 1 and 1 x 10^{-6} respectively.

6.4.1.1 *Terrestrial Hot Spot Analysis*

The approach for the hot spot analysis for the terrestrial Lowland AOC and development of RBTLs are presented in Section 5.1.1.1. Soil hot spot locations are summarized below and are depicted on Figures 5-9, 5-10 and 5-11. As presented in Section 5.1.1.1, the B(a)P TEQ RBTL is based on the current RSL for protection of the commercial/industrial worker, the dioxin TEQ RBTL is based on the back-calculated site-specific value for the OU-E BHHERA occasional recreator, and lead is based on the concentration recommended for the commercial/industrial worker in the HERO HHRA Note Number 3 (DTSC/HERO 2013).

- B(a)P TEQ[7]:
  - Powerhouse and fuel barn AOI: HSA-4.3 (2-2.5);
  - Sawmill #1 AOI: OUE-DP-073 (2-3), OUE-DP-074 (2-3), OUE-DP-075 (2-3), and OUE-DP-026 (2-3.5);
  - Waste treatment and truck dump AOI: OUE-DP-099 (0.5-1.0) and OUE-DP-100 (2.5-3.5);
- Dioxin TEQ:
  - Powerhouse and fuel barn AOI: OUE-DP-052 (0.5-1.5 & 0-0.5);
- Lead:
  - Sawmill #1 AOI: OUE-DP-070 (3-4) and DP-05.57 (0.5-1) ;
  - Powerhouse and fuel barn AOI: OUE-DP-094 (5.5-6) and OUE-DP-090 (5.5-6).

Residual soil EPCs for B(a)P TEQ and Dioxin TEQ assuming removal of the following samples are presented for each exposure depth interval in the following table.

[7] B(a)P TEQ concentrations in the baseline 0 to 0.5 ft bgs interval dataset are already less than the site-specific RBTLs (maximum concentration is 0.24 mg/kg).

Residual Soil EPCs and HHRA RBTLs: B(a)P TEQ and Dioxin TEQ

Constituent	HHRA RBTL	EPCs			
		0-0.5 ft bgs	0-2 ft bgs	0-6 ft bgs	0-10 ft bgs
B(a)P TEQ	0.3 mg/kg	0.0397*	0.0801	0.0618	0.0559
Dioxin TEQ	53 pg/g	6.311	4.85	7.15	8.52

Note:
* A hot spot was not identified for B(a)P TEQ in the 0-0.5 feet bgs depth interval. Therefore, no residual EPC is calculated, and the value presented is the baseline EPC.
mg/kg = milligrams per kilogram
pg/g = picograms per gram

As shown above, assuming hot spots removal, the residual EPCs for B(a)P TEQ and dioxin TEQ for each depth interval are less than the RBTL.

Residual EPCs for lead based on the (1) arithmetic mean, consistent with USEPA recommendations (USEPA 2011b) and (2) the lesser of the maximum and the UCL as EPCs, were calculated assuming the removal of hot spot exposures, and are presented in the following table. It was not necessary to calculate residual EPCs for the 0 to 0.5 ft bgs interval because the maximum lead concentration (i.e., 230 mg/kg) is less than the risk-based RBTL and no hot spots were identified in this interval.

As shown below, residual lead EPCs are below the HHRA RBTLs.

Residual EPCs and HHRA RBTLs: Lead

Constituent	HHRA RBTL	EPCs			Mean		
		0-2 ft bgs	0-6 ft bgs	0-10 ft bgs	0-2 ft bgs	0-6 ft bgs	0-10 ft bgs
Lead	320 mg/kg	39.5	48.7	45.0	25.1	33.81	32.0

Note:
mg/kg = milligrams per kilogram

6.4.2 Aquatic Exposure Area

As described in Section 6.2, cancer and noncancer risks were evaluated for occasional recreators in the aquatic exposure area. In Table 6-12, ELCRs and HIs are shown by sediment depth interval for each receptor evaluated in the aquatic exposure units. For each value in Table 6-12 greater than 1×10^{-6}, the comments explain the medium and COPCs that make up the greatest proportion of the risk or hazard. Two sets of risk estimates are presented for this receptor in Table 6-12: one that considers a recreator exposure frequency of 12 days per year (Section 6.4.2.1) and another that considers the DTSC requested alternative exposure frequency of 50 days per year (Section 6.4.2.2; comment # 4; letter dated January 30, 2013). In addition, individual Pond AOCs were evaluated and results are also presented in Table 6-12. Results for the individual Pond AOCs are discussed in Section 6.4.2.3.

6.4.2.1 *Aquatic AOC - 12 Day Exposure Frequency*

ELCRs and HIs for the occasional recreator are below the target thresholds for potential cancer and noncancer effects when a 12 day exposure frequency is considered.

6.4.2.2 *Aquatic AOC - 50 Day Exposure Frequency*

When assuming the conservative alternative exposure frequency (50 days per year) for the occasional recreator, the HIs are below one in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals. ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals are 5×10^{-6} and 6×10^{-6}, respectively, which are within the range of 1×10^{-4} to 1×10^{-6} established in the NCP (40 CFR 300.430; 2014) and by CalEPA (1996a). Sediment ingestion exposures to dioxin TEQ contribute the greatest proportion of the ELCR for this alternative recreator scenario (54 percent in the 0 to 0.5 ft bgs interval and 63 percent in the 0 to 2 ft bgs interval). Arsenic sediment ingestion exposures account for 40 percent of the 0 to 0.5 ft bgs interval ECLR, and 31 percent of the 0 to 2 ft bgs interval ECLR. Section 6.4.2.3 discusses COPC concentrations in each individual pond AOC. Actual exposures to sediments, are likely to be limited due to site-specific factors that discourage access such as dense vegetation, steep banks, and cold surface water and air temperatures for much of the year.

6.4.2.3 *Aquatic AOC - Lead Hazard*

Target levels were developed and compared against (1) the arithmetic mean, consistent with USEPA recommendations (USEPA 2011b) and (2) the lesser of the maximum and the UCL as EPCs. Table 6-10 compares lead EPC as the arithmetic mean in each depth interval in each exposure area to receptor-specific target levels (Section 6.2.1; Appendix G). Results of the lead in soil and sediment hazard evaluation indicate the arithmetic mean EPCs for lead in the exposure areas in OU-E are below target levels for all receptors.

Table 6-11 compares the lead EPC (95^{th} percentile UCL) in each exposure area in OU-E against receptor-specific target levels. Lead EPCs are below the target levels for all receptors in OU-E. Results of the lead evaluation for individual Pond AOCs are discussed in Section 6.4.2.4.

6.4.2.4 *Pond AOCs*

This section summarizes the results for the individual pond aquatic exposure areas in OU-E (See Section 5.1). ELCRs and HIs were estimated to account for the COPCs and impacted media (Table 6-12). Human receptor dose and ELCR and HI estimate tables are provided in Appendix G. HHRA methodology used for this assessment was identical to the single aquatic AOC. Each pond was evaluated using a conservative exposure frequency of 50 days per year for the adult and child occasional recreator. Since a lower exposure frequency would be expected in Ponds 1 through 4 because proposed uses in this portion of the site are “industrial” and “urban reserve”, an alternate scenario is also presented in this BHHERA for Ponds 1 through 4 assuming potential exposures of 12 days per year.

- For both exposure frequencies of 12 days per year and 50 days per year for Ponds 1 through 4, the HIs are below one.
    - When an exposure frequency of 12 days per year is considered, ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals are both 2 x 10^{-6}. Arsenic (detected concentrations ranging from 4.1 mg/kg and 81.6 mg/kg; EPC = 53.6 mg/kg) and dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 995.5 pg/g; EPC = 493 pg/g) are the primary risk drivers in 0 to 0.5 ft bgs interval via incidental sediment ingestion. In 0 to 2 ft bgs interval, arsenic (detected concentrations ranging from 1.66 mg/kg to 98.9 mg/kg; EPC = 45.8 mg/kg) and dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 1285 pg/g; EPC = 442 pg/g) are the primary risk drivers. COPC-specific ELCRs for arsenic and dioxin TEQ are both less than 10^{-6}.
    - When an exposure frequency of 50 days per year is considered, ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals in the Ponds 1 through 4 are 8 x 10^{-6} and 7 x 10^{-6} respectively. Arsenic (detected concentrations ranging from 4.1 mg/kg to 81.6 mg/kg; EPC = 53.6 mg/kg) and dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 995.5 pg/g; EPC = 493 pg/g) are the primary risk drivers in 0 to 0.5 ft bgs interval via incidental sediment ingestion. In the 0 to 2 ft bgs interval, arsenic (detected concentrations ranging from 1.66 mg/kg to 98.9 mg/kg; EPC = 45.8 mg/kg) and dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 1285 pg/g; EPC = 442 pg/g) are the primary risk drivers.

Summary of Human Health Risks for the Passive Recreator Results in Ponds 1-4

Exposure Frequency	Depth Interval (ft bgs)	Child/Adult Passive recreator*	
		ELCR	HI
12 days/year	0-0.5	2 x 10^{-6}	0.1
	0-2	2 x 10^{-6}	0.1
50 days/year	0-0.5	8 x 10^{-6}	0.5
	0-2	7 x 10^{-6}	0.4

Note: *The ELCRs are cumulative risks for child and adult passive recreators, while the HIs are based on the child recreator.

- Occasional adult recreator HIs and ELCRs for Pond 5 and Pond 9 considering a 50 day per year exposure frequency are below 1 and 1 x 10-6 respectively. HIs for the remaining ponds (i.e., Pond 6, Pond 7, Pond 8 and North Pond), assuming an exposure frequency of 50 days per year are less than 1. ELCRs are greater than 1 x 10^{-6}, but are less than 1 x 10^{-4}.
    - The Pond 6 ELCR is 4 x 10^{-6} in the 0 to 0.5 ft bgs exposure interval. Arsenic (detected concentrations ranging from 0.61 mg/kg to 37.2 mg/kg; EPC = 37.2 mg/kg) and dioxin TEQ (detected concentrations ranging from 3.7 pg/g to 175 pg/g; EPC = 175 pg/g) are the primary risk drivers in the 0 to 0.5 ft bgs interval via incidental sediment ingestion. In the 0 to 2 ft bgs interval, the ELCR for the occasional recreator is 3 x 10^{-6}. In the 0 to 2 ft bgs interval, arsenic (detected concentrations ranging from 0.61 mg/kg to 37.2 mg/kg; EPC = 28.2 mg/kg) and dioxin TEQ (detected concentrations ranging from 2.1 pg/g to 175 pg/g; EPC = 175 pg/g) are the primary risk drivers.
    - Pond 7 ELCRs are 2 x 10^{-5} in both the 0 to 0.5 ft bgs and the 0 to 2 ft bgs depth intervals. Arsenic (detected concentrations ranging from 11 mg/kg to 103 mg/kg; EPC = 103 mg/kg) and dioxin TEQ (detected concentrations ranging from 753 pg/g to 1,227 pg/g; EPC = 1,227 pg/g) are the primary risk drivers in the 0 to 0.5 ft bgs interval via incidental sediment ingestion. In the 0 to 2 ft bgs interval, arsenic (detected concentrations ranging from 11 mg/kg to 115 mg/kg; EPC = 132 mg/kg) and dioxin TEQ (detected concentrations ranging from 753 pg/g to 1,668 pg/g; EPC = 1,688 pg/g) are the primary risk drivers.
    - North Pond ELCRs are 2 x 10-6 (0 to 0.5 ft bgs and 0 to 2 ft bgs). Arsenic (detected concentrations ranging from 1.5 mg/kg to 103 mg/kg; EPC = 103 mg/kg) is the primary risk contributor in the North Pond.
    - Pond 8 ELCRs are 2 x 10^{-6} (0 to 0.5 ft bgs and 0 to 2 ft bgs). Arsenic (detected concentrations ranging from 1.7 mg/kg to 27.6 mg/kg; EPC = 12.3 mg/kg) and dioxin TEQ (detected concentrations ranging from 4 pg/g to 231 pg/g; EPC = 118 pg/g) are the primary risk drivers in the 0 to 0.5 ft bgs interval via incidental sediment ingestion. In the 0 to 2 ft bgs interval, arsenic (detected concentrations ranging from 1.7 mg/kg to 27.6 mg/kg; EPC = 11.2 mg/kg) and dioxin TEQ (detected concentrations ranging from 4 pg/g

to 231 pg/g; EPC = 110 pg/g) are the primary risk drivers. From a practical standpoint, exposure to the sediments in Pond 8 for any duration is remote due to site-specific factors that discourage access such as dense vegetation, steep banks, and cold surface water and air temperatures for much of the year. From a risk analysis standpoint, arsenic concentrations in Pond 8 are comparable to background, so arsenic ECLRs are not associated with site conditions for the Pond 8 AOC. When the Pond 8 occasional recreator is evaluated without considering background arsenic exposures, the resulting cumulative ELCR in Pond 8 is 1×10^{-6}.

Lead was evaluated in each pond consistent with methods presented above, using the arithmetic mean and the lesser of the maximum and the UCL as EPCs. Table 6-10 compares lead EPC as the arithmetic mean in each depth interval and Pond AOC to receptor-specific target levels. Results of the lead in sediment hazard evaluation indicate the arithmetic mean EPCs for lead in the Pond AOCs in OU-E are below target levels for all receptors. Table 6-11 compares the lead EPC (95^{th} percentile UCL) in each Pond AOC in OU-E against receptor-specific target levels. Lead EPCs are below the target levels for all receptors in OU-E.

6.5 Uncertainty Analysis

This section discusses the uncertainties associated with the BHHRA. Within the four steps of the risk assessment process, assumptions must be made due to a lack of absolute scientific knowledge. Some of the assumptions are supported by considerable scientific evidence, while others have less support. Assumptions introduce some degree of uncertainty into the risk assessment process. The exposure parameter assumptions used in the BHHRA reflect estimates based on upper-bound exposure estimates and the BHHRA evaluation includes conservative assumptions to demonstrate that human health and the environment are protected. Therefore, when the assumptions are combined, it is much more likely that actual risks are overestimated rather than under-estimated.

The assumptions that make the largest contribution to uncertainty in this risk assessment are discussed within the sections below.

6.5.1 Data Evaluation

The COPC identification methods used in this assessment are consistent with USEPA (1989) guidelines. The inclusion of known human carcinogens detected in less than 5% of the samples addressed DTSC concerns and may result in an overestimate of cancer risk. As discussed in Section 5, conservative data management methods were selected to develop the BHHRA data sets. For instance, when a duplicate sample was reported as a non-detect and the main sample was reported as a detected value, only the detected value was selected for inclusion in the dataset. Also, for summed analytes (e.g., total DDT, total chlordane, dioxin TEQ), non-detect results were replaced with detected proxy values, as described in

Section 5. This data management step leads to an overestimate of concentrations at sampling locations where COPC were reported as non-detects

Screening metals against background levels may impact the risk assessment significantly. If the background levels are inappropriately low, the result will be a higher number of COPCs and potentially higher risk estimates that are actually associated with ambient conditions and not site-related influences. If the background levels are inappropriately high, a lower number of COPCs will be evaluated and result in an underestimate of risks. In general, high confidence exists in the site-specific background levels, as the datasets are robust. However, the overall method for selecting background levels has subjective elements with the goal of resulting in a conservative (health-protective) comparison. Additionally, because a 99th percentile value was used to represent the upper-bound concentration of the background population, on average, 1 in 100 samples will be classified as site-related when they are actually within the background population. The maximum site COPC concentrations were used as a conservative site comparison to determine the applicability of background.

6.5.2 Receptors Evaluated and Relevant, Complete, and Significant Exposure Pathways

Based on assessment of potential human receptors likely to be present at OU-E, the commercial/industrial worker, the construction worker, the utility/trench worker, and the two recreational visitors (adult frequent and child/adult passive) were evaluated in the BHHRA. The passive recreational visitor was also evaluated in the aquatic exposure area, despite the limited potential for these exposures to occur. Based on the current and projected future land use scenarios (Mill Site Coordinating Committee 2012; Figure 2-6), no other receptors are expected to have higher exposures to site-related COPCs. Exposure pathways considered complete and significant were quantitatively evaluated for these receptors. The BHHRA quantified impacts associated with some exposure pathways (i.e., recreational exposures to sediment and surface waters) that are unlikely to occur. The inclusion of such pathways was conservative and contributes to an overestimate of potential health impacts.

6.5.3 General Exposure Assessment Methodology

The exposure assessment relied on a number of different exposure intake assumptions, many of which were based on statistical analyses of human populations. A reasonable maximum exposure assessment (the “highest exposure that is reasonably expected to occur at the site” [USEPA 1989]) was conducted, and in some cases (as noted in Tables 5-1 through 5-8) EPCs were based on maximum detected concentrations, which will result in an overestimate of health impacts at OU-E.

ADDs of COPCs to which receptors are potentially exposed were calculated based on assumptions about the frequency and intensity of potential exposures. The BHHRA does not assume that engineering controls or personal protective equipment (PPE) will be used during worker activities. Future construction activities are likely to occur under the guidance of a soil management plan and/or site specific health and safety plan and, therefore, workers will be protected from potential exposures via the use of engineering controls such as dust suppression or PPE, such as gloves. As such, the actual intensity of exposure during construction work is likely to be much lower than assumed by the BHHRA and, therefore, the potential health risks discussed here are overestimates.

In HHRA Note 2 (DTSC/HERD 2009) entitled "*Remedial Goals for Dioxins and Dioxin-like Compounds for Consideration at California Hazardous Waste Sites*", the soil/sediment pathway risk estimates for dioxin are divided by 10 to account for the minimal contribution of soil and dust to the dioxin human body burden as shown in the University of Michigan Dioxin Exposure Study (Garabrant 2008 and 2009) and similarly documented in a study of women in West Virginia (Diliberto 2008). This adjustment was not accounted for in the risk estimates presented in this report. Therefore, the dioxin TEQ-specific risks presented in this BHHERA are an overestimate of potential soil and sediment exposures. Most importantly, if the methods used in HHRA Note 2 are applied to the sediment pathway risks for dioxin TEQ, the dioxin TEQ-specific ELCRs for the occasional (passive) recreator in the 50 day scenario would be below 1×10^{-6} in all individual Ponds, with the exception of Pond 7.

6.5.4 Evaluation of Ambient Carcinogenic PAH Concentrations

In the BHHRA, each PAH identified as a COPC within an exposure area is evaluated separately. Carcinogenic PAHs can be converted to benzo (a) pyrene (B(a)P) equivalents for comparison to published ambient concentrations of B(a)P equivalents. DTSC recommended using the 95% UCL urban background B(a)P equivalent values reported for northern California in the DTSC Advisory, *Use of the Northern and Southern California PAH Studies in the Manufactured Gas Plant Site Cleanup Process* (DTSC 2009d). B(a)P equivalents in soil in OU-E are shown as B(a)P TEQ in Tables provided in Section 5. The comparison found that B(a)P TEQ EPC concentrations in OU-E are below or similar to the 95% UCL background value of 0.4 mg/kg listed in the DTSC Advisory.

6.5.5 Route-to-Route Extrapolation and Bioavailability

Route-to-route extrapolations were used to evaluate noncarcinogenic effects resulting from potential exposure to organic constituents. Oral RfDs were used to evaluate dermal exposure to some COPCs. There is considerable uncertainty associated with the absorption of constituents via different routes of exposure. This uncertainty may contribute to an overestimate or underestimate of risk.

The approach for BHHRA used the default arsenic RBA of 60% published by USEPA (2012). Based on the site-specific speciation data for arsenic in sediment, the default 60% RBA for arsenic is a conservative estimate of bioavailability to base exposure and risk calculations and appears to overestimate potential arsenic risks by 30 to 50 percent higher than they would be if a site-specific RBA was used.

6.5.6 Use of Surrogate Toxicity Values

Surrogates selected for compounds without toxicity values are presented in Table 6-9. Surrogates were selected (noncarcinogens only) based on similar molecular weight, chemical structure, chemical metabolism, and environmental fate. Additionally, surrogates for inhalation exposure were selected only for VOCs because the toxic endpoints of non-volatile compounds such as metals are heavily dependent on the route of exposure.

DDT, DDE, and DDD concentrations were combined and treated as one COPC. The most conservative toxicity values were used to evaluate these compounds. This approach will result in an overestimate of risk. Similarly alpha and gamma chlordane concentrations were combined and in the absence of available information, the toxicity values developed for technical chlordane was used to evaluate these congeners. Because technical chlordane consists of both the alpha and gamma congeners, this approach is not likely to result in an underestimate of risks.

USEPA developed three different toxicity values for Aroclors: high risk and persistence; low risk and persistence; and lowest risk and persistence. As a conservative measure the most conservative toxicity value (high risk and persistence) was used to evaluate Aroclors. This approach will result in an overestimate of risks.

6.5.7 General Risk Characterization Methodology

The risk of adverse human health effects depends on estimated levels of exposure and on dose-response relationships. Once exposure to and risk from each of the selected compounds is calculated, the total risk posed by exposure to each media is calculated by combining the health risk contributed by each compound. Where COPCs do not interact, do not affect the same target organ, or do not have the same mechanism of action, summing the risks for multiple COPCs results in an overestimate of risk posed by the site. However, in order not to understate the risk, it is assumed that the effects of different compounds may be added together. While greater than additive effects (synergism) among compounds with effects on the same target organ are possible, assuming a cumulative toxicological effect is expected to conservatively estimate health risks.

7 Ecological Risk Assessment

The OU-E specific approach to the ecological risk assessment is based on constituent sources, exposure pathways, and receptors identified in the upland and aquatic CSMs presented on Figures 5-1 and Figure 5-2, respectively. Methods for the exposure assessment (e.g., EPC estimation, daily dose estimates, and effects assessment) are consistent with the Site-Wide RAWP (ARCADIS BBL 2008a) as amended in the OU-E BHHERA Work Plan (ARCADIS 2013b). In addition to baseline risk characterization, a hot spot analysis was conducted (Section 5.1.1.1) for the terrestrial Lowland AOC. Comparisons of dioxin TEQ and lead residual EPCs, following hot spot removal, to DTSC selected screening values are also presented in the ERA.

7.1 Exposure Assessment

The following sections describe the exposure assessment for the ERA. This includes defining exposure areas and calculating EPCs. EPCs are media-specific conservative estimates of constituent concentrations to which a receptor may be exposed. As discussed in Section 5, two exposure areas were evaluated for the ERA (i.e., terrestrial exposure area [i.e., OU-E Lowland AOC] and aquatic exposure area [i.e., combined pond AOCs]). In addition, individual Pond AOCs were evaluated as an alternate exposure scenario and results are discussed in Section 7.3.4. Soil, sediment, and surface water EPCs for the ERA are summarized in Tables 5-14 through 5-16. Exposure parameters, bioaccumulation factors, bioaccessibility factors, and TRVs used in the exposure estimates are presented in Tables 7-2 through 7-5 and 7-13. Appendix I also presents exposure estimate information and summary spreadsheets outlining the exposure estimate calculations. Tables I-24 and I-25 in Appendix I present example step-by-step calculations for ornate shrew exposure to dioxin and lead in the terrestrial exposure area. The approach for developing exposure estimates for specific receptors is described in the following sections.

7.1.1 Assessment and Measurement Endpoints

Assessment endpoints (AEs) are selected based on the ecological receptor groups and complete exposure pathways identified in the CSM. AEs identify ecological values at the site to be protected. Measurement endpoints (MEs) are developed as a means of measuring potential ecological effects to AEs and assessing whether potential risk is associated with COPC concentrations in each medium (USEPA 1997). AEs and MEs are consistent with the Site-Wide RAWP (ARCADIS BBL 2008a) and are presented in Table 7-1.

7.1.2 Direct Contact Exposure for Plants, Invertebrates, and Amphibians

For plants, soil invertebrates, and sediment invertebrates, exposure is estimated based on soil, sediment, and surface water COPC concentrations. For these receptors, the exposure estimate is simply the soil, sediment, or surface water EPC described in Section 5.4 for each exposure area compared to screening values. Porewater was evaluated by comparing individual results to applicable surface water screening levels. Additionally, invertebrates potentially exposed to PAHs and pesticides in sediment were evaluated using equilibrium partitioning sediment benchmarks (ESBs) in accordance with USEPA guidance (2003b and 2008). The effects assessment for direct contact exposure to lower trophic level receptors is further discussed in Section 7.2.1. Potential amphibian effects in OU-E were also assessed through direct contact exposure by comparing surface water EPCs to screening values as discussed in Section 7.2.4.

7.1.3 Food Web Exposure for Wildlife

Wildlife receptors may be exposed to site-related COPCs via direct exposures and via ingestion of COPC that bioaccumulate into prey. Wildlife receptors evaluated in this ERA include herbivorous, invertivorous, and carnivorous birds and mammals (Table 7-2).

7.1.3.1 *Receptor Daily Dose Equation*

To account for food-web exposures, a standard dose model was used to estimate COPC daily intake via ingestion (USEPA 1993). The dose model uses the general equation as follows:

$$Dose = \frac{SUF \times \{IR_{food}\left[\left(C_{prey} \times Pd_{prey}\right) + \left(C_{invert} \times Pd_{invert}\right) + \left(C_{plant} \times Pd_{plant}\right) + \left(C_{media} \times Pd_{media}\right)\right] + \left[IR_{water} \times C_{water}\right]}{BW}$$

Where:

Dose	=	estimated daily dose of COPC from ingestion (mg/kg body weight/day)
SUF	=	site use factor (unitless)
IR_{food}	=	amount of food ingested per day (kg [dry weight])/day)
C_{prey}	=	EPC of COPC in prey items (mg/kg dry weight)
Pd_{prey}	=	proportion of diet from prey items (unitless)
C_{invert}	=	EPC of COPC in invertebrate items (mg/kg dry weight)
Pd_{invert}	=	proportion of diet from invertebrate items (unitless)
C_{plant}	=	EPC of COPC in plant items (mg/kg dry weight)
Pd_{plant}	=	proportion of diet from plant items (unitless)
C_{media}	=	EPC of COPC in media (i.e., EPC in water [mg/L] or soil and sediment [mg/kg-dry weight])
Pd_{media}	=	proportion of diet from soil, sediment, or water (unitless
IR_{water}	=	amount of drinking water ingested per day (L/day)
C_{water}	=	EPC of COPC in drinking water (mg/L)
BW	=	body weight (kg)

The dose model inputs into the daily dose equation are briefly explained below, as applicable to the receptors and pathways evaluated for OU-E.

7.1.3.2 *Species-Specific Exposure Parameters*

The above model inputs, except for C_{prey}, C_{invert}, C_{plant} and C_{media}, are receptor-specific. Receptor-specific inputs are based on USEPA (1993) and peer-reviewed literature. Exposure parameters are presented for each selected representative receptor species in Table 7-2, consistent with the OU-E BHHERA Work Plan (ARCADIS 2013b).

7.1.3.3 *Derivation of Media and Tissue Concentrations*

The exposure parameters, C_{prey}, C_{invert}, $C_{plant,}$ and C_{media}, are environmental media concentrations calculated for each of the OU-E exposure areas separately. In the ERA, C_{media} was the EPC reported in the media of interest. C_{prey}, C_{invert}, and C_{plant} are the COPC concentrations in tissue as estimated by literature-based or site-specific bioaccumulation equations. When a statistically significant relationship between the site abiotic and biotic media was observed, COPC concentrations were modeled using the EPC in the relevant site media (i.e., soil or sediment) and a conservative estimated uptake regression model. When a statistically significant relationship between the abiotic and biotic media was not observed, the 95% UCL of site-specific tissue concentration was used as the EPC. When the relationship between abiotic and biotic media is linear, bioaccumulation factors (BAFs) follow the general equation below.

$$C_{tissue} = C_{media} \times BAF_{media-tissue}$$

Where:

C_{tissue}	=	Modeled COPC concentration in prey (plants, invertebrates, small mammals)
C_{media}	=	COPC EPC for relevant media (soil, sediment)
$BAF_{media\text{-}tissue}$	=	BAF between relevant media and tissue (prey, invertebrate, or plant);

Alternatively, a regression equation, which can be log-based, similar to that presented below can be used to estimate bioaccumulation.

$$C_{tissue} = mC_{media} + b$$

Where:

m = the slope of the line

b = the y intercept

BAFs were selected from the following sources. If site-specific data were available, these were preferentially used over literature-based BAFs.

- *Data Summary Report – Additional Investigation Pond 8 Sediment* (ARCADIS 2011d).
- *Remedial Investigation Report, Operable Unit A Coastal Trail and Parkland Zone* (ARCADIS BBL 2008c).

- Guidance and peer-reviewed literature as cited in Tables 7-3 and 7-4.

Application of site-specific bioaccumulation data generated from Pond 8 to other Pond AOCs is appropriate in the absence of pond AOC specific-data. BAFs for organic constituents were normalized to organic carbon and lipid content. When bioaccumulation regressions were significant, these regression equations were applied to other Pond AOCs assuming a conservative estimate of organic content for the ponds (i.e., the 95% lower confidence limit of the mean of all available sediment organic carbon data [12.8%]) and an average lipid content of invertebrates used in the bioaccumulation studies (i.e., 1.3%). The surface sediment TOC data for each of the Pond AOC, including data collected through the 2013 porewater sampling event, were reviewed and statistically demonstrated, using analysis of variance testing, that the differences between mean TOC values in each Pond AOC were statistically insignificant at a p-value of 0.05 (Appendix K[8]). Therefore, use of these regressions normalizes for organic carbon content that influences organic constituent bioaccumulation. Tables 7-3 (soil) and 7-4 (sediment) present the COPC-specific BAFs, regressions, or 95% UCL values used in the ERA for each media. For site-specific data the following approach was used:

- For inorganics, bioaccumulation regressions were based on unnormalized data.
- For organics, if lipid and TOC data were available, bioaccumulation regressions were based on TOC and lipid normalized data.
- For organics, if TOC or lipid data were not available, bioaccumulation regressions were based on unnormalized data.

For organics, if lipid data were unavailable, bioaccumulation regressions were compared between data sets using 1). unnormalized tissue data and TOC normalized soil/sediment data and 2). unnormalized tissue data and unnormalized soil/sediment data. Selection of the regression to be used followed the decision matrix below:

- If neither regression was significant, the 95% UCL of the tissue data for the COPC was used to estimate tissue in exposure models.
- If one of the two regressions was significant, the significant regression was used to estimate tissue concentrations in exposure models.

[8] At the five percent significance level ($\alpha = 0.05$), we concluded that there is not a statistically significant difference in mean TOC concentrations between the seven Pond AOCs (p-value = 0.135; Table K-3).

- If both regressions were significant, the regression with the lower p-value was used to estimate tissue concentrations in exposure models.

For constituents without BAFs, models for surrogate constituents (similar structure and function) were used. In mammalian models a BAF of one was assumed for pesticides for which BAFs were unavailable. Chemicals with low octanol-water partitioning coefficient (log K_{ow}) values generally do not bioaccumulate (CalEPA 1996b, USEPA 2000). Only COPCs with the potential to bioaccumulate were evaluated for the food ingestion pathway, generally with log K_{ow} values greater than 3.5 (USEPA 2000). VOCs and ionic compounds with high water solubility and low log K_{ow} were assumed to not bioaccumulate. Therefore, BAFs were equal to zero for such compounds (Tables 7-3 and 7-4). As the VOCs found onsite were at low concentrations and have log K_{ow} values less than 3.5, these compounds are evaluated for soil ingestion only. Mammalian BAFs for PAHs were also assumed to be negligible, as mammals metabolize PAHs and are not expected to retain them in tissues (USEPA 2011a). Therefore, the ingestion of COPCs in prey items was assumed to be an insignificant exposure pathway for VOCs and PAHs in small mammals. Calculations for concentrations of COPCs in plants, invertebrates, and prey tissue are presented in Appendix I.

7.1.3.4 *Bioaccessibility*

The use of total COPC concentrations provides a conservative exposure estimate, because it assumes that receptors will absorb 100% of the ingested constituent. To cause adverse effects to a receptor, ingested constituents must be bioavailable (i.e., in a state that is biologically available), and bioaccessible, meaning they must be dissolved in the gastrointestinal tract of the organism (Alexander 2000). The inclusion of bioaccessibility during ecological risk assessment allows for a more realistic estimate of constituent exposure (Kelley et al. 2002).

To better estimate potential concentrations of constituents to which a receptor is actually exposed, bioaccessibility factors were incorporated into the dose models when available. For the purposes of the ERA, bioaccessibility data that pertain to soil are assumed to be comparable to bioaccessibility in sediment. Table 7-5 presents the selected bioaccessibility factors for metals and dioxin. Evaluations of literature data used to support selection of these values are presented below.

Kaufman et al. (2007) used models to simulate gastric conditions of mammalian (i.e., eastern cottontail [*Sylvilagus floridanus*] and short-tailed shrew [*Blarina brevicauda*]) and avian (i.e., American robin [*Turdus migratorius*]) receptors to investigate the proportion of lead in soil, earthworms, and vegetation mobilized into digestive fluids (i.e., the bioaccessible fraction).

In the mammalian gastric model, bioaccessible lead averaged 66% for soil, averaged 77% for earthworm tissue, and averaged 50% for vegetation. In the avian gizzard model, the bioaccessible fraction of lead averaged 53% for soil and averaged 73% for earthworm tissue (Kaufman et al. 2007). These average values were selected for use in the exposure models. The bioaccessible fraction of lead in plant tissue for avian species is assumed to be 50%, consistent with the mammalian gastric model.

Few data are available that discuss bioaccessibility of zinc to ecological receptors. One study by Pelfrene et al. (2010) evaluated the bioaccessibility of cadmium, lead, and zinc in humans exposed to contaminated topsoil near smelters. The study showed that zinc was less bioaccessible than lead. Turner et al. (2000 and 2008) investigated zinc bioaccessibility in model marine invertebrate and fish gastric systems. Data indicated less than 1% to 58% of zinc in sediment was potentially bioaccessible to marine invertebrates and fish. Therefore, bioaccessibility factors for ecological receptors for lead are assumed to be a conservative surrogate for zinc.

Saunders et al. (2011) evaluated bioaccessibility of total arsenic in soil to meadow voles (*Microtus pennsylvanicus*) at five locations in Canada. Median bioaccessibility at each location ranged from below detection to 21%, with an average of 13%. Due to the lack of adequate information regarding bioaccessibility of arsenic in diets of ecological receptors, and the observations that arsenic bioaccessibility in soil is lower for mammals (Saunders et al. 2011) than it is for lead (Kaufman et al. 2007), the values for lead for dietary bioaccessibility are considered sufficient to be used as a surrogate in the dose models.

In a study by Fries and Marrow (1975), rats were given TCDD in a laboratory prepared diet continuously for 42 days. Fries and Marrow (1975) reported the absorption of TCDD into the tissue to be 50 to 60%, with an average of 55%. Fifty-five percent bioaccessibility was used in the diet for mammalian exposure models.

Swine and rats have been used most frequently in studies to assess the relative bioavailability of dioxin from soil (Budinsky et al. 2008, Wittsiepe et al. 2007, Finley et al. 2009, Lucier et al. 1986, Shu et al. 1988). In the swine studies, the total TEQ relative bioavailability average was 28%. In the rat studies, the total TEQ relative percent bioavailability average was 41%. The mean of these is 35% (USEPA 2010). Thirty-five percent bioaccessibility in soil was used for mammalian exposure models.

7.2 Effects Assessment

The effects assessment identifies toxicological effects data used as benchmarks to compare to site COPC exposure concentrations or doses. In general, benchmarks were selected to represent conservative thresholds for potential toxic effects.

7.2.1 Plant and Invertebrate Direct Contact Toxicity

Direct contact ecological screening values for soil (plants and soil invertebrates) and sediment (plants) are presented in Table 7-6 and 7-7. Exposure to plants from COPCs in sediment was evaluated using terrestrial plant benchmarks as surrogates. Benthic organism exposure to COPC in sediment was initially evaluated using consensus based threshold effect concentrations (TECs) and preliminary effect concentrations (PECs) from MacDonald et al. (2000) presented in Table 7-8. Sources and derivation of screening levels are available in the Appendix D of the OU-E RI (ARCADIS 2013a). Following the TEC and PEC screening, potential risk to benthic organisms exposed to metals partitioning from sediment to porewater were evaluated through comparison of porewater concentrations to freshwater ecological chronic criteria for surface water (Appendix D of the OU-E RI [ARCADIS 2013a]; Table 7-9). Additional evaluation of benthic organism risk from PAHs and pesticides in sediment was evaluated though ESBs in accordance with USEPA (2003b and 2008). Additional PAH and pesticide analyses are discussed in Sections 7.2.1.2 and 7.2.1.3.

7.2.1.1 *Dioxins*

Dioxin toxicity is expressed via the aryl hydrocarbon receptor in vertebrates. However, invertebrates lack the aryl hydrocarbon receptor, and aryl hydrocarbon receptor homologues identified in invertebrates have been shown to not bind dioxin compounds (Céspedes et al. 2010, Hahn 2002, West et al. 1997). Furthermore, toxicity testing conducted on various invertebrate species has shown no toxicity associated with tissue concentrations up to 9.5 mg/kg lipid (West et al. 1997). Therefore, dioxin toxicity to terrestrial or aquatic invertebrates is not considered further in this OU-E BHHERA.

7.2.1.2 *PAHs*

ARCADIS evaluated potential risk to benthic organisms from exposure to PAHs in sediment three ways. One-carbon (i.e., total organic carbon) and two-carbon (i.e., natural organic carbon and black carbon) equilibrium partitioning (EqP) models were conducted to estimate potential porewater concentrations to which benthic organisms could be exposed (Table 7-10). Additionally, direct measurements of porewater PAH concentrations were made through SPME laboratory analyses. These three methods allowed for a multiple line of evidence approach to evaluate potential risk to benthic organism from exposure to the bioavailable fraction of PAHs associated with site sediment (i.e., PAHs that partition from sediment to the porewater dissolved phase).

The one-carbon EqP model was conducted following USEPA (2003b) guidance. The USEPA (2003b) EqP method estimates PAH porewater concentrations based on partitioning behavior between sediment associated total organic carbon and porewater. The two-carbon EqP model estimates PAH porewater concentrations based on partitioning from sediment associated natural organic carbon (i.e., the difference between the measured total organic carbon and measured black carbon), sediment associated black carbon, and porewater. The two-carbon partitioning model uses the following equation (Accardi-Dey and Gschwend 2002):

$$C_S = f_{OC}*K_{OC}*C_W + f_{BC}*K_{BC}*C_W^n$$

Where:

C_S = the concentration in sediment,

f_{OC} = the fraction of natural organic carbon in sediment,

K_{OC} = the natural organic carbon partitioning coefficient,

C_W = the concentration in porewater,

f_{BC} = the fraction of black carbon in sediment,

K_{BC} = the black carbon partitioning coefficient,

n = the Freundlich isotherm exponent.

C_S, f_{OC}, and f_{BC} were measured analytical values. K_{OC} was calculated based on USEPA (2003b) guidance. K_{BC} was calculated based on a regression of octanol-water partition coefficients against K_{BC} values assuming a Freundlich isotherm exponent of 0.7 (Koelmans et al. 2006). The Freundlich isotherm exponent was assigned a value of 0.7 based on information presented in Hauck et al. (2007) and Koelmans et al. (2006). Using Microsoft Excel Solver, ARCADIS iteratively solved for the C_W concentration based on the other known values presented in the partitioning equation.

Porewater concentrations estimated in the one- and two-carbon models were compared to final chronic values (FCVs) presented in USEPA (2003b) guidance. Porewater concentrations estimated from analytical values for detectable concentrations of PAHs (i.e., non-detect values for PAHs were assumed to be 0) were divided by their respective FCV to obtain a HQ. Following USEPA (2003b) guidance, HQ values at each location were summed to obtain a HI as the final indicator of potential risk to benthic organisms (i.e., HIs greater than or equal to one indicates that a potential risk may be present that should be evaluated further).

Potential risks were also evaluated by comparing SPME porewater analytical data to FCVs presented in USEPA (2003b) guidance. Analytical values for detectable concentrations of PAHs (i.e., non-detect values for PAHs were assumed to be 0) were divided by their respective FCV to obtain a HQ. To parallel the sediment partitioning analysis, HQs were summed to obtain a HI as the final indicator of potential risk.

7.2.1.3 *Pesticides*

This ERA evaluated potential risk to benthic organisms from exposure to pesticides in sediment using organic carbon EqP methods for non-ionic organic compounds outlined by the USEPA (USEPA 2008).

Constituents were evaluated on a point-by-point basis using these methods if the EPC exceeded the TEC in an exposure unit (see Section 7.2.1). For the EqP analysis, the constituent-specific secondary chronic value (SCV) was used if a FCV was unavailable. Organic carbon normalized pesticide concentrations were compared to equilibrium partitioning sediment guidelines to assess potential risk (Table 7-11).

7.2.2 Amphibian Direct Contact Toxicity

Direct contact COPC exposures to amphibians were assessed in this ERA by comparing surface water concentrations to applicable screening levels, as presented in Table 7-12. Amphibian-specific chronic water toxicity reference values (TRVs) were selected for surface water COPCs based on the LC_{10} values developed by Westerman et al. (2003). Westerman et al. (2003) developed a screening-level tool considering relative tolerance of amphibian species, based on laboratory toxicity test results on the embryo-larval stage of development (i.e., the most sensitive amphibian developmental stage). When multiple LC_{10} values were available, the lowest value was conservatively selected.

7.2.3 Food Web Toxicity Reference Values (for Wildlife)

COPC exposures to wildlife (herbivorous, invertivorous, and carnivorous birds and mammals) occur via ingestion of media and prey. Food-web TRVs are used to evaluate potential effects to wildlife, and represent a COPC that is protective of a receptor. The selection hierarchy for the low TRV (i.e., no-observed adverse effect level [NOAEL]) TRVs for the effects assessment is consistent with the Site-Wide RAWP (ARCADIS BBL 2008a). The selection hierarchy for the high TRV (i.e., lowest observed adverse effect level [LOAEL] TRV is consistent with methods updated in the OU-C/OU-D RI (ARCADIS 2011a). Table 7-13 presents TRVs and the source of each value. The following hierarchy was used to select TRVs, and other values are provided only for reference: Eco-SSL, Region 9 Biological Technical Assistance Group, and Sample et al. (1996).

7.2.4 Toxicity Assessment for Specific Classes of Chemicals

The potential cumulative effect of specific classes of chemicals was evaluated for PAHs, VOCs, and dioxins/furans. Total PAH exposure in upper trophic levels was separated into two classes based on molecular weight (i.e., LMW and HMW PAHs). Because the availability of individual PAH TRVs is limited, B(a)P was used as a surrogate for HMW PAHs and naphthalene was used as a surrogate for LMW PAHs. Dioxins/furans exposure in upper trophic level receptors was evaluated by applying World Health Organization 2005 TEFs (Van den Berg et al., 2006) to individual congeners, summing the resulting values, and comparing the 2,3,7,8-TCDD TEQ concentrations to the Oak Ridge National Laboratory TRV for 2,3,7,8-TCDD. Xylenes were evaluated as a mixture and NOAEL and LOAEL for xylenes were obtained from Sample et al. (1996).

7.3 Risk Characterization

The HQ was used to assess potential risks for a given COPC. For direct exposure, the HQ represents the ratio of estimated EPC to a toxicity benchmark.

$$HQ = \frac{EPC}{Direct\ Contact\ Benchmark\ or\ EcoSSL}$$

For food-web assessment, the HQ represents the ratio of an estimated daily dose to a wildlife TRV.

$$HQ = \frac{Dose}{TRV}$$

Where:

HQ	=	hazard quotient
EPC	=	exposure point concentration in exposure media (mg/kg or micrograms per liter [µg/L])
Dose	=	daily intake of a COPC via ingestion normalized by receptor body weight (mg/kg-day)
TRV		toxicity reference value measured as an effects-level threshold concentration of COPC normalized by receptor body weight (mg/kg-day)

Consistent with USEPA guidance (1997), a NOAEL-based HQ equal to or less than one indicates potential risks are negligible. A NOAEL-based HQ greater than one or a LOAEL-based HQ equal to or greater than one indicates a potential for an unacceptable risk. HQs were calculated based on low and high benchmarks. Low benchmarks are generally based on chronic NOAELs or equivalents. High benchmarks are generally based on chronic LOAELs or equivalents. The HQs for the terrestrial and aquatic exposure areas are presented in the following sections. Furthermore, when evaluating risk management decisions based on HQ values, risk managers should consider the inherent level of conservatism in the benchmark used. For instance, screening values used to assess potential risk from direct contact are often conservative and do not account for site specific factors that may affect bioavailability. Therefore, potential risk based on inherently conservative benchmarks may require additional refinement before risk management actions are recommended.

7.3.1 Terrestrial AOC

Table 7-6 presents a summary of HQs for plants and invertebrates exposed to COPC in soil, and Table 7-14 presents a summary of HQs for upper trophic level receptors (i.e., birds and mammals) exposed to COPC in soil. The following sections discuss the risk characterization for representative receptors evaluated in the terrestrial AOC.

7.3.1.1 *Plants*

HQs for direct contact of plant populations to COPCs in soil (Table 7-6) were equal to or less than one with the exception of the following:

- 0 to 0.5 ft bgs:
    - *Metals:* Barium (HQ = 4) and chromium (HQ = 30).
- 0 to 2 ft bgs:
    - *Metals:* Barium (HQ = 2), chromium (HQ = 30), and vanadium (HQ = 20).

The EPCs for chromium in both 0 to 0.5 ft bgs and 0 to 2 ft bgs depth intervals and the EPC for vanadium in the 0 to 2 ft bgs depth interval are less than the site specific background. Site concentrations at or below ambient conditions indicate risk from site-related sources is not discernible from background.

The barium plant screening value (i.e., 500 mg/kg) is based on laboratory tests using a highly soluble form of barium (i.e., barium nitrate). Due to the marine origin of soils on the site, barium in site soil is likely present as barium sulfate or barium carbonate, both of which are less soluble (McGinty et al. 2007) and, therefore, less toxic than more soluble forms of barium (United States Department of Health and Human Services 2007). The lowest plant effects concentrations for barium sulfate identified in Tindal (2007) was 500,000 mg/kg. Additionally, the EPCs for barium are driven by four sample locations collected from 0 to 1 ft bgs in the vicinity of the Powerhouse and Fuel Barn AOI (OUE-HA-029, OUE-HA-030, OUE-HA-031 and OUE-HA-032; Appendix D), indicating barium exposure for populations of plants in the OU-E Lowland AOC is limited. Due to the likely insoluble form of barium present in soil that substantially decreases toxicity and the geographic isolation of the locations exceeding the conservative barium nitrate screening value, potential risk to populations of terrestrial plants is likely negligible. Furthermore, no indications of stress (e.g., chlorosis) or plant death has been observed during site investigations.

7.3.1.2 *Invertebrates Exposed to Soil*

HQs for direct contact of invertebrate populations to COPCs in soil (Table 7-6) were equal to or less than one with the exception of the following:

- 0 to 0.5 ft bgs:
    - *Metals:* Barium (HQ = 6) and chromium (HQ = 80).

- 0 to 2 ft bgs:
  - *Metals:* Barium (HQ = 3), chromium (HQ = 80), and vanadium (HQ = 50).

As mentioned above, the EPCs for chromium and vanadium are below the site-specific background concentration. Site concentrations at or below ambient conditions indicate risk from site-related sources is not discernible from background. Additionally, the barium forms used in toxicity testing used to develop the invertebrate screening level (i.e., 330 mg/kg) were highly soluble forms (i.e., barium oxide and barium nitrate). Whereas, Tindal (2007) demonstrated that the likely insoluble form of barium in site soil (e.g. barium sulfate or carbonate) does not cause toxicity to soil invertebrates at concentrations as high as 589,000 mg/kg. Furthermore, as described in Section 7.3.1.1, the EPC for barium is driven by four sample locations, indicating barium exposure for populations of soil invertebrates in the OU-E Lowland AOC is limited. Therefore, risks to invertebrate populations are likely negligible.

7.3.1.3 *Avian Receptors Exposed to Soil*

HQs for terrestrial upper trophic level avian receptors (i.e., American kestrel, mallard, killdeer, and California quail; Table 7-14) were equal to or less than one for all COPCs. In addition, terrestrial upper trophic level receptors were evaluated assuming 100% bioaccessibility for COPCs with literature-based BAcFs discussed in Section 7.1.3.4. The following table presents the HQ values for terrestrial receptors using literature-based and 100% BAcF values for COPCs where literature-based BAcF values are available. The American kestrel exposed to dioxin TEQ is the only avian receptor with an HQ greater than one (NOAEL HQ = 2) assuming 100% bioaccessibility. Implications of the HQ differences using the various BAcF values are further discussed in Section 7.4.2.

Comparison of Avian Terrestrial HQs using Differing BAcFs

COPC	American Kestrel		Mallard		Killdeer		California Quail	
	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ
Arsenic								
Lit BAcF	0.002	0.001	0.0005	0.004	0.0007	0.0004	0.01	0.006
100% BAcF	0.003	0.002	0.0008	0.0005	0.001	0.0007	0.02	0.01
Lead								
Lit BAcF	0.05	0.03	0.01	0.005	0.01	0.007	0.1	0.05
100% BAcF	0.08	0.04	0.02	0.007	0.02	0.01	0.2	0.1
Zinc								

COPC	American Kestrel		Mallard		Killdeer		California Quail	
	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ
Lit BAcF	0.02	0.02	0.004	0.003	0.005	0.004	0.03	0.02
100% BAcF	0.03	0.02	0.007	0.005	0.007	0.006	0.05	0.04
Dioxin TEQ								
Lit BAcF	1	0.1	0.008	0.0008	0.02	0.002	0.4	0.04
100% BAcF	**2**	0.2	0.02	0.002	0.05	0.005	1	0.1

7.3.1.4 *Mammalian Receptors Exposed to Soil*

HQs for terrestrial upper trophic level mammalian receptors (i.e. mule deer, red fox, and ornate shrew; Table 7-14) were equal to or less than one with the following exceptions:

- *Metals*: NOAEL-based and LOAEL-based HQs for ornate shrew exposed to nickel (HQs = 4 and 2, respectively) and the NOAEL-based HQs for ornate shrew exposed to antimony (HQ = 3) and dioxin TEQ (HQ = 2).

The EPC for nickel is less than the site-specific background concentration for the site. Site concentrations at or below ambient conditions indicate risk from site-related sources is not discernible from background. Risk interpretation is particularly uncertain when estimated exposure doses are greater than the NOAEL-based TRV, but less than the LOAEL-based TRVs, as is the case for antimony. In addition, the BAF selected for uptake from soil-to-invertebrates was based on an average of empirical data for other inorganics, as a chemical-specific BAF was not available. Potential risk for field manifestation of adverse effects to populations of ornate shrew based on exposure to antimony is uncertain, but unlikely, based on the LOAEL-based HQ being below 1.

Terrestrial upper trophic level receptors were also evaluated assuming 100% bioaccessibility for COPCs with literature-based BAcFs discussed in Section 7.1.3.4. The following table presents the HQ values for terrestrial receptors using literature-based and 100% BAcF values for COPCs where literature-based BAcF values are available. Implications of the HQ differences using the various BAcF values are further discussed in Section 7.4.2.

Comparison of Avian Terrestrial HQs using Differing BAcFs

COPC	Mule Deer		Red Fox		Ornate Shrew	
	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ
Arsenic						
Lit BAcF	0.0002	0.0001	0.00002	0.00001	0.1	0.09
100% BAcF	0.0006	0.0004	0.0001	0.00006	0.02	0.01
Lead						
Lit BAcF	0.0007	0.0004	0.0004	0.0002	0.7	0.4
100% BAcF	0.001	0.0007	0.0006	0.0003	0.9	0.5
Zinc						
Lit BAcF	0.0007	0.0006	0.0004	0.0003	0.8	0.7
100% BAcF	0.001	0.001	0.0005	0.0004	1	0.9
Dioxin TEQ						
Lit BAcF	0.01	0.001	0.1	0.01	**2**	0.2
100% BAcF	0.03	0.003	0.3	0.03	**4**	0.4

7.3.1.5 *Hot Spot Analysis*

The approach for the hot spot analysis for the terrestrial Lowland AOC and development of site-specific RBTLs are presented in Section 5.1.1.1. Residual EPCs for Dioxin TEQ and lead based on the removal of identified hot spots are presented for each exposure depth interval in the following table. The maximum lead concentration currently observed in the 0 to 0.5 ft bgs interval (i.e., 230 mg/kg) is already less than three times the site-specific RBTL (Section 5.1.1.1), and it was not necessary to calculate a residual EPC. Assuming hot spot removals, the residual EPCs for each depth interval are less than the site-specific risk-based RBTL developed for ecological receptors. Dioxin TEQ and lead were not identified in the ERA as potential risk drivers for plants, soil invertebrates, and upper trophic level receptors, and because the removal of hot spots further reduces the EPCs, potential risk is not identified for ecological receptors exposed to Dioxin TEQ and lead.

Residual EPCs and ERA RBTLs: Dioxin TEQ and Lead

Constituent	ERA RBTL	EPCs		
		0-0.5 ft bgs	0-2 ft bgs	0-6 ft bgs
Dioxin TEQ	1920 pg/g	6.31	4.85	7.15
Lead	127 mg/kg	49.5*	39.5	48.7

Note:
* A hot spot was not identified for lead in the 0-0.5 feet bgs depth interval. Therefore, no residual EPC is calculated, and the value presented is the baseline EPC.
mg/kg = milligrams per kilogram
pg/g = picograms per gram

7.3.2 Aquatic AOC

Tables 7-7 through 7-12 present risk summaries for lower trophic level receptors exposed to COPC in sediment, porewater, and surface water. Table 7-15 presents a summary of HQs for upper trophic level receptors exposed to COPC in sediment and surface water. The following sections discuss the risk characterization for representative receptors evaluated in the aquatic AOCs.

7.3.2.1 *Plants Exposed to Sediment*

HQs for direct contact of plant populations to COPCs in sediment (Table 7-7) were equal to or less than one with the exception of the following:

- *Metals*: Arsenic (HQ = 2), barium (HQ = 4), chromium (HQ = 40), copper (HQ = 2), molybdenum (HQ = 10), selenium (HQ = 2), vanadium (HQ = 30), and zinc (HQ = 3).
- *PAHs*: Naphthalene (HQ = 3) and phenanthrene (HQ = 2).

The plant screening levels used were developed to be protective of terrestrial plants exposed to soil, not aquatic plants exposed to sediment. See Section 7.3.1.1 for a discussion of the selected plant screening level. The EPC for chromium (45 mg/kg) was similar to the site-specific background (42 mg/kg), and the EPC for vanadium was less than the site-specific background. Site concentrations at or below ambient conditions indicate risk from site-related sources is not discernible from background. Potential risk to plants exposed to molybdenum (HQ = 10) in site sediment is highly uncertain. Efroymson et al. (1997) stated that the confidence in the molybdenum soil screening value is low, because it is based on a single study that reports unspecified toxic effects when molybdenum was added to soil in experimental exposures. Arsenic, barium, copper, selenium, and zinc have HQs slightly greater than one (ranging between two and four) indicating a low potential for risk. Based on these screening evaluations and the presence of a thriving plant community and no field observations of stressed (e.g., chlorosis) or dead vegetation, no potential risk of adverse effects to populations of plants in the aquatic portions of OU-E is identified.

7.3.2.2 *Invertebrates Exposed to Sediment and Porewater*

TECs and PECs were used as an initial step to evaluate direct contact of invertebrate populations to COPCs in sediment (Table 7-8). HQs were equal to or less than one with the exception of the following:

- *Metals*: Arsenic (HQ = 4), copper (HQ = 5), lead (HQ = 2), molybdenum (HQ = 8), and zinc (HQ = 4) exceeded the TEC. The PEC-based HQs for arsenic, copper, and zinc were equal to one.

- *PAHs*: Several PAHs exceeded the TEC. HQs ranged from two to 10, with the exception of acenaphthylene (HQ = 100). Only naphthalene exceeded the PEC (HQ = 4), and the PEC-based HQs for phenanthrene and pyrene were equal to one.

- *Pesticides*: 4,4-DDD (HQ = 3), 4,4-DDE (HQ = 2) and heptachlor (HQ = 2) exceeded the TEC. No pesticides exceeded the PEC.

The direct application of screening levels does not consider partitioning of metals, PAHs, and other COPCs from sediment to porewater, with porewater being the primary medium of exposure for benthic invertebrates. Therefore, risk characterization based on generic screening levels without consideration of site-specific conditions that affect bioavailability may overestimate risks to benthic organisms.

Table 7-9 presents the risk summary for invertebrates exposed to metals in porewater using data collected during the OU-E BHHERA investigation outlined in Section 4. Concentrations on a point-by-point basis for metals in porewater were compared to screening levels. Two sample locations in the southern Ponds (i.e., Ponds 1 through 4) AOC exceeded ecological screening levels for invertebrates exposed to barium in porewater. These samples are representative of approximately 12% of the total area of the Ponds 1 through 4 AOC. Therefore, given the small size of the potentially affected areas, an unacceptable risk to invertebrate populations in Ponds 1 through 4 AOC is not expected. Similar to the southern ponds AOC, Pond 8 is driven by one location out of the 10 sampled, and unacceptable risk to populations in Pond 8 is not expected based on this single sampling location. Three out of three samples in Pond 7 exceed the screening levels for barium in porewater, indicating potential risk for invertebrates exposed through direct contact to porewater based on the screening level selected (i.e., 1000 µg/L; RWQCB 2013).

PAHs and pesticides were evaluated using one-carbon (i.e., total organic carbon) and two-carbon (i.e., natural organic carbon and black carbon) EqP models (Tables 7-10 and 7-11), as described in Section 7.2.1. Results in Table 7-11 for pesticides indicate the following:

- USEPA EqP for non-polar organics: No sample locations indicate potential risk based on a comparison to screening levels.

Results in Table 7-10 for PAHs indicate the following:

- USEPA EqP HI for 13 PAHs: 6 sample locations- Pond 2-01 (HI = 2.6), Pond 2-02 (HI = 12), Pond 8-06 (HI = 1.4), Pond 8-08 (HI =1.6), Pond 7-01 (HI =1.9) and Pond 7-02 (HI =2.4) indicate potential risk based on the estimated HIs.

- USEPA EqP HI for 34 PAHs: Two locations- Pond 8-08 (HI =2.0) and Pond 8-17 (HI = 1.7) indicate potential risk based on the estimated HIs.

- Two-carbon EqP HI: No sample locations indicate potential risk based on the estimated HIs.

- SPME HI: Three sample locations-Pond 8-05 (HI = 1.9 [collected 4/11/2013]), Pond 8-08 (HI = 2.5) and Pond 8-17 (HI = 25) indicate potential risk based on the estimated HIs.

The potential risk posed to benthic organisms exposed to PAHs in sediment and porewater was evaluated using sequentially more realistic models (Sediment benchmarks > USEPA EqP HI for 13 PAHs >USEPA EqP HI for 34 PAHs > Two-carbon EqP HI). As shown in Table 7-10 and discussed above, as the risk model becomes more realistic, fewer sample locations may have a potential risk, with no sample locations having a potential risk using the two-carbon EqP method. However, SPME-PAH porewater analysis, which directly measures PAH porewater concentrations instead of modeling them as in the EqP analyses indicated three sample locations exhibiting an HI greater than one.

Uncertainty associated with the porewater analytical data as it reflects potential risk is highlighted in sample location Pond 8-05 which was collected and analyzed twice. Of the two samples from this single location, one had a hazard index greater than one (1.9), with the other being 0.77, a 2.5-fold difference. Because of this, the risk associated with Pond 8-05, and also Pond 8-08 (HI = 2.5), is uncertain because they are near the risk threshold. Unacceptable risk to populations of benthic organisms in Pond 8 is uncertain, and unlikely, due to benthic organism exposure to PAHs in sediment and porewater at Pond 8-05 and Pond 8-08.

The absence of risk at 46 out of 47 sample locations throughout the site analyzed for PAH exposure to invertebrates indicates the absence of site-wide risk. Although the HI of sample location Pond 8-17 (HI =25) indicates potential for unacceptable risk at the location, even when taking into account the uncertainty associated with the analytical method, EqP porewater estimations predicted minimal (one-carbon model) to negligible (two-carbon model) risk. Based on results of the porewater, EqP, and SPME evaluations, no risk of adverse effects to populations of benthic organisms in the aquatic areas of OU-E is identified. However, there may be localized risk in Pond 7 from sediment porewater barium exposure, based on comparison to selected screening values (i.e., 1000 µg/L; RWQCB 2013).

7.3.2.3 *Invertebrates and Amphibians Exposed to Surface Water*

HQs for direct contact to surface water (Table 7-12) were less than one with the exception of amphibians exposed to chromium (HQ = 2) and zinc (HQ = 5). The EPC for zinc is of similar magnitude when compared to ambient inputs (i.e., City storm drains) as indicated by analytical results from Stations D and CE presented in the Mill Pond Storm Water Sampling Report (ARCADIS 2012). Site concentrations at or below ambient conditions indicate risk from site-related sources is not discernible from background. Potential chromium risk is based on a single sample result (110 μg/L at DP-7.9) more than an order of magnitude greater than the next highest result (8.5 μg/L). With the exception of the maximum concentration, the remaining chromium concentrations are less than or similar to the screening level (e.g., 8.5 μg/L, 6.3 μg/L and 6.2 μg/L compared to a screening level of 6 μg/L). Therefore, no risk of adverse effects to populations of amphibians from chromium is identified.

7.3.2.4 *Avian Receptors Exposed to Sediment and Surface Water*

HQs for upper trophic level avian receptors (i.e., mallard duck and Virginia rail) exposed to COPCs in sediment (Table 7-15) were less than one with the exception of the following:

- *Metals*: NOAEL-based and LOAEL-based HQs for Virginia rail exposed to barium exceeded one (HQs = 4 and 2, respectively), and the NOAEL-based HQ for selenium exceeded one (HQ = 2).

The EPC for selenium (1.2 mg/kg) is only slightly greater than the site-specific background concentration for the site (0.82 mg/kg). Site concentrations at or below ambient conditions indicate risk from site-related sources is not discernible from background. While the Virginia rail barium HQ values are above one, it is unlikely that barium poses a potential risk to birds for the following reasons.

- Absorption of naturally occurring barium from food is about 2% of the total dietary barium content because barium occurs in bound or insoluble forms (Venugopal and Luckey 1978, Reeves 1986). Therefore, because the majority of barium exposure estimated in the food web models is associated with invertebrate ingestion, the actual exposure dose is likely a fraction of the modeled dose.

- Because barium toxicity is mediated through the free barium ion, toxicity is closely related to the solubility of barium compounds (United States Department of Health and Human Services 2007). The avian barium TRV used in this OU-E BHHERA to characterize potential risk is based on a highly soluble barium hydroxide exposure (Johnson et al. 1960). However, many metals when absorbed by invertebrates form detoxification products by binding to metallothioneins proteins or by forming salt particulate bodies with sulfur or calcium (U.S. Army Corps of Engineers 2012). Barium sulfate solubility is one to two orders of magnitude less than what is expected for highly soluble barium, and the toxicity of barium sulfate is expected to be much less than soluble barium compounds by at least this amount (Menzie et al. 2008). Therefore, it is likely that barium ingested from invertebrate consumption is not in the highly soluble form and is not likely to be toxic.

Antimony and beryllium do not have an available avian TRV, however, they were quantitatively assessed for mammals and HQs were less than one. Although this AE is not directly related to avian species, the quantitative assessment results from this AE provide an evaluation of ecological risk that can be used to provide context for decision making regarding potential avian risk from these COPCs.

Additionally, aquatic upper trophic level receptors were evaluated assuming 100% bioaccessibility for COPCs with literature-based BAcFs discussed in Section 7.1.3.4 (i.e., dioxin, arsenic, lead, and zinc), and also were evaluated for both bioaccessibility scenarios (i.e., literature-based BAcFs and BAcFs of 100 percent) on an individual pond basis. Tables 7-17 and 7-21 through 7-34 present the HQ values for the alternative exposure scenarios. Under all exposure scenarios, the only aquatic receptor with HQ values greater than one was the Virginia rail. HQs were greater than one under various exposure scenarios for Virginia rail exposure to barium and selenium. Variations of BAcF values used in the exposure scenarios did not result in any HQ values greater than one for any aquatic receptors under any of the exposure scenarios. The following table presents all HQ values for COPCs that were greater than one for any of the exposure scenarios evaluated.

Comparison of Virginia Rail HQs Under Different Exposure Scenarios

	COPC	Barium	Selenium
All Aquatic Areas	Low Benchmark HQ	**4**	**2**
	High Benchmark HQ	**2**	0.4
Ponds 1-4	Low Benchmark HQ	**4**	1
	High Benchmark HQ	**2**	0.3
Pond 5	Low Benchmark HQ	0.4	0.2
	High Benchmark HQ	0.2	0.05
Pond 6	Low Benchmark HQ	0.2	0.06
	High Benchmark HQ	0.09	0.02
Pond 7	Low Benchmark HQ	0.1	0.04
	High Benchmark HQ	0.06	0.009
Pond 8	Low Benchmark HQ	**3**	**2**
	High Benchmark HQ	**2**	0.4
Pond 9	Low Benchmark HQ	0.3	0.3
	High Benchmark HQ	0.2	0.07
North Pond	Low Benchmark HQ	0.04	0.02
	High Benchmark HQ	0.02	0.006

Implications of the HQ differences using the various BAcF values and exposure areas are further discussed in Section 7.4.2.

7.3.2.5 *Mammalian Receptors Exposed to Sediment and Surface Water*

NOAEL-based and LOAEL-based HQs for upper trophic level mammalian receptors (i.e., raccoon) exposed to COPCs in sediment (Table 7-15) were below one. Thus, potential risks to mammalian receptors in the aquatic AOC is negligible.

Additionally, aquatic upper trophic level receptors were evaluated assuming 100% bioaccessibility for COPCs with literature-based BAcFs discussed in Section 7.1.3.4 (i.e., dioxin, arsenic, lead, and zinc), and also were evaluated for both bioaccessibility scenarios (i.e., literature-based BAcFs and BAcFs of 100 percent) on an individual pond basis. NOAEL and LOAEL HQs for mammalian receptors under all alternative exposure scenarios were less than one, indicating negligible risk. Tables 7-17 and 7-21 through 7-34 present the HQ values for the alternative exposure scenarios. Results of the alternative exposure scenario analyses are discussed further in Section 7.4.2.

7.3.3 ERA Results Summary

Unacceptable risks are not expected for populations of plants, soil invertebrates, birds, or mammals exposed to COPC in soil. Unacceptable risks are not expected for populations of plants, amphibians, birds, or mammals exposed to COPC in sediment. However, barium in Pond 7 sediment/porewater may pose a risk to benthic organisms in this AOC based on comparison to the selected surface water screening level (RWQCB 2013).

7.4 Uncertainty Analysis

An understanding of the underlying uncertainties inherent in the data, inputs, models, and conclusions of the ERA is a critical aspect of a risk-based decision-making process. Identifying the sources and implications of the major uncertainties is crucial to the appropriate interpretation of ERA results. Uncertainties associated with developing exposure estimates, and selecting, applying, and interpreting ecological effects data to develop risk estimates, are discussed in the following sections.

7.4.1 Analytical Methods

There is potential uncertainty associated with the SPME analysis for PAHs (particularly alkylated homologues) in porewater, because there are no calibration standards for alkylated PAH homologues and values are not quantitatively evaluated. The extraction efficiency of the parent PAH compounds is used for the alkylated PAH homologues during analysis (calibration standards for parent PAH compounds are subjected to the porewater extraction procedure). To compensate for the uncertainty associated with the extraction efficiency, the laboratory applied the relative response factor (ARRF) of the alkyl PAH to the parent PAH, also known as the Hawthorne factor, which increases or decreases (dependent on the specific ARRF) the concentration estimated from the chromatograms. Furthermore, because of the aforementioned manipulations to the measured concentrations and the lack of analytical standards, the laboratory flags each detected alkylated PAH homologue as estimated.

Table H-4 of Appendix H presents a comparison of ARRF and non-ARRF adjusted data and the subsequent risks for sample locations showing porewater PAH HQs greater than one. In all cases, the HQs are reduced when the ARRF is not applied, and in one case, the HQ falls below one (Pond 8-05-4/11/2013). In addition, the EqP evaluation does not indicate potential risk at the three locations where SPME HI values exceeded one (Table 7-13).

7.4.2 Additional Exposure Scenarios

Three additional exposure scenarios were evaluated for potential exposure to ecological receptors to provide a range of potential risk and are discussed further in the following sections. EPCs used in these scenarios are based on baseline data and do not consider removal of hot spots.

- The aquatic and terrestrial AOCs were evaluated to assess potential risk to upper trophic level receptors assuming 100% bioaccessibility for arsenic, lead, zinc, and dioxin in sediment (Tables 7-16 and 7-17).
- Individual ponds were evaluated as AOCs to assess potential risk to lower (Tables 7-18 through 7-20) and upper trophic level receptors (Tables 7-21 through 7-27). Literature-based bioaccessibility factors (Table 7-5) were selected for upper trophic level receptors exposed to arsenic, lead, zinc, and dioxin in sediment.
- Individual ponds were evaluated as AOCs to assess potential risk to upper trophic level receptors assuming 100% bioaccessibility for arsenic, lead, zinc, and dioxin in sediment (Tables 7-28 through 7-34).

7.4.2.1 *Terrestrial and Aquatic AOCs Assuming 100% Bioaccessibility*

The terrestrial and aquatic AOCs were evaluated for upper trophic level receptors (i.e., birds and mammals) assuming 100% bioaccessibility in soil and sediment for arsenic, lead, zinc, and dioxin. All other ERA methods are identical. Individual upper trophic level receptor dose models and risk estimates are presented in Appendix J.

7.4.2.1.1 Avian Receptors

NOAEL-based and LOAEL-based HQs for upper trophic level avian receptors (i.e., American kestrel, mallard, killdeer, California quail, and Virginia rail) exposed to COPCs in soil and/or sediment (Table 7-16 and 7-17) were less than one with the exception of the following:

- NOAEL-based HQ for American kestrel exposed to dioxin in soil (HQ = 2). The maximum concentration is located at DP-052, which was identified as a hot spot (Section 5.1.1.1). Therefore, potential risk is reduced when this location is excluded from the terrestrial dataset (i.e., it is assumed the hot spot will be remediated), and HQ is estimated as less than one indicating negligible risk.

7.4.2.1.2 Mammalian Receptors

NOAEL-based and LOAEL-based HQs for upper trophic level mammalian receptors (i.e., mule deer, red fox, ornate shrew, and raccoon) exposed to COPCs in soil or sediment (Table 7-16 and 7-17) were less than one, with the exception of the following:

- NOAEL-based HQ for ornate shrew exposed to dioxin in soil (HQ = 4). Consistent with results for the American kestrel, the maximum concentration is located at DP-052, which was identified as a hot spot (Section 5.1.1.1). Therefore, potential risk is reduced when this location is excluded from the terrestrial dataset (i.e., it is assumed the hot spot will be remediated), and the HQ is estimated as less than 1 indicating negligible risk.

7.4.2.2 Pond AOCs Assuming Literature-Based Bioaccessibility Factors

Exposure units and area use factors for upper trophic level receptors were based on the terrestrial exposure area (i.e., OU-E Lowland AOC) and aquatic exposure area (combined are of pond AOCs; Figure 2-1). As requested by DTSC, the following sections provide an ERA using each pond AOC as a separate exposure unit, and using area use factors based on the respective pond AOC acreages. All other ERA methods are identical to exposure estimates used in the all terrestrial and all aquatic scenarios. Summaries of the COPCs selected for the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals in each pond AOCs and EPCs are presented in Tables 5-7 through 5-17 (sediment) and Tables 5-20 through 5-26 (surface water). Individual upper trophic level receptor dose models and risk estimates are presented in Appendix J.

Pond AOCs were also evaluated for potential risk to upper trophic level receptors assuming 100% bioaccessibility for arsenic, lead, zinc, and dioxin in sediment. Those results are presented in Section 7.3.4.3.

7.4.2.2.1 Plants Exposed to Sediment

HQs for direct contact of plant populations COPCs in sediment for pond AOCs can be found in Table 7-18. HQs were similar to or below those in the combined aquatic AOC except for the following:

- *Metals*: Chromium in the Pond 7 AOC (HQ = 90), molybdenum in the Pond 8 AOC (HQ = 20).

- *PAHs*: Acenaphthylene in the Pond 7 AOC (HQ = 3), fluoranthene in Ponds 1 through 4 and Pond 7 AOCs (HQ = 2), and pyrene in Ponds 1 through 4 and Pond 7 AOCs (HQ = 2).

Despite the HQ values calculated from conservative direct contact screening values, no stressed or dead vegetation was observed during numerous site visits. Potential risk to plants exposed to chromium and molybdenum in site sediment based on the selected screening values is highly uncertain. Efroymson et al.

(1997) stated that the confidence in the molybdenum and chromium soil screening value is low (see Section 7.3.2.1 regarding molybdenum). The chromium screening value is based on only two studies that used chromium VI to test effects on crop plants (i.e., soy beans, tomatoes, lettuce, and oats). Chromium exists in sediments primarily in two oxidation states: Cr(III), which is relatively insoluble and nontoxic, and Cr(VI), which is much more soluble and toxic. Cr(VI) is thermodynamically unstable in anoxic sediments and AVS is formed only in anoxic sediments; therefore sediments with measurable AVS concentrations should not contain toxic Cr(VI) (USEPA 2005b). Therefore, given no field observations of effects and the uncertainty associated with the chromium and molybdenum screening values, unacceptable risk to plant populations in all Pond AOCs is unlikely.

7.4.2.2.2 Invertebrates Exposed to Sediment and Porewater

TECs and PECs were used as an initial step to evaluate direct contact of invertebrate populations to COPCs in sediment (Table 7-19). HQs for invertebrates exposed to COPC in sediment are comprised of the same constituent classes as for the individual aquatic AOCs (metals, PAHs, and pesticides). HQs for direct contact of invertebrate populations exposed to COPCs in sediment and porewater can be found in Tables 7-9 through 7-11.

Potential for an unacceptable risk was evaluated on a sample location-by-sample location basis for porewater based on porewater comparisons to screening levels and sediment EqP methods (Tables 7-9 through 7-11). Therefore, the risk characterization rationale and results described in Section 7.3.2.2 for benthic organisms exposed to porewater are identical for the individual pond AOCs. No COPCs except PAHs and barium had an HQ/HI that exceeded one. Potential risk in Pond 8 from PAH exposure is primarily driven by one location (i.e., Pond 8-17) out of 14. In Pond 7, potential risk to benthic organisms from barium exposure in sediment is possible. Therefore, potential risk to populations of benthic organisms is likely to be negligible, except in Pond 7 where potential risk is possible based on comparison of barium porewater concentrations to the selected screening level (RWQCB 2013). Based on the potential risk to benthic organisms from barium in sediment, the BHHERA concludes that the Pond 7 AOC should be further assessed in the feasibility study.

7.4.2.2.3 Invertebrates and Amphibians Exposed to Surface Water

HQs for direct contact of invertebrate and amphibian populations to COPCs in surface water for pond AOCs can be found in Table 7-20. HQs for invertebrates exposed to surface water were less than one. HQs for amphibians exposed to surface water in pond AOCs were similar to or below those in the aquatic AOC except for the following:

- *Metals*: Chromium in Ponds 1 through 4 AOC (HQ = 10).

The chromium EPC in Ponds 1 through 4 AOC (57 µg/L) is driven by one sample location (DP-7.9, 110 µg/L). In the remaining Ponds 1 through 4 AOC dataset, there is one other sample greater than the screening level (DP-7.13, 8.5 µg/L). Because elevated chromium concentrations are localized in Ponds 1 through 4 AOC and the EPC is driven by one sample, unacceptable risk to populations of amphibians in Ponds 1 through 4 AOC is unlikely.

7.4.2.2.4 Avian Receptors Exposed to Sediment and Surface Water

HQs for upper trophic level avian receptors (i.e., mallard duck and Virginia rail) exposure to sediment and surface water can be found in Tables 7-21 through 7-27. HQs for upper trophic level avian receptors for each individual pond AOC were similar to or lower than those in the all aquatic exposure area. The risk characterization discussion for upper trophic level avian receptors in Section 7.3.2.4 is applicable to the individual pond AOCs. Risk to avian receptors in each individual pond AOC and the site-wide aquatic AOC is not likely.

7.4.2.2.5 Mammalian Receptors Exposed to Sediment and Surface Water

NOAEL-based and LOAEL-based HQs for upper trophic level mammalian receptors (i.e., raccoon) exposed to COPCs in sediment were less than one in each pond AOC (Tables 7-21 through 7-27). Thus, risk to mammalian receptors in each individual pond AOC and the site-wide aquatic exposure area is not likely.

7.4.2.3 *Pond AOCs Assuming 100% Bioaccessibility*

The aquatic pond AOCs were evaluated for upper trophic level receptors (i.e., birds and mammals) assuming 100% bioaccessibility in sediment for arsenic, lead, zinc, and dioxin. All other ERA methods are identical. Individual upper trophic level receptor dose models and risk estimates are presented in Appendix J. HQ summaries can be found in Tables 7-28 through 7-34 and are summarized below.

7.4.2.3.1 Avian Receptors

NOAEL-based and LOAEL-based HQs for upper trophic level avian receptors (i.e., mallard duck and Virginia rail) exposed to arsenic, lead, zinc, and dioxin in sediment for the pond AOCs (Tables 7-28 through 7-34) were less than one. Thus, potential risks to avian receptors in the aquatic pond AOCs are negligible.

7.4.2.3.2 Mammalian Receptors

NOAEL-based and LOAEL-based HQs for upper trophic level mammalian receptors (i.e., raccoon) exposed to arsenic, lead, zinc, and dioxin in sediment (Tables 7-28 through 7-34) were below one. Thus, potential risks to mammalian receptors in the aquatic pond AOCs are negligible.

8 Portions of Operable Units C and D Deferred to OU-E BHHERA

The risks associated with AOIs within Operable Units C and D were evaluated in the DTSC-approved OU-C/OU-D RI (ARCADIS 2011a). The OU-C/OU-D RI concluded that several areas, including the IRM, West of IRM and the Riparian AOIs, should be carried forward into the remedial planning process. Risks associated with the IRM and West of IRM were evaluated in the OU-C/OU-D RI and are not further discussed. Risks associated with the Riparian AOI were further evaluated as part of this report and are discussed below in detail.

8.1 Riparian AOI

The Riparian AOI was evaluated for ecological risks in the approved OU-C and OU-D RI as part of the open space exposure unit (Figure 8-1). The OU-C and OU-D BERA for the open space exposure unit included upper and lower trophic level receptors (Section 10.6.2.5 of the approved OU-C and OU D RI). In the riparian area, baseline ecological risk assessment (BERA) hazard quotients were less than one for all avian and mammalian receptors. The tables below summarize the OU-C and OU-D RI avian and mammalian screening level ecological risk assessment hazard quotients for COPCs that were greater than 1 and the BERA hazard quotients for the same COPCs indicating negligible risk (i.e., BERA HQs less than 1).

OU-C and OU-D RI SERA COPCs with HQs Greater than 1

COPC	Mallard		Virginia Rail	
	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ
Arsenic	<1	<1	**2**	<1
Barium	**3**	**2**	**10**	**5**
Selenium	<1	<1	**2**	<1
Vanadium	<1	<1	**2**	<1
Zinc	<1	<1	**2**	<1

OU-C and OU-D RI BERA HQs for SERA COPCs with HQs Greater than 1

COPC	Mallard		Virginia Rail	
	Low Benchmark HQ	High Benchmark HQ	Low Benchmark HQ	High Benchmark HQ
Arsenic	--	--	0.2	--
Barium	0.3	0.1	0.9	0.5
Selenium	--	--	0.3	--
Vanadium	--	--	0.3	--
Zinc	--	--	0.2	--

Note:
-- indicates SERA HQ for this COPC was not greater than 1 and evaluation in the BERA was unnecessary.

The OU-C/OU-D RI (ARCADIS 2011a) identified metals, PAHs and dioxins exceeding conservative sediment screening levels for protection of benthic organisms in the riparian area of OU-D (undeveloped, wooded land with a wetland ditch located along the eastern boundary of Parcel 7; Figure 8-1). In order to further evaluate the risks posed by metal and PAH concentrations, porewater and sediment data were collected under the OU-E BHHERA investigation (Section 4).

The screening for invertebrates exposed to metals in porewater is presented in Table 7-9 and the screening for invertebrates exposed to PAHs in sediment and porewater is presented in Table 7-10. Analytical results are presented in Appendix C. Results of the screening are summarized below.

- *Metals*: No sample locations indicate potential risk to benthic invertebrates based on a direct screen of porewater data against surface water screening levels.
- *PAHs*: No sample locations indicate potential risk to benthic invertebrates based on the EqP HI for 34 PAHs and the SPME HI.

No further evaluation for dioxin/furan risk was performed because invertebrates lack specific biochemical receptors essential to produce dioxin related toxicity (Céspedes et al. 2010; Hahn 2002; West et al. 1997). Dioxin toxicity is expressed via the aryl hydrocarbon receptor in vertebrates. However, invertebrates lack the aryl hydrocarbon receptor, and aryl hydrocarbon receptor homologues identified in invertebrates have been shown to not bind dioxin compounds (Céspedes et al. 2010; Hahn 2002; West et al. 1997). Furthermore, toxicity testing conducted on various invertebrate species has shown no toxicity associated with tissue concentrations up to 9.5 mg/kg lipid (West et al. 1997). Based on the outcomes of the metals and PAH evaluations described above, risk in the OU-D riparian area is negligible.

9 Conclusions

This section presents conclusions regarding potential baseline human health and ecological risks associated with site operations at OU-E, as well as updated baseline ecological risk estimates for the Riparian AOI in OU-D. This OU-E BHHERA relies on data presented in the OU-E RI and additional data collected in April 2013, as outlined in the OU-E BHHERA Work Plan (ARCADIS 2013b). This OU-E BHHERA describes the analytical data for OU-E, identifies COPCs in OU-E environmental media, provides toxicity values for COPCs and scenario-specific EPCs, and quantifies potential risk and hazard for human and ecological receptors in accordance with methods presented in the Site-Wide RAWP (ARCADIS BBL 2008a), the OU-E BHHERA Work Plan, and additional scenarios based on input from DTSC. Additional scenarios in the HHRA and the ERA evaluate the Ponds collectively as one exposure area and each pond AOC individually as an exposure area.

DTSC also requested a hot spot analysis to assess the contribution of specific COPCs to the risks and hazards identified in the BHHERA (DTSC 2014). DTSC asked for hot spot identification based on a comparison of COPC concentrations in soil to the site-specific RBTLs for B(a)P TEQ, dioxin TEQ, and lead. DTSC defined a hot spot as a COPC concentration in soil greater than three times the site-specific RBTL. For each identified hot spot, residual EPCs were calculated excluding hot spot concentrations to assess residual risks and hazards assuming hot spot removal.

The following sections present a summary of soil hot spot locations, a summary of potential risks at the site, as well as specific areas recommended for the OU-E feasibility study. The results of this BHHERA will serve as the basis of the Feasibility Study, the Remedial Action Plan, and subsequent Remedial Action Plan implementation activities for areas of OU-E.

9.1 Terrestrial Hot Spot Analysis

The hot spot analysis identified sample locations in the terrestrial exposure area based on the DTSC approach (DTSC 2014). The following table lists the identified soil hot spots and compares the residual soil EPC to the site-specific RBTL assuming removal of the identified hot spots.

Constituent	Human Health RBTL	Residual EPCs and Depth Interval				Sample Removed (depth in feet bgs)
		0-0.5 ft bgs	0-2 ft bgs	0-6 ft bgs	0-10 ft bgs	
B(a)P TEQ (mg/kg)	0.3	Not applicable	0.0801	0.0618	0.0559	HSA-4.3 (2-2.5)- Powerhouse and fuel barn AOI; OUE-DP-073 (2-3)- Sawmill #1 AOI; OUE-DP-074 (2-3) - Sawmill #1 AOI; OUE-DP-075 (2-3) - Sawmill #1 AOI; OUE-DP-026 (2-3.5) -Sawmill #1 AOI; OUE-DP-099 (0.5-1.0)- Waste treatment and truck dump AOI; OUE-DP-100 (2.5-3.5) - Waste treatment and truck dump AOI
Dioxin TEQ (pg/g)	53	6.311	4.85	7.152	8.522	OUE-DP-052 (0.5-1.5 & 0-0.5) - Powerhouse and fuel barn AOI
Lead (mg/kg)	320	Not applicable	39.54	48.65	44.97	OUE-DP-070 (3-4) -Sawmill #1 AOI; OUE-DP-094 (5.5-6) - Powerhouse and fuel barn AOI; OUE-DP-090 (5.5-6) - Powerhouse and fuel barn AOI; DP-05.57 (0.5-1) -Sawmill #1 AOI

Note:
mg/kg = milligrams per kilogram
pg/g = picograms per gram

The hot spot analysis for the terrestrial AOC indicates the following:

- Removal of the dioxin TEQ soil hot spot identified as sample location DP-052 decreases the dioxin TEQ EPC to less than the site-specific RBTL of 53 pg/g. In turn, the change in the dioxin TEQ EPC reduces the HIs and ECLR in the terrestrial AOC to below 1 and 1 x 10^{-6} respectively.

- Four locations were identified as hot spots for lead and three locations were identified as hot spots for B(a)P TEQ even though baseline EPCs for lead and B(a)P TEQ were below the RBTLs.

9.2 Risk Characterization

Risks to human and ecological receptors were estimated for the terrestrial exposure area and aquatic exposure area in accordance with the CSMs presented in Figures 5-1 and 5-2. Terrestrial human receptors evaluated included construction workers, maintenance/utility workers, recreational visitors, and commercial/industrial workers, while aquatic human receptors included recreational visitors. Ecological receptors evaluated included plants, soil and sediment invertebrates, and terrestrial and aquatic wildlife (amphibians, birds, and mammals).

9.2.1 Human Health Risk Characterization Results

Potential OU-E future receptors were identified based on reasonable likely future land use in accordance with State and Federal guidance and stakeholder input. Sources of stakeholder input on reasonable likely future land use include the City of Fort Bragg Mill Site Specific Plan (City of Fort Bragg 2015), City of Fort Bragg Draft Municipal Service Review (City of Fort Bragg 2013), and the California Coastal Act (CCC 2014).

The City of Fort Bragg Mill Site Specific Plan (City of Fort Bragg 2015) identifies the northern portion of OU-E as the "Mill Pond and Open Space District" (Figure 2-6). The "Mill Pond and Open Space District" extends southward to include the Riparian AOI and portions of the IRM and West of IRM AOIs formerly included in OU-C/D and now included in OU-E. The southern portion of OU-E is surrounded by area designated as "Mill Site Urban Reserve" and "Mill Site Industrial".

As discussed in Section 2 of the BHHERA, all ponds in OU-E and approximately 1.7 acres of the OU-E Lowland AOC delineated as wetlands, are designated as ESHAs in the Environmentally Sensitive Habitat Areas Delineation Report (ARCADIS 2011b). Furthermore, as discussed in Section 6.1.1, in accordance with the California Coastal Act (CCC 2014), ESHAs are "protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas" (Section 30240). As such, the aquatic portions of OU-E will be protected as ESHAs in accordance with the California Coastal Act (CCC 2014), restricting significant disruption of habitat values and preventing visitors from entering these areas (e.g., by placement of boardwalks/trails outside of sensitive habitat areas, fencing, and/or signage).

As presented in the DTSC-approved OU-E BHHERA Work Plan and further summarized in Section 6.1 of the BHHERA, likely and reasonably anticipated current and future human receptors in terrestrial areas evaluated in OU-E include construction workers, maintenance/utility workers, recreational visitors, and commercial/industrial workers, while recreational visitors were the human receptors for the aquatic areas. Based on the information presented in DTSC approved documents for OU-E and City of Fort Bragg planning documents, ESHA designations of OU-E ponds and wetlands, state and federal regulations and guidance, it is appropriate to conclude that residential receptors are not an appropriate AE for OU-E under current or reasonable future land uses.

Exposure pathways for human receptors in the terrestrial and aquatic exposure areas were evaluated in accordance with the CSMs presented in the DTSC-approved OU-E BHHERA Work Plan (ARCADIS 2013b). Exposure pathways for human receptors in the terrestrial exposure area included: incidental soil ingestion, dermal contact with soil, inhalation of particulates, and contact with groundwater (construction and utility workers only). Exposure pathways for the passive recreator receptor in the aquatic area included: incidental sediment ingestion, dermal contact with sediment, and contact with surface water.

The results of the BHHRA indicate that terrestrial ELCRs are either below 1 x 10^{-6} or are within the risk management range (1 x 10^{-4} to 1 x 10^{-6}) established in the NCP (40 CFR 300.430; 2014) and by the CalEPA Risk Assessment Advisory Committee (1996a). Hazard Indices for the construction worker in the terrestrial exposure area are above 1. Dioxin TEQ concentrations in soils in the terrestrial OU-E Lowland AOC represent the largest contributor to potential cancer risk and non-cancer hazard. As noted above, the HIs and ELCRs in the terrestrial OU-E Lowland AOC are acceptable when dioxin TEQ soil hot spot (Powerhouse and Fuel Barn AOI hot spot associated with sample location DP-052) is removed from the terrestrial dataset.

Estimated ELCRs and HIs for each terrestrial receptor are presented below:

- Construction worker HI and ELCR in the 0 to 0.5 ft bgs exposure interval are 2 and 1 X 10^{-6} respectively. Dioxin TEQ (detected concentrations ranging from 0.32 pg/g to 203 pg/g; EPC = 132 pg/g) is the primary risk contributor in the 0 to 0.5 ft bgs interval. In the 0 to 2 ft bgs depth interval the HI and ELCR for the construction worker are 5 and 5 x 10^{-6} respectively, with Dioxin TEQ as the primary risk driver (detected concentrations ranging from 0.051 pg/g to 2,729 pg/g; EPC =132 pg/g). In the 0 to 6 ft bgs depth interval the HI and ELCR for the construction worker are 3 and 4 x 10^{-6} respectively, with Dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 2,729 pg/g; EPC = 395 pg/g) as the primary risk driver. For the 0 to 10 ft bgs interval, the construction worker HI and ELCR are 3 and 3 x 10^{-6} respectively. Barium (detected concentrations ranging from 18 mg/kg to 8,200 mg/kg; EPC = 869 mg/kg) and Dioxin TEQ (detected concentrations ranging from 0.01 pg/g to 2,729 pg/g; EPC = 326 pg/g) are the main contributors to the non-cancer hazard, while Dioxin TEQ is the primary cancer risk driver.

- Utility worker HIs are all below 1 in the 0 to 0.5 ft bgs (HI=0.2), 0 to 2 ft bgs (HI=0.4) and 0 to 6 ft bgs (HI=0.3) exposure intervals. The utility worker ELCR for the 0 to 0.5 ft bgs exposure interval is below 1 x 10^{-6}. In the 0 to 2 ft bgs depth interval the ELCR for the utility worker is 3 x 10^{-6}, with Dioxin TEQ (detected concentrations ranging from 0.051 pg/g to 2,729 pg/g; EPC =132 pg/g) as the primary risk driver. In the 0 to 6 ft bgs depth interval the ELCR for the utility worker is 2 x 10^{-6}, with Dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 2,729 pg/g; EPC = 395 pg/g) as the primary risk driver.

- Terrestrial child and adult recreational visitor (passive) HIs are below 1 in the 0 to 0.5 ft bgs (HI=0.1), and 0 to 2 ft bgs (HI=0.5) exposure intervals. ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure interval are 2 x 10^{-6} and 6 x 10^{-6}, respectively. Arsenic (detected concentrations ranging from 0.94 mg/kg to 13 mg/kg; EPC = 6.62 mg/kg) is the primary risk driver in the 0 to 0.5 ft bgs interval, while Dioxin TEQ (detected concentrations ranging from 0.051 pg/g to 2,729 pg/g; EPC =132 pg/g) is the primary risk driver in 0 to 2 ft bgs interval. Arsenic soil EPCs are below the site-specific background concentration (10 mg/kg).

- Terrestrial recreational visitor (frequent) HIs are below 1 in the 0 to 0.5 ft bgs (HI=0.1), and 0 to 2 ft bgs (HI=0.4) exposure intervals. ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals are 4 x 10^{-6} and 2 x 10^{-5}, respectively. Arsenic (detected concentrations ranging from 0.94 mg/kg to 13 mg/kg; EPC = 6.62 mg/kg) and dioxin TEQ (detected concentrations ranging from 0.32 pg/g to 203 pg/g; EPC = 132 pg/g) are the primary risk drivers in the 0 to 0.5 ft bgs interval, while dioxin TEQ (detected concentrations ranging from 0.051 pg/g to 2729 pg/g; EPC = 132 pg/g) is the primary risk driver in the 0 to 2 ft bgs interval. Arsenic soil EPCs are below the site-specific background concentration (10 mg/kg).

- Commercial/industrial worker HIs are below 1 in the 0 to 0.5 ft bgs (HI=0.1), and 0 to 2 ft bgs (HI=0.4) exposure intervals. ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure interval are 1 x 10^{-5} and 4 x 10^{-5}. Arsenic (detected concentrations ranging from 0.94 mg/kg to 13 mg/kg; EPC = 6.62 mg/kg) and Dioxin TEQ (detected concentrations ranging from 0.32 pg/g to 203 pg/g; EPC = 132 pg/g) are the primary risk drivers in the 0 to 0.5 ft bgs interval, while Dioxin TEQ (detected concentrations ranging from 0.051 pg/g to 2,729 pg/g; EPC =132 pg/g) is the primary risk driver in the 0 to 2 ft bgs interval. Arsenic soil EPCs are below the site-specific background concentration (10 mg/kg).

Separate evaluations were performed for occasional (passive) adult/child recreators in the aquatic exposure area (consisting of all Pond AOCs) assuming 50 days and 12 days of exposure per year. Results of these evaluations indicate the following:

- ELCRs and HIs for the occasional (passive) recreator are below 1 x 10^{-6} and 1 respectively for both 0 to 0.5 ft bgs and 0 to 2 ft bgs depth intervals when a 12 day per year exposure frequency is considered.

- HIs for the occasional (passive) recreator are below 1 for potential noncancer effects when a 50 day exposure frequency is considered. The ELCR in the 0 to 0.5 ft bgs interval is 5 x 10^{-6}. Arsenic (detected concentrations ranging from 0.61 mg/kg to 103 mg/kg; EPC = 34.5 mg/kg) and Dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 1,227 pg/g; EPC = 340 pg/g) are the primary risk drivers in the 0 to 0.5 ft bgs interval via incidental sediment ingestion. In the 0 to 2 ft bgs interval, the ELCR for the occasional recreator is 6 x 10^{-6}. Arsenic (detected concentrations ranging from 0.61 mg/kg to 115 mg/kg; EPC = 30.5 mg/kg) and Dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 1,688 pg/g; EPC = 457 pg/g) via sediment ingestion exposures are the primary risk drivers in the 0 to 2 ft bgs interval.

In addition to the combined aquatic AOC evaluation, results for individual ponds as separate aquatic exposure areas in OU-E were estimated. Each pond was evaluated using a conservative exposure frequency of 50 days per year for the adult and child occasional (passive) recreator. Since a lower exposure frequency would be expected in Ponds 1 through 4 because proposed uses in this portion of the site are “industrial” and “urban reserve”, an alternate scenario is also presented in this BHHERA for Ponds 1 through 4 assuming potential exposures of 12 days per year. Results of these evaluations indicate the following:

- For Ponds 1 through 4, HIs are below one. ELCRs for the 50 days per year scenario in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals are 8 x 10^{-6} and 7 x 10^{-6}, respectively. Potential exposure to arsenic and dioxin TEQ from sediment ingestion in Ponds 1 through 4 are primary contributors to the ELCRs with the COPC-specific ELCRs for arsenic and Dioxin TEQ greater than 1 x 10^{-6}. ELCRs for 12 days per year scenario in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals are both 2 x 10^{-6}. Potential exposure to arsenic and dioxin TEQ from sediment ingestion in Ponds 1 through 4 is the primary contributor to the ELCRs and the COPC-specific ELCRs for arsenic and dioxin TEQ both equal 1 x 10^{-6}. Arsenic (detected concentrations ranging from 4.1 mg/kg to 81.6 mg/kg; EPC = 53.6 mg/kg) and dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 995.5 pg/g; EPC = 493 pg/g) are the primary risk drivers in the 0 to 0.5 ft bgs interval via incidental sediment ingestion. In the 0 to 2 ft bgs interval, arsenic (detected concentrations ranging from 1.66 mg/kg to 98.9 mg/kg; EPC = 45.8 mg/kg) and dioxin TEQ (detected concentrations ranging from 0.02 pg/g to 1285 pg/g; EPC = 442 pg/g) are the primary risk drivers via incidental sediment ingestion. For the 12 day exposure scenario, the cumulative ELCR in Ponds 1 through 4 for the adult/child occasional recreator would be equal to 1 x 10^{-6} if the minimal contribution of soil and dust to human body burden for dioxin TEQ were taken into account in calculating baseline risks.

- Occasional recreator HIs and ELCRs for Pond 5 and Pond 9 are below 1 and 1 x 10^{-6} respectively. HIs for the remaining ponds (i.e., Pond 6, Pond 7, Pond 8 and North Pond), assuming an exposure frequency of 50 days per year are less than 1, though the ELCRs are in the 1 x 10^{-6} to 1 x 10^{-4} range.

    - Pond 6 ELCRs are 4 x 10^{-6} in 0 to 0.5 ft bgs exposure interval. Arsenic (detected concentrations ranging from 0.61 mg/kg to 37.2 mg/kg; EPC = 37.2 mg/kg) and dioxin TEQ (detected concentrations ranging from 3.7 pg/g to 175 pg/g; EPC = 175 pg/g) are the primary risk drivers in 0 to 0.5 ft bgs interval via incidental sediment ingestion. In the 0 to 2 ft bgs interval, ELCR for the occasional recreator is 3 x 10^{-6}. In the 0 to 2 ft bgs interval, arsenic (detected concentrations ranging from 0.61 mg/kg to 37.2 mg/kg; EPC = 28.2 mg/kg) and dioxin TEQ (detected concentrations ranging from 2.1 pg/g to 175 pg/g; EPC = 175 pg/g) are the primary risk drivers.

    - Pond 7 ELCRs are 2 x 10^{-5} in both the 0 to 0.5 ft bgs and 0 to 2 ft bgs depth intervals. Arsenic (detected concentrations ranging from 11 mg/kg to 103 mg/kg; EPC = 103 mg/kg) and dioxin TEQ (detected concentrations ranging from 753 pg/g to 1,227 pg/g; EPC = 1,227 pg/g) are the primary risk drivers in the 0 to 0.5 ft bgs interval via incidental sediment ingestion. In the 0 to 2 ft bgs interval, Arsenic (detected concentrations ranging from 11 mg/kg to 115 mg/kg; EPC = 132 mg/kg) and dioxin TEQ (detected concentrations ranging from 753 pg/g to 1,668 pg/g; EPC = 1,688 pg/g) are the primary risk drivers.

    - North Pond ELCRs are 2 x 10^{-6} in both the 0 to 0.5 ft bgs and 0 to 2 ft bgs depth intervals. Arsenic (detected concentrations ranging from 1.5 mg/kg to 103 mg/kg; EPC = 103 mg/kg) is the primary risk contributor in North Pond.

- o Pond 8 ELCRs are 2 x 10^{-6} in both the 0 to 0.5 ft bgs and 0 to 2 ft bgs depth intervals. Arsenic (detected concentrations ranging from 1.7 mg/kg to 27.6 mg/kg; EPC = 12.3 mg/kg) and dioxin TEQ (detected concentrations ranging from 4 pg/g to 231 pg/g; EPC = 118 pg/g) are the primary risk drivers in the 0 to 0.5 ft bgs interval via incidental sediment ingestion. Arsenic (detected concentrations ranging from 1.7 mg/kg to 27.6 mg/kg; EPC = 11.2 mg/kg) and dioxin TEQ (detected concentrations ranging from 4 pg/g to 231 pg/g; EPC = 110 pg/g) are the primary risk drivers in the 0 to 2 ft bgs interval. From a practical standpoint, exposure to the sediments in Pond 8 for any duration is remote due to site-specific factors that discourage access such as dense vegetation, steep banks, and cold surface water and air temperatures for much of the year. From a risk analysis standpoint, arsenic concentrations in Pond 8 are comparable to background, so arsenic ECLRs are not associated with site conditions for the Pond 8 AOC. When the Pond 8 occasional recreator is evaluated without considering background arsenic exposures, the resulting cumulative ELCR in Pond 8 is 1 x 10^{-6}. If the minimal contribution of soil and dust to human body burden for dioxin TEQ were taken into account in calculating baseline risks in Pond 8, the cumulative ELCR would decrease by an order of magnitude.

Cancer and noncancer risks were evaluated for occasional recreators in the aquatic exposure area. As noted above, actual recreational exposures to pond sediments and surface water are unlikely. ELCRs and HIs for the occasional recreator in aquatic areas are below target thresholds for potential cancer and noncancer effects when a 12 day exposure frequency is considered. When a conservative alternative exposure frequency requested by DTSC (50 days per year) is assumed, the HIs are below one, and the ELCRs in the 0 to 0.5 ft bgs and 0 to 2 ft bgs exposure intervals remain low (5 x 10^{-6} and 6 x 10^{-6}, respectively) though are above 1 x 10^{-6}. Dioxin sediment ingestion exposures make up the greatest proportion of the ELCR for this alternative recreator scenario (54% for the 0 to 0.5 ft bgs interval and 63% for the 0 to 2 ft bgs interval). Within the aquatic exposure area, the highest concentrations of dioxin TEQ were detected in sediments collected from Pond 7 (samples Pond 7-01 and Pond 7-02). Expected exposures to sediments are unlikely and the exposure frequency of 50 days per year is highly unlikely.

9.2.2 Ecological Risk Characterization Results

The ecological risk assessment focused on assessment and measurement endpoints presented in the approved OU-E BHHERA Work Plan (ARCADIS, 2013b) and Table 7-1. Exposure pathways for ecological receptors illustrated in the CSMs (Figures 5-1 and 5-2) included direct contact (plants, invertebrates, and amphibians) or the ingestion of soil/sediment and prey (wildlife). Ecological receptors were assessed for the terrestrial OU-E Lowland AOC and an aquatic exposure area (i.e., combined Pond AOCs and each Pond AOC separately). In addition, ecological risks for the Riparian AOI in OU-D, were refined using methods discussed in Section 8. The ERA results are summarized below.

- *Terrestrial AOC*: Unacceptable risks for populations of plants, soil invertebrates, birds, and mammals exposed to COPC in soil are unlikely. HQs are generally less than one, or COPC EPCs were below site-specific background concentrations. Barium HQs for plants, invertebrates, and invertivorous mammals were greater than one, but are driven by a few samples located in a small area of the site indicating potential population-level exposure is limited. Furthermore, even if barium in soil in this localized area does pose a potential risk, which is unlikely due to the insoluble form of barium likely present in soil (i.e., barium sulfate or barium carbonate), exposure of individual receptors in a small area would not result in unacceptable effects to local populations.

- o As discussed in Section 7.3.1.5 (Hot Spot Analysis), residual EPCs calculated for each depth interval assuming the removal of hot spots are less than the site-specific RBTL developed for ecological receptors. Therefore, potential risk is not identified for ecological receptors exposed to Dioxin TEQ and lead. Hot spots removed are consistent with the list provided in Section 9.1.1 for the human health results.

- o Assuming 100% bioaccessibility for arsenic, lead, zinc, and dioxin TEQ, NOAEL-based HQs for American kestrel and ornate shrew exposed to dioxin in soil are greater than one. The maximum concentration is located at DP-052, which was identified as a hot spot (Section 5.1.1.1). Therefore, potential risk is reduced when this location is excluded from the terrestrial dataset, and HQ is estimated less than 1 indicating that risk is *de minimis* following removal of the PRA.

- *Aquatic Exposure Area and Riparian AOI*: Unacceptable risks are not expected for populations of plants, benthic organisms, amphibians, birds, or mammals exposed to COPC in sediment. However, there is potential for localized risk to benthic organisms from barium exposure in Pond 7 sediment, based on comparison of porewater barium concentrations to the selected surface water screening level (RWQCB 2013).

    - o Potential risk was also estimated on an individual pond basis and HQs were greater than one for Virginia rail in Ponds 1 through 4 (barium) and Pond 8 (barium and selenium). Potential risk from barium is not expected consistent with Section 7.3.2.4. The selenium EPC is just slightly greater than background and the LOAEL-based HQ is less than one, indicating potential risk is unlikely.

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