

APPENDIX 6
HUMAN HEALTH RISK ASSESSMENT

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DRAFT BASELINE HUMAN HEALTH RISK ASSESSMENT REPORT

**MSGRP Northern Study Area
Industri-Plex Superfund Site
Operable Unit 2
Woburn, Massachusetts**

**Text, Figures,
Tables and Appendices**

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EXECUTIVE SUMMARY

A Baseline Human Health Risk Assessment for the Northern Study Area of the Multiple Source Groundwater Response Plan (MSGRP) Remedial Investigation (RI) was conducted by Metcalf & Eddy, Inc. for USEPA Region I. For the risk assessment, the Northern Study Area (i.e., the study area) includes groundwater, surface water, sediment, and soil contamination from the Industri-plex Superfund Site (i.e., the site), south to Mishawum Road and Interstate 95/Route 128 in North Woburn, Massachusetts. The study area also includes groundwater within the boundaries of the site, and the Aberjona River, Halls Brook Holding Area (HBHA), and associated wetland areas located north of Interstate 95/Route 128. The southern boundary of the study area is the edge of the Interim Wellhead Protection Area (IWPA) for municipal wells G and H. The MSGRP comprehensive RI merges the Northern Study Area and Southern Study Area (i.e., the Aberjona River south of Interstate 95/Route 128 to the Mystic Lake).

The study area contains numerous commercial and light industrial businesses as well as a regional transportation center. The site was historically used for chemical and glue manufacturing which generated wastes containing residues of arsenic insecticides, benzene, toluene, and the metals chromium, copper, lead, and zinc. The hide wastes, consolidated into four hide piles and portions of a utility right-of-way, and contaminated soils were capped as part of the soil remedy for the site.

The objective of the baseline human health risk assessment is to determine whether contaminated media (surface water, sediment, sediment cores, fish, soil, groundwater, and soil gas) within the study area, remaining after completion of the site soil remedy, pose risks to human health.

The field program for the study area was conducted between 1999 and 2004, and included the collection and analysis of surface water, sediment, sediment cores, surface and subsurface soil, fish, groundwater, and soil gas samples. Chemical classes of concern included volatile organics

(VOCs), semi-volatile organics (SVOCs), and inorganics. Twelve reference stations were also identified from which surface water, sediment, and fish tissue were collected.

For the purposes of the risk assessments, the study area was divided into:

- three soil areas where residual contamination may remain (designated HB04, SO, and A6);
- seven sediment areas where recreational exposures are currently occurring or may occur under future use conditions (designated HB01, HB02, HB03, AR, BE-1, BE-2, and MC-13);
- four sediment core locations where future dredging activities are possible (designated SC01 through SC04);
- three surface water sampling locations where baseflow and storm event data have been collected (designated SW-02-TT, SW-03-TT, and SW-04-TT);
- two groundwater areas: 1) the Class A Properties (i.e., those on the east side of the site without soil contamination); and (2) the remainder of the study area; and
- soil gas samples collected from seven areas displaying the maximum shallow groundwater volatile contaminant levels, representative of maximum potential air impacts at the study area.

Groundwater collected from the most downgradient portion of the study area (the AF- and P-1 series wells) was also of interest to determine potential contaminant impacts to the Wells G&H IWPA from the upgradient study area. Contaminant levels in these wells were compared to drinking water standards (i.e., Maximum Contaminant Levels or MCLs) because although municipal wells G and H are inactive, they are still considered a potential source of public drinking water in the future. Because sediment station MC-13 is considered difficult to access due to its remote location and the presence of dense vegetation, sampling data collected from this station was not quantitatively evaluated in the human health risk assessment.

Prior to completion of the risk assessment, an arsenic bioavailability study was performed to assist in the quantification of sediment risks. This site-specific study determined that arsenic is absorbed

less efficiently from sediment than from a water medium. The relative bioavailability estimate determined in this recent study was used to quantify sediment ingestion risks at the study area. In addition, site-specific chromium VI (hexavalent chromium) data for sediments and soils were collected and used in the risk assessment to more accurately characterize sediment and soil risks at the study area.

Based on current and future land use considerations, the following receptors were selected for evaluation in the baseline risk assessment: (1) recreational users at stations where exposure to contaminants in soil, sediment, surface water, and fish fillet tissue may occur during activities including wading and fishing; (2) groundskeepers, construction workers, and day care children who have the potential for contact with residual contaminants in soil at commercial areas within the study area; and (3) workers who may be exposed to deeper sediments during potential dredging of the wetland areas within the study area. Use of land for a day care facility was also included in the evaluation since this use is occurring and is likely to continue into the future.

The Massachusetts Department of Environmental Protection (MADEP) groundwater use and value determination for the Industri-plex Superfund Site (MADEP, 1997) supports a low use and value for groundwater at the study area, such that use of groundwater as a potable water supply is not considered appropriate for risk evaluation. For risk evaluation purposes, a low use and value classification states that groundwater exposures evaluated should include: (1) vapor seepage into buildings; (2) use of groundwater in industrial processes; and (3) worker exposures associated with excavations into groundwater (see *MADEP Groundwater Use and Value Determination* included as Appendix 6M of this report). Several groundwater wells in the vicinity of, but outside the study area, are used for non-potable activities such as irrigation. Therefore, the pumping and industrial use of groundwater from the study area is possible in the future. Specific industrial groundwater use evaluated in the human health risk assessment includes process water use, with incidental ingestion, dermal contact, and inhalation exposures, and the use of groundwater in a warm water car wash with primarily inhalation exposures. Because groundwater throughout the study area is shallow, future construction workers may also be exposed to groundwater

contaminants during excavations down to the water table. Soil gas sampling data were collected to more accurately characterize potential groundwater volatile impacts to indoor and outdoor air quality within the study area. However, soil gas contaminant concentrations were found to be below conservative screening values. Therefore, this pathway was not quantitatively evaluated in the baseline human health risk assessment.

Receptors evaluated in the baseline risk assessment include:

- current and future teenage recreational users;
- current and future adult and young child consumers of fish;
- current and future groundskeepers;
- current and future day care children;
- future dredging worker;
- future industrial worker;
- future car wash worker; and
- future construction worker.

Whenever possible, 95% Upper Confidence Limits (UCLs), calculated using USEPA's software ProUCL version 3.0, were used as exposure point concentrations. Exposure point concentration, in combination with toxicity information, were used to quantitatively estimate potential noncarcinogenic and carcinogenic human health risks for the central tendency (CT) and reasonable maximum exposure (RME) cases. An overall summary of carcinogenic and noncarcinogenic risk estimates are presented in Table ES-1 and Figures ES-1 through ES-3. In Table ES-1, risks are summarized for both the RME and CT receptors only for media and locations where site-specific risks exceed risk management guidelines adopted by the CERCLA program (a carcinogenic risk greater than 10^{-4} and/or a noncarcinogenic hazard greater than 1). When risks were estimated for the young child and adult receptor (i.e., fish consumers), the young child noncarcinogenic hazard is presented as the most conservative. In contrast, the cancer risk presented is the sum of the young child and adult risks (i.e., a total receptor risk) as cancer risks are additive. Sediment, soil, and surface water risks, presented for the study area stations, have

been summed together under the assumption that the teenager is exposed to all three media during recreational activities. For the construction worker, soil and groundwater risks were summed. Estimated risks were compared to the USEPA target cancer risk range of 10^{-6} to 10^{-4} and a target hazard index (HI) of 1 for noncarcinogenic effects.

Risks Under Current Condition. Carcinogenic and noncarcinogenic risks estimated for the teenage recreational user exposure scenario (surface water, sediment, and soil) were less than or within the target cancer risk range of 10^{-6} to 10^{-4} and less than the target HI of 1 for each station (i.e., HB01, HB03, AR, and BE-1). Fish ingestion risks for an adult and young child were also less than or within the target cancer risk range of 10^{-6} to 10^{-4} and less than the target HI of 1. In addition, estimated risks for groundskeeper exposures to soil were less than or within the target cancer risk range of 10^{-6} to 10^{-4} and less than the target HI of 1 at both soil exposure points (i.e., HB04 and SO). Day care child risks to surface soil at soil area SO were also less than or within the target cancer risk range of 10^{-6} to 10^{-4} and less than the target HI of 1

An evaluation of lead in soil and sediments indicated that exposures to lead, under current conditions, did not result in teenage or adult blood lead levels in excess of the blood lead level goal.

Potential Risks Under Future Conditions. For the future teenage recreational user scenario, cancer risks and HIs for all stations (i.e., HB01, HB02, HB03, AR, BE-1, and BE-2) were less than or within the target cancer risk range of 10^{-6} to 10^{-4} and less than the target HI of 1. Risk associated with baseflow and storm event surface water were comparable, and not associated with risks above EPA risk management guidelines. Future estimated risks for the groundskeeper and construction worker were also less than or within the target cancer risk range of 10^{-6} to 10^{-4} and less than the target HI of 1 for exposures to surface soil at both soil exposure points (i.e., HB04 and SO). Estimated risks associated with the future dredging of sediments from the study area were less than or within EPA risk management guidelines of 10^{-4} and an HI of 1 for sediment core locations SC01, SC03, and SC04. Construction worker exposures to groundwater at the Class A

Properties were associated with risks below a cancer risk of 10^{-4} and an HI of 1. Risks estimated for the future use of groundwater as process water and in a warm water car wash did not exceed EPA risk management guidelines of 10^{-4} and an HI of 1 for groundwater at the Class A Properties.

The HI exceeded the target of 1 for sediment dredging exposures at sediment core location SC02. The exceedance was due primarily to the presence of arsenic in the 0-1 foot interval. The HI exceeded 1 and/or the cancer risk exceeded 10^{-4} for future day care child exposures to surface and subsurface soils at area SO. The HI also exceeded the target of 1 for future construction worker exposures to subsurface soils at area SO and to shallow groundwater within the study area. The exceedances were due primarily to the presence of arsenic in surface soil at locations SO-13, SO-14, and SO-16, arsenic in subsurface soil at locations SO-13, SO-11, SO-3, and SO-14, and arsenic in shallow groundwater monitoring wells B7-01, B4-04, and B7-02. Figure ES-1 shows the soil and sediment core locations with elevated concentrations of arsenic in the surface and subsurface. Figure ES-2 shows locations of monitoring wells with elevated concentrations of arsenic in shallow groundwater.

Risks in excess of 10^{-4} and an HI of 1 were estimated for study area groundwater used as process water use and in a warm water car wash. Primary risk contributors for process water use and the use of groundwater in a warm water car wash include benzene, trichloroethene, and naphthalene. Arsenic was also identified as a primary risk contributor for the process water exposure scenario. For these primary risk contributors, the highest concentrations were seen in monitoring wells: B7-01, B4-04, B7-02, B6-03, B5-02, and B8-04 for arsenic; B5-01, W5-06, W5-05, B7-03, B9-02, B9-01, W5-03, RX-1 through RX-10, and RX-15 through RX-19 for benzene; AE-03, W5-03, AE-02, AE-04, and AE-06 for trichloroethene; and W5-05 for naphthalene. Additional minor risk contributors for process water and warm water car wash use include: 1,2-dichloroethane, chloroform, and methyl tert-butyl ether. Pentachlorophenol was also identified as a minor risk contributor for the process water exposure scenario. Figure ES-2 shows the locations of

monitoring wells with elevated concentrations of arsenic while Figure ES-3 shows the locations of monitoring wells with elevated concentrations of benzene, trichloroethene, and naphthalene.

Inhalation risks and hazards for the process water and car wash scenarios were based on air concentrations generated from groundwater data through the use of volatilization and dispersion modeling. Parameter values used in these models were selected to represent reasonable maximum exposures that may occur in the future should groundwater be used as process water or for use in a warm water car wash. The risk associated with future groundwater use may be less than estimated should groundwater uses that result in a lower degree of worker exposures be considered (e.g., use of groundwater for cooling in a closed system).

An evaluation of lead in soil and sediment indicated that exposures to lead, under future conditions, did not result in young child, teenage, or adult blood lead levels in excess of the blood lead level goal.

Contaminant concentrations in the P-1 transect and the AF-series monitoring wells, immediately upgradient of the Wells G&H IWPA, were compared to primary and secondary MCLs. Figure ES-4 depicts the wells in which groundwater concentrations exceed primary MCLs. For the P-1 transect and AF-series monitoring wells, only arsenic exceeded its primary MCL. Groundwater data collected from the AF-series wells did not contain elevated levels of total suspended solids and are considered representative of groundwater quality as it leaves the study area and enters the Wells G&H IWPA. Filtered results were used for comparison to MCLs and secondary MCLs for the P-1 transect wells because a number of the wells could not be stabilized prior to sampling and may have contained elevated levels of total suspended solids.

A separate risk assessment has been completed for the Aberjona River south of Interstate 95/Route 128 that includes environmental data collected from the Wells G&H Superfund Site to the Mystic Lakes. Collectively, the two risk assessments evaluate the environmental data collected along the entire river from the Industri-Plex Superfund Site in North Woburn to the

Mystic Lakes. Section 6.0 of the Comprehensive MSGRP RI Report merges, summarizes, and refines the two human health risk assessments. The comprehensive RI Report documents all the data collected along the Aberjona River and Halls Brook Holding Area from North Woburn to the Mystic Lakes, and further explains the nature and extent of contaminants and their fate and transport mechanisms.

TABLE ES-1
SUMMARY OF RECEPTOR RISKS
HUMAN HEALTH RISK ASSESSMENT
INDUSTRI-PLEX SUPERFUND SITE

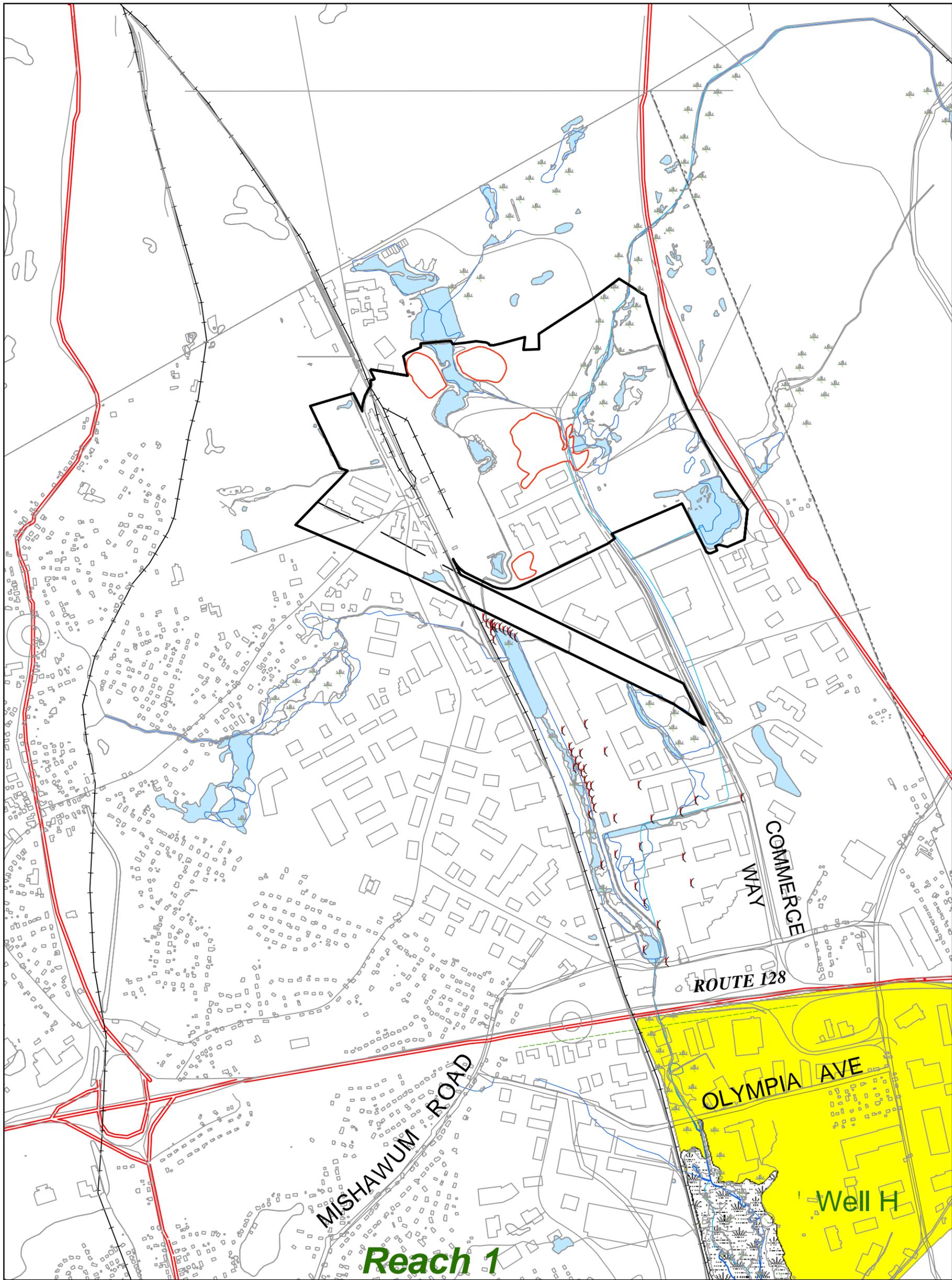
Station	Scenario/Receptor	RME or CT	Total Cancer Risks	Total Noncancer Risks	Media > 1E-04 or HI > 1	Major contributors to risk (> 1E-06, HI > 1)
SC02	Future Dredger	RME CT	5E-05 6E-06	4E+00 1E+00	sediment	(NC) - As
SO	Future Day Care Child (surface soil)	RME CT	1E-04 2E-05	2E+00 1E+00		(C) - As
	Future Day Care Child (subsurface soil)	RME CT	1E-03 3E-04	4E+01 2E+01	soil	(C) - As (NC) - As
	Future Const. Worker (subsurface soil)	RME CT	4E-05 1E-05	7E+00 2E+00	soil	(NC) - As N/A
Study Area	Future Const. Worker	RME CT	2E-05 6E-06	3E+00 9E-01	groundwater	(NC) - As
	Future Industrial Worker	RME CT	1E-03 4E-04	2E+01 2E+01	groundwater indoor air	(C) - 1,2-Dichloroethane, benzene, chloroform, trichloroethene, pentachlorophenol, MTBE, As (NC) - Benzene, naphthalene, As
	Future Car Wash Worker	RME CT	1E-03 4E-04	2E+01 2E+01	indoor air	(C) - 1,2-Dichloroethane, benzene, chloroform, trichloroethene, MTBE (NC) - Benzene, naphthalene

Notes

Bolded values exceed a cancer risk of 1E-04 or a target organ HI of 1.

HI - Hazard Index
RME - Reasonable Maximum Exposure
CT - Central Tendency Exposure
As - Arsenic
MTBE - Methyl tert-butyl ether

(C) - Carcinogenic Risk
(NC) - Noncarcinogenic Risk
NE - Not Evaluated
N/A - Not Applicable



LEGEND

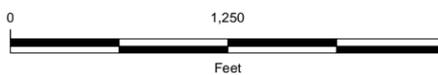
- +— Rail Lines
- Study Area Reach
- Culvert

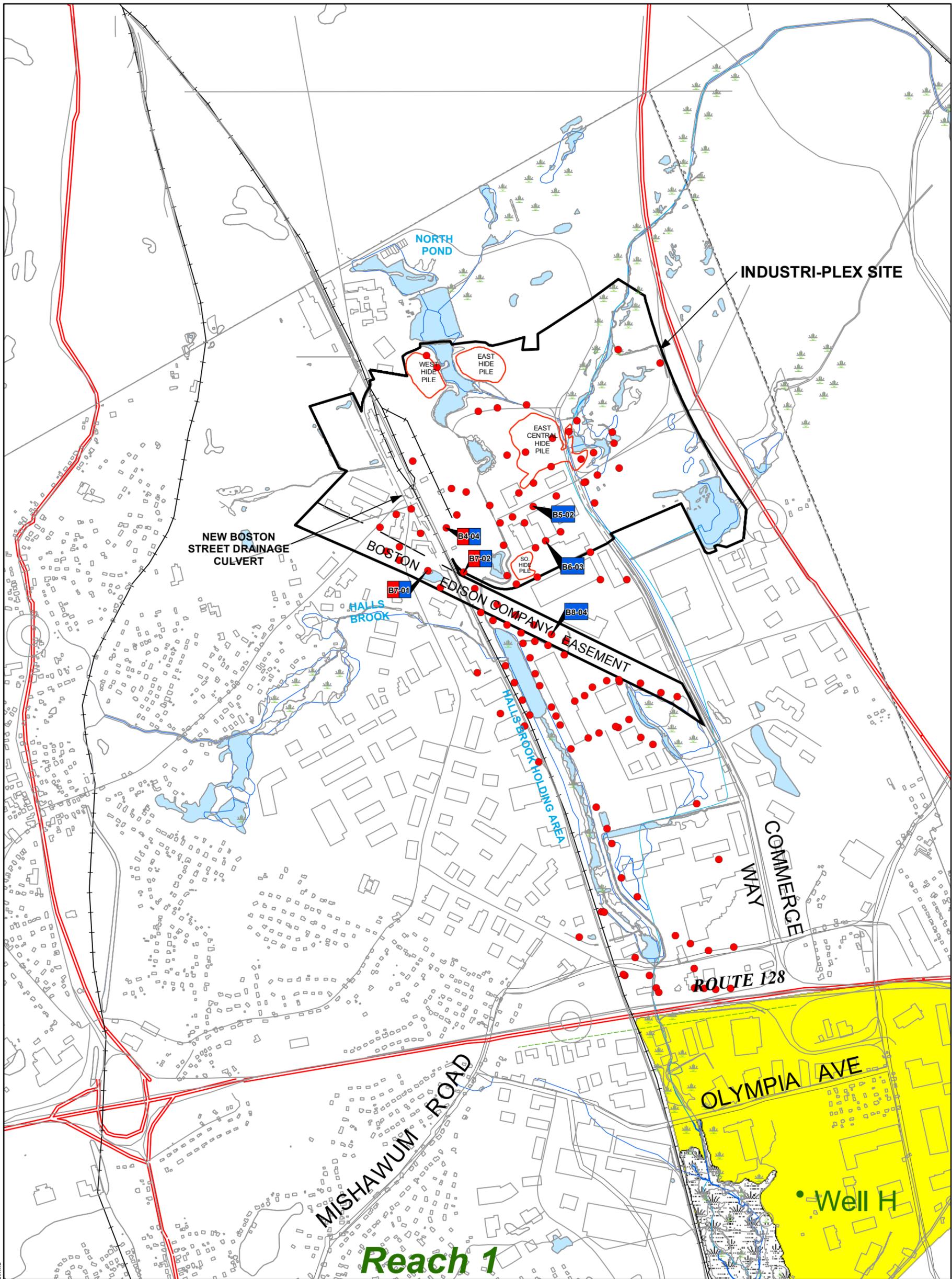


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**FIGURE ES-1.
SOIL/SEDIMENT
SAMPLING LOCATIONS
WITH FUTURE
HUMAN HEALTH RISK**

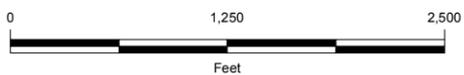
**INDUSTRI-PLEX
SUPERFUND SITE**





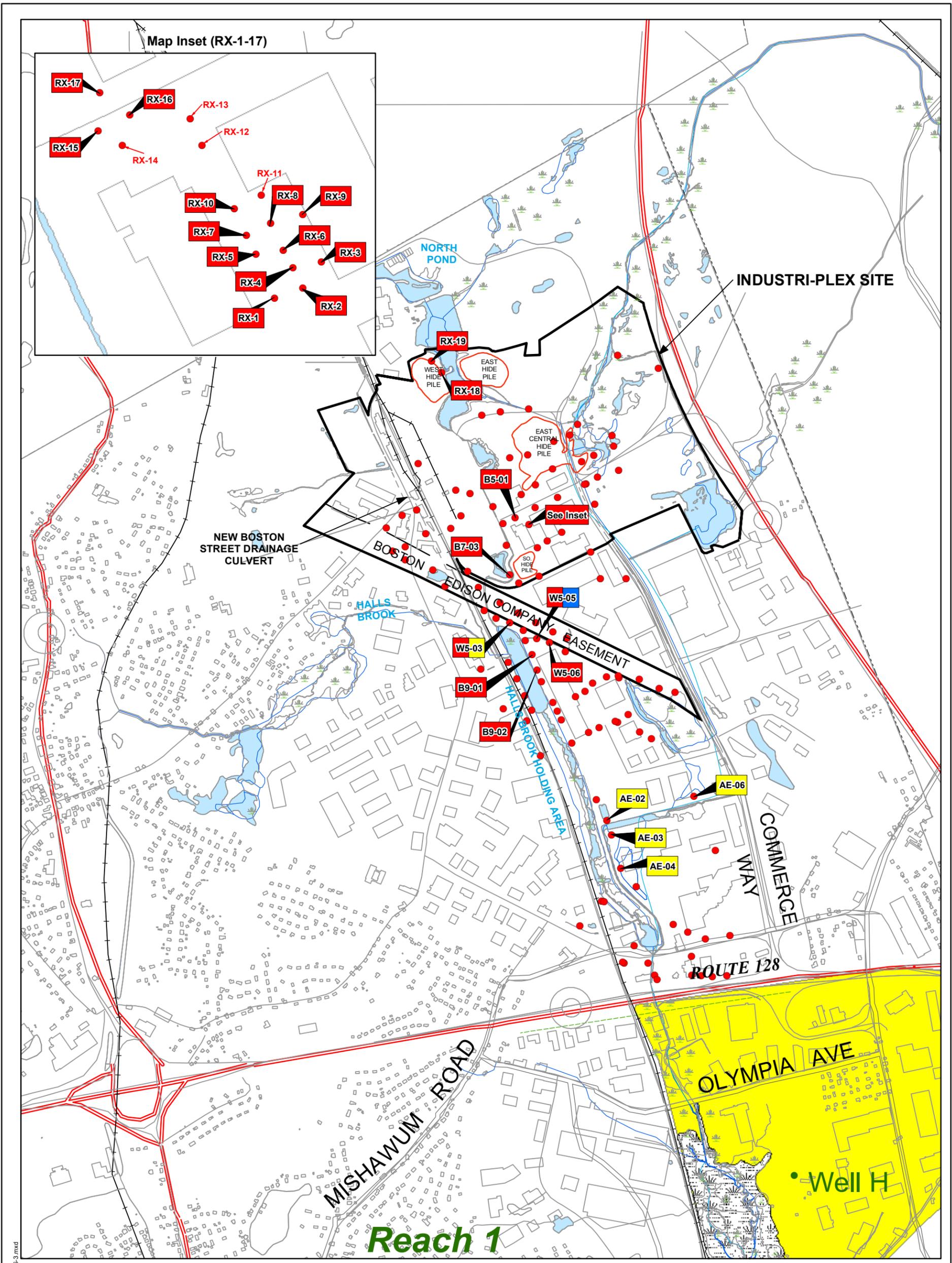
LEGEND

- Rail Lines
- Study Area Reach
- Culvert
- Wetlands
- Former Cranberry Bog
- Wells G & H Superfund Site
- Sampling Location
- Aberjona River
- Bodies of Water
- Buildings
- B7-01 Shallow
- B8-04 All Depths Combined



**FIGURE ES-2.
MONITORING WELLS
WITH FUTURE HUMAN
RISK-ARSENIC
INDUSTRI-PLEX
SUPERFUND SITE**

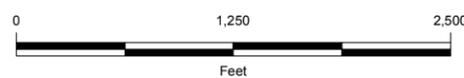
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LEGEND

- | | | | |
|--|----------------------------|--|-------------------|
| | Rail Lines | | Sampling Location |
| | Study Area Reach | | Aberjona River |
| | Culvert | | Bodies of Water |
| | Wetlands | | Buildings |
| | Former Cranberry Bog | | Trichloroethene |
| | Wells G & H Superfund Site | | Benzene |
| | | | Napthalane |



**FIGURE ES-3.
MONITORING WELLS
WITH FUTURE HUMAN
RISK-ORGANICS

INDUSTRI-PLEX
SUPERFUND SITE**

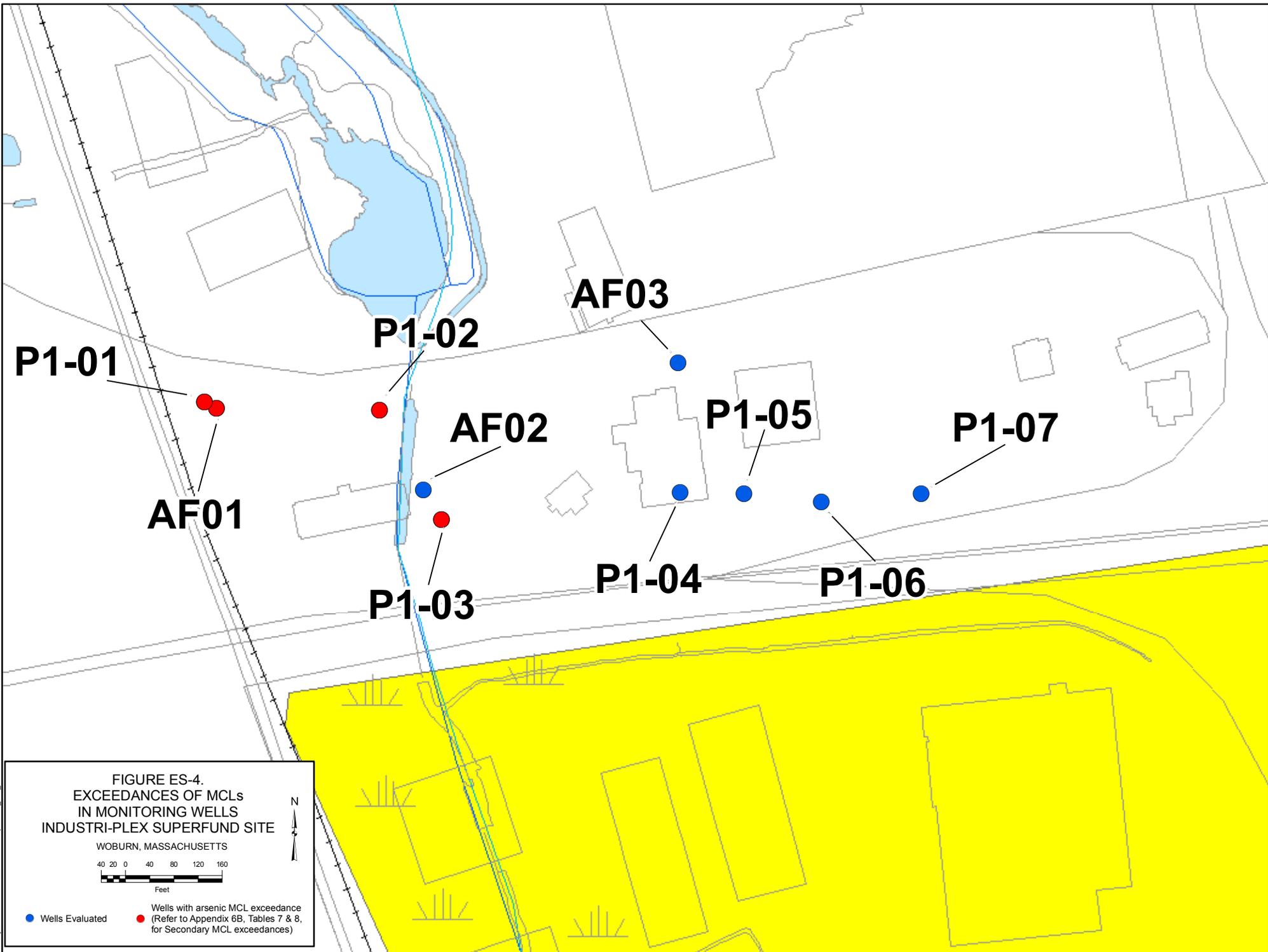
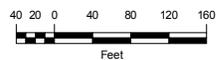


FIGURE ES-4.
EXCEEDANCES OF MCLs
IN MONITORING WELLS
INDUSTRI-PLEX SUPERFUND SITE

WOBURN, MASSACHUSETTS



- Wells Evaluated
- Wells with arsenic MCL exceedance
 (Refer to Appendix 6B, Tables 7 & 8,
 for Secondary MCL exceedances)

APPENDIX 6A
BASELINE HUMAN HEALTH RISK ASSESSMENT
MSGRP NORTHERN STUDY AREA

1.0 INTRODUCTION

This appendix to the comprehensive Remedial Investigation(RI) Report, also known as the Multiple Source Groundwater Response Plan (MSGRP) RI, contains the baseline human health risk assessment conducted for Northern Study Area (i.e., the study area). For the risk assessment, the study area, located in North Woburn, Massachusetts, is defined as the area from the Industri-plex Superfund Site south to Interstate 95/Route 128 and includes groundwater, surface water, sediment, and soil contamination in areas adjacent to the Industri-plex Superfund Site. The study area also includes groundwater within the boundaries of the Industri-plex Superfund Site. The Aberjona River, Halls Brook Holding Area (HBHA), and associated wetland areas north of Interstate 95/Route 128 are significant features of the study area. However, surface water within the Industri-plex Site boundaries is excluded from the study area. Figure 1 shows significant study area features and the relationship of the study area to the surrounding land. The study area is also defined as "Reach 0" of the Aberjona River in the MSGRP RI (see Figure 1). A more detailed description of the study area can be found in Section 1 of the MSGRP RI.

The focus of this evaluation is the quantitative evaluation of current and potential future risks to: (1) recreational users at stations¹ where exposure to contaminants during recreational activities may occur; (2) workers and children who have the potential for contact with residual contaminants at commercial areas of the study area; and (3) workers who may be exposed to deeper sediments during potential dredging of the wetland areas within the study area. Recreational receptors utilizing the Aberjona River, HBHA, and related wetlands could potentially contact contaminants in soil, sediment, surface water, and fish fillet tissue while engaging in activities including wading and fishing. Worker-related exposures may occur to contaminants in sediment cores, soil, groundwater, and soil gas impacted by volatile compounds

¹ The term station is used to describe a distinct recreational area along the river, HBHA or related wetlands where human exposures are reasonably assumed to occur currently or in the future. Specific surface water, sediment, and soil samples are assigned to a station in order to estimate risk associated with exposures occurring at that station. See Attachment 1 for sediment, surface water, and soil samples that comprise each station.

present in the subsurface. Use of land within the study area for a day care facility has also been included in the evaluation since this use is currently occurring and is likely to continue into the future.

Some areas of the Aberjona River, HBHA, and related wetlands are currently difficult to access due to the presence of dense vegetation and/or deep water. Some of these difficult-to-access stations may become accessible in the future should the study area undergo additional development resulting in the removal of the dense vegetation.

The East Drainage Ditch, Landfill Creek, and the New Boston Street Drainway, located within the boundaries of the study area, are not being assessed in the baseline human health risk assessment because these drainage features were previously addressed as part of the Industri-plex Superfund Site soil remedy. Sections of the East Drainage Ditch and Landfill Creek that are outside the boundaries of the study area are being investigated under the auspices of the Massachusetts Department of Environmental Protection (MADEP) Bureau of Waste Site Cleanup (BWSC) and its cleanup regulations 310 CMR 40.0000 (the Massachusetts Contingency Plan [MCP]) as part of site investigations at the Olin Chemical Company facility in Wilmington, and under the MADEP Office of Solid Waste's regulations 310 CMR 19.000 through post-closure monitoring activities at the Woburn Landfill. These data include sediment samples with the designation "SD-ED-", and surface water samples collected for gauging stations SW-01-IP through SW-03-IP and SW-05-IP through SW-08-IP. Similarly, groundwater monitoring wells installed outside the boundaries of the study area (i.e., the AA-series wells) are not being addressed in the baseline risk assessment because they were installed to characterize upgradient impacts on the study area.

1.1 Purpose and Scope

The purposes of the baseline human health risk assessment are: 1) to evaluate the potential human health risks that may be posed by chemical contamination of the surface water, sediment, sediment cores, fish fillet tissue, soil, groundwater, and soil gas within currently accessible and future potentially accessible portions of the study area; and 2) to provide a basis for decisions as to whether remedial action is necessary. This baseline risk assessment may also be used qualitatively to identify study area conditions (chemicals, exposure pathways, locations) of greatest potential concern.

According to USEPA guidelines (USEPA, 1989), the baseline risk assessment generally consists of four basic steps summarized below:

Hazard Identification. Determination of the nature and amount of chemicals that could potentially be encountered at a site, and selection of those chemicals that are of potential concern for the assessment of the impact on human health.

Exposure Assessment. Quantification of the extent, frequency, and duration of actual or potential exposure to chemicals by pathways relevant to a site and the activities of potential receptors.

Toxicity Assessment. Identification of the types of health effects that could be associated with exposure to these chemicals, determination of the relationship between exposure (dose) and the probability of occurrence of the health impact (response).

Risk Characterization. Estimation of the probability that an adverse health impact may occur as a result of exposure to chemicals in the amount and by the pathways identified and the uncertainty in those estimates.

The baseline human health risk assessment for the study area was conducted using methodologies required by USEPA guidelines (USEPA, 1989; 1991a; 1992; 1994b; 1995; 1996; 1997a; 2001a; 2002c; 2003a; 2004a; and 2004c). A baseline risk assessment is intended to be site-specific; therefore, site-specific information was incorporated into the evaluation whenever available. In the absence of site-specific information, default assumptions, as specified by USEPA guidance, or professional judgment were used.

The baseline human health risk assessment provides estimates of risk, under both current use and hypothetical future use scenarios, to both the central tendency (CT) receptor and the reasonable maximum exposed (RME) receptor. The CT receptor is used to represent average exposures occurring at a site while the RME receptor is used to represent the maximum (upper-bound) exposure that is reasonably expected to occur. Exposure pathways and exposure routes are selected based on current and future land use. Exposure assessments model human exposure by these pathways according to equations presented in relevant guidance documents. Variables contributing most to estimates of risk or to the uncertainty in the risk assessment have been identified. Each of these steps is discussed in more detail in the appropriate sections of the report.

This baseline human health risk assessment consists of several sections. Section 2.0, Hazard Identification, describes the environmental samples used for the risk assessment, the selection of

chemicals of potential concern (COPCs) from among the chemicals identified at the study area, and the determination of exposure point concentrations (EPCs). Section 3.0, Exposure Assessment, describes the selection of receptors and exposure pathways to be evaluated and the calculation of dose to the receptors selected. Section 4.0, Toxicity Assessment, summarizes the toxicity of the COPCs including both potential carcinogens and noncarcinogens. Section 5.0, Risk Characterization, includes a summary of study area risks and an uncertainty analysis.

Table 1 (Selection of Exposure Pathways) provides a conceptual model for the study area, identifying the exposure media, exposure points, receptors, and routes of exposure quantitatively evaluated as part of the baseline human health risk assessment.

1.2 Study Area Description and History

The study area is located in the northeast corner of Woburn, Massachusetts and is bordered to the north, south, and west by mainly commercial and light industrial properties. Route 93 runs along its eastern border, and a commuter rail line crosses its western side. Physical features of the study area are shown on Figure 1. The Aberjona River, HBHA, and several associated tributaries and wetlands traverse the study area. Recreational users have been observed fishing within these surface water bodies.

The study area contains numerous commercial and light industrial businesses as well as a regional transportation center. Most of the developed land is covered with buildings, asphalt, concrete, or other cover material.

The Industri-plex Superfund Site (approximately 245 acres in area) is situated in the northern portion of the study area and was used for chemical manufacturing from 1853 through 1931. Wastes from these operations were used to fill low or wet areas, or to build dikes and levees to contain liquid wastes. The waste materials may have contained residues of arsenic insecticides, benzene, and toluene. Subsequent to 1934, a glue manufacturing plant operated and disposed of glue manufacturing byproducts (hides and sludge) in a manner similar to the chemical wastes. These wastes may have contained chromium, copper, lead, and zinc. The hide wastes, consolidated into four hide piles and portions of a utility right-of-way, and contaminated soil were capped as part of the soil cover remedy for the Industri-plex Site. A detailed historical account and physical description of the study area can be found in Section 1 of the MSGRP RI.

The areas of interest with respect to the human health risk assessment include three soil areas where residual contamination may remain, seven sediment areas where recreational exposures are currently occurring or may occur under future reuse conditions, four sediment core locations where future dredging activities are possible, three surface water sampling locations where baseflow and storm event data have been collected, and groundwater on the Class A Properties (see Figure 1) and the remainder of the study area. Groundwater collected along the P-1 transect, the most downgradient portion of the study area (along Interstate 95/Route 128), is also of interest to determine potential off-site contaminant impacts. In addition, subsurface volatile contamination may impact indoor air quality at current and future commercial buildings within the study area.

The three soil areas are designated areas A6, HB04, and SO (see Figure 2). Area A6 is located along the banks of the HBHA Pond where recreational users have been known to fish. This area is immediately outside the limits of the capped Boston Edison right-of-way and may contain residual levels of arsenic, lead, and chromium. HB04 designates an upland undeveloped area along Cabot Road, near the HBHA. Past flooding of the HBHA may have impacted the soils at this location. Individuals have been observed walking along trails in this area. The SO samples were collected in unpaved developed areas (i.e., tree belts and planters) where residual contamination may be present, associated with the former Mishawum Lake bed. This lake received historical wastes which may remain in the subsurface. In the early 1970s, the lake was filled and the Aberjona River relocated to its current position.

The seven sediment areas are HB01, HB02, HB03, AR, BE-1, BE-2, and MC-13 (see Figure 3). HB01, HB02, and HB03 represent the HBHA Pond, the HBHA near Cabot Road, and the HBHA near Mishawum Road, respectively. Station AR is represented by the Aberjona River stream bed between Commerce Way and Mishawum Road. Stations BE-1 and BE-2 represent the wetland areas adjacent to the Boston Edison right-of-way. Station BE-1 (samples BE01 through BE06) is along Commerce Way while station BE-2 (samples BE08 through BE11) is within the drainage channel immediately adjacent to the right-of-way. MC-13 is located south of Route 128 within a remote stretch of the Aberjona River.

Sediment core samples were collected at four locations (SC01 through SC04) within the study area (see Figure 3). At each sediment core location, samples were collected from four discrete intervals: 0-1 foot, 1-2 foot, 2-3 foot, and 3-4 foot. SC01 through SC03 were collected from the

HBHA near Cabot Road and SC04 was collected near the outlet of the HBHA at Mishawum Road.

The three surface water sampling locations (SW-02-TT, SW-03-TT, and SW-04-TT; see Figure 4) have been designated HB01, AR, and HB03, respectively, to correspond to their sediment sampling location of closest proximity. Surface water sampling locations SW-02-TT and SW-04-TT are co-located with sampling stations SW-04-IP and SW-09-IP, respectively. HB01 represents the HBHA Pond and includes additional grab samples collected from the HBHA Pond in 1999 (samples SW-MC-05, SW-MC-06, and SW-MC-07). AR represents the Aberjona River stream bed. HB03 represents the outlet of the HBHA at Mishawum Road and includes additional grab samples collected from the HBHA along Cabot and Mishawum Roads in 1999 (SW-MC-08, SW-MC-09, SW-MC-10, and SW-MC-11). As noted previously, both baseflow and storm event data are available for these surface water sampling locations.

Groundwater data have been collected using low-flow techniques from monitoring wells within the developed and undeveloped portions of the study area (see Figure 5). Depth to groundwater is variable, but typically less than 10 feet across the study area. The area is currently serviced by municipal water. Several groundwater wells in the vicinity of, but outside the study area, are used for non-potable activities such as irrigation (MADEP, 1997). MADEP evaluated the use and value of the groundwater aquifer within the Industri-plex Superfund Site (MADEP, 1997). The determination supports a low use and value for groundwater at the study area, and states that groundwater exposures evaluated should include: (1) vapor seepage into buildings; (2) use of groundwater in industrial processes; and (3) worker exposures associated with excavations into groundwater (see *MADEP Groundwater Use and Value Determination* included as Appendix 6M of this report). Because groundwater throughout the study area is shallow, current and future buildings may be impacted by subsurface volatile compound infiltration, and future construction workers may be exposed to groundwater contaminants during excavations down to the water table. The pumping and industrial use of study area groundwater is possible in the future.

The Class A properties (see Figure 1) are those properties comprised of land defined as “unrestricted” land within the boundaries of the Industri-plex Superfund Site where contamination is not expected to be present. Section 1 of the MSGRP RI contains a thorough discussion of the land classes. Some of the Class A properties may have been included in the site only as part of the regulatory settlement with the land owner. Therefore, groundwater data collected at the Class

A properties are evaluated as a separate exposure point since groundwater in this portion of the study area contains overall lower contaminant levels than groundwater in the remainder of the study area.

Soil gas sampling data have been collected to more accurately characterize potential groundwater volatile impacts to indoor and outdoor air quality. Soil gas data were collected from seven areas displaying the highest shallow groundwater volatile contaminant levels, representative of maximum potential air impacts at the study area (see Figure 6).

The southern boundary of the study area is the northern edge of the Wells G&H Interim Wellhead Protection Area (IWPA). Municipal wells G and H are inactive, but are still considered a potential source of public drinking water in the future. Therefore, study area groundwater contaminants concentrations, at the edge of the Wells G&H IWPA, have been compared to drinking water standards. The area where the P-1 transect and the AF-series monitoring wells were installed, at the southern boundary of the study area, is considered an additional area of interest because these wells are immediately upgradient of the Wells G&H IWPA (see Figure 5).

Each of these areas of interest represent exposure points that have been evaluated in the baseline human health risk assessment, as described in the following subsection.

1.3 Identification of Current/Future Exposure Points

Exposure points are locations where human receptors are currently contacting or could reasonably contact contaminated media in the future. Sampling has been conducted in appropriate media to evaluate contaminant exposures at each exposure point. Table 1 identifies the exposure points considered for evaluation in the baseline human health risk assessment under current and potential future land use conditions.

Current Exposure Points. Human receptors are potentially utilizing the Aberjona River, HBHA, and associated wetlands for current recreational activities. Because recreational activities involve exposure to multiple media (e.g., soil, surface water, and sediment), recreational exposure points have been termed stations (see Table 1). The following summarizes the media combined for each of the current stations:

- T station HB01/A6: HB01 sediment samples and sediment sample SD-MC-06, HB01 surface water (including SW-02-TT, SW-04-IP, SW-MC-05, SW-MC-06, and SW-MC-07), and A6 soil samples;
- T station HB03: HB03 sediment samples, and HB03 surface water (including SW-04-TT, SW-09-IP, SW-MC-08, SW-MC-09, SW-MC-10, and SW-MC-11);
- T station AR: AR sediment samples and AR surface water (SW-03-TT);
- T station HB04: HB04 soil samples; and
- T station BE-1: sediment samples BE01 and BE02.

Tables 1 through 3 in Appendix 6B list the surface water, sediment, and soil samples, respectively, that have been considered for use at each of the stations. Each of the current stations is accessible to human receptors since no barriers are in place to prevent access to the river/wetland areas. These stations are in areas of mild to moderate vegetation, generally shallow (i.e., less than two feet) and slow moving surface water, and gradual banks with few, if any, physical barriers present (e.g., fencing or other access obstacles). Appendix 6B, Table 2, provides a listing of the sediment samples collected at each station and the depth of surface water above each sediment collection point. This information is important since only sediment data from surficial near-shore locations should be used to evaluate direct contact recreational exposures in a human health risk assessment (USEPA, 1989). Therefore, sediment sampling locations below greater than two feet of surface water have not been quantitatively evaluated for recreational exposures in this risk assessment. Some individual sediment sampling locations have also been excluded from use in the baseline human health risk assessment due to the lack of proximity to currently utilized areas, the presence of physical barriers, and/or the distance of the sampling point from the shoreline. The rationale for exclusion of individual sediment sampling points is presented in Appendix 6B, Table 2.

Two stations, designated HB02 and MC-13, are currently difficult to access due to the presence of dense vegetation, steep banks, deep water, and their remote location. Due to their current low human exposure potential, these stations have not been evaluated as current sediment exposure areas in the quantitative human health risk assessment. Humans would access these station with significantly less frequency, if at all, than the stations located in less remote locations, which are considered currently accessible.

Surface water collected at these difficult-to-access stations is considered accessible due to its

mobile nature, rendering exposures possible at downstream locations after surface water migration. Therefore, surface water samples collected within the vicinity of station HB02 have been evaluated for current exposures occurring at station HB03, its nearest downstream station. Since the area downstream of station MC-13 is part of the Wells G&H OU-3 Aberjona River Study Area (OU-3), station MC-13 surface water data have been evaluated as part of the Wells G&H Aberjona River Study (OU-3) Baseline Human Health Risk Assessment (M&E, 2004).

One additional station, designated BE-2, is also classified as currently difficult to access. This station is located in a drainage channel at the toe of the capped area of the Boston Edison right-of-way, where dense briars and underbrush are present. Use of this capped area is currently restricted. This station is not in close proximity to commercial or recreational areas. Again, humans would access this station with significantly less frequency than the stations located along currently utilized recreational or commercial areas, which are considered currently accessible.

For soil, groundskeepers may be exposed to contaminants in areas that are periodically mowed and maintained. These soil areas include HB04 and SO. Area A6 is not a maintained area due to its location along the steep banks of the HBHA Pond. Therefore, Area A6 has not been evaluated for current groundskeeper exposures. Current day care children may also be exposed to soil contaminants present in the vicinity of the current daycare facility on Cabot Road. Table 3 in Appendix 6B presents the study area soil samples available for evaluation and identifies the samples used to evaluate the current groundskeeper and daycare child receptors..

Because fishing has been observed within the surface water bodies of the study area, the fish ingestion pathway is considered potentially complete. Therefore, a quantitative evaluation of fish ingestion risks, associated with recreational fishing, has been included for the study area. Receptors that may ingest fish include young children and adults of families where recreational fish are caught and consumed. Table 4 in Appendix 6B presents the study area fish fillet samples available for evaluation.

No current direct groundwater exposures are occurring since groundwater at the study area is not currently used as a source of industrial water, and direct contact exposures are not known to be occurring. However, volatile contaminants present in the subsurface may currently impact indoor air in occupied commercial buildings. Therefore, seven existing commercial buildings within the area of maximum groundwater volatile contaminant impacts have been evaluated as current

exposure points for the indoor air pathway.

Future Exposure Points. Those stations and soil exposure points considered currently accessible to humans are considered accessible under future land use conditions as well. However, stations BE-2 and HB02, classified as currently difficult to access, may become accessible in the future should the capped area be used for recreational purposes or the commercial land near station HB02 be developed. Therefore, stations BE-2 and HB02 have been quantitatively evaluated as potential future exposure points. Receptors accessing station HB02 may also be exposed to nearby HB04 soils. Therefore, this future station is designated station HB02/HB04. The following summarizes the media combined for each of the future stations:

- T station HB01/A6: HB01 sediment samples and sediment sample SD-MC-06, HB01 surface water (including SW-02-TT, SW-04-IP, SW-MC-05, SW-MC-06, and SW-MC-07), and A6 soil samples;
- T station HB02/HB04: HB02 sediment samples, HB03 surface water (including SW-04-TT, SW-09-IP, SW-MC-08, SW-MC-09, SW-MC-10, and SW-MC-11), and HB04 soil samples;
- T station HB03: HB03 sediment samples, and HB03 surface water (including SW-04-TT, SW-09-IP, SW-MC-08, SW-MC-09, SW-MC-10, and SW-MC-11);
- T station AR: AR sediment samples and AR surface water (SW-03-TT);
- T station BE-1: sediment samples BE01, BE02, BE04, BE05, and BE06; and
- T station BE-2: sediment samples BE08 through BE11 and HB01 surface water (including SW-02-TT, SW-04-IP, SW-MC-05, SW-MC-06, and SW-MC-07).

Because station MC-13 is considered difficult to access due to the presence of steep banks and proximity to land that is unlikely to be developed in the future, this station is considered to remain difficult to access in the future. The conditions limiting access currently are unlikely to change in the future. No quantitative human health evaluation has been conducted for this station.

Additional future exposure points have been identified for sediment. These include four locations within the HBHA where sediment core data have been collected. The exposure points are designated SC01 through SC04 and represent areas where deeper sediments may be contacted by workers should the HBHA be dredged in the future.

Because a future day care facility may be opened anywhere within the study area, exposure of day care children to soil contaminants present in HB04 and SO samples may occur. Table 3 in Appendix 6B identifies the soil samples used to evaluate the future groundskeeper and daycare child receptors..

Three future exposure points have been identified for groundwater: (1) the P-1 transect and A-F series monitoring wells where groundwater contaminant concentrations were compared to drinking water standards; (2) the Class A Properties where residual contamination is minimal; and (3) the study area groundwater which includes all groundwater monitoring well data except those located on the Class A Properties. Table 5 in Appendix 6B lists the groundwater monitoring wells and samples used for these exposure points.

Under a future scenario, groundwater from the study area may be used as industrial process water or for commercial purposes (e.g., a car wash). In addition, shallow groundwater may be contacted directly by construction workers involved in subsurface excavations down to the water table. These subsurface excavations may occur due to future study area development, including the construction of new buildings. Because soil gas samples from the areas of maximum groundwater volatile contaminant impacts have been collected, inhalation exposures to future construction workers and indoor air impacts to future buildings beyond this area of maximum volatile contaminant impact are adequately accounted for through the use of the “worst-case” soil gas data.

2.0 HAZARD IDENTIFICATION

The purpose of this section is the determination of the type and amount of chemicals present at the study area and the selection of the COPCs with regard to human health. In addition, this section summarizes the methodology used to determine EPCs for COPCs in each medium.

Environmental data used in this hazard identification include surface water, sediment, soil, fish fillet tissue, groundwater, and soil gas samples collected during multiple sampling events between 1999 and 2004, at both study area and reference locations. The locations of the sediment sampling stations relative to reference stations are presented on Figure 7. Sampling locations for surface water, sediment, soil, groundwater, and soil gas are presented on Figures 2 through 6,

respectively. A complete discussion of the sampling activities conducted for the study area are contained in Section 2.0 of the MSGRP RI.

Surface water data collected prior to 1999 have not been quantitatively used in the risk assessment. These data are unlikely to represent current study area conditions and have been determine to be of insufficient quality for risk assessment purposes (e.g., data were not validated). In addition, the most recent rounds of groundwater data, collected between 2001 and 2003, have been quantitatively evaluated since data collected from previous years are unlikely to represent current study area conditions.

The following briefly describes the sampling data quantitatively evaluated in the baseline human health risk assessment. Menzie-Cura conducted sediment, surface water, and fish fillet tissue sampling within the HBHA in 1999. Additional baseflow and storm event surface water sampling from the HBHA was conducted by Roux Associates in 2000/2001. Co-located baseflow and storm event surface water sampling, plus sampling within the Aberjona River, was conducted by TetraTech NUS in 2001/2002. In 2002/2003, USEPA conducted supplemental sediment sampling throughout the study area, including the collection of sediment core data from four locations. Soil sampling was conducted by USEPA at the same time to characterize residual contamination at the edges of the Boston Edison cap, and to determine whether periodic flooding of the HBHA had contaminated floodplain surface soils. Roux Associates conducted soil sampling in May 2001 to characterize residual contaminant levels within the former Mishawum Lake bed area.

For groundwater, O'Brien and Gere conducted transect sampling in 2001/2002, with TetraTech NUS and Roux Associates providing supplemental characterization of groundwater in portions of the study area not evaluated by the transects. Only analytical data from groundwater samples collected using low-flow sampling procedures were used in the quantitative evaluation. Groundwater analytical results from samples collected using non-low flow protocols (i.e., check value results) have not been included due to the presence of elevated levels of total suspended solids which are not representative of conditions within the aquifer. In addition, samples that did not achieve stabilization prior to sample collection (i.e., "NS" samples) have not been quantitatively evaluated. These samples are also considered unrepresentative of aquifer conditions.

Total metals results were selected for quantitative risk estimation since the scenarios evaluated would likely involve exposure to groundwater in its native, unfiltered state. However, for the comparison of P-1 transect data to MCLs, filtered results have been used since it is likely that potable groundwater use would include the removal of suspended particulate material prior to household use.

Historical soil gas screening data were collected by Roux Associates with laboratory data gathered in May 2004 to characterize potential impacts to current and future commercial buildings located within the areas of maximum groundwater volatile contaminant levels.

A detailed reporting of these data can be found in Section 2 Appendices of the MSGRP RI.

2.1 Reference Samples

Reference samples for surface water, sediment, and fish fillet tissue were collected as part of investigational activities conducted for the study area. In addition, surface water, sediment, and fish fillet reference samples collected in support of the Wells G&H Superfund Site Aberjona River Study (OU-3) Investigation have been used to augment the reference investigation. Reference stations are identified as stations 23 through 27, 01-IP through 04-IP, 12-IP, HB and SA. Reference locations are shown relative to the study area on Figure 7. For both efforts, samples were collected from areas not considered to be affected by study area activities and not displaying visual evidence of contamination. Tables 1, 2, and 4 in Appendix 6B identify the reference stations, individual samples collected at each station, and the rationale for any individual samples excluded from consideration in the baseline human health risk assessment.

The reference data for the media evaluated for human exposures are presented in data summary tables in Appendix 6C; Table 2.1 for surface water, Table 2.5 for sediment, and Table 2.9 for fish fillet tissue. Analytical data for individual reference samples are presented in Section 4.0 Appendices of the MSGRP RI. Reference analyte concentrations do not impact the selection of COPCs (subsection 2.4) or EPCs (subsection 2.4).

2.2 Data Used in Risk Assessment

Detailed discussions of sampling approaches and the quality assurance and control activities implemented during the collection of the data are provided in Section 2.0 of the MSGRP RI. The sampling data were validated according to USEPA's Region 1's Contract Laboratory Program (CLP) procedures and guidelines, as described in the MSGRP RI. The analytical results are discussed in the Section 4.0 (Nature and Extent of Contamination) of the MSGRP RI.

The analytical data were summarized by environmental medium and grouped into exposure points or stations. For the baseline human health risk assessment, the following media and exposure points/stations were selected for quantitative evaluation:

- Surface water at stations HB01/A6, HB03, and AR (current)
- Surface water at stations HB01/A6, HB02/HB04, HB03, AR, and BE-2 (future)
- Sediment at stations HB01/A6, HB03, AR, and BE-1 (current)
- Sediment at stations HB01/A6, HB02/HB04, HB03, AR, BE-1, and BE-2 (future)
- Sediment cores at SC01, SC02, SC03, and SC04 (future)
- Surface soil at area SO and stations HB01/A6 and HB04 (current)
- Surface soil at area SO and stations HB01/A6 and HB02/HB04 (future)
- Subsurface soil at area SO and station HB01/A6 (future)
- Fish fillet tissue (current/future)
- Soil gas within the area of greatest volatile contaminant impact (current/future)
- Shallow groundwater at the Class A Properties (future)
- All groundwater at the Class A Properties (future)
- Shallow groundwater at the study area (future)
- All groundwater at the study area (future)
- P-1 transect and AF-series groundwater (future)

Study area groundwater includes all low-flow groundwater data collected across the study area (including the P-1 transect and AF-series well data), except for those collected from the Class A Properties. The following sections summarize the environmental data available for use for each of the media quantitatively evaluated in the baseline human health risk assessment.

Surface Water. Baseflow surface water grab samples were collected from discrete locations in 1999, and from gauging stations within the study area between 2000 and 2002. Storm event data

were also collected from the surface water gauging stations between 2000 and 2002. Analytical results of compounds detected in individual surface water samples collected from the study area are presented in Section 4.0 Appendices of the MSGRP RI. Sampling locations are shown on Figure 4.

Only baseflow surface water sampling data collected between May and October have been used to quantitatively evaluate human exposures since these sampling dates corresponds with the time period over which recreational human exposures are likely to occur (i.e., the warmest six months of the year). All storm event data have been quantitatively evaluated, distinct from baseflow data, because humans may contact contaminants present in surface water during flooding events, regardless of time of year. No surface water data are available for station BE-1.

For the baseline human health risk assessment, surface water samples have been grouped to evaluate exposures occurring at each of the stations identified. This approach acknowledges that surface water is a mobile medium. Therefore, humans accessing a specific station may encounter surface water from all sampling locations within the vicinity of that station. Appendix 6B, Table 1, presents the surface water data available for use in the baseline human health risk assessment, and assigns the individual samples into stations for further evaluation. Analyses performed on each of these surface water samples are presented on tables in Section 2.0 of the MSGRP RI.

Baseflow surface water analytical results are summarized by station for current exposures in Table 2.1. Baseflow data summaries for future exposures are provided by station in Table 2.2. Storm event data are also summarized in Table 2.2. The summary tables for chemicals detected in surface water provide the frequency of detection, range of detection limits, range of detected concentrations, and location of maximum detected result for each detected chemical.

Sediment. Sediment samples were collected from the HBHA Pond, HBHA near Cabot and Mishawum Roads, and the Aberjona River and wetland areas within the study area between 1999 and 2002. In 2003, data from four sediment core sampling locations (SC01 through SC04) were collected from the HBHA. The sediment cores characterized the 0 to 1 foot, 1 to 2 foot, 2 to 3 foot, and 3 to 4 foot depth interval to which workers may be exposed should dredging of this area be necessary in the future as a flood control measure. Analytical results of compounds detected in individual sediment samples collected from the study area are presented in Section 4.0 Appendices of the MSGRP RI. Sampling locations are shown on Figure 3.

Because recreational human exposures are likely to occur only to sediments located below two feet or less of standing water, depth of surface water at the sediment sampling locations was determined at times of the year when human exposures are likely to occur. Sediment samples collected from within the study area are presented in Appendix 6B, Table 2. This table provides the rationale for the exclusion of specific samples from the baseline human health risk assessment. Analyses performed on each of these sediment samples are presented on tables in Section 2.0 of the MSGRP RI.

Sediment analytical results are summarized for current stations in Table 2.3. For future stations, sediment analytical data are summarized in Table 2.4. Sediment core data are also provided in Table 2.4. The summary tables for chemicals detected in sediment provide the frequency of detection, range of detection limits, range of detected concentrations, and location of maximum detected result for each detected chemical.

Soil. Both surface and subsurface soil samples were collected at station HB01/A6 and area SO. Surface soil is defined as the most surficial soil interval (0-6 inches or 0-12 inches). Subsurface soil samples are representative of the deeper interval (greater than 12 inches but less than 15 feet) which recreational, daycare, and/or construction receptors may encounter under future use conditions. Only 0 to 6 inch surface soil samples were collected at station HB04. For area A6 soils, the 0 to 1 foot, 1 to 2 foot and 2 to 3 foot intervals were characterized. For area SO, the 0 to 1 foot interval was characterized along with soils up to 24 feet in depth. Analytical results of compounds detected in individual soil samples collected from the study area are presented in Section 4.0 Appendices of the MSGRP RI. Sampling locations are shown in Figure 2.

Surface soil and subsurface soil samples are presented, by exposure point or station, on Table 3 in Appendix 6B. Collection depth interval is also presented for each sample. Because surface and subsurface soil data are available for area SO and station HB01/A6, two exposure points have been identified for each of these area.

Surface soil data are summarized by exposure point or station in Table 2.5. Surface and subsurface soil data are summarized in Table 2.6. Each of the soil summary tables provide the frequency of detection, range of detection limits, range of detected concentrations, and location of maximum detected result for each detected chemical.

Fish Fillet Tissue. The risks associated with fish fillet ingestion were evaluated for the study area. All fish fillet data collected from the study area were combined since the surface water bodies present within the study area support similar species and sizes of fish, and are in close physical proximity to each other. Fillet samples obtained within the study area were not separated by species under the assumption that individual anglers do not target one particular type of fish. Analytical results of detected compounds for each of the fish fillet samples are presented in Section 4.0 Appendices of the MSGRP RI.

Fish tissue sampling was conducted in 1999. Even though offal samples were collected from the study area, it was assumed that human receptors reasonably consume only fish fillet tissue. Fish fillet samples collected from within the study area are presented in Appendix 6B, Table 4. Analyses performed on each of the fillet samples are presented on tables in Section 2.0 of the MSGRP RI.

Fillet tissue sampling results are collectively summarized in Table 2.7. This summary table provides the frequency of detection, range of detection limits, range of detected concentrations, and location of maximum detected result for each detected chemical.

Groundwater. O'Brien and Gere conducted transect sampling in 2001/2002, with TetraTech NUS and Roux Associates providing supplemental characterization of groundwater in portions of the study area not evaluated by the transects. Analytical results of compounds detected in the individual monitoring wells are presented in Section 4.0 Appendices of the MSGRP RI. Analyses performed on each of these groundwater samples are presented on tables in Section 2.0 of the MSGRP RI.

Table 5 in Appendix 6B indicates specific instances in which individual monitoring well data were not used quantitatively in this evaluation and provides the rationale for exclusion of the data. Total metals results from groundwater samples collected using low-flow methods have been quantitatively evaluated. Monitoring well data were excluded from quantitative use if low-flow sampling techniques were not employed. This includes data from thirteen wells that were sampled using a check valve. These results are likely bias high and not representative of conditions within the aquifer due to the presence of high levels of suspended particulate material. In addition, samples that did not achieve stabilization prior to sample collection (i.e., "NS" samples) have not been quantitatively evaluated. These samples are also considered

unrepresentative of aquifer conditions.

A large number of groundwater samples were analyzed by both Brooks Rand and Lancaster Laboratories for total arsenic. The two sets of results are not considered duplicate results because the samples were collected discretely, not as split samples. Both sets of analytical results are considered usable for risk assessment purposes. In most cases, agreement between the two laboratories was high. However, in a small number of cases, the difference between the two reported results for a single sample was greater than an order of magnitude. Because the samples were collected discretely, the large difference between the two methods likely represents sample variability rather than analytical bias. Therefore, the higher of the two reported total arsenic results for each sample was selected for quantitative use.

Table 5 in Appendix 6B also indicates those monitoring wells considered representative of shallow (i.e., less than 15 feet) groundwater contamination potentially contacted during excavation into the water table. Monitoring wells are further segregated into three exposure points: the Class A Properties, the study area which includes all groundwater data except those collected from the Class A Properties, and the P-1 transect/AF-series monitoring wells. Monitoring well locations are shown on Figure 5.

On Table 2.8, 2001/2002 groundwater analytical results for the study area monitoring wells and for the Class A Properties are presented. These results are used to assess direct contact exposures associated with future industrial groundwater use. Shallow monitoring well data for the two groundwater exposure points are summarized on Table 2.9. The shallow groundwater results are used to assess direct contact exposures associated with future excavation into the water table. The summary tables provide the frequency of detection, range of detection limits, range of detected concentrations, and location of maximum detected result. AF-series monitoring well data and filtered P-1 transect data are summarized on Tables 7 and 8, respectively, in Appendix 6B.

To evaluate the impact of future industrial and commercial groundwater use on indoor air quality, the maximum detected groundwater concentrations of volatile contaminants presented in Table 2.8 were modeled to an indoor air concentration using methods and assumptions provided in Appendix 6D. Volatile contaminants were defined as those compounds with Henry's Law Constants greater than $1E-05$ atm-m³/mole and molecular weights less than 200 grams/mole

(USEPA, 1991b). Indoor air concentrations were modeled based on two groundwater use scenarios: (1) use of groundwater as process water; and (2) use of groundwater in a warm water car wash. For the process water scenario, the Toxchem+ software package (Enviromega, 2003) was utilized to estimate emissions for an assumed future set of conditions (e.g., size of process tanks, flow rate of water, and building ventilation rate). Toxchem+ models the fate of analytes in water processes using mass transfer algorithms. Emission rates from these processes are converted to air concentrations utilizing estimated/assumed ventilation rates. For estimation of air concentrations in a warm water car wash scenario, the shower model approach presented by Foster and Chrostowski (1986; 1987) was assumed to be proportionally representative of conditions similar to a car wash. The maximum modeled indoor air concentrations for the study area and Class A Properties are presented in Table 2.10, based on groundwater use as process water, and in Table 2.11, based on the use of groundwater in a warm water car wash. Because only one set of air concentrations were modeled, only one set of concentrations (i.e., maximum concentrations) appear on Tables 2.10 and 2.11.

Soil Gas. Soil gas field screening surveys were conducted in November 1997 and August 2001 in areas of the study area with residual sources of benzene and toluene (e.g., Atlantic Avenue, hide piles). The areas of interest, containing elevated levels of volatile compounds in groundwater, were located at the west hide pile, south of the east central hide pile (north of Atlantic Avenue), and north and east of the south hide pile (south of Atlantic Avenue). In May 2004, soil gas sampling was conducted to further characterize the potential impact of subsurface volatile contaminants on indoor and outdoor air quality.

Based on recent groundwater monitoring data, volatile contaminants present in shallow groundwater were determined to maximally impact air quality in the vicinity of monitoring wells B3-06, B5-01, B6-03, B7-03, B9-01, W5-04, and MW04 (see Figure 6). Therefore, soil gas sampling was conducted adjacent to and beneath current buildings located in the immediate vicinity of these groundwater monitoring wells. The evaluation of areas maximally impacted by subsurface volatile contamination is protective of exposures that may be occurring in areas of lesser contaminant impacts. Eight soil gas samples were collected, corresponding to the following seven exposure points:

- ABC Roofing 110 Commerce Way (1 subslab sample)
- Ganglani 130 Commerce Way (1 subslab sample)

- Graphique de France 10 Atlantic Avenue (1 subslab sample)
- Pacer 112 Commerce Way (1 subslab sample)
- Sacco 41 Atlantic Avenue (2 perimeter samples)
- Teradyne 36 Cabot Road (1 subslab sample)
- Vining 20 Atlantic Avenue (1 subslab sample)

Soil gas sampling locations are shown in Figure 6. Table 4 in Appendix 6D lists the soil gas contaminants detected at each exposure point. Concentrations of volatile contaminants detected in soil gas were modeled to estimate indoor air concentrations that may be present in a current or future building. The soil gas contaminant levels were also modeled to estimate outdoor airborne concentrations a future worker may be exposed to during trenching activities at the study area. The Johnson and Ettinger model (USEPA, 2003c) was used to perform the soil gas to air modeling. Appendix 6D documents the assumptions used in the modeling of indoor and outdoor air concentrations as well as inputs to the model. Tables 2.12 and 2.13 list the maximum modeled indoor and outdoor air concentrations, respectively, at each of the seven exposure points.

2.3 Data Evaluation

Data were qualified by the analytical laboratory and validated as described in RI. The qualification and validation of the analytical data included a comparison of the study area data to corresponding blank (laboratory, field, equipment, and trip) concentration data. Data rejected by the validation (“R” qualified) were not used. Estimated values (e.g., “J” qualified) were used in the risk assessment without modification. Analytical data from duplicate samples were combined as described in Appendix 6E. The treatment of non-detect results is also described in Appendix 6E. Frequency of detection was calculated as the number of samples in which the chemical was detected over the total number of samples analyzed after the exclusion of rejected (“R” qualified) data.

A subset of the sediment sampling locations were analyzed for chromium VI using both a colorimetric method (Method 7196A) and ion chromatography. Limitations with the use of the colorimetric analytical method for sediment resulted in some data rejection. Ion chromatography data support the opinion that it is unlikely that chromium VI exists in sediments at appreciable levels within the study area. Chromium VI results and data validation information have been included in Appendix 6F. Chromium VI was present at low concentrations (0.472 mg/kg to

0.802 mg/kg) in samples with total chromium values that ranged from 10.2 mg/kg to 566 mg/kg. All sediment samples analyzed for chromium VI had detectable levels present.

For soil, a subset of the area A6 sampling locations were analyzed for chromium IV via Method 7196A. These data support the opinion that chromium VI does not exist at appreciable levels in study area soils. Chromium VI was present at low concentrations (0.61 mg/kg to 9.16 mg/kg) in samples with total chromium values that ranged from 21.4 mg/kg to 1690 mg/kg. Soil samples with total chromium levels less than 20 mg/kg did not have levels of chromium VI above the method detection limit (0.4 mg/kg).

Using the sediment ion chromatography data and soil Method 7196A data, it can be conservatively inferred that approximately 1% of total chromium in sediments and approximately 2% of total chromium in soils within the study area are present as chromium VI. Therefore, 1% of the total chromium value for each sediment sample was assumed to be present as chromium VI unless sample-specific chromium VI analysis had been performed. Likewise, 2% of the total chromium value for each soil sample was assumed to be present as chromium IV unless sample-specific chromium VI analyses were available. Chromium IV levels in soil can be assumed to be non-detect for samples with total chromium results less than 20 mg/kg. Chromium VI values were calculated for sediment and soil by assuming that 1% or 2%, respectively, of the total chromium result represents chromium VI.

Because chromium VI analysis was not performed for surface water, groundwater, or fish fillet tissue, all chromium detected in these media are conservatively assumed to exist as chromium VI.

2.4 Identification of COPCs

The scope of the baseline human health risk assessment includes identification of COPCs based on the chemical substances found at the study area. This list was developed using the simple screening process described below. For each medium evaluated, all available and appropriate data from each exposure point were used to select COPCs for the exposure point.

2.4.1 Selection Criteria. The maximum detected concentration of a chemical in soil, sediment, surface water, groundwater, or indoor/outdoor air was compared to preliminary remedial goals (PRGs) published by USEPA Region 9 (USEPA, 2004d). Because Region 9 has not developed

PRGs for the fish ingestion pathway, the maximum detected concentration of a chemical in fish fillet tissue was compared to USEPA Region III risk-based concentrations (RBCs; USEPA, 2004b). Both PRGs and RBCs are chemical concentrations back-calculated using toxicity criteria and either a 1×10^{-6} target risk level for potential carcinogens or a hazard quotient (HQ) of 1 for noncarcinogens. For purposes of this screening analysis, a HQ of 0.1 was used to add a ten-fold measure of safety to reduce the chance of omitting chemicals from the list of COPCs that could contribute to a total hazard index (HI) of 1. To accomplish this, PRGs and RBCs for noncarcinogenic chemicals were divided by 10 prior to comparison to maximum detected values.

Tap water PRGs were used for comparison to maximum detected groundwater and surface water concentrations, residential soil PRGs were used for comparison to the maximum detected soil and sediment concentrations, ambient air PRGs were used for comparison to maximum modeled indoor/outdoor air concentrations, and fish RBCs were used for comparison to maximum fish fillet tissue concentrations. The comparison of surface water and groundwater concentrations to tap water PRGs provides a conservative screening evaluation. Ambient Water Quality Criteria (AWQCs) (USEPA, 2002d) developed to be protective of human health following the ingestion of water and organisms from fishable surface water bodies, were also used as screening criteria for surface water. Maximum Contaminant Levels (MCLs; USEPA, 2003b) were additionally used as screening criteria for groundwater. MCLs are regulatory criteria not strictly based on health risk considerations, but additionally consider technological feasibility and aesthetics.

A maximum detected chemical concentration less than its screening value indicated that the excess lifetime cancer risk associated with exposure to that chemical concentration would be less than one in one million and the HQ associated with exposure would be less than 0.1. Chemicals detected at concentrations below their screening criteria (and also below AWQCs for surface water and MCLs for groundwater) were, therefore, eliminated from further evaluation. Chemicals with maximum concentrations greater than the relevant screening criteria (or relevant AWQCs for surface water and MCLs for groundwater) were selected as COPCs.

Comparisons of maximum concentrations to screening criteria are presented in the data summary tables for each medium by exposure point (Tables 2.1 through 2.13). For certain analytes lacking compound-specific screening criteria (e.g., gamma-chlordane), a surrogate compound was selected (e.g., chlordane) and its screening criteria was used for COPC screening. Specific instances where surrogate assignments were made are identified in footnotes on Tables 2.1

through 2.13.

For four essential human nutrients that lacked screening criteria (i.e., calcium, magnesium, potassium, and sodium), the maximum detected concentrations were compared to concentrations in drinking water, soil, and fish fillet tissue that would not significantly increase the dietary Allowable Daily Intakes (ADIs), as follows: for calcium (400,000 Kg/l water; 1,000,000 mg/kg soil; 50,000 mg/kg fish); for magnesium (805,000 Kg/l water; 1,000,000 mg/kg soil; 100,630 mg/kg fish); for potassium (100,000 Kg/l water; 1,000,000 mg/kg soil; 12,500 mg/kg fish); and for sodium (100,000 Kg/l water; 1,000,000 mg/kg soil; 12,500 mg/kg fish). Derivations of these ADIs are provided in Appendix 6G. Back-calculated soil concentrations for magnesium and calcium have been adjusted so as not to exceed 1,000,000 mg/kg (i.e., 100%). If no concentrations exceeded the ADIs, these chemicals were not further evaluated.

Since PRGs were not available for lead, the maximum detected lead concentration in soil and sediment for each exposure area was evaluated relative to the residential soil screening level of 400 mg/kg (USEPA, 1994a). The maximum lead concentration in groundwater and surface water was evaluated relative to a drinking water concentration of 15 Kg/l, a criterion protective of blood lead levels in children (USEPA, 2003b).

Three additional inorganic chemicals, aluminum, cobalt, and iron, were eliminated as COPCs because the PRGs were based on provisional toxicity criteria provided by the Superfund Technical Support Center. USEPA Region I does not concur with the use of these values. These metals are abundant in the earth's crust and are unlikely to cause substantial toxicity at concentrations commonly encountered.

2.4.2 Chemicals Selected as COPCs. This subsection describes the chemicals selected as COPCs and refers to lists of the selected chemicals.

COPCs in Surface Water. Baseflow surface water analytical results for the stations quantitatively evaluated are summarized in Tables 2.1 and 2.2. Storm event surface water data are also summarized in Table 2.2. The specific samples summarized and evaluated are listed in Appendix 6B, Table 1. Tables 2.1 and 2.2 list all chemicals detected in surface water samples for each station as well as the chemicals selected as COPCs in surface water based on comparison to tapwater PRGs and AWQCs. The maximum detected results for the following compounds

exceed their respective PRGs or AWQCs and were selected as baseflow surface water COPCs for current/future exposures:

- HB01** trichloroethene, antimony, arsenic, manganese, thallium, and vanadium;
- HB02** trichloroethene, arsenic, chromium, manganese, and vanadium;
- HB03** trichloroethene, arsenic, chromium, manganese, and vanadium;
- AR** arsenic and manganese; and
- BE-2** trichloroethene, antimony, arsenic, manganese, thallium, and vanadium.

The maximum detected results for the following compounds exceed their respective PRGs or AWQCs and were selected as storm event surface water COPCs:

- HB01** arsenic, cadmium, and manganese;
- HB02** bis(2-ethylhexyl)phthalate, antimony, arsenic, manganese, and thallium;
- HB03** bis(2-ethylhexyl)phthalate, antimony, arsenic, manganese, and thallium;
- AR** arsenic and manganese; and
- BE-2** arsenic, cadmium, and manganese.

Surface water exposures at the study area are evaluated for dermal exposures only since wading is expected to be the primary activity. Surface water ingestion is unlikely for a wading scenario. See Section 3.0 (Exposure Assessment) for additional discussion.

No essential nutrients were detected at maximum concentrations in excess of their respective ADIs for surface water.

COPCs in Sediment. Sediment analytical results for the stations quantitatively evaluated are summarized in Tables 2.3 and 2.4. Sediment core data are also summarized in Table 2.4. The specific samples summarized and evaluated are listed in Appendix 6B, Table 2. Tables 2.3 and 2.4 list all chemicals detected in sediment samples for each station as well as the chemicals selected as COPCs in sediment based on comparison to residential soil PRGs. The maximum detected results for the following compounds exceed their respective PRGs and were selected as current and/or future sediment COPCs:

- HB01/A6** benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, bis(2-

	ethylhexyl)phthalate, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, antimony, arsenic, cadmium, copper, lead, manganese, mercury, thallium, vanadium, and zinc;
HB02/HB04	antimony, arsenic, cadmium, copper, lead, manganese, mercury, thallium, vanadium, and zinc;
HB03	antimony, arsenic, cadmium, copper, manganese, mercury, thallium, vanadium, and zinc;
AR	antimony, arsenic, cadmium, copper, lead, manganese, mercury, thallium, and vanadium;
BE-1 (current)	arsenic and vanadium;
BE-1 (future)	arsenic, manganese, thallium, and vanadium;
BE-2	arsenic, cadmium, manganese, thallium, vanadium, and zinc;
SC01	arsenic, cadmium, manganese, mercury, and vanadium;
SC02	arsenic, cadmium, copper, manganese, mercury, vanadium, and zinc;
SC03	arsenic; and
SC04	arsenic, cadmium, manganese, mercury, and vanadium.

No essential nutrients were detected at maximum concentrations in excess of their respective ADIs for sediment.

COPCs in Soil. Surface soil and subsurface soil analytical results for the exposure areas and stations quantitatively evaluated are summarized in Tables 2.5 and 2.6. The specific samples summarized and evaluated are listed in Appendix 6B, Table 3. Tables 2.5 and 2.6 list all chemicals detected in soil samples from the stations and exposure areas as well as the chemicals selected as COPCs in soil based on comparison to residential soil PRGs. COPCs were selected independently for each of the stations and exposure areas.

The maximum detected results for the following compounds exceed their respective PRGs and were selected as current or future surface soil COPCs:

SO	benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, phenanthrene, arsenic, manganese, mercury, and vanadium;
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- HB01/A6** antimony, arsenic, copper, lead, manganese, mercury, thallium, vanadium, and chromium VI;
- HB04** arsenic, thallium, and vanadium; and
- HB02/HB04** arsenic, thallium, and vanadium.

The maximum detected results for the following compounds exceed their respective PRGs and were selected as future subsurface soil COPCs:

- SO** benzo(a)pyrene, antimony, arsenic, cadmium, copper, lead, manganese, mercury, thallium, vanadium, and zinc; and
- HB01/A6** antimony, arsenic, copper, lead, manganese, mercury, thallium, vanadium, and chromium VI.

No essential nutrients were detected at maximum concentrations in excess of their respective ADIs for soil.

COPCs in Fish Fillet Tissue. Fish fillet tissue analytical results from 28 study area samples are summarized in Table 2.7. The specific samples summarized and evaluated are listed in Appendix 6B, Table 4. Table 2.7 lists all chemicals detected in fish fillet tissue samples from the study area as well as the chemicals selected as COPCs in fish tissue based on comparison to fish RBCs. The maximum detected results for arsenic, chromium, mercury, selenium, and vanadium exceed their respective RBCs and were selected as fish fillet tissue COPCs.

COPCs in Groundwater. Groundwater analytical results from the study area and Class A Properties monitoring wells are summarized in Table 2.8 and for shallow monitoring wells in Table 2.9. The specific samples summarized and evaluated are listed in Appendix 6B, Table 5. Tables 2.8 and 2.9 list all chemicals detected in groundwater from these monitoring wells as well as the chemicals selected as COPCs in groundwater based on comparison to tap water PRGs and MCLs. These COPCs are applicable to the direct contact future industrial groundwater use scenario (Table 2.8 - all depths) and direct contact future construction worker scenario (Table 2.9 -shallow groundwater). The maximum detected results for the following compounds exceed their respective PRGs and/or MCLs and were selected as groundwater COPCs:

Class A properties - all depths

arsenic, cadmium, chromium, manganese, and thallium;

Class A properties - shallow

arsenic, chromium, and manganese;

study area - all depths

1,1-dichloroethene, 1,2-dichloroethane, 1,4-dichlorobenzene, acetone, benzene, chlorobenzene, chloroethane, chloroform, cis-1,2-dichloroethene, methyl tert-butyl ether, tetrachloroethene, toluene, trichloroethene, vinyl chloride, xylene, 2,4-dichlorophenol, 2-methylphenol, bis(2-ethylhexyl)phthalate, naphthalene, pentachlorophenol, antimony, arsenic, barium, beryllium, cadmium, chromium, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc; and

study area - shallow

1,4-dichlorobenzene, benzene, chlorobenzene, chloroform, methyl tert-butyl ether, tetrachloroethene, toluene, trichloroethene, vinyl chloride, bis(2-ethylhexyl)phthalate, naphthalene, antimony, arsenic, barium, cadmium, chromium, lead, manganese, mercury, selenium, thallium, vanadium, and zinc.

Calcium and sodium were detected at maximum concentrations in excess of their respective ADIs for water in study area monitoring wells. Sodium was detected in excess of its ADI at the Class A Properties. However, due to a lack of toxicity values, these essential nutrients have not been further evaluated in the risk assessment.

COPCs in Indoor Air. Maximum indoor air concentrations, modeled from maximum groundwater VOC concentrations, are presented on Tables 2.10 and 2.11 for the future use of groundwater as process water and for a warm water car wash, respectively. Table 2.12 presents the modeled indoor air concentrations based on measured soil gas concentrations at the seven current commercial buildings under evaluation. Appendix 6D documents the assumptions used in the modeling as well as inputs to the model

The following lists the indoor air COPCs selected for the use of groundwater as process water and for the use of groundwater in a warm water car wash at both the study area and Class A Properties, based on a comparison of modeled air concentrations to ambient air PRGs:

study area - process water

1,1-dichloroethene, 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,2-dichloroethane, 1,4-dichlorobenzene, 2-butanone, 4-methyl-2-pentanone, acetone, benzene, chlorobenzene, chloroethane, chloroform, cis-1,2-dichloroethene, methyl tert-butyl ether, tetrachloroethene, toluene, trichloroethene, vinyl chloride, xylene, 2-chloronaphthalene, and naphthalene;

study area - car wash

1,1-dichloroethene, 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,2-dichloroethane, 1,4-dichlorobenzene, 4-methyl-2-pentanone, acetone, benzene, chlorobenzene, chloroethane, chloroform, cis-1,2-dichloroethene, methyl tert-butyl ether, tetrachloroethene, toluene, trans-1,2-dichloroethene, trichloroethene, vinyl chloride, xylene, 2-chloronaphthalene, and naphthalene;

Class A Properties - process water methyl tert-butyl ether; and

Class A Properties - car wash methyl tert-butyl ether and xylene.

Indoor air concentrations, due to subsurface volatile contaminant infiltration, were modeled from soil gas concentrations and are presented in Table 2.12 for each of the seven exposure points. Appendix 6D documents the assumptions used in the modeling as well as inputs to the model. All modeled indoor air concentrations are less than ambient air PRGs. Therefore, no indoor air COPCs have been selected for the subsurface infiltration pathway, and this pathway was not further evaluated in the risk assessment. Because the soil gas samples were collected from areas maximally impacted by volatile contaminants in groundwater, the use of these samples is protective of exposures that may occur beyond the area of maximal contaminant impact.

COPCs in Outdoor Air. Outdoor air concentrations, modeled from soil gas concentrations, are presented in Table 2.13 for each of the seven exposure points. Appendix 6D documents the assumptions used in the modeling as well as inputs to the model. All modeled outdoor air concentrations are less than ambient air PRGs. Therefore, no air COPCs have been selected and this pathway was not further evaluated in the risk assessment. Because the soil gas samples were collected from areas maximally impacted by volatile contaminants in groundwater, the use of these samples is protective of exposures that may occur beyond the area of maximal contaminant impact.

2.5 Determination of Exposure Point Concentrations

To evaluate the magnitude of potential human exposures, the concentration of each COPC in each exposure medium must be estimated. An estimate of this concentration is referred to as an EPC. EPCs were determined for the COPCs in each medium and for each exposure point.

USEPA requires the use of the UCL providing 95% coverage on the arithmetic mean concentration for the estimation of both the CT and RME risk (USEPA 1989; 1992; 1994b; 2002c; and 2004c). Therefore, whenever possible, the UCL has been calculated and used as the EPC for both the RME and CT exposure cases. UCLs were calculated using USEPA's program "ProUCL Statistical Software" (version 3.0). Appendix 6H contains documentation for the calculation and selection of the UCL values. UCL values could be calculated by this program if four or more samples were available for summarization from a station. When less than four samples were available, the program was unable to calculate a UCL value.

When one sample was available for an exposure area, the maximum detected COPC concentrations were used as the EPCs for both the CT and RME exposure cases. When the UCL value for a COPC exceeded the maximum detected concentration because of small sample sizes or high variability or if the UCL could not be calculated (< 4 samples), the maximum detected value was used as the EPC for the RME scenario, and the arithmetic mean value was used as the EPC for the CT exposure case (USEPA 1989 and 1994b). In cases where the arithmetic mean value exceeded the maximum detected value, the maximum detected value was used as the EPC for both the RME and CT cases.

Tables 3.1 through 3.4 list the surface water and sediment COPCs detected, by station, along with their maximum detected concentrations, arithmetic mean concentrations, and UCL values, if calculated. Tables 3.5 and 3.6 for soil and Table 3.7 for fish fillet tissue, list the medium-specific COPCs detected by exposure area, along with their maximum detected concentrations, arithmetic mean concentrations, and UCL values, if calculated. Tables 3.8 and 3.9, for all groundwater (future direct contact during commercial use) and shallow groundwater (future direct contact during excavation), respectively, list the COPCs along with their selected average, maximum, or UCL values for each exposure point. UCL values have been provided for these media at exposure points where enough samples were collected (i.e., > 4 samples).

For the future use of groundwater for industrial and commercial purposes, the indoor air exposure pathway was also assessed. Air COPCs were selected as previously described, and are presented on Tables 2.10 and 2.11 for the process water and car wash scenarios. For each air COPC selected, groundwater data were used to generate a groundwater UCL value which was then modeled to estimate an airborne UCL concentration a worker may be exposed to during process water use or during water use in a warm water car wash. Because no COPCs were selected for the outdoor air pathway, construction worker inhalation exposures were not further evaluated. Appendix 6D documents the groundwater UCLs, assumptions used in the modeling, and the inputs to the model. Tables 3.10 and 3.11 list the air COPCs detected along with their modeled UCL air concentrations for process water use and car wash water use, respectively. Because the UCL values were used as EPCs for both the RME and CT exposure scenarios, average airborne concentrations were not modeled. Maximum modeled airborne concentrations are presented on Tables 2.10 and 2.11.

3.0 EXPOSURE ASSESSMENT

The purpose of the exposure assessment is the quantification of the extent, frequency, and duration of actual or potential exposure to chemicals by pathways relevant to the study area and activities of the potential receptors.

3.1 Identification of Potentially Exposed Populations and Potential Exposure Pathways

As part of the exposure assessment, current and potential future exposure pathways were determined through which identified populations may be exposed to the COPCs at the study area.

An exposure pathway describes the course a chemical follows while moving through environmental media to the receptor. An exposure pathway may consist of a mechanism of release of contaminants to an environmental medium (e.g., sediment), an exposure route (e.g., ingestion), and a receptor (e.g., recreational user). An exposure pathway is considered complete when contact by a receptor with contaminated media may occur currently or in the future. For purposes of this risk assessment, only potentially complete exposure pathways were quantitatively evaluated.

USEPA (1989 and 1991a) guidance requires that plausible exposures under both current and future land-use scenarios be evaluated in a baseline risk assessment. Accordingly, potential human exposure pathways were identified for both current and potential future land-use scenarios at the study area. The current land-use scenario examines the potential for human exposure under current conditions, while the future land-use scenario evaluates potential exposures following possible changes in study area use (assuming no additional remedial action occurs). Table 1 presents a summary of the current and potential future exposure routes quantitatively evaluated in the baseline human health risk assessment as well as the human exposure points and receptors.

3.1.1 Potential Exposure Pathways and Receptors Under Current Land-Use Conditions.

The study area, located within the community of North Woburn, Massachusetts, is currently an industrial/commercial area with wetlands and ponds utilized for recreational activities, including fishing. Areas of interest for this assessment include six surface water and sediment stations where recreational activities have been observed, four soil areas where commercial and/or recreational exposures may occur, and seven commercial buildings that may be impacted by volatile compounds in groundwater beneath the structures. Residences are not located in close proximity to the study area. Groundwater within the study area is not used for potable purposes.

Human receptors could potentially contact contaminants in surface soil, sediment, and baseflow surface water while using the wetland areas for recreational purposes. The most likely receptor to utilize the study area is a teenager (ages 12 to 18). The teenage recreational user is likely to be exposed to contaminants in surface soil and sediment by incidental ingestion and dermal contact, and to contaminants in surface water by dermal contact during wading. Even though the HBHA has surface water of sufficient depth to support swimming, surface waters within the study are primarily shallow. Therefore, wading is likely to be the most common recreational activity. Ingestion of surface water is not quantitatively evaluated for wading since it is unlikely that teenagers would ingest more than a negligible amount of surface water. Inhalation of contaminants from surface soil, sediment, and surface water is assumed to be negligible because the levels of volatile compounds and airborne particulates are low, and would be further diluted and dispersed into ambient air.

Commercial workers (i.e., groundskeepers) may be exposed to contaminants in surface soil within unpaved areas of the study area by incidental ingestion and dermal contact. Contact with sediment and surface water are unlikely to occur. However, the evaluation of surface water and

sediment contact by the teenager is likely to be a conservative representation of commercial exposures, should they be occurring. Therefore, exposures to contaminated media within the wetland areas have not been quantitatively evaluated for the groundskeeper. Since this worker is unlikely to be performing invasive activities at the study area, inhalation of contaminants from surface soil is assumed to be negligible because the levels of volatile compounds and airborne particulates are low, and would be further diluted and dispersed into ambient air.

Young children at the current daycare facility on Cabot Road may also be exposed to surface soil contaminants in samples collected within close proximity of the facility, representative of potential contaminant levels at or nearby the facility. Day care children may be exposed to contaminants in soil via incidental ingestion and dermal contact. Inhalation of contaminants from surface soil is assumed to be negligible because the levels of volatile compounds and airborne particulates are low, and would be further diluted and dispersed into ambient air. The inhalation of indoor air impacted by subsurface volatile contamination is also a potentially complete exposure pathway. However, because no COPCs were selected for this pathway, no quantitative evaluation has been included for the subsurface vapor intrusion pathway.

Fishing has been observed at the HBHA. Bioaccumulating compounds present in sediment and surface water may impact fish tissue concentrations, resulting in a potential hazard associated with the fish ingestion pathway. Therefore, fish fillet tissue contaminant concentrations within the study area have been quantitatively evaluated for the ingestion pathway. Receptors may include young children and adults in families where recreational fish are consumed.

3.1.2 Potential Receptors and Exposure Pathways Under Future Land-Use Conditions.

To evaluate potential future exposures, it was assumed that no remedial action will be taken, and that the levels of contamination currently existing at the study area would remain the same in the future. Should no land-use change occur, the exposures described under current land-use conditions for the teenage recreational user and commercial workers would continue in the future. However, future teenage recreational users may contact surface as well as subsurface soils under the assumption that soils, currently at depth, are moved to the surface where exposures could occur. In addition, to determine if the risk associated with exposure to contaminants in surface water during storm events is elevated relative to baseflow conditions, separate evaluations have been conducted for the baseflow surface water and storm event surface water data.

For the purposes of this baseline risk assessment, it was assumed that study area development would occur in the future. Future commercial and recreational development has been considered; development of the study area for residential use has not been assumed. Should portions of the study area undergo development for recreational use, the study area would become more attractive to recreational users. Therefore, future recreational users of the study area would be exposed to contaminated media via the same pathways as assumed for the current teenager, but with an increased exposure frequency.

In the future, excavation worker exposures may occur to sediment core samples collected from areas that may be targeted for dredging activities to control flooding. Therefore, worker-related dredging exposures to sediment core COPCs have been quantitatively evaluated.

During recreational or commercial development of the study area, construction workers would be exposed to surface and subsurface soil during invasive activities. Construction workers would likely be exposed to soil via incidental ingestion, dermal contact, and inhalation of fugitive dust. Because the depth to groundwater at the study area is generally less than ten feet below ground surface, dermal contact with and incidental ingestion of groundwater encountered during excavation activities is also assumed to occur, along with inhalation of volatile contaminants from the subsurface. However, because no COPCs were selected for the subsurface vapor pathway, no further evaluation of this pathway has been performed.

A day care facility is currently operating in the vicinity of the SO soil area, and use of the commercial areas may include operation of a day care center in the future. Therefore, future young child exposures to soils have also been evaluated. Contact with surface as well as subsurface soils have been evaluated under the assumption that soils, currently at depth, may be moved to the surface during future development activities. Day care children may be exposed to contaminants in soil via incidental ingestion and dermal contact. The inhalation of indoor air impacted by subsurface volatile contamination is also a potentially complete exposure pathway. However, because no COPCs were selected for this pathway, no quantitative evaluation has been included for the subsurface vapor intrusion pathway. The adult day care worker has not been evaluated because the teenage recreational user and adult groundskeeper scenarios are likely to provide a conservative indication of day care worker exposures, should they occur in the future.

Based on the MADEP groundwater use and value determination, residential groundwater use is

assumed not to occur in the future. However, use of contaminated groundwater for commercial purposes (e.g., process water and use in a car wash) is assumed. During the use of groundwater as process water, incidental ingestion of and dermal contact with groundwater contaminants may occur along with the inhalation of volatile compounds released from groundwater during use. For the warm water car wash scenario, inhalation of volatile compounds released from groundwater would be the primary exposure pathway.

3.1.3 Summary of Pathways and Receptors Selected for Consideration. The following items summarize the pathways quantitatively evaluated for each exposure scenario:

Teenage recreational user scenario, current

Incidental ingestion pathways: surface soil, sediment

Dermal contact pathways: surface soil, sediment, surface water

Teenage recreational user scenario, future

Incidental ingestion pathways: surface and subsurface soil, sediment

Dermal contact pathways: surface and subsurface soil, sediment, surface water

Adult/young child fish consumption scenario, current/future

Ingestion pathways: fish fillet tissue

Adult groundskeeper scenario, current/future

Incidental ingestion pathways: surface soil

Dermal contact pathways: surface soil

Adult industrial worker (process water) scenario, future

Incidental ingestion pathways: groundwater

Dermal contact pathways: groundwater

Inhalation pathway: volatiles in indoor air

Adult car wash worker scenario, future

Inhalation pathway: volatiles in indoor air

Young child daycare scenario, current

Incidental ingestion pathways: surface soil

Dermal contact pathways: surface soil

Young child daycare scenario, future

Incidental ingestion pathways: surface and subsurface soil

Dermal contact pathways: surface and subsurface soil

Adult construction worker scenario, future
Incidental ingestion pathways: surface and subsurface soil, groundwater
Dermal contact pathways: surface and subsurface soil, groundwater
Inhalation pathways: particulates in outdoor air

Adult dredging worker scenario, future
Incidental ingestion pathway: sediment cores
Dermal contact pathway: sediment cores

3.2 Calculation of Dose

The purpose of the exposure assessment is to identify exposure equations to be used in the risk assessment and to document assumptions made for each of the parameters used in these equations. USEPA Region 1 *Risk Updates, No. 2* (USEPA, 1994b) requires the calculation of CT exposure and RME estimates and provides default exposure parameters for each of these estimations. The risk assessment used the default CT exposure parameters to evaluate average exposures and high-end exposure parameters to calculate RME estimates. USEPA guidance documents used in the exposure assessment include *RAGS, Part A* (USEPA, 1989); *Exposure Factors Handbook* (USEPA, 1997a); and *RAGS Part E (Supplemental Guidance for Dermal Risk Assessment)* (USEPA, 2004a), and *Risk Updates No. 2* (USEPA, 1994b).

3.2.1 Selection of Exposure Equations. Equations are presented for the calculation of chronic daily intake (CDI) values for the ingestion, dermal, and inhalation pathways of exposure. The equations are used for calculating a lifetime average daily dose (LADD) relevant to cancer risk (i.e., cancer intake) or for calculating an average daily dose (ADD) relevant to noncancer risk (i.e., noncancer intake). The medium-specific equations used for the calculation of carcinogenic and noncarcinogenic intakes of the COPCs are presented in Tables 4.1 through 4.11. Additional equations used in calculating dose following dermal exposure to organics in surface water and groundwater are contained in Appendix 6I.

3.2.2 Exposure Parameters. The exposure parameters used for each of the receptors evaluated in the risk assessment are described below and are presented in Tables 4.1 through 4.11. Since exposure parameters vary depending on the exposure pathway and receptors being evaluated, the exposure parameters are presented by pathway in the tables and are discussed by receptor. Table 6 in Appendix 6B presents a summary of receptor-specific and medium-specific exposure frequency values selected for use in the baseline human health risk assessment.

Teenage Recreational User Exposure Parameters. The exposure parameters for the teenage recreational user receptor (12 to 18 years of age) are shown in Tables 4.1 (current surface water), 4.2 (current sediment), 4.3 (current surface soil), 4.5 (future surface water), 4.6 (future sediment), 4.8 (future surface soil), and 4.9 (future subsurface soil). These exposure parameters rely partially on default CT and RME parameters presented in *Exposure Factors Handbook* (USEPA, 1997a), and *RAGS, Part E* (USEPA, 2004a).

Since the weather in the area is cold and not conducive to outdoor activities for about 6 months of the year, it was assumed that the current teenage recreational user may venture onto the study area and engage in activities resulting in surface soil, sediment, and surface water exposure 26 days/year for both the CT and RME cases. This value represent an exposure frequency of one day per week for the warmest six months of the year. For the future scenario, exposure frequencies of 52 days/year and 26 days/year were assumed for the RME and CT cases, respectively. The exposure frequency of 52 days/year represents two days per week for the warmest six months of the year. The increased exposure frequency under future RME land use assumes that the study area becomes more accessible and attractive to recreational users. The future surface water exposure parameters were also used to conservatively evaluate exposures to surface water during storm events and provide a comparison of surface water risks under both baseflow and storm event conditions.

The fraction of soil and sediment ingested from the study area was assumed to be 50% for both the CT and RME cases. Use of a fraction ingested term assumes that a receptor receives a portion of medium-specific daily intake from the study area and a portion from wetland and upland areas not impacted by the study area (i.e., background areas). This assumption is reasonable for the study area since the teenage recreational user is likely to spend a portion of the day in residential yards or other background areas and incur a portion of their daily exposure from these background areas. Using a 50% fraction ingested term assumes that half of the daily intake is from the study area.

For the teenage soil ingestion rate, the adult ingestion rate of 100 mg/day for the RME scenario and 50 mg/day for the CT scenario was used (USEPA, 1997a). For the sediment ingestion pathway, the CT and RME soil ingestion rates were used to provide a conservative evaluation of sediment exposure. Surface water exposure time was set at 0.5 hours/day for the CT case, and 1

hour/day for the RME case, based on professional judgement.

For the dermal pathway, teenager skin surface areas were calculated for the body parts that could contact surface soil, surface water, and sediment, using statistical distributions of surface areas provided in the *RAGS, Part E* (USEPA, 2004a). Teenagers were assumed to contact environmental media with 4,500 cm² of body surface area for both the CT and RME cases (50th percentile value; USEPA, 2004a). The surface area assumes exposure to the hands, feet, and lower legs. A soil-to-skin adherence factor of 0.2 mg/cm²-day was used for the CT and RME cases for soil and sediment exposures (USEPA, 2004a). This value is a 50th percentile weighted adherence factor for children playing in wet soil, the activity selected to be a reasonable high-end activity for the teenage receptor. The same surface area and soil-to-skin adherence factors selected for soil have also been used for sediment since USEPA (2004a) suggests using the same approach for sediments as that used for soil.

The default high-end exposure duration of 6 years was used for the RME case, while an average exposure duration of 2 years was used for the CT exposure case (USEPA, 1997a). The value of 57 kg for a teenager body weight was used for both CT and RME exposures (USEPA, 1997a). The averaging time for noncarcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard USEPA lifetime duration (70 years; USEPA, 1989).

Arsenic, cadmium, and PAHs were assessed for dermal exposures to soil and sediment through the use of chemical-specific dermal absorption factors (USEPA, 2004a). Dermal absorption factors of 0.1%, 3%, and 13% for cadmium, arsenic, and benzo(a)pyrene (for all PAHs), respectively, were used in both the CT and RME cases. In the absence of recommended dermal absorption factors, dermal exposures to the remaining soil and sediment COPCs were not assessed. For the surface water dermal exposure pathway, absorbed doses were calculated for each chemical using equations and chemical-specific factors described in Appendix 6I. The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight, and averaging time) were the same as the values described for the soil ingestion pathways.

Groundskeeper Exposure Parameters. The exposure parameters for the adult groundskeeper scenario are shown in Tables 4.3 (current surface soil) and 4.8 (future surface soil). The exposure parameters rely partially on default CT and RME exposure parameters presented in *Exposure*

Factors Handbook (USEPA, 1997a) and *RAGS Part E* (USEPA, 2004a).

For the soil ingestion pathway, a soil ingestion rate of 100 mg/day (USEPA, 2001b) for an outdoor industrial setting was used for both the RME and CT cases. It was assumed that current groundskeepers may be exposed to soil at the study area 30 days/year for the RME scenario and 15 days/year for the CT scenario. The exposure frequencies represent a frequency of one day per week and one day every other week for the warmest seven months of the year. Because the area of exposed soil may increase in the future, due to the removal of existing pavement, future groundskeepers were assumed to be exposed 100 days/year for the RME scenario and 50 days/year for the CT scenario. The fraction of soil ingested from the study area was assumed to be 100% for both the CT and RME cases.

The default high-end exposure duration of 25 years was used for the RME case, while an average exposure duration of 9 years was used for the CT exposure case (USEPA, 1997a). The default value of 70 kg for an adult body weight was used for both CT and RME exposures (USEPA, 1997a). Finally, as recommended in *RAGS* (USEPA, 1989), the averaging time for noncarcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard USEPA lifetime duration (70 years).

For the dermal pathway, skin surface areas were calculated for the body parts that could contact soil, using statistical distributions of surface areas provided in *RAGS Part E* (USEPA, 2004a). Groundskeepers were assumed to contact soils with 3,300 cm² of body surface area for both the CT and RME cases (50th percentile value; USEPA, 2004a). The surface area assumes exposure to the face, forearms, hands and lower legs. A soil-to-skin adherence factor of 0.2 mg/cm²-day was used for both the CT and RME cases (USEPA, 2004a). This value is a 50th percentile weighted adherence factor for utility workers. Cadmium, arsenic, and PAHs were assessed for dermal exposures as previously described. The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight, and averaging time) were the same as the values described for the soil ingestion pathway.

Adult/Young Child Fish Ingestion Exposure Parameters. The exposure parameters for the young child and adult fish ingestion scenario are shown in Table 4.4. These exposure parameters rely partially on default CT and RME parameters presented in *Risk Updates, No. 2* (USEPA, 1994b) and *Exposure Factors Handbook* (USEPA, 1997a).

For the ingestion of fish tissue, time-weighted ingestion rates of 5 g/day and 13 g/day were used for the adult CT and RME cases, respectively (USEPA, 1997). The ingestion rates are recommended mean and 95th percentile values for adult freshwater anglers from the New England region. For the young child, ingestion rates of 2.5 g/day and 6.5 g/day for recreational fish were used for the CT and RME cases, respectively, under the assumption that a young child ingests approximately 50% of the daily fish intake of an adult (USEPA, 1997a). These ingestion rates were used in conjunction with an exposure frequency of 365 days/year (USEPA, 1994b). The fraction of dietary fish ingested from the study area was assumed to be 50% for both the RME and CT cases. Using a 50% fraction ingested term assumes that half of the daily fish ingested is from the study area.

For the adult, the default high-end exposure duration of 24 years was used for the RME case, while an average exposure duration of 7 years was used for the CT exposure case (USEPA, 1994b). For the young child, default exposure durations of 6 years and 2 years were used for the RME and CT cases, respectively (USEPA, 1994b). Default values of 70 kg for an adult body weight and 15 kg for a young child body weight were used for both CT and RME exposures (USEPA, 1994b). Finally, as recommended in *RAGS, Part A* (USEPA, 1989), the averaging time for noncarcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard USEPA lifetime duration (70 years).

Dredger Exposure Parameters. For this scenario, it is assumed that workers may be exposed to contaminated sediments up to four feet in depth, should dredging be conducted as a flood control measure in the future. The exposure parameters for the dredger scenario are shown in Table 4.7 (future sediment cores). The exposure parameters rely partially on default CT and RME exposure parameters presented in *Exposure Factors Handbook* (USEPA, 1997a) and *RAGS, Part E* (USEPA, 2004a).

For the sediment ingestion pathway, the default contact intensive soil ingestion rate of 200 mg/day (USEPA, 1997a) is used for both the CT and RME cases to provide a conservative evaluation of exposure. To be consistent with the Wells G&H OU-3 baseline human health risk assessment (M&E, 2004), it is assumed that dredgers may be exposed to sediment cores for 83 days/year for the CT scenario (a four-month project) or 167 days/year for the RME scenario (an eight-month project). The fraction of sediment ingested from the study area is assumed to be

100% for both the CT and RME cases.

Assumed exposure durations of 1 year and 2 years, respectively, are used for the CT and RME cases. The default value of 70 kg for an adult body weight is used for both CT and RME exposures (USEPA, 1997a). Finally, as recommended in *RAGS* (USEPA, 1989), the averaging time for noncarcinogens is set equal to the exposure duration, and the averaging time for carcinogens is the standard USEPA lifetime duration (70 years).

For the dermal pathway, skin surface areas are calculated for the body parts that could contact sediment, using statistical distributions of surface areas provided in *RAGS, Part E* (USEPA, 2004a). Dredgers are assumed to contact sediments with 3,300 cm² of body surface area for both the CT and RME cases (50th percentile value; USEPA, 2004a). A soil-to-skin adherence factor of 0.2 mg/cm²-day was used for both the CT and RME cases (USEPA, 2004a). COPCs were assessed for dermal exposures as previously described. The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight, and averaging time) are the same as the values described for the sediment ingestion pathway.

Day Care Child Exposure Parameters. The exposure parameters for the young day care child are shown in Tables 4.3 (current surface soil), 4.8 (future surface soil), and 4.9 (future subsurface soil). These exposure parameters rely partially on default CT and RME parameters presented in *Risk Updates, No. 2* (USEPA, 1994b), *Exposure Factors Handbook* (USEPA, 1997a), and *RAGS Part E* (USEPA, 2004a).

It was assumed that a young day care child engages in outdoor activities resulting in soil exposure 150 days/year for both the RME and CT scenarios. This value represents the typical number of outdoor days of exposure for a residential child which is plausible for a full-time day care child cared for at a facility for up to 250 days/year. The fraction of soil ingested from the study area was assumed to be 100% for both the CT and RME cases. Using a 100% fraction ingested term assumes that all of the daily intake is from the study area. The young child ingestion rate for soil was set at 200 mg/day for the RME receptor and 100 mg/day for the CT receptor (USEPA, 1997a). Because no indoor air COPCs were selected, indoor air exposures were not evaluated.

The default high-end exposure duration of 6 years was used for the RME case, while an average exposure duration of 2 years was used for the CT exposure case (USEPA, 1994b). The default

value of 15 kg for a young child body weight was used for both CT and RME exposures (USEPA, 1997a). Finally, as recommended in *RAGS, Part A* (USEPA, 1989), the averaging time for noncarcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard USEPA lifetime duration (70 years).

For the dermal pathway, skin surface areas were calculated for the body parts that could contact soil, using statistical distributions of surface areas provided in the *RAGS Part E* (USEPA, 2004a). A young day care child was assumed to contact soil during outdoor activities with 2,800 cm² of body surface area for both the CT and RME cases (50th percentile value; USEPA, 2004a). A soil-to-skin adherence factor of 0.2 mg/cm²-day was used for both the CT and RME cases (USEPA, 2004a). The same dermal absorption factors used for the teenager were also used for the child. The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight, and averaging time) were the same as the values described for the soil ingestion pathway.

Construction Worker Exposure Parameters. The exposure parameters for the construction worker are shown in Tables 4.8 (future surface soil), 4.9 (future subsurface soil), and 4.10 (future shallow groundwater). The exposure parameters rely partially on default CT and RME exposure parameters presented in *Exposure Factors Handbook* (USEPA, 1997a) and *RAGS Part E* (USEPA, 2004a).

For the soil ingestion pathway, the default contact intensive soil ingestion rate of 200 mg/kg (USEPA, 1997a) was used for both the CT and RME cases to provide a conservative evaluation of exposure. It was assumed that construction workers may be exposed to soil and shallow groundwater at the study area for 40 day/year for the CT scenario (a two-month project) or 125 days/year for the RME scenario (a six-month project). The fraction of soil ingested from the study area was assumed to be 100% for both the CT and RME cases. The groundwater exposure time was set at 0.5 hours/day for the CT case, and 1 hour/day for the RME case. The groundwater incidental ingestion rate was set at 50 ml/day, a value representing approximately one mouthful.

An assumed exposure duration of 1 year was used for both the CT and RME cases. The default value of 70 kg for an adult body weight was used for both CT and RME exposures (USEPA, 1997a). Finally, as recommended in *RAGS* (USEPA, 1989), the averaging time for

noncarcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard USEPA lifetime duration (70 years).

For the dermal pathway, skin surface areas were calculated for the body parts that could contact soil and groundwater, using statistical distributions of surface areas provided in *RAGS Part E* (USEPA, 2004a). Workers were assumed to contact soils with 3,300 cm² of body surface area for both the CT and RME cases (50th percentile value; USEPA, 2004a). A soil-to-skin adherence factor of 0.2 mg/cm²-day was used for both the CT and RME cases (USEPA, 2004a). Cadmium, arsenic, and PAHs were assessed for dermal exposures as previously described. For the groundwater dermal exposure pathway, absorbed doses were calculated for each chemical using equations and chemical-specific factors previously described for the teenager. The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight, and averaging time) were the same as the values described for the soil ingestion pathway.

For the inhalation pathway, workers were assumed to be involved in activities resulting in the inhalation of particulates from the subsurface for 8 hours/day. Because no outdoor air volatile COPCs were selected, outdoor air exposures to VOCs were not evaluated. Fugitive dust EPCs were modeled using a default particulate emission factor of 4.63E+09 m³/kg (USEPA, 1991b). The remaining exposure parameters used for the inhalation pathway (i.e., exposure frequency, exposure duration and averaging time) were the same as the values described for the soil ingestion pathway.

Industrial Worker Exposure Parameters. The exposure parameters for the adult industrial worker scenario are shown in Table 4.11 (future groundwater). This receptor is assumed to contact COPCs during future use of groundwater as process water. The exposure parameters rely partially on default CT and RME exposure parameters presented in *Exposure Factors Handbook* (USEPA, 1997a) and *RAGS Part E* (USEPA, 2004a).

The groundwater incidental ingestion rate was set at 50 ml/day, a value representing approximately one mouthful. The groundwater exposure time was set at 0.5 hours/day for the CT case, and 1 hour/day for the RME case. Industrial workers are also assumed to be exposed to volatile COPCs in indoor air. For the inhalation pathway, the exposure time was assumed to be equivalent to a typical 8-hour work day for both the CT and RME cases (USEPA, 1997a).

Exposure frequencies of 250 days/year and 219 days/year were used for the RME and CT cases, respectively (USEPA, 1997a). These values represent the 95th percentile and mean number of days worked per year. The default high-end exposure duration of 25 years was used for the RME case, while an average exposure duration of 9 years was used for the CT exposure case (USEPA, 1997a). As recommended in *RAGS* (USEPA, 1989), the averaging time for noncarcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard USEPA lifetime duration (70 years).

For the dermal pathway, skin surface areas were calculated for the body parts that could contact groundwater, using statistical distributions of surface areas provided in *RAGS Part E* (USEPA, 2004a). Workers were assumed to contact groundwater with 3,300 cm² of body surface area for both the CT and RME cases (50th percentile value; USEPA, 2004a). Absorbed doses were calculated for each chemical using equations and chemical-specific factors previously described for the teenager. The remaining exposure parameters used for the dermal exposure pathway (i.e., exposure frequency, exposure duration, body weight, and averaging time) were the same as the values described for the soil ingestion pathway.

Car Wash Worker Exposure Parameters. The exposure parameters for the adult car wash worker scenario are shown in Table 4.11 (future groundwater). This receptor is assumed to contact COPCs during future use of groundwater in a warm water car wash. The exposure parameters rely on default CT and RME exposure parameters presented in *Exposure Factors Handbook* (USEPA, 1997a).

Car wash workers are assumed to be exposed to volatile COPCs in indoor air only. For the inhalation pathway, the exposure time was assumed to be equivalent to a typical 8-hour work day for both the CT and RME cases (USEPA, 1997a). Exposure frequencies of 250 days/year and 219 days/year were used for the RME and CT cases, respectively. These values represent the 95th percentile and mean number of days worked per year. The default high-end exposure duration of 25 years was used for the RME case, while an average exposure duration of 9 years was used for the CT exposure case (USEPA, 1997a). As recommended in *RAGS* (USEPA, 1989), the averaging time for noncarcinogens was set equal to the exposure duration, and the averaging time for carcinogens was the standard USEPA lifetime duration (70 years).

4.0 TOXICITY ASSESSMENT

The toxicity assessment presented here was conducted in accordance with USEPA guidance (1989). The methodology used for classifying health effects from exposure to chemicals is recommended by USEPA (1989). The health effects analysis considers chronic (long-term) exposures. For potentially carcinogenic chemicals, less than chronic exposures would result in less risk than chronic exposure; therefore, if chronic risk is below a regulatory limit, risk from subchronic exposures will also be below the regulatory limit. For noncarcinogenic chemicals, acute hazards could be assessed; however, only irritating substances such as sulfur dioxide would likely present an acute hazard. Chronic exposures would result in higher hazards than subchronic exposures; therefore, again, if chronic risks are below a regulatory limit, subchronic risks are also below the regulatory limit.

The chronic toxicity criteria were obtained from USEPA's Integrated Risk Information System (IRIS) (USEPA, 2005). This source lists the most recent toxicity values recommended by USEPA for use in human health risk assessments. In the event that toxicity values for a COPC were not available through IRIS, provisional toxicity values were obtained from the National Center for Environmental Assessment (NCEA), a division of USEPA. Values from IRIS are the preferred criteria, if available, followed by NCEA provisional values. Toxicity criteria from the Health Effects Assessment Summary Tables (HEAST; USEPA, 1997b) were used only if values were not available from either IRIS or NCEA.

4.1 Toxicity Information for Noncarcinogenic Effects

Systemic toxic effects other than cancer can be associated with exposures to chemicals. Reference doses (RfDs), for oral exposures, and reference concentrations (RfCs), for inhalation exposures, are the toxicity values that are used to evaluate the potential of developing noncarcinogenic effects as a result of exposure to potentially toxic chemicals. RfDs and RfCs have been developed on the premise that there are protective mechanisms that must be overcome before an appreciable risk of adverse health effects is manifested during a defined exposure period. It is assumed that there is a threshold dose that must be exceeded before adverse effects can occur.

Chemicals classified as carcinogens may also produce other systemic effects. These chemicals

were also evaluated for potential noncarcinogenic toxic effects and were included in the determination of chronic toxicity HQs, which characterize noncancer hazards. Carcinogenic effects, however, are usually manifested at levels that are significantly lower than those associated with systemic toxic effects; thus, cancer is usually the predominant adverse effect for contaminants that may elicit carcinogenic as well as noncarcinogenic responses.

Table 5.1 summarizes the oral noncarcinogenic toxicity values (i.e., RfDs) and the corresponding critical effects for the COPCs at the study area. This table contains both chronic and subchronic toxicity values. Subchronic toxicity values are applicable to the construction worker and dredger scenarios where exposures are expected to occur over a brief (i.e., less than 1 year) duration. Chronic toxicity values are applicable to all other receptors whose exposures are expected to occur over a longer interval of time. Subchronic toxicity values are not found in IRIS. Instead, subchronic toxicity values have been developed from chronic toxicity values. According to EPA guidance (USEPA, 1989), if a chronic toxicity value has been developed based on subchronic data, a subchronic toxicity value may be developed by removal of the uncertainty factor used to extrapolate from subchronic to chronic exposures (typically a factor of 10). If subchronic data are not available and the chronic toxicity value is derived from chronic data, the chronic toxicity value is adopted as the subchronic toxicity value. Table 5.2 summarizes the inhalation noncarcinogenic toxicity values (i.e., RfCs) and the corresponding critical effects for volatile COPCs at the study area.

Oral RfDs for manganese were developed based on USEPA Region I guidance (USEPA, 1996) as recommended in IRIS (USEPA, 2005). These RfDs were based on a total allowable manganese intake of 10 mg/day (USEPA, 2005). After adjusting for background intake (the average dietary manganese intake in the U.S. population; 5 mg/day), the remaining intake (5 mg/day) was then normalized for body weight (70 kg) to arrive at the manganese RfD for surface water, sediment, surface soil, and fish tissue exposures (0.07 mg/kg-day). An additional uncertainty factor of 3 was applied for groundwater exposures resulting in a groundwater RfD of 0.024 mg/kg-day.

For mercury, the RfD for inorganic mercury was used to evaluate groundwater and surface water exposures. However, since mercury in soil, sediments, and fish tissue is likely to exist as organic mercury compounds, the RfD for organic mercury was used to evaluate soil, sediment, and fish ingestion exposures.

All chromium in surface water, groundwater, and fish fillet tissue from the study area was conservatively assumed to be chromium VI since no speciation data were collected for these media. Based on chromium VI analysis performed on study area sediments, sediment cores, and soils, total chromium detected in these media is assumed to be chromium III since low levels of chromium VI were either detected or assumed to be present based on available data (see subsection 2.3 for discussion).

Additional information on the noncarcinogenic effects for each COPC is presented in the toxicity profiles in Appendix 6J. Chemical-specific permeability coefficients (K_p s), used to evaluate the surface water and groundwater dermal pathways, are provided in Appendix 6I.

4.2 Toxicity Information for Carcinogenic Effects

The potential for human carcinogenic effects is evaluated based on the chemical-specific slope factors (SFs) and unit risk (UR) values along with the weight-of-evidence classification (categories A through E) of the USEPA. The SF and UR values are the toxicity values that quantitatively define the dose-response relationship of a known or suspected carcinogen. The SF and UR values are a mathematical extrapolation of the slope of the dose-response curve from high doses administered to animals (or the exposures observed in epidemiological studies) to the low doses commonly experienced in the environment. The USEPA has developed SFs and URs for chemicals classified as carcinogens, based on the premise that there is no threshold, i.e., there is no level of exposure below which there is no risk of a carcinogenic effect.

USEPA's *Draft Final Guidelines for Carcinogen Risk Assessment* (USEPA, 2003d) classifies human carcinogenic potential as "known/likely," "cannot be determined," and "not likely," to replace the weight of evidence categories A through E. The proposed guidelines also acknowledge that the mode of action of a carcinogen may involve both threshold and non-threshold mechanisms.

Table 6.1 summarizes the oral carcinogenic toxicity values (i.e., SFs) and the corresponding weight-of-evidence classifications. Table 6.2 summarizes the inhalation carcinogenic toxicity values (URs) for volatile COPCs. For PAHs, the SF for benzo(a)pyrene, along with the appropriate relative potency factors (USEPA, 1993), have been used to evaluate the potency of the individual carcinogenic PAHs. For trichloroethene, cancer risks have been estimated using the

high-end provisional oral slope factor of $0.4 \text{ (mg/kg-day)}^{-1}$ and high-end provisional unit risk of $1.1\text{E-}04 \text{ (Kg/m}^3\text{)}^{-1}$. Because the carcinogenicity of this compound is currently under review, risk estimates using the slope factor and unit risk from the low-end provisional value, California EPA value, and MADEP value have been included. Similarly for tetrachloroethene, cancer risk has been estimated using California EPA cancer potency estimates. An additional cancer risk estimate has been included using the MADEP cancer toxicity values. The additional cancer risk estimates appear in footnotes at the bottom of appropriate Table 9s. Additional discussion on each carcinogenic COPC is provided in toxicity profiles presented in Appendix 6J.

4.3 Adjustment of Toxicity Factors

No RfDs or SFs are available for evaluating dermal exposure. Therefore, cancer and noncarcinogenic risks associated with dermal exposure may be evaluated using an oral SF or RfD, adjusted such that the toxicity value is appropriate for the dermal pathway. As detailed by USEPA (1989), for purposes of evaluating dermal exposure, it is generally necessary to adjust an oral toxicity factor (i.e., RfD or SF) from an administered (i.e., applied) dose to an absorbed (i.e., internal) dose. Because the toxicity values for the COPCs at the study area are expressed as orally administered doses (i.e., applied or intake-based), it is necessary to adjust both the RfDs and SFs for these substances in estimating exposure on an absorbed-dose basis when assessing dermal exposure.

The oral RfDs and oral SFs for each COPC were modified according to the following equations (USEPA, 1989) for use in assessing dermal exposure:

$$\begin{aligned} \text{ERfD}_o &= \text{RfD}_o \times \text{BF}_{o,a} \\ \text{ESF}_o &= \text{SF}_o / \text{BF}_{o,a} \end{aligned}$$

where:

- ERfD_o = effective absorbed-dose oral RfD for each chemical (i.e., adjusted dermal RfD)
- RfD_o = oral RfD for each chemical
- BF_{o,a} = absolute oral bioavailability factor for each chemical (i.e., oral to dermal adjustment factor)
- ESF_o = effective absorbed-dose oral SF for chemical (i.e., adjusted dermal SF)

SF_o = oral SF for each chemical

Tables 5.1 and 6.1 present the oral to dermal adjustment factors used to adjust the oral toxicity criteria for the COPCs evaluated in the dermal exposure pathways. Oral bioavailability values used were obtained from USEPA (2004a) or from toxicological profiles provided by the Agency for Toxic Substances and Disease Registry (ATSDR, 2002). No adjustment for oral absorption efficiency has been applied to any COPC with an absorption efficiency of greater than 50%. These COPCs include all VOCs, SVOCs including PAH compounds, arsenic (except for sediments; see subsection 4.4), copper, organic mercury, selenium, thallium, and zinc. Additional information on compound-specific oral to dermal adjustment factors is provided in Appendix 6J.

4.4 Toxicity Information for Arsenic in Sediment

To more accurately assess the oral toxicity of arsenic in sediments at the study area, a site-specific oral bioavailability study was conducted. This study was initiated because current default information on the oral bioavailability of arsenic from environmental media indicates that arsenic may be absorbed from the gastrointestinal tract with an efficiency approaching 100%. However, oral bioavailability studies at other sites have indicated that the actual oral bioavailability of arsenic from some soils is significantly less than 100%.

Appendix 6K contains the report, *Relative Bioavailability of Arsenic in Sediments from the Aberjona River*, that details the methods and results of the study conducted for the study area. In this study, young swine were fed sediments from the study area that contained arsenic at various known levels. Data were collected to calculate the relative bioavailability (RBA) of arsenic from these sediments. RBA is an estimate of the oral bioavailability of arsenic from study area sediments compared to that of a reference arsenic compound administered in drinking water. “Best Estimate” RBA values determined in this study ranged from 37% to 51%, indicating that arsenic from sediments is absorbed less extensively than arsenic from drinking water. These site-specific RBA estimates are also less than the default value of 100% for oral absorption efficiency of arsenic. The most conservative RBA value determined for study area sediments (51%) was selected as the most appropriate to evaluate the oral toxicity of arsenic in sediments at all stations within the study area.

The site-specific RBA value of 51% was used to adjust the oral RFD and SF for arsenic to derive

a site-specific estimate of oral toxicity of arsenic in sediments. The oral RfD and oral SF for arsenic were modified according to the following equations (see Appendix 6K) for use in assessing oral sediment exposures for arsenic:

$$\begin{aligned} \text{RfD}_{\text{adjusted}} &= \text{RfD}_{\text{IRIS}} / \text{RBA} \\ \text{SF}_{\text{adjusted}} &= \text{SF}_{\text{IRIS}} \times \text{RBA} \end{aligned}$$

where:

$\text{RfD}_{\text{adjusted}}$	=	adjusted oral RfD for arsenic in sediment
RfD_{IRIS}	=	oral RfD for arsenic as listed in IRIS (USEPA, 2005)
RBA	=	site-specific relative bioavailability factor for arsenic (i.e., 0.51)
$\text{SF}_{\text{adjusted}}$	=	adjusted oral SF for arsenic in sediment
SF_{IRIS}	=	oral SF for arsenic as listed in IRIS (USEPA, 2005)

Tables 5.3 and 6.3 present the adjusted oral RfD and adjusted oral SF for arsenic, respectively. These adjusted toxicity values were used to evaluate incidental ingestion exposures to arsenic in sediment only. Arsenic toxicity values were not changed for the evaluation of arsenic in other media or by the dermal route of exposure.

4.5 Toxicity of Lead

Lead was selected as a COPC for surface soil at area A6, subsurface soils at area A6 and SO, sediment at stations HB01, HB02, and AR, and study area monitoring wells where the maximum detected concentration exceeded the screening value. No RfD or SF is available for lead. Therefore, USEPA has recommended some alternative approaches to evaluate lead exposures.

Childhood lead exposures for future recreational use were evaluated through the use of the Integrated Exposure Uptake Biokinetic (IEUBK) Model (USEPA, 2002b). Appendix 6L contains summary information showing the IEUBK model inputs. This model uses algorithms to determine whether exposure to a soil lead concentration will result in an exceedance of a childhood blood lead level goal of 10 Kg/dL. The average time-weighted soil lead concentration was used as the soil concentration in the model. Default values, as recommended in the model, were used for all other inputs.

Adult and teenage exposures to lead were evaluated through the use of methodology provided in *Recommendations of the Technical Workgroup for Lead for an Approach to Assessing Risk Associated with Adult Exposures to Lead in Soil* (USEPA, 2003a). This methodology uses an algorithm to relate soil lead intake to blood lead concentrations in women of childbearing age; this group is assumed to be the most sensitive to lead exposure, among adults. This methodology uses algorithms to relate soil lead intake to blood lead concentrations in women of childbearing age. The model determines whether exposure to a soil lead concentration will result in an exceedance of a site-specific maternal blood lead level that is protective of a 95th percentile fetal blood level goal of 10 µg/dL. Appendix 6L documents the calculation of a maternal blood lead level of 4.2 µg/dL, using a geometric standard deviation (GSD) in intake and biokinetics of 1.8, which is typical of populations in small areas dominated by a single source of lead exposure. A typical blood lead concentration in women of child-bearing age in the absence of study area exposures was assumed to be 2.0 µg/dL, which is a mid-range default assumption (USEPA, 2003a). All other model inputs are presented in Appendix 6L.

5.0 RISK CHARACTERIZATION

Risk characterization combines estimates of exposure with toxicity data to develop estimates of the probability that an adverse effect will occur under the specified conditions of exposure. The risk characterization was divided into three phases: 1) risk estimation; 2) risk description; and 3) uncertainty analysis.

Risk estimation is undertaken by combining the toxicity factors and exposure assessment equations to calculate estimates of risks. Noncarcinogenic risks are reported as pathway-specific hazard indices (HIs), which are the sum of individual COPC hazard quotients (HQs) for that pathway. Only HQs from COPCs that affect the same target organ are summed to generate HIs. Estimates of carcinogenic risks are reported as incremental (above background) lifetime cancer incidence risks (ILCRs). Current practice considers carcinogenic risks to be additive when assessing exposure to a mixture of hazardous substances. Risk description entails several discussions, including the relative contributions of individual exposure pathways to the total risk for each medium. The significance of the risk estimates are relative to risk management criteria set forth in USEPA policy. The uncertainty analysis describes and quantifies, where possible, the impact of data uncertainty and variability, exposure assumptions, and toxicity values on estimates

of risk.

5.1 Risk Estimation

Noncancer risk is estimated by means of a HQ. To calculate noncarcinogenic HQs, the ADDs, calculated as described in subsection 3.2, were divided by the RfDs as follows:

$$\text{HQ} = \text{ADD} / \text{RfD}$$

The sum of this ratio for all chemicals within an exposure point and pathway that have the same target organ or type of toxicity is termed the pathway HI. The HI is useful as a reference point for gauging potential effects of environmental exposures to complex mixtures. In general, HIs that are less than 1 are not of regulatory concern; however, a HI of greater than 1 does not automatically indicate that an adverse effect will occur and should not automatically be interpreted as posing an unacceptable risk to the exposed population.

The total pathway HI for each exposure point was calculated by summing the HQs for COPCs having similar systemic effects. Total HIs for each receptor, by medium, were calculated by summing the total pathway HIs across pathways within the media (e.g., summing dermal and ingestion soil risks). As a first approximation, all COPCs are assumed to have additive effects. Total pathway HIs, assuming additivity of effects, are presented on Tables 7.1 through 7.12. However, in cases where the total pathway HI for a receptor exceeded 1, only COPCs having similar systemic effects (i.e., target organs) were summed for each pathway and medium. Target organ HIs are presented on Tables 9.1 through 9.39.

The cancer risk of each receptor is estimated for each medium by means of an ILCR. USEPA (1991a) states that where the cumulative incremental current or future carcinogenic risk to an individual is less than 10^{-4} , and where the noncarcinogenic HI is less than 1, action generally is not warranted unless there are adverse environmental impacts.

To calculate ILCR, the chemical- and pathway-specific LADDs, calculated as described in subsection 3.2, were multiplied by SFs as follows:

$$\text{ILCR} = \text{SF} \times \text{LADD}$$

The resulting value represents the incremental upper-bound probability that an individual could develop cancer over his or her lifetime due to exposure to potential carcinogens under the conditions specified in the exposure scenario. For example, carcinogenic risk levels of 10^{-6} and 10^{-4} represent an incremental chance of one-in-one-million and one-in-ten-thousand, respectively, that an individual could contract cancer over a lifetime.

The cancer risk for each pathway (e.g., the soil ingestion pathway) was calculated by summing the risks from each COPC at each exposure point within the pathway, while receptor risks for each medium were calculated by summing ILCRs for each pathway within the medium (e.g., the soil incidental ingestion and dermal contact pathways). Recreational receptor cancer risks from exposure to soil, surface water and sediment at a station were determined by adding the risk from sediment and soil incidental ingestion to the risk from dermal contact with sediment, surface water and soil from this station. Pathway and receptor ILCRs are presented on Tables 7.1 through 7.12. ILCRs were further summed to derive total receptor cancer risks. The total receptor ILCRs are presented on Tables 9.1 through 9.39.

Total receptor cancer risk from each medium is presented by exposure point. Risk was not summed across exposure points since the parameter values used assume maximal exposure within each exposure area. This approach assumes that an individual would not be maximally exposed to a medium at more than one exposure point (e.g., at station HB01/A6 and station AR).

5.2 Risk Description

This subsection summarizes the human health risks potentially associated with exposures to environmental media (soil, surface water, sediment, groundwater and air). Individual chemical-specific carcinogenic risks are expressed as probabilities of contracting cancer (i.e., ILCRs), while noncarcinogenic risks are expressed as HIs. All carcinogenic and noncarcinogenic risks were calculated using both CT and RME methods. The RME represents the reasonable maximum exposure and risk a receptor may receive from an exposure point. The CT represents the average

exposure and risk at an exposure point.

The risk description for the study area is provided below in two parts. First, the relative contributions of the various exposure pathways within each medium are analyzed for each receptor. Second, the relative contributions of each contaminant are analyzed for each receptor. The noncarcinogenic and carcinogenic risks associated with COPCs in each medium for the receptors evaluated are presented in Tables 7.1 through 7.12 for the RME and CT cases (e.g., 7.1.RME and 7.1.CT).

Tables 9.1 through 9.39 present target-organ specific HIs, which are discussed if a medium-specific HI exceeds 1. For the recreational fish ingestion scenario, the child and adult ILCRs have been summed to present the total receptor cancer risk. However, because the child receptor is the most sensitive receptor for the estimation of noncarcinogenic risk, only the child receptor HIs have been presented on Table 9s for this scenario.

5.2.1 Description of HI Estimates. HI estimates represent the risk of health effects other than cancer from exposure to contaminants within the study area, as described in subsection 5.1. Tables 7.1 through 7.12 present the noncarcinogenic risks by receptor and medium. When a receptor-specific HI for an exposure medium exceeded 1, HIs were segregated by target organ and discussed as to whether target organ-specific HIs exceed risk management criteria. These target organ-specific HIs are presented on Tables 9.1 through 9.39.

Current Teenage Recreational User. The estimated HIs for each pathway and medium, presented by station, are listed for the current teenage recreational user in Table 7.1. The summed risks for the media evaluated are presented in Tables 9.1 through 9.5. HIs for surface soil, surface water, and sediment incidental ingestion and/or dermal contact were all less than the target HI of 1 for all stations.

Current/Future Groundskeeper. The estimated HIs for surface soil exposure pathways, presented by exposure point (SO and HB04), are listed for the current groundskeeper receptor in Table 7.2 and for the future groundskeeper receptor in Table 7.7. The risks, segregated by target organ, are presented in Tables 9.6 and 9.7 for the current scenario, and in Tables 9.17 and 9.18 for the future scenario. HIs for surface soil incidental ingestion and dermal contact were less than the target HI of 1 for both exposure points.

Current/Future Adult Recreational User. The estimated HI for fish ingestion pathway is listed for the adult recreational user in Table 7.4 for current and future land use. HIs for fish fillet tissue ingestion were less than the target HI of 1.

Current/Future Young Child Recreational User. The estimated HI for fish ingestion pathway is listed for the young child recreational user in Table 7.5 for current and future land use. HQs, segregated by target organ, are presented on Table 9.9. HIs for fish fillet tissue ingestion were less than the target HI of 1.

Future Teenage Recreational User. The estimated HIs for each pathway and medium, presented by station, are listed for the future teenage recreational user in Table 7.6. The summed risks for the media evaluated are presented in Tables 9.10 through 9.16 assuming exposure to surface water under baseflow conditions. HIs for surface soil, surface water and sediment incidental ingestion and/or dermal contact were all less than the target HI of 1 for all stations. Assuming exposure to surface water during storm events (Tables 9.34 through 9.39), total receptors risks do not exceed the target HI of 1 for all stations.

Future Dredger. The estimated HIs for the sediment core exposure pathways, presented by exposure point (SC01 through SC04), are listed for the future dredging receptor in Table 7.8. The risks, segregated by target organ, are presented in Tables 9.19 through 9.22. HIs for sediment incidental ingestion and dermal contact were less than the target HI of 1 for SC01, SC03, and SC04. The HI exceeded the target HI of 1 at sediment core SC02 for the RME scenario. The RME HI was 4, primarily due to the presence of arsenic in the 0 to 1 foot interval. The CT HI at SC02 was equal to the target HI of 1.

Current/Future Day Care Child. The estimated HIs for surface and subsurface soil exposure pathways, presented by exposure point (SO and HB04), are listed for the current and future day care child receptor in Tables 7.3 and 7.9, respectively. The risks, segregated by target organ, are presented in Tables 9.8 and 9.23 through 9.25. RME and CT HIs for surface soil incidental ingestion and dermal contact were less than or equal to the target HI of 1 for HB04 (future) and SO (current). However, RME and CT HIs exceeded the target HI of 1 for future surface and subsurface soil exposures at area SO. The surface soil RME HI of 2, the subsurface RME HI of 40 and the subsurface CT HI of 20 were primarily attributable to the presence of arsenic at soil

locations SO-13 (0 to 1-foot and 8-foot intervals), SO-14 (0 to 1-foot and 8-foot intervals), SO-16 (0 to 1-foot interval), SO-11 (12-foot interval), and SO-3 (8-foot interval).

Future Construction Worker. The estimated HIs for each pathway and medium, presented by exposure point (SO and HB04), are listed for the future construction worker receptor in Table 7.10. The estimated HIs for construction workers exposure to shallow groundwater within the study area and at the Class A Properties are also presented on Table 7.10. The risks, segregated by target organ, are presented in Tables 9.26 through 9.29. Since no COPCs were selected for the outdoor air pathway, risks have not been estimated for this medium. HIs for surface soil exposure at SO and HB04 (Tables 9.26 and 9.27) and for shallow groundwater contact at the Class A Properties (Table 9.29) were less than the target HI of 1. HIs for the RME receptor from contact with subsurface soil at area SO and for shallow groundwater contact at the study area exceeded the target HI of 1. For subsurface soil exposure at area SO (Table 9.27), the RME and CT HIs were 7 and 2, respectively. The RME shallow groundwater HI was 3. The largest contributor to the HIs in excess of 1 for subsurface soil at area SO and groundwater within the study area was arsenic at soil locations SO-13 (8-foot interval) and SO-11 (12-foot interval), and in shallow monitoring well locations B7-01, B4-04, and B7-02.

Future Industrial Worker. The estimated HIs for each pathway, presented by exposure point (study area and Class A Properties), are listed for the future industrial worker receptor in Table 7.11. This receptor is assumed to be exposed to groundwater via incidental ingestion, dermal contact, and inhalation of volatile compounds released from groundwater during process water use. The risks, segregated by target organ, are presented in Tables 9.30 and 9.31. HIs for groundwater use at the Class A Properties (Table 9.31) were less than the target HI of 1. HIs for the RME and CT receptor from exposure to groundwater from the study area exceeded the target HI of 1 (HIs of 60 and 50 for RME and CT, respectively; Table 9.30). The largest contributors to the HIs in excess of 1 for groundwater within the study area were arsenic (for incidental ingestion and dermal contact) and benzene and naphthalene (for inhalation during process water use). The highest concentrations of the risk contributors were seen in monitoring wells: B7-01, B4-04, B7-02, B6-03, B5-02, and B8-04 for arsenic; B5-01, W5-06, W5-05, B7-03, B9-02, B9-01, W5-03, RX-1 through RX-10, and RX-15 through RX-19 for benzene; and W5-05 for naphthalene.

Future Car Wash Worker. The estimated HIs for the inhalation pathway, presented by exposure point (study area and Class A Properties), are listed for the future car wash worker

receptor in Table 7.12. This receptor is assumed to be exposed to volatile groundwater contaminants via inhalation during the operation of a warm water car wash. The risks, segregated by target organ, are presented in Tables 9.32 and 9.33. HIs for groundwater use at the Class A Properties (Table 9.33) were less than the target HI of 1. HIs for the RME and CT receptor for groundwater from the study area exceeded the target HI of 1 (HIs of 80 and 70 for RME and CT, respectively; Table 9.32). The largest contributor to the HIs in excess of 1 for groundwater within the study area were benzene and naphthalene. The highest concentrations of the risk contributors were seen in monitoring wells: B5-01, W5-06, W5-05, B7-03, B9-02, B9-01, W5-03, RX-1 through RX-10, and RX-15 through RX-19 for benzene; and W5-05 for naphthalene.

5.2.2 Description of ILCR Estimates. Estimates of ILCR represent the incremental risk of cancer from the study area, as described in subsection 5.1. Tables 7.1 through 7.12 present the cancer risks by receptor and medium for exposure to COPCs. For each receptor, medium-specific ILCRs for COPCs are summed and presented as total receptor risks on Tables 9.1 through 9.39. ILCRs were summed for the young child and adult recreational receptors to derive a total receptor risk for the fish ingestion pathway. The total receptor cancer risks, summed for the adult and child recreational receptors, are presented on Table 9s.

Current Teenage Recreational User. The estimated ILCRs for each pathway and medium, presented by station, are listed for the current teenage recreational user receptor in Tables 9.1 through 9.5. ILCRs for surface soil, surface water, and sediment incidental ingestion and/or dermal contact were estimated to be below or within the target risk range of 10^{-4} to 10^{-6} for all stations.

Current/Future Groundskeeper. The estimated ILCRs for soil exposure pathways, presented by exposure area (SO and HB04), are listed for the current groundskeeper in Tables 9.6 and 9.7, and for the future groundskeeper in Tables 9.17 and 9.18. ILCRs for surface soil incidental ingestion and dermal contact were estimated to be within or below the target risk range of 10^{-4} to 10^{-6} for both exposure points.

Current/Future Young Child/Adult Recreational User. The estimated ILCRs for the fish ingestion pathway are listed for the current and future adult and young child recreational user in Tables 7.4 and 7.5, respectively. The total receptor ILCRs (child and adult risks combined) are

presented in Table 9.9. RME and CT ILCRs for fish ingestion did not exceed the target risk range of 10^{-4} to 10^{-6} .

Future Teenage Recreational User. The estimated ILCRs for each pathway and medium, presented by station, are listed for the future teenage recreational user receptor in Tables 9.10 through 9.16. ILCRs for surface and subsurface soil, surface water, and sediment incidental ingestion and/or dermal contact were estimated to be below or within the target risk range of 10^{-4} to 10^{-6} for all stations. Assuming exposure to surface water during storm events (Tables 9.34 through 9.39), total receptors risks were within or below the target risk range for all stations.

Future Dredger. The estimated ILCRs for sediment exposure pathways, presented by sediment core locations (SC01 through SC04), are listed for the future dredger in Tables 9.19 through 9.22. ILCRs for sediment incidental ingestion and dermal contact were estimated to be within or below the target risk range of 10^{-4} to 10^{-6} for all sediment core locations.

Current/Future Day Care Child. The estimated ILCRs for soil exposure pathways, presented by exposure area (SO and HB04), are listed for the current day care child in Table 9.8, and for the future day care child in Tables 9.23 through 9.25. ILCRs for current and future surface soil incidental ingestion and dermal contact were estimated to be within or below the target risk range of 10^{-4} to 10^{-6} for surface soils at both exposure points. The RME and CT ILCRs of 1×10^{-3} and 3×10^{-4} exceed the target risk range for subsurface soils at area SO attributable to the presence of arsenic at soil locations SO-13 (8-foot interval), SO-11 (12-foot interval), SO-3 (8-foot interval), and SO-14 (8-foot interval).

Future Construction Worker. The estimated ILCRs for each pathway and medium, presented by exposure area (SO and HB04), are listed for the future construction worker on Tables 9.26 through 9.28. The estimated ILCRs for construction worker exposure to shallow groundwater at the Class A Properties are presented on Table 9.29. Since no COPCs were selected for the air pathway, risks have not been estimated for this medium. ILCRs for soil and groundwater incidental ingestion and dermal contact were estimated to be below or within the target risk range of 10^{-4} to 10^{-6} for all exposure areas.

Future Industrial Worker. The estimated ILCRs for each pathway, presented by exposure

point (study area and Class A Properties), are listed for the future industrial worker receptor in Tables 9.30 and 9.31. This receptor is assumed to be exposed to groundwater via incidental ingestion, dermal contact, and inhalation of volatile compounds released from groundwater during process water use. ILCRs for groundwater use at the Class A Properties (Table 9.31) were less than the target risk range of 10^{-4} to 10^{-6} . ILCRs for the RME and CT receptor from exposure to groundwater from the study area exceeded the target risk range (RME ILCR of 5×10^{-3} and CT ILCR of 1×10^{-3} ; Table 9.30). The largest contributors to the ILCRs in excess of the target risk range for groundwater within the study area were benzene, trichloroethene, and arsenic. The highest concentrations of the risk contributors were seen in monitoring wells: B7-01, B4-04, B7-02, B6-03, B5-02, and B8-04 for arsenic; B5-01, W5-06, W5-05, B7-03, B9-02, B9-01, W5-03, RX-1 through RX-10, and RX-15 through RX-19 for benzene; and AE-03, W5-03, AE-02, AE-04, and AE-06 for trichloroethene. Additional minor risk contributors include: 1,2-dichloroethane, chloroform, pentachlorophenol, and methyl tert-butyl ether.

Future Car Wash Worker. The estimated ILCRs for each pathway, presented by exposure point (study area and Class A Properties), are listed for the future car wash worker receptor in Tables 9.32 and 9.33. This receptor is assumed to be exposed to groundwater via inhalation of volatile compounds released from groundwater during use in a warm water car wash. ILCRs for groundwater exposure at the Class A Properties (Table 9.33) were less than the target risk range of 10^{-4} to 10^{-6} . ILCRs for the RME and CT receptor from exposure to groundwater from the study area exceeded the target risk range (RME ILCR of 6×10^{-3} and CT ILCR of 2×10^{-3} ; Table 9.32). The largest contributors to the ILCRs in excess of the target risk range for groundwater within the study area were benzene and trichloroethene. The highest concentrations of the risk contributors were seen in monitoring wells: B5-01, W5-06, W5-05, B7-03, B9-02, B9-01, W5-03, RX-1 through RX-10, and RX-15 through RX-19 for benzene; and AE-03, W5-03, AE-02, AE-04, and AE-06 for trichloroethene. Additional minor risk contributors include 1,2-dichloroethane, chloroform, and methyl tert-butyl ether.

5.2.3 Risks Associated with Exposure to Lead. Lead is a COPC for surface soil at station HB01/A6, subsurface soils at stations HB01/A6 and SO, sediment at stations HB01/A6, HB02/HB04, and AR, and study area monitoring wells where the maximum detected concentration exceeded the screening value. Childhood soil lead exposures at the study area were evaluated through use of the IEUBK model (USEPA, 2002b). Adult worker soil exposures and

teenage recreational user sediment and soil lead exposures were evaluated using the methodology provided by USEPA (2003a). The results of the lead evaluation for the study area are contained in Appendix 6L. For adult and teenager exposures, the calculated central estimate of the blood lead concentration in women of childbearing age did not exceed the goal of 4.2 Kg/dL for current and future land use. Likewise, assumed childhood lead exposures were not estimated to result in blood lead levels exceeding the goal of 10 Kg/dL. Appendix 6L provides inputs and outputs for both of these models. Lead in groundwater is discussed in the subsection 5.2.4.

5.2.4 Comparison to MCLs. As previously noted, the southern boundary of the study area is the edge of the Wells G&H IWPA. Municipal wells G and H are inactive, but are still considered a potential source of public drinking water in the future. Therefore, study area groundwater contaminant concentrations entering the IWPA have been compared to drinking water standards (i.e., Maximum Contaminant Levels or MCLs). The area where the P-1 transect and the AF-series monitoring wells were installed is immediately upgradient of the Wells G&H IWPA. Therefore, AF-series unfiltered monitoring well data and P-1 transect filtered monitoring well data are presented on Tables 7 and 8, respectively, in Appendix 6B along with a comparison of contaminant concentrations to MCLs.

For the AF-series monitoring wells, only arsenic exceeded the primary MCL. Aluminum, iron, and manganese exceeded secondary MCLs in a number of wells. Groundwater data collected from the AF-series wells were not reported as containing elevated levels of total suspended solids and are considered representative of groundwater quality as it leaves the study area and enters the Wells G&H IWPA.

For the P-1 transect wells, only arsenic exceeds the primary MCL in wells P1-01, P1-02, and P1-03. Exceedances of secondary MCLs were noted for aluminum, iron, and manganese in a number of wells. Filtered results were used for comparison to MCLs and secondary MCLs because a number of the P-1 transect wells could not be stabilized prior to sampling and may have contained elevated levels of total suspended solids.

5.2.5 Reference Evaluation. Reference samples for fish fillet tissue, surface water, and sediment were collected from outside the areas of impact as part of investigational activities conducted for the study area. No background data were available for soil or groundwater. For surface water, sediment, and fish tissue, reference samples are identified on Tables 1, 2, and 4, respectively, in

Appendix 6B. Summaries of these reference samples, by medium, are presented in Appendix 6C.

Appendix 6C also contains risk calculations for the reference samples. As done for study area data, reference data were compared to applicable screening criteria to select medium-specific reference COPCs. Once COPCs were selected, EPCs were calculated for each reference COPC using the same procedures employed for study area data. Risks were then estimated using the same scenarios and exposure assumptions applied to the study area data. These reference risk calculations are used in this section to frame study area risks, relative to ambient conditions in the vicinity of the study area, as necessary. Because surface water and fish fillet tissue exposures were not estimated to result in risk above regulatory guidelines, no discussion of these media has been included.

Arsenic was identified as the only risk contributor at sediment core location SC02. Arsenic was also selected as a COPC in reference sediments. Arsenic was present in all sediment samples collected from the reference stations. However, detected levels at the reference stations ranged from 3.8 mg/kg to 44.5 mg/kg (see Appendix 6C; Table 2.5) compared to a range at sediment core location SC02 of 27 mg/kg to 1,600 mg/kg (Table 2.4). The noncancer risk estimated for arsenic at location SC02 exceeds the noncancer risk estimated for arsenic in reference sediment by 20-fold.

5.3 Description of Uncertainties

Estimation of risks to human health that may result from exposure to chemicals in the environment is a complex process that often requires the combined efforts of multiple disciplines. Each assumption, whether regarding the toxicity value to use for a particular chemical or the value of a parameter in an exposure equation, has a degree of variability and uncertainty associated with it. In each step of the risk assessment process, beginning with the data collection and analysis and continuing through the toxicity assessment, exposure assessment, and risk characterization, conservative assumptions are made that are intended to be protective of human health and to ensure that risks are not underestimated. For the study area, there is a probability of overestimating health risks or hazards for a number of reasons. The following subsections

provide a discussion of the key uncertainties that may affect the final estimates of human health risk in this risk assessment. Uncertainties are arranged by topic.

5.3.1 Environmental Sampling and Analysis. The process of environmental sampling and analysis results in uncertainties from several sources, including errors inherent in sampling procedures or analytical methods. One area of uncertainty is sampling procedures. Since it is not possible to sample the entire area of interest at a given site, several samples are taken from each medium within each area of a study area, and the results are considered to be representative of the chemicals present throughout the area. For all media, it was assumed that the samples collected were representative of the chemicals present within the study area. This assumption may overestimate or underestimate risk.

Even though low flow sampling techniques were used, a number of monitoring wells could not be stabilized prior to the collection of groundwater samples. These samples may have contained elevated levels of suspended particulate materials, resulting in an overestimate of the bioavailable contaminant levels in the samples. However, turbidity measurements were lacking for a number of the groundwater samples. Risk estimates based on groundwater samples containing elevated levels of suspended solids may overestimate risk. Filtered groundwater results were not used since groundwater may not be filtered prior to process water use and construction workers would directly contact groundwater in its native state, regardless of turbidity.

Analytical methods also involved uncertainties. Due to uncertainty of quantification, individual chemicals were sometimes listed as detected, but with the value qualified as estimated by laboratory qualification or validation procedures. The estimated value was used in the risk assessment. This uncertainty may either over- or underestimate risk depending on how close the estimated value is to the true value. In some cases, analytical errors or sampling errors resulted in the rejection of data, which decreased the amount of data available and increased uncertainty associated with the representativeness of the detected chemical concentrations. Again, this may result in either an overestimation or underestimation of risk.

To decrease the uncertainty associated with this risk assessment, two specific analytical studies were conducted. The site-specific relative bioavailability study was performed to decrease the uncertainty associated with the degree of absorption following incidental ingestion of arsenic-containing sediment. This study involved the feeding of arsenic to swine in a sediment matrix.

The oral absorption of arsenic from the sediment matrix was quantified and determined to be less than the absorption of arsenic from a water medium. Two relative bioavailability estimates, representing the mean bioavailability values for two different sediment types, were determined from the study. The most conservative “best estimate” relative bioavailability value was then used in the human health risk assessment to more accurately characterize the risk associated with sediment ingestion at the study area. Use of the most conservative “best estimate” of oral bioavailability may have resulted in an overestimate of risk. It should be noted that the results of this study are most applicable to sediments containing arsenic within the range evaluated within the study (i.e., 300 to 600 mg/kg). Arsenic present in sediment at levels outside this range may be absorbed with greater or lesser efficiency than determined in the study. Therefore, risk estimates may also be underestimated should oral absorption be greater than predicted in the study for sediments containing arsenic outside the concentration range used in the study.

The second analytical study performed involved the determination of the most reliable analytic method to measure chromium VI in sediments and soils. This study resulted in site-specific chromium speciation data that were used to more accurately characterize risk associated with chromium exposures at the study area. The chromium speciation study indicated that approximately 1% of total chromium in sediments and 2% of total chromium present in soils existed in the hexavalent state, the more toxic form. Use of these value may result in either and underestimate or overestimate of risk depending on the representativeness of the value to the entire data set.

With respect to determining exposure point concentrations for this evaluation, one assumption was that the concentrations of chemicals in the medium evaluated would remain constant over time. Depending on the properties of the chemical and the medium in which it was detected, this assumption may overestimate risks, depending on the degree of chemical degradation to less toxic species or transport to other media. Conversely, environmental bioactivation of chemicals to more toxic chemicals (e.g., the environmental conversion inorganic mercury to organic forms of mercury) was also not considered. Therefore, this assumption may underestimate risk if bioactivation mechanisms are significant.

5.3.2 Selection of Chemicals for Evaluation. A comparison of maximum detected chemical concentrations to USEPA Region 9 PRGs for surface water, sediment, air, and soil, and Region

III RBCs for fish was conducted. PRGs and RBCs are conservative risk-based values that are used when selecting COPCs so as not to omit a chemical that might contribute significantly to risk. Chemicals whose maximum concentrations were below their respective cancer screening value or 10% of their noncancer screening value were not carried through the assessment. It is unlikely that this risk-based screening excluded chemicals that would be of concern, based on the conservative exposure assumptions and conservatively derived toxicity criteria that are the basis of the screening criteria. Although following this methodology does not provide a quantitative risk estimate for all chemicals, it focuses the assessment on the chemicals accounting for the greatest risks (i.e., chemicals whose maximum concentrations exceeded their respective PRGs or RBCs). Although the overall risk estimates are uncertain, it is not expected that actual risks will be significantly greater than estimated risks given that a reasonable effort was made to characterize current and future potential health risks given current knowledge..

AWQCs for human health were also used to select COPCs for surface water. It should be noted that the arsenic AWQC is currently under review and may be revised to a higher value in the future. Regardless, arsenic would still be selected as a surface water COPC since arsenic concentrations exceed Region 9 PRGs, additionally used to select surface water COPCs.

5.3.3 Toxicological Data. Uncertainty is associated with the toxicity values and toxicity information available to assess potential adverse effects.

One of the major contributors to uncertainty is the accuracy of the toxicity values used. A cancer potency value is a mathematical extrapolation of the slope of the dose-response curve from high doses administered to animals (or the exposures observed in epidemiological studies) to the low doses commonly experienced in the environment. The USEPA has developed potency values for chemicals classified as carcinogens, based on the premise that there is no threshold, i.e., there is no level of exposure below which there is no risk of a carcinogenic effect. USEPA's *Draft Final Guidelines for Carcinogen Risk Assessment* (USEPA, 2003d) acknowledges that the mode of action of a carcinogen may involve both threshold and non-threshold mechanisms. To the extent that the approach used to develop the potency estimate is incorrect, the extrapolated risks may be over- or underestimates. However, it should be noted that in the derivation of toxicity values, conservative assumptions are employed. Therefore, toxicity values tend to be biased toward overestimating risk.

One chemical for which there is some evidence of a nonlinear dose-response is arsenic (Chen *et al.*, 1992; Tseng, 1977; Tseng *et al.*, 1968). Since arsenic is a primary contributor to potential cancer risks to recreational and dredging receptors from the incidental ingestion of sediment, the interpretation of whether there is a non-toxic threshold for arsenic could affect whether arsenic levels in sediment result in risks in excess of risk management criteria. The quantitative estimates of risk presented in this risk assessment assumes no threshold for carcinogenicity from arsenic, which may overestimate risks. More recent epidemiological studies (Lewis *et al.*, 1999; Moore *et al.*, 2002), which were not available at the time of development of the cancer slope factor for arsenic, failed to demonstrate a significant correlation between arsenic exposure and cancer. However, exposure levels were much lower than those believed to have occurred in study that serves as the basis for the oral slope factor derivation.

Trichloroethene and tetrachloroethene are being re-evaluated for carcinogenic potency by EPA. Estimates of carcinogenic potency for these compound range over nearly two orders of magnitude. The high-end of the range of oral slope factors and unit risk values has been used for carcinogenic risk estimation for trichloroethene in Tables 9.1 through 9.38. Toxicity values provided by California EPA have been used for tetrachloroethene. Footnotes on Tables 9.1 through 9.38 also present the cumulative receptor cancer risks using the low-end of the range of oral slope factors and unit risk values and MADEP toxicity values. Tetrachloroethene was not identified as a risk contributing COPC in the risk assessment. Trichloroethene was identified as a primary risk contributor (i.e., ILCR greater than 1×10^{-4}) for the use of groundwater as process water and in a warm water car wash. Use of the low-end of the range for the oral slope factor and unit risk or the MADEP cancer toxicity values would reduce the risk associated with TCE to below 1×10^{-4} . However, trichloroethene would still be identified as a risk contributing COPC (i.e., ILCR greater than 1×10^{-6}) because the total receptor risk would continue to exceed 1×10^{-4} .

For dermal exposure pathways, the absence of dermal toxicity criteria necessitated the use of oral toxicity data. To calculate risk estimates for the dermal pathway, absolute oral bioavailability factors that reflect the toxicity study conditions were used to modify the oral toxicity criteria. For the chemicals with oral absorption exceeding 50% (i.e., the PAHs), a default oral absorption factor of 100% was used. The risk estimates for the dermal pathways may be over- or underestimated depending on how closely these values reflect the difference between the oral and dermal routes. Dermal absorption fractions (USEPA, 2004a), which estimate the penetration of sediment- or soil-associated compounds through the skin, are additionally used to assess dermal

exposures for sediments and soils. These estimates are uncertain, and may result in either an overestimation or underestimation of risk.

Chronic toxicity values, developed based on continuous lifetime exposures, were used for the evaluation of discontinuous, less-than-lifetime exposures (e.g., the teenage recreational user). Therefore, total receptor risk estimates may be overestimated, with the degree of overestimation dependent on the degree of deviation from a continuous exposure scenario.

Toxicity values were lacking for a small number of COPCs. For example, there are no non-carcinogenic toxicity values (i.e., RfDs) for the carcinogenic PAHs. However, the noncarcinogenic effects of these compounds are likely to be adequately protected against by the evaluation of carcinogenic risks (i.e., carcinogenic effects appear at a lower dose than non-carcinogenic effects). However, the lack of toxicity values for some COPCs contributes to an underestimation of risk.

5.3.4 Exposure Assessment. The primary areas of uncertainty affecting exposure parameter estimation involve the assumptions regarding exposure pathways, the estimation of exposure point concentrations, and the parameters used to estimate chemical doses. The uncertainties associated with these various sources are discussed below.

To better quantify exposure point concentrations, USEPA's software program, Pro UCL version 3.0, was used to determine UCLs. This software has been extensively reviewed and provides the best available science for the statistical determination of EPCs. The use of this program is believed to result in the more accurate estimation of EPCs than previously used methods. However, in cases where there is high degree of variability between the data points for a COPC, a UCL may be uncertain. For example, the sediment RME EPC for arsenic at sediment core location SC02 is uncertain due to one elevated arsenic detect (1,600 mg/kg in the 0 to 1 foot depth interval) compared to the remainder of the data set. This uncertainty is also applicable to SO soils due to sampling location SO-13 (2,680 mg/kg in the 8-foot interval). This uncertainty may result in either an overestimate or underestimate of risk.

The parameter values used to describe the extent, frequency, and duration of exposure are associated with some uncertainty. Actual risks for some individuals within an exposed population may vary from those predicted depending upon their actual intake rates (e.g., sediment ingestion

rates) or body weights. The exposure assumptions were selected to produce a reasonable upper-bound estimate of exposure in accordance with USEPA guidelines regarding evaluation of potential exposures at Superfund sites (e.g., exposures were assumed to occur for 6 to 2 years for recreational teenagers). Therefore, exposures and estimated potential risks for the evaluated receptors are likely to be representative of reasonable upper-bound exposures. Risks may be underestimated for those individuals exposed to a greater degree than assumed in the evaluation.

Future air EPCs for the industrial and commercial groundwater use scenarios were generated from groundwater data through the use of volatilization and dispersion modeling. Parameter values used in these models were selected to represent reasonable maximum exposures that may occur in the future should groundwater be used as process water or for use in a warm water car wash. The risk associated with future groundwater use may be less than estimated should groundwater uses that result in a lower degree of worker exposures be considered (e.g., use of groundwater for cooling in a closed system).

Only sediment samples collected from below two feet or less of standing water were used in the human health risk assessment. This approach limited the number of samples available to calculate sediment EPCs at some stations. For these stations, the maximum detected level of a COPC in sediment may have been used as the RME EPC for some COPCs. Use of the maximum detected result instead of the UCL value for the RME EPC most likely results in an overestimate of risk. Depending on the representativeness of the available samples to the study area as a whole, this approach may have resulted in an over- or underestimation of risk.

5.3.5 Risk Characterization. Cancer risks and HIs for each receptor were not summed across all media. For example, the risks to the recreational receptor from surface water, sediment and surface soil incidental ingestion and dermal contact were not summed with those from fish fillet tissue ingestion. In addition, risks from a given medium were not summed across exposure areas (i.e., stations). That is, for the recreational receptor, risks from incidental ingestion of and dermal contact with sediment were assumed to occur within a given station. This assumption is uncertain since a given recreational receptor may spend half his time in one exposure area and half in another. Risks to such an individual would be intermediate between the risks to individuals exposed solely within each exposure area.

Use of the range of oral slope factors and inhalation unit risk for trichloroethene and

tetrachloroethene results in the calculation of a range of cancer risk estimates for surface water and groundwater. The high-end of the range was used to calculate the RME and CT risks presented in the main text and tables of the report. Risk estimates using the low-end of the range of toxicity values are presented in footnotes on Tables 9.1 through 9.38. The cumulative receptor risks presented for all media, based on the range of oral slope factors and unit risks, do not significantly differ from each other because trichloroethene and tetrachloroethene are not the dominant risk contributors for these media.

5.4 Summary of Human Health Risks

An overall summary of cancer and noncancer risk estimates for the current/future teenage recreational user, current/future adult/young child recreational user, current/future groundskeeper, current/future day care child, future industrial worker, future car wash worker, and future construction worker scenarios is presented in Appendix 6B, Table 9. In this table, risks are summarized for both the RME and CT receptors. When risks were estimated for a young child and adult receptor (i.e., recreational user), the young child HIs are presented as the most conservative, while ILCRs presented are the sum of the young child and adult risks (i.e., a total receptor risk). Sediment, soil, and surface water risks, presented for the study area stations, have been summed together under the assumption that the teenager is exposed to all three media during recreational activities. For the construction worker, soil and groundwater risks were summed. In addition, HIs, segregated by systemic effects, are presented. In cases where the total HI exceeded 1, COPCs having similar systemic effects were summed for each pathway and medium. Tables 10.1 through 10.6 summarize the primary risk contributors for those receptors with estimated ILCRs greater than the target range of 10^{-6} to 10^{-4} and target organ-specific HIs greater than 1.

Risks Under Current Condition. ILCRs and HIs estimated for the current teenage recreational user exposure scenario (surface water, sediment, and soil) were below an ILCR of 10^{-4} and an HI of 1 for each station. Fish ingestion risks for a current adult/young child recreational user were also below an ILCR of 10^{-4} and an HI of 1. In addition, estimated risks were below an ILCR of 10^{-4} and an HI of 1 for current groundskeeper exposures to soils at both soil exposure points (HB04 and SO) and current day care child exposures at soil area SO.

An evaluation of lead in HB01/A6 soil and HB01/A6, HB02/HB04, and AR sediments indicated that exposures to lead, under current conditions, did not result in teenage or adult blood lead

levels in excess of the blood lead level goal.

Potential Risks Under Future Conditions. For the future teenage recreational user scenario, ILCRs and HIs for all stations were below an ILCR of 10^{-4} and an HI of 1. Risk associated with baseflow and storm event surface water were comparable, and not associated with risk above regulatory guidelines. Future estimated risks for the groundskeeper were also below an ILCR of 10^{-4} and an HI of 1 at both soil exposure points. Estimated risks associated with the future dredging of sediments from the study area were below an ILCR of 10^{-4} and an HI of 1 for sediment core locations SC01, SC03, and SC04. Estimated risks were below an ILCR of 10^{-4} and an HI of 1 for construction worker exposures at HB04 and for exposures to surface soils at area SO. Construction worker exposure to groundwater at the Class A Properties was also associated with risks below an ILCR of 10^{-4} and an HI of 1. Furthermore, ILCRs and HIs for the future use of groundwater as process water and in a warm water car wash did not result in estimated risks above an ILCR of 10^{-4} or an HI of 1 for groundwater at the Class A Properties.

The HI exceeded 1 for sediment dredging exposures at sediment core location SC02. The exceedance was due primarily to the presence of arsenic (Tables 10.1.RME) in the 0-1 foot interval.

The HI exceeded 1 and/or the ILCR exceeded 10^{-4} for future day care child exposures to surface and subsurface soil at area SO (Tables 10.2.RME, 10.3.RME, and 10.3.CT). The HI also exceeded 1 for future construction worker exposures to subsurface soil at area SO and to shallow groundwater within the study area (Table 10.4.RME). The exceedances were due primarily to the presence of arsenic in surface soil at locations SO-13, SO-14, and SO-16, arsenic in subsurface soil at locations SO-13, SO-11, SO-3, and SO-14, and arsenic in shallow groundwater monitoring wells B7-01, B4-04, and B7-02.

Risks in excess of an ILCR of 10^{-4} and/or an HI of 1 were estimated for study area groundwater (Tables 10.5 for industrial process water use and Table 10.6 for use in a warm water car wash). Primary risk contributors for industrial process water use and the use of groundwater in a warm water car wash include benzene, trichloroethene, and naphthalene. Arsenic was also identified as a primary risk contributor for the process water exposure scenario. For these primary risk contributors, the highest concentrations were seen in monitoring wells: B7-01, B4-04, B7-02, B6-03, B5-02, and B8-04 for arsenic; B5-01, W5-06, W5-05, B7-03, B9-02, B9-01, W5-03, RX-

1 through RX-10, and RX-15 through RX-19 for benzene; AE-03, W5-03, AE-02, AE-04, and AE-06 for trichloroethene; and W5-05 for naphthalene. Additional minor risk contributors for process water and warm water car wash use include: 1,2-dichloroethane, chloroform, and methyl tert-butyl ether. Pentachlorophenol was also identified as a minor risk contributor for the process water exposure scenario.

An evaluation of lead in HB01/A6 and SO soil and HB01/A6, HB02/HB04, and AR sediment indicated that exposures to lead, under future conditions, did not result in child, teenage, or adult blood lead levels in excess of the blood lead level goals.

The southern boundary of the study area is the edge of the Wells G&H IWPA. Municipal wells G and H are inactive, but are still considered a potential source of public drinking water in the future. Therefore, contaminant concentrations in the AF-series and P-1 transect monitoring wells, immediately upgradient of the Wells G&H IWPA, were compared to primary MCLs. For the AF-series monitoring wells, only arsenic in well AF-01 exceeded the primary MCL. Groundwater data collected from the AF-series wells were not reported as containing elevated levels of total suspended solids and are considered representative of groundwater quality as it leaves the study area and enters the Wells G&H IWPA.

For the P-1 transect wells, only arsenic exceeds the primary MCL in wells P1-01, P1-02, and P1-03. Filtered results were used for comparison to MCLs because a number of the P-1 transect wells could not be stabilized prior to sampling and may have contained elevated levels of total suspended solids.

A second risk assessment has been completed for the Aberjona River south of Interstate 95/Route 128 that includes environmental data collected from the Wells G&H Superfund Site to the Mystic Lakes. Collectively, the two risk assessments evaluate the environmental data collected along the entire river from the Industri-Plex Superfund Site in North Woburn to the Mystic Lakes. The comprehensive risk assessment is summarized in Section 6.0 of the comprehensive MSGRP RI Report which documents all the data collected along the Aberjona River and Halls Brook Holding Area from North Woburn to the Mystic Lakes, and further explains the nature and extent of contaminants and their fate and transport mechanisms.

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