

Section 9. Remedial Action Objectives

This section identifies RAOs for contaminated media at Parcel E-2, as identified in [Section 8](#), that will satisfy the remedial action goals for protecting human health and the environment. RAOs are medium-specific goals and specify: 1) the analytes of concern; 2) the exposure route(s) and receptor(s); and 3) an acceptable contaminant concentration or range of concentrations for each exposure pathway and medium. RAOs include both an exposure pathway and a contaminant concentration for a given medium because protectiveness can be achieved by either limiting (or eliminating) the pathway or by reducing (or eliminating) the contaminant.

The RAO evaluation for Parcel E-2 is based on information from the RI field activities, subsequent environmental investigations, and risk assessments for human health and the environment. The NCP details the expectations for remedy selection in 40 CFR Part 300.430 (a)(1)(iii). These expectations were used to evaluate RAOs for Parcel E-2. In addition, the U.S. Department of Defense integrates these NCP expectations with BRAC program objectives for expediting the transfer of U.S. Department of Defense property for reuse and development.

An important component of developing RAOs is the determination of future land use. According to EPA's land use directive ([EPA, 1995](#)), RAOs "...should reflect the reasonably anticipated future land use or uses..." thereby allowing for the development of "alternatives that would achieve cleanup levels associated with the reasonably anticipated future land use..." of the site. The EPA land use directive states that "in cases where future land use is relatively certain, the RAOs generally should reflect this land use..." and "...need not include alternative land use scenarios..." ([EPA, 1995](#)).

RAOs developed for Parcel E-2 are based on the city's planned reuse, which is considered the reasonable anticipated end use of the property as described in the HHRA. According to the redevelopment plan, most of the planned reuse for Parcel E-2 is open space; however, other planned reuses of areas within Parcel E-2 include industrial and research and development ([SFRA, 1997](#)). As discussed in [Subsection 1.8](#), land uses other than open space are incompatible with the landfill area, and restrictive covenants will address this incompatibility. Therefore, the planned reuse scenario evaluated for Parcel E-2, as discussed in [Subsection 7.1.1.1](#), is limited to open space reuse.

The following subsections discuss the RAOs for: 1) solid waste, soil, and sediment; 2) landfill gas; 3) groundwater; and 4) surface water.

9.1. RAOS FOR SOLID WASTE, SOIL, AND SEDIMENT

Separate RAOs were developed for human health receptors and ecological receptors. For human health receptors, the HHRA for Parcel E-2 evaluated risk associated with the planned reuse (open space). The exposure scenario applicable to open space reuse is recreational. In addition, the construction worker exposure scenario was evaluated for Parcel E-2. According to the HHRA, the primary human health exposure pathways to contaminated soil, under both the recreational user and construction worker scenarios, are through ingestion, dermal contact, and inhalation. For terrestrial ecological receptors, the onshore SLERA for Parcel E-2 evaluated risk associated with direct exposure to soil at 0 to 3 feet bgs. For aquatic ecological receptors, the shoreline SLERA evaluated risk associated with direct exposure to intertidal sediment in the Shoreline Area (0 to 2.5 feet bgs).

9.1.1. Chemicals of Concern in Solid Waste, Soil, and Sediment

COCs and the associated remediation goals for each exposure scenario are summarized in the table below. These COCs and remediation goals form the basis for the RAOs presented in [Subsection 9.1.2](#).

Exposure Scenario	Chemicals of Concern	Remediation Goal (mg/kg)	Chemicals of Concern	Remediation Goal (mg/kg)
Human Health, Recreational ^a	Antimony	270	Benzo(b)fluoranthene	1.3
	Aroclor-1248	0.74	Benzo(k)fluoranthene	1.3
	Aroclor-1260	0.74	Dieldrin	0.12
	Arsenic ^b	11.1	Lead	1.3
	Benzo(a)anthracene	1.3	Indeno(1,2,3-cd)pyrene	155
	Benzo(a)pyrene	0.33	PCB-156 ^b	0.03
Human Health, Construction Worker ^d	2,3,4,7,8-PECDF	0.0002	Benzo(k)fluoranthene	6.5
	Antimony	120	Cadmium	150
	Aroclor-1016	7.4	Copper	11,000
	Aroclor-1242	2.1	Dibenz(a,h)anthracene	1.1
	Aroclor-1248	2.1	Dieldrin	0.57
	Aroclor-1254	2.1	Indeno(1,2,3-cd)pyrene	6.5
	Aroclor-1260	2.1	Iron	93,000
	Arsenic ^c	11.1	Lead	800
	Benzo(a)anthracene	6.5	Naphthalene	75
	Benzo(a)pyrene	0.65	Vanadium	310
	Benzo(b)fluoranthene	6.5	Total TPH ^d	3,500
Ecological, Terrestrial Receptors	Cadmium	4.2	Manganese	2433.2
	Copper	469.6	Vanadium ^b	117.2
	Lead	441.9	Zinc	719.3
Ecological, Aquatic Receptors	Antimony	25	Zinc	410
	Copper	270	Total DDTs ^f	0.046
	Lead	218	Dieldrin	0.008
	Mercury	0.71	Endrin	0.045
	Nickel ^e	112	Total PCBs	0.18

Notes:

- ^a COCs identified for this exposure scenario are based on the planned reuse for Parcel E-2 as open space.
- ^b The remediation goal is based on the Hunters Point Ambient Level (PRC, 1995).
- ^c The construction worker exposure scenario is not associated with a specific planned reuse for Parcel E-2.
- ^d The TPH remediation goal is based on the Draft Petroleum Hydrocarbon Corrective Action Plan (TtEMI, 2002f).
- ^e The remediation goals are based on the San Francisco Bay Ambient Values (RWQCB San Francisco Bay Region, 2000).
- ^f The remediation goal includes concentrations of DDD and DDE.

9.1.2. Solid Waste, Soil, and Sediment RAOs for the Protection of Human Health and the Environment

The RAOs for solid waste, soil, and sediment at Parcel E-2 for the protection of human health and the environment are summarized below:

1. Prevent human exposure to organic and inorganic compounds greater than the remediation goals (developed in the HHRA in [Section 7.1](#)) for the following exposure pathways:
 - Ingestion of, outdoor inhalation of, and dermal exposure to solid waste, soil, or sediment from 0 to 2 feet bgs by recreational users throughout Parcel E-2.
 - Soil ingestion, outdoor air inhalation, and dermal exposure to solid waste, soil, or sediment from 0 to 10 feet bgs by construction workers throughout Parcel E-2.
2. Prevent ecological exposure to organic and inorganic compounds in solid waste or soil greater than the remediation goals (identified in the onshore SLERA in [Appendix L](#)) from 0 to 3 feet bgs by terrestrial receptors throughout Parcel E-2.
3. Prevent ecological exposure to organic and inorganic compounds in intertidal sediment greater than the remediation goals (identified in the shoreline SLERA in [Appendix G](#)) from 0 to 2.5 feet bgs by aquatic receptors throughout the Shoreline Area.

9.2. LANDFILL GAS RAOS

Landfill gas RAOs address both methane gas and NMOCs present at the Parcel E-2 Landfill. Methane gas emitted from the landfill may migrate off site and could accumulate in structures and confined spaces to create an explosive or oxygen-deficient atmosphere. NMOCs could cause unacceptable risk to human health and the environment. Previous risk assessments were performed using the Johnson and Ettinger vapor intrusion model ([EPA, 2003](#)), and resulted in the development of an NMOC action level of 500 ppmv for subsurface gas measurements (discussed in [Subsection 8.3.3](#)) that is considered protective of human health.

27 CCR § 20921 sets limits for both methane gas and NMOCs at the Parcel E-2 Landfill, which are the guiding principles for development of the RAOs for landfill gas. The RAOs for landfill gas are as follows:

1. Control methane concentrations to 5 percent (by volume in air) or less at the subsurface points of compliance.

2. Control methane concentrations to 1.25 percent (by volume in air) or less in on-site structures (“on-site” for this FS is defined as any area within the subsurface points of compliance for landfill gas).
3. Prevent exposure to NMOCs at concentrations greater than 500 ppmv at the subsurface points of compliance.
4. Prevent exposure to NMOCs at concentrations greater than 5 ppmv above background levels in the breathing zone of on-site workers and visitors.

9.3. GROUNDWATER RAOS

RAOs for Parcel E-2 groundwater were evaluated based on: 1) human health risks through the domestic use exposure pathway from the B-aquifer; 2) human health risks to construction workers from dermal contact and inhalation of volatilized compounds emitted from the A-aquifer; and 3) potential migration of COPCs that could result in surface water concentrations above aquatic water quality criteria. The identified chemicals in groundwater that may pose a risk to aquatic receptors in the Bay ([Appendix M](#)) are considered COPCs (that is, of potential concern) given the qualitative nature of the analysis. A quantitative analysis that would identify COCs and specify risk-based remediation goals cannot be prepared until a method for comparing groundwater data to saltwater aquatic criteria, in a manner that accounts for chemical attenuation and the near-shore mixing process, has been agreed to by the Navy and the regulatory agencies..

9.3.1. Chemicals of Concern in Groundwater

COCs and the associated remediation goals for each exposure scenario are summarized in the table on the following page. These COCs and remediation goals form the basis for the RAOs presented in [Subsection 9.3.2](#).

Exposure Scenario	Chemicals of Concern	Remediation Goal (µg/L)	Chemicals of Concern	Remediation Goal (µg/L)
Domestic Use ^a	1,1,2,2-Tetrachloroethane	1	Chrysene	2
	1,1-Dichloroethane	5	Copper	1,460
	1,2,3-Trichloropropane	1	Dibenz(a,h)anthracene	2
	1,2-Dichloroethane	0.5	Dieldrin	0.2
	1,4-Dichlorobenzene	5	Gamma-Chlordane	0.1
	4-Nitrophenol	3.4	Heptachlor	0.01
	Antimony	43.26	Hepatachlor epoxide	0.01
	Aroclor-1242	0.5	Hepatachlor epoxide A	0.01
	Aroclor-1254	0.5	Hepatachlor epoxide B	0.01
	Aroclor-1260	0.5	Indeno(1,2,3-cd)pyrene	2
	Arsenic	27.3	Iron	10,950
	Benzene	1	Lead	15
	Benzo(a)anthracene	2	Mercury	11
	Benzo(a)pyrene	2	Naphthalene	1
	Benzo(b)fluoranthene	2	Pentachlorophenol	5
	Benzo(k)fluoranthene	2	Tetrachloroethene	5
	Bis(2-ethylhexyl)phthalate	5	Trans-1,3-dichloropropene	0.5
	Carbon tetrachloride	0.5	Trichloroethene	5
	Chloroform	80	Vinyl chloride	0.5
	Human Health, Construction Worker ^b	Benzo(a)anthracene	2	Ideno(1,2,3-cd)pyrene
Benzo(a)pyrene		2	Lead	15
Benzo(b)fluoranthene		2	Napthalene	1
Benzo(k)fluoranthene		2	Tetrachloroethene	1
Dibenz(a,h)anthracene		2		
Aquatic Receptors ^c	Total TPH	1,400-20,000 ^d		

Notes:

^a Data from the A-aquifer were also used in the domestic use evaluation to account for potential communication between the A- and B-aquifers in some areas of Parcel E-2.

^b The construction worker exposure scenario is not associated with a specific planned reuse for Parcel E-2.

^c COCs cannot be defined and remediation goals cannot be established until a method for comparing groundwater data to aquatic criteria, in a manner that accounts for chemical attenuation and the near-shore mixing process, is agreed to by the Navy and the regulatory agencies. The following are chemicals of potential concern based on a qualitative analysis (see [Appendix M](#)): unionized ammonia, cyanide, sulfide, copper, lead, mercury, zinc, total PCBs, total DDT, endosulfan II, gamma chlordane, heptachlor, and heptachlor epoxide,

^d Total TPH aquatic criteria assigned as a function of distance from shoreline; the source of these criteria is the April 2004 "Draft Addendum to the Final Petroleum Hydrocarbon Corrective Action Plan, Parcel B, Hunters Point Shipyard, San Francisco, California" (TtEMI, 2004b).

9.3.2. Groundwater RAOs for the Protection of Human Health

The A-aquifer is not considered a domestic use aquifer, and as a result, exposure to COCs via domestic use of groundwater is not a potentially complete pathway (see [Subsection 2.2.6](#)). The B-aquifer was assessed for potential domestic use exposure pathways (see [Subsection 2.2.6](#) and [Appendix I](#)) and determined to pose a potential human health risk. The following RAOs will be applied to protect human health for the domestic use exposure pathway:

1. Prevent direct exposure to groundwater that may contain COCs greater than the remediation goals (developed in the HHRA in [Subsection 7.1](#)) through the domestic use pathway.
2. Prevent or minimize migration of B-aquifer groundwater that may contain COCs greater than the remediation goals (developed in the HHRA in [Subsection 7.1](#)) beyond the compliance boundary (defined in [Appendix N, Subsection N2.1.1](#)).
3. Prevent direct exposure to groundwater that may contain COCs greater than the remediation goals from existing and future groundwater monitoring wells.

Exposure to benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, ideno(1,2,3-cd)pyrene, lead, naphthalene, and PCE in groundwater presents a potential unacceptable risk to construction workers at Parcel E-2. As a result, the following RAO will be applied to protect human health for the construction worker exposure pathway:

1. Prevent or minimize dermal exposure to and vapor inhalation from A-aquifer groundwater containing COCs greater than remediation goals (developed in the HHRA in [Subsection 7.1](#)) by construction workers.

9.3.3. Groundwater RAOs for the Protection of Ecological Receptors

The current concentrations of anions, metals, PCBs, pesticides, VOCs, and total TPH are present in shoreline wells at concentrations that may pose a risk to aquatic receptors in the Bay. The following RAOs were developed to address the potential migration of contaminated groundwater in the A-aquifer into the Bay:

1. Prevent or minimize migration of A-aquifer groundwater to the San Francisco Bay that would result in surface water concentrations of COPCs (listed in [Table 8-1](#)) greater than aquatic water quality criteria.
2. Prevent or minimize migration of A-aquifer groundwater containing total TPH concentrations greater than the remediation goal (where commingled with CERCLA substances) into the San Francisco Bay. Monitor potential groundwater migration in areas with total TPH soil concentrations greater than the source criterion of 3,500 milligrams per kilogram (applicable to soil from 0 to 10 feet bgs),

9.4. SURFACE WATER RAOS

Surface water RAOs address point discharges from Parcel E-2 into the Bay. Surface water is monitored for water quality and toxic pollutant parameters in accordance with the NPDES General Permit for HPS.

The following RAO was developed to address the potential migration of contaminated soil via surface water erosion into the Bay:

1. Prevent or minimize migration of surface water that may contain COCs greater than aquatic water quality criteria (listed in current Parcel E-2 SWDMP) into San Francisco Bay.

9.5. SUMMARY OF RAOS

The following table summarizes the RAO goals for each media.

Media / Receptor	Goal
Waste, Soil, and Sediment / Human Receptors	Prevent exposure to organic and inorganic compounds greater than the remediation goals in: a) solid waste, soil, or sediment from 0 to 2 feet bgs by recreational users; or b) solid waste, soil, or sediment from 0 to 10 feet bgs by construction workers.
Waste, Soil, and Sediment / Ecological Receptors	Prevent ecological exposure to organic and inorganic compounds in solid waste or soil greater than the remediation goals from 0 to 3 feet bgs by terrestrial receptors throughout Parcel E-2. Prevent ecological exposure to organic and inorganic compounds in intertidal sediment greater than the remediation goals from 0 to 2.5 feet bgs by aquatic receptors throughout the Shoreline Area.
Landfill Gas	Control methane concentrations to: a) 5 percent (by volume in air) or less at the subsurface points of compliance; and b) 1.25 percent (by volume in air) or less in on-site structures. Prevent exposure to NMOCs at concentrations: a) greater than 500 ppmv at the subsurface points of compliance; and b) greater than 5 ppmv above background levels in the breathing zone of on-site workers and visitors.
Groundwater / Human Receptors	Prevent direct exposure to groundwater that may contain COCs greater than the remediation goals through the domestic use pathway. Prevent or minimize migration of B-aquifer groundwater that may contain COCs greater than the remediation goals beyond the compliance boundary. Prevent direct exposure to groundwater that may contain COCs greater than the remediation goals from existing and future groundwater monitoring wells. Prevent or minimize dermal contact and inhalation of volatilized compounds emitted from A-aquifer groundwater containing COCs greater than remediation goals by construction workers.
Groundwater / Ecological Receptors	Prevent or minimize migration of A-aquifer groundwater into San Francisco Bay that would result in surface water concentrations of COCs greater than aquatic water quality criteria. Prevent or minimize migration of A-aquifer and B-aquifer groundwater containing total TPH concentrations greater than the remediation goal (where commingled with CERCLA substances) into San Francisco Bay. Monitor potential groundwater migration in areas with total TPH soil concentrations greater than the source criterion of 3,500 milligrams per kilogram (applicable to soil from 0 to 10 feet bgs),
Surface Water / Ecological Receptors	Prevent or minimize migration of surface water that may contain COCs greater than aquatic water quality criteria into San Francisco Bay.

