SECTION 2
PROBLEM FORMULATION

2.1 ENVIRONMENTAL SETTING AND CHEMICALS OF POTENTIAL CONCERN FOR THE SITE

2.1.1 Environmental Setting

Information for the site location, history, and land use are obtained primarily from the following sources: the site management plan (SMP) for the Pearl Harbor Naval Complex (PHNC) (USN 1995), an *Evaluation of Sediment Contamination in Pearl Harbor* (Grovhoug 1992), observations noted during a site reconnaissance conducted in July 1994 as a prelude to the SRA, and the Final Work Plan for the Pearl Harbor Sediment Study RI/FS (USN 1996a). Specifically, Pearl Harbor is a large complex natural estuary and a major feature located on the south coast of Oahu in the Hawaiian Islands. A majority of Pearl Harbor lies within the PHNC and is located in the southern portion of the Ewa Plain, approximately 5.8 miles (mi) northwest of downtown Honolulu (Figure 2.1.1-1). Pearl Harbor contains approximately 1,943 hectares (ha) (7.5 square miles [sq mi]; 4,800 acres [ac]) of surface water area and 64 kilometers (km) (40 mi) of linear shoreline. Through the influence of drainage, the Pearl Harbor estuary is the receptacle for runoff from approximately 28,502 ha (110 sq mi; 70,400 ac) of upland habitat comprising the watershed for much of the southern portion of the island of Oahu.

2.1.1.1 Site History

As described in Grovhoug (1992), the PHNC has existed for nearly 100 years and has undergone extensive changes since the mid-1800s when the harbor was a large natural inland lagoon. Numerous walled fishponds located inside the harbor were used to cultivate various species of fish until the 1890s.

As one of the finest natural harbors in the Pacific Basin, Pearl Harbor was identified as a strategically important military asset. The U.S. Navy acquired rights to the harbor in an agreement with King David Kalakaua in 1873 (U.S. Department of the Interior 1969). After 1898, when Hawaii became a territory of the United States, plans were developed to dredge the harbor entrance channel and to construct docking facilities inside the harbor. In 1901, the U.S. Navy acquired 800 ac of land to establish a Naval Station on Pearl Harbor (USN 1983). The first major dredging of the entrance channel began in 1908, followed by construction of the first dry dock in Hawaii at the Pearl Harbor Navy Yard (Nystedt 1977).

During World War I, a dozen warships were repaired and overhauled at the Navy Yard. From 1917 to 1918, a temporary submarine base was relocated from Magazine Island (Kuahua Island) to Quarry Point on the eastern shoreline of Southeast Loch. A naval ammunition depot was commissioned in 1919 at Magazine Island. Around 1920, many walled fishponds still remained intact.

During the 1920s and 1930s, developments continued on shore facilities and additional land was acquired by the Navy. Ford Island became a naval air station in the early 1920s, and work began on concrete moorings along the south side of Ford Island. Industrial development was greatly accelerated in the Pearl Harbor area during the late 1930s and early 1940s. A considerable amount of acreage in the PHNC has been created since 1930 by the deposition of dredge spoil materials (USN 1947).

On December 7, 1941, the Japanese Imperial Navy launched an air attack on the U.S. Fleet in Pearl Harbor. During the attack, 21 of the 86 U.S. Navy warships in the harbor either sank or were severely damaged (Lenihan 1989; USN 1989a). Chemical evidence of this event (i.e., elevated concentrations of copper, lead, and zinc) remains detectable in Middle Loch in buried sediments that have not been disturbed by dredging activities (Ashwood and Olsen 1988).

From 1940 to 1943, large amounts of dredged material were placed on Waipio Peninsula and areas adjacent to the Submarine Base (USN 1983). These landfill operations formed the present shoreline configuration of the inner harbor. From 1942 to 1944, the number of facilities and personnel at the PHNC increased greatly to support the World War II effort in the Pacific. Storage facilities for ordnance and materiel filled nearly all available land regions near Pearl Harbor.

Immediately following World War II, the number of service personnel and active facilities at Pearl Harbor decreased markedly. However, operations and support personnel at the PHNC again increased during the Korean War and the Vietnam conflict, although not to the same extent as during World War II. Today, Pearl Harbor is a major fleet Homeport for nearly 40 warships; service force; vessels and submarines; and associated support, training, and repair facilities. The region is also listed as a National Historic Landmark.

2.1.1.2 Human Activities in Pearl Harbor

During the last century, numerous human activities have concentrated along the shoreline and within the upland drainage basins that empty into the harbor. These activities include industrial and operational activities of the U.S. Navy; private industrial operations; municipal, commercial, and urban activities; and agriculture. These activities potentially release numerous chemicals into the air, water, and soil along the shoreline and within the drainage basins to the harbor. Sediments in Pearl Harbor can act as a sink or repository for chemicals entering the harbor.

2.1.1.2.1 Present-day Pearl Harbor Naval Complex Activities

The present-day PHNC is an outgrowth of more than 100 years of development that has resulted in (1) dredging to construct a channel and berthing area of sufficient depth to allow passage of the “largest of ships” (Grovhoug 1992) and (2) construction of extensive shoreside facilities including ship mooring and repair facilities, fuel storage, handling, transfer, and recycling facilities as well as operations, maintenance, and support facilities. Military vessels using the harbor on a regular basis include U.S. Navy surface ships, submarines and harbor craft; U.S. Army cargo transport vessels; U.S. Coast Guard buoy tenders and patrol vessels; and foreign naval vessels. Harbor navigation channels and mooring areas at piers and wharves are maintained at water depths necessary for safe navigation through a program of routine maintenance dredging. New facilities are developed as needed and can include in-water construction and project-specific dredging. The following five major activities, which include military and civilian operations, have evolved under Commander, Navy Region Hawaii (COMNAVREG Hawaii).

- Naval Station (NAVSTA), Pearl Harbor
- Naval Submarine Base (SUBASE), Pearl Harbor
- Fleet and Industrial Supply Center (FISC), Pearl Harbor
- Navy Public Works Center (PWC), Pearl Harbor
- Naval Magazine (NAVMAG), Pearl Harbor

The Naval Shipyard (NAVSHIPYD), Pearl Harbor constitutes the other major activity at the PHNC. All of the above activities are likely sources for chemicals to harbor sediments.

2.1.1.2.2 Non-Navy Activities On and Adjacent to Pearl Harbor

Similar to the present-day PHNC, urban and rural areas in the vicinity of Pearl Harbor (including Honolulu and its suburbs) reflect more than 100 years of development. Over this period, land use in private and public areas adjacent to the harbor has shifted from primarily agricultural (including sugar cane, pineapple, taro, and watercress farming) to commercial, industrial, and residential activities. For example, a marked increase in urban development on leeward Oahu is reflected in recent extensive housing development in the Pearlridge, Waimalu, and Waiawa areas of Pearl City since 1970. The Waipahu and Ewa Beach regions have experienced greatly increased residential growth in recent years. Commercial and light industrial complexes have accompanied this growth. The sum of the preceding past and present-day non-Navy activities involves mixed land uses including various light industrial, municipal, commercial, and urban activities with the potential to contribute broad ranges of chemicals to harbor sediments. Additionally, past agricultural practices and related activities (including sugar refining operations) and present-day golf courses, which exist at numerous locations in the vicinity of the harbor, are likely contributors for diverse mixtures of pesticides and herbicides. Landfills (e.g., the City/County landfill at the head of West Loch) may also be sources for both past and present-day inputs of chemicals to the harbor. Finally, on-water operations for non-Navy activities that can contribute chemicals include commercial freighters and tankers, commercial tour craft, commercial fishing vessels (focused on collection of baitfish), and recreational vessels (e.g., sailboats and motorized vessels).

2.1.1.3 Marine Environment of Concern

Pearl Harbor contains approximately 1,943 ha (4,800 ac) of soft-bottom (e.g., mud and sand) benthic or harbor bottom habitat. Although specific species in the benthic community may change with water depth and location in the harbor, the major biotic components generally include infauna that burrow and live in sediments (e.g., crustacea such as shrimp and amphipods, polychaete worms, and mollusks such as clams and snails) as well as epifauna living on or in proximity to the sediment surface (e.g., epibenthic crabs and fish). Benthic organisms serve as important forage items for a variety of higher trophic level consumers including other benthic organisms (e.g., fish and crabs consume epifaunal and infaunal invertebrates), a variety of waterbirds, shorebirds, and seabirds, and ultimately humans. Grovhoug (1992) summarizes past biological investigations in Pearl Harbor and reports that the harbor is characterized by high biological complexity and productivity. More than 90 species of marine fishes, 114 species of benthic organisms, and 71 species of micromollusks have been identified in the harbor ecosystem (Evans et al. 1974).

2.1.1.4 Related Environments of Concern

Several wetland areas are located adjacent to Pearl Harbor in East Loch, Middle Loch, West Loch, and the Waipio Peninsula. The Pearl Harbor National Wildlife Refuge has two units located at Honouliuli in West Loch and Waiawa on the Pearl City Peninsula (State of Hawaii 1979). These areas are known habitats for several endemic and endangered waterbird species that use the harbor, including the Hawaiian stilt (*Himantopus knudseni*), the Hawaiian coot (*Fulica americana alai*), the Hawaiian duck

(*Anas wyvilliana*), and the Hawaiian moorhen or gallinule (*Gallinula chloropus sandvicensis*) (USN 1982 and 1989b).

2.1.2 Chemicals of Potential Concern

Initial identifications of COPCs for the SRA for sediments in Pearl Harbor address both present-day and historical human activities for contributions of chemicals to the harbor (e.g., Johnston et al. 1989; Grovhoug 1992; USN 1996a). General input sources include metals, petrochemicals, oil, lubricants, solvents and degreasers, plasticizers, polychlorinated biphenyls (PCBs), chlorinated dioxins and furans, ordnance and related materials, and pesticides and herbicides. Individual COPCs from these sources include a variety of chemicals in the following groups (USN 1996a).

- metals
- butyltins
- polycyclic aromatic hydrocarbons (PAHs) comprised of low molecular weight PAHs (LMWPAHs; 2- and 3-ring PAHs) and high molecular weight PAHs (HMWPAHs; 4-, 5-, and 6-ring PAHs)
- non-PAH semivolatile organic compounds
- chlorinated pesticides
- PCBs
- polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDDs and PCDFs)
- organophosphorus pesticides
- chlorinated herbicides
- triazine pesticides
- carbamate/urea pesticides
- ordnance compounds

The full list of COPCs considered for the SRA is presented in Table 2.1.2-1.

Measurements for all COPCs in samples for the SRA are performed with low level chemistry methods (described in the Quality Assurance Project Plan; USN 1996b). Use of low level methods is intended to minimize the possibility of overlooking potential risk for COPCs at the SRA level. A chemistry value reported as a detected concentration by the laboratory for a COPC is applied as the reported detect value. A chemistry value reported as a nondetect concentration by the laboratory for a COPC is applied as half the reported nondetect value following the approach suggested in Nehls and Akland (1973) and noted in Gilbert (1987). Evaluations of the adequacy of these nondetect concentrations for addressing objectives of the SRA are presented in Sections 6.1 and 6.3.

In addition to individual COPCs, Table 2.1.2-1 also identifies the following composite COPC groupings that are considered for the SRA.

- tLMWPAH: sum of all 2-ring + 3-ring PAHs
- tLMWPAH-Long95: sum of subset of LMWPAHs including acenaphthene + acenaphthlylene + anthracene + fluorene + 2-methynaphthalene + naphthalene + phenanthrene (Long et al. 1995)
- tHMWPAH: sum of all 4-ring + 5-ring + 6-ring PAHs
- tHMWPAH-Long95: sum of subset of HMWPAHs including benz(a)anthracene + benzo(a)pyrene + chrysene + dibenz(a,h)anthracene + fluoranthene + pyrene (Long et al. 1995)
- tPAH: sum of all tLMWPAH + tHMWPAH
- tPAH-Long95: sum of tLMWPAH-Long95 + tHMWPAH-Long95
- tDDT: sum of 2,4'-dichlorodiphenyldichloroethane (DDD) + 4,4'-DDD + 2,4'-dichlorodiphenyldichloroethylene (DDE) + 4,4'-DDE + 2,4'-dichlorodiphenyltrichloroethane (DDT) + 4,4'-DDT
- tChlordane: sum of alpha-Chlordane + gamma-Chlordane + cis-Nonachlor + trans-Nonachlor + Heptachlor + Heptachlor epoxide + Oxychlordane
- tPCB – Toxicity Equivalent Quotient (TEQ)-birds: sum of values for all 27 PCB congeners adjusted for 2,3,7,8-TCDD Toxic Equivalency Factors (TEFs) for birds (Van den Berg et al. 1998)
- tPCB – TEQ-fish: sum of values for all 27 PCB congeners adjusted for 2,3,7,8-TCDD TEFs for fish (Van den Berg et al. 1998)

- tPCB – Aroclor: Aroclor equivalent concentration calculated from PCB congener distribution and measured congener concentrations
- tPCB – NOAA-18: sum of the NOAA 18 congeners multiplied by 2 as described in Technical Appendix 2 in Valoppi et al. (1998)
- tDioxin/Furan: sum of all 17 dioxin/furan congeners
- tDioxin/Furan – TEQ-birds: sum of values for all 17 dioxin/furan congeners adjusted for 2,3,7,8-TCDD TEFs for birds (Van den Berg et al. 1998)
- tDioxin/Furan – TEQ-fish: sum of values for all 17 dioxin/furan congeners adjusted for 2,3,7,8-TCDD TEFs for fish (Van den Berg et al. 1998)

The composite groupings reflect commonalities in input sources and/or toxic mechanisms for individual COPCs. In support of the concept for composite COPC groupings, USEPA (1997; p. 2-4) notes the following for additive effects of appropriate COPC groupings as represented by sums of hazard quotients (HQs) (see Section 5): "If multiple contaminants of potential ecological concern exist at the site, it might be appropriate to sum the HQs for receptors that could be simultaneously exposed to the contaminants that produce effects by the same toxic mechanism."

For the above COPC groupings, lower molecular weight PAHs (i.e., tLMWPAHs) are generally characterized by significant acute toxicities whereas higher molecular weight PAHs (i.e., tHMWPAHs) show limited acute toxicity. In contrast, known carcinogens, cocarcinogens, and tumor producers are contained in the HMWPAH grouping (Neff 1985; Eisler 1987b). The subsets of tLMWPAH-Long95, tHMWPAH-Long95, and tPAH-Long95 reflect reduced sets of PAHs for which Effects Range-Low and Effects Range-Median values (i.e., ER-Ls and ER-Ms) have been developed for sediments (Long et al. 1995). The tDDT grouping represents the parent pesticide (DDT) and its degradation products (DDE and DDD) (e.g., Mearns et al. 1991). ER-L and ER-M values have also been developed for the tDDT grouping (Long et al. 1995). The tChlordane grouping represents primary components in and/or degradation products resulting from technical chlordane (e.g., Dearth and Hites 1991; Kawano et al. 1988; Mearns et al. 1991; Eisler 1990).

A number of PCDD, PCDF, and PCB congeners exhibit toxic responses similar to those caused by 2,3,7,8-TCDD, which is the most potent of the dioxin congeners. Consequently, TEFs relative to 2,3,7,8-TCDD have been developed for numerous PCDD, PCDF, and PCB congeners to facilitate composite risk estimates for mixtures of congeners (Van den Berg et al. 1998). Congener-specific TEFs are developed based on evidence of a common reaction mechanism involving binding of congeners to an aryl hydrocarbon (Ah) receptor as an initial step. The TEF concept reflects toxicities of congeners relative to that of 2,3,7,8-TCDD for effects that are Ah-receptor mediated. As noted in Van den Berg et al. (1998), TEF-adjusted concentrations can be used to calculate summed TEQ concentrations for PCDD, PCDF, and PCB congeners with the following expression:

$$TEQ = \Sigma_{n1}[PCDD_i \text{ X } TEF_i] + \Sigma_{n2}[PCDF_i \text{ X } TEF_i] + \Sigma_{n3}[PCB_i \text{ X } TEF_i]$$

At the same time, TEFs for individual congeners have been determined to differ between phylogenetic groups. Based on available *in vivo* and *in vitro* data for congener-specific toxicities, Van den Berg et al. (1998) identify separate TEFs for mammals, fish, and birds. Therefore, separate fish and bird TEQ sums for PCBs and PCDDs/PCDFs are developed for Steps 1 and 2 of the SRA. At the same time, PCB and PCDD/PCDF TEQs are not developed for invertebrate receptors in the SRA because TEFs have not been developed nor are they recommended for invertebrates because of limited evidence for ligand activation of the Ah-receptor or TCDD-like toxicity in invertebrates (Van den Berg et al. 1998).

In addition to TEQ estimates, sample-specific measurements for PCB congeners are also used to estimate total PCB in samples as both "NOAA-18 total" values and Aroclor-equivalent values. The "NOAA-18 total" value is based on a method developed in National Oceanic and Atmospheric Administration's (NOAA's) Status and Trends Program and described in Valoppi et al. (1998). The method involves summing concentrations for 18 PCB congeners (i.e., PCBs 8, 18, 28, 44, 52, 66, 101, 105, 118, 128, 138, 153, 170, 180, 187, 195, 206, and 209) and multiplying the sum by 2. Development of the Aroclor-equivalent value is patterned after information from

Newman et al. (1998) and involves a two-step process. First, estimation is made for the most appropriate Aroclor type from the congener distribution in a sample based on congener distributions in primary Aroclor mixtures. As described in Newman et al. (1998), primary congeners in Aroclor 1260 include PCBs 138, 153, and 180; primary congeners in Aroclor 1254 include PCBs 101, 118, and 138. Therefore, Aroclor type designations (e.g., Aroclor 1260 or Aroclor 1254) in samples for the SRA are determined from concentration ratios for detected values of (PCB-153 + PCB-180) relative to values for (PCB-101 + PCB-118). The most appropriate Aroclor type is designated as Aroclor 1260 if a ratio is greater than 1 [(PCB-153 + PCB-180) > (PCB-101 + PCB-118)]; the Aroclor type is designated as Aroclor 1254 if a ratio is less than 1 [(PCB-153 + PCB-180) < (PCB-101 + PCB-118)]. Following determination of the most appropriate Aroclor type, measured concentrations for selected congeners are used to estimate the Aroclor-equivalent concentration in a sample. Based on information in Newman et al. (1998), the mass fraction for (PCB-138 + PCB-153 + PCB-180) in Aroclor 1260 is 0.333 grams per gram (g/g) of total Aroclor 1260; the mass fraction for (PCB-101 + PCB-118 + PCB-138) in Aroclor 1254 is 0.254 g/g of total Aroclor 1254. Therefore, an Aroclor 1260 equivalent concentration is estimated by dividing the concentration sum for (PCB-138 + PCB-153 + PCB-180) by 0.333 for a sample designated as Aroclor 1260. An Aroclor 1254 equivalent concentration is estimated by dividing the concentration sum for (PCB-101 + PCB-118 + PCB-138) by 0.254 for a sample designated as Aroclor 1254. As illustrated in Figure 2.1.2-1, the two approaches for estimating total PCB (i.e., tPCB – NOAA-18 and tPCB - Aroclor) show remarkably good agreement for sediment and whole-body tissue samples of wild-caught aquatic organisms collected from Pearl Harbor for the SRA. The latter agreement is important because information in the scientific literature for available toxicity reference values for total PCB are consistently provided as Aroclor concentrations.

2.2 CONTAMINANT FATE AND TRANSPORT MECHANISMS

For the Pearl Harbor environment, COPCs released in areas adjacent to and upland of the harbor can be transported to the harbor through a variety of mechanisms. Once in the harbor, the chemicals can then be deposited and accumulate in sediments. Therefore, the harbor sediments act as an ultimate reservoir or sink for COPCs from multiple sources. Transport mechanisms for COPCs to Pearl Harbor can be associated with natural and anthropogenic activities including surface water runoff, erosion, storm drain inputs, point and nonpoint source discharges, and aerial fallout or deposition. The diversity of point and nonpoint sources can result in inputs of complex mixtures of not only parent COPCs but also degradation products and metabolites. Additionally, COPCs in harbor sediments can reflect inputs from present-day as well as historical sources. Fate and transport pathways for COPCs to harbor sediments are illustrated in Figure 2.2-1.

Present-day point and nonpoint sources for COPCs are derived from both Navy and non-Navy activities. Unintentional releases from marine vessels occur from hull cleaning and painting operations; dry dock activities; in-water releases from vessels (e.g., antifouling coatings); and from liquids such as fuels, solvents, and waste paints. Accidental discharges from solid waste and industrial activities can also contribute chemical inputs. Agricultural practices contribute not only pesticides but also less specific agriculture-related chemicals (e.g., fuels, solvents, etc.). Historical point sources of COPCs are generally similar to present-day sources, but also include additional inputs such as past municipal sewage discharges (no longer discharging to the harbor) and the December 7, 1941 bombing event. Present-day and historical nonpoint sources include surface runoff from a variety of areas related to Naval operations, commercial and urban streets, commercial and industrial work areas, miscellaneous liquid releases (e.g., fuels, solvents, and waste paints), and offsite combustion activities.

2.3 MECHANISMS OF ECOTOXICITY AND ECOLOGICAL RECEPTORS OF CONCERN

For considerations of ecotoxicity at the SRA level, USEPA (1997; p. 1-7) notes that "Adverse effects on populations can be inferred from measures related to impaired reproduction, growth, and survival." Therefore, considerations of ecotoxicity for ecological receptors for the SRA focus on effects related to growth or development, reproduction, and survival for target receptors.

To assess ecological risks for COPCs for the SRA, ecological resources of value are identified as the following.

1. Aquatic organisms comprising both forage items for target bird receptors and commercial and recreational resources for humans: Aquatic organisms of value include composite benthic macroinfauna (i.e., larger organisms living in the sediments such as ghost and snapping shrimps, and polychaete worms), epibenthic crabs (*Thalamita crenulata*), and epibenthic fish represented by tilapia (*Oreochromis mossambicus*) and bandtail goatfish (*Upeneus taeniopterus*). Composite benthic macroinfauna collected in samples from Pearl Harbor include primarily ghost shrimp (*Callianassa* spp.), pistol or snapping shrimp (*Alpheus* spp.), and polychaete worms. The macroinfauna can serve as important forage items for the variety of higher trophic level receptors (e.g., the epibenthic crabs, epibenthic fish, shorebirds, and waterbirds). Epibenthic crabs and fish serve as important forage items for target waterbirds, shorebirds, and seabirds as well as humans.

2. Omnivorous waterbirds, shorebirds, and seabirds: Birds of value include waterbirds (represented by the Hawaiian stilt [*Himantopus mexicanus knudseni*], Hawaiian coot [*Fulica americana alai*], Hawaiian duck [*Anas wyvilliana*], Hawaiian common moorhen or gallinule [*Gallinula chloropus sandvicensis*], and black-crowned night heron [*Nycticorax nycticorax*]), shorebirds (represented by the wandering tattler [*Heteroscelus incana*]), and piscivorous seabirds (represented by the sooty tern [*Sterna fuscata*]). Potential exposures for birds to sediment-related COPCs can occur from ingestion of not only sediment-associated forage items (e.g., composite benthic macroinfauna, epibenthic crabs, and epibenthic fish such as tilapia and bandtail goatfish) but also incidental sediment for waterbirds and shorebirds. Ingestion items for the various bird receptors for the SRA are summarized in Table 2.3-1. The table also includes body weights for each of the birds, which are minimum values for adult birds from Dunning (1993).

More detailed descriptions for each of the target aquatic and bird receptors will be presented in Step 3a of the BERA. The latter descriptions will more fully address natural history aspects for each receptor, including not only physical characteristics but also feeding habits, anticipated foraging areas (i.e., area use), and seasonality considerations if a receptor is not anticipated to spend its entire foraging time in the Pearl Harbor area (i.e., seasonality).

2.4 COMPLETE EXPOSURE PATHWAYS

For a COPC to pose an ecological risk, a complete exposure pathway must exist between a source for the COPC (i.e., harbor sediments) and an ecological receptor of concern (i.e., birds, fish, or aquatic invertebrates). If a complete exposure pathway does not exist, a receptor has acceptably low risk because it will not receive exposure to the COPC.

Primary exposure routes to sediment COPCs for target ecological receptors for the SRA include (1) direct exposure to sediments through ingestion or physical contact (i.e., direct contact by bottom dwelling aquatic receptors; incidental ingestion for waterbirds and shorebirds from foraging activities) and (2) indirect exposure through food web bioaccumulation (i.e., consumption of forage items that have bioaccumulated COPCs either directly or indirectly from sediments). Figure 2.4-1 illustrates likely complete exposure pathways for COPCs from sediments to target ecological receptors for the SRA. The figure also indicates whether a particular pathway relates to direct sediment contact exposure or indirect food web bioaccumulation exposure for a receptor.

For the SRA, sediment-related exposures for target aquatic receptors (i.e., represented as composite benthic macroinfauna, epibenthic crabs, tilapia, and bandtail goatfish) are inferred from measured COPC concentrations in whole-body tissue samples of wild-caught organisms from the harbor. Sediment-related exposures for target waterbirds (i.e., represented as the Hawaiian stilt, Hawaiian coot, Hawaiian duck, Hawaiian moorhen, and black-crowned night heron) and shorebirds (i.e., represented as the wandering tattler) are estimated as either (1) 100% consumption of whole-body tissue residues for wild-caught forage items (i.e., composite benthic macroinfauna, epibenthic crabs, tilapia, or bandtail goatfish) or (2) 100% consumption of incidental sediment related to foraging activities for sediment locations with water depths of 2 meters or less. More realistic consumption mixtures of forage items and incidental sediment for waterbirds and shorebirds will be addressed in refined exposure scenarios for Step 3a of the BERA. Sediment-related exposures for the target seabird (i.e., sooty tern) are estimated as 100% consumption of whole-body tissue residues in wild-caught tissue forage items of tilapia and bandtail goatfish. All exposure estimates are based on maximum measured concentrations for a particular COPC in a particular matrix type (i.e., wild-caught tissue samples of composite benthic macroinfauna, epibenthic crabs, tilapia, or bandtail goatfish; sediment samples from all locations with water depths of 0 to 2 meters for incidental sediment ingestion by waterbirds and shorebirds).

2.5 Assessment Endpoints and Measures of Effects

A critical component for an ecological risk assessment is identification of appropriate assessment endpoints and measures of effect that serve to focus and guide the overall assessment. For assessment endpoints, USEPA (1997; p. I-4) notes: "Assessment endpoints should relate to statutory mandates (e.g., protection of the environment), but must be specific enough to guide the development of the risk assessment study design at a particular site. Useful assessment endpoints define both the valued ecological entity at the site (e.g., a species, ecological resource, or habitat type) and a characteristic(s) of the entity to protect (e.g., reproductive success, production per unit area, areal extent)." As an example assessment endpoint relevant to the Pearl Harbor Sediment RI/FS, USEPA (1997; p. I-6) identifies "sufficient rates of survival, growth, and reproduction to sustain populations of carnivores typical for the area." Representative carnivores/omnivores for the SRA include the aquatic and bird receptors identified in Section 2.3.

Assessment endpoints for the SRA are the following.

- No adverse effect on populations of aquatic ecological receptors represented by composite benthic macroinfauna, epibenthic crabs, tilapia, and bandtail goatfish inferred from bioaccumulation measures related to lowest literature-derived NOAELs for whole-body tissue residue levels for combined effect endpoints of impaired growth or development, reproduction, and survival.

- No adverse effects on populations of omnivorous waterbirds (i.e., represented by the Hawaiian stilt, Hawaiian coot, Hawaiian duck, Hawaiian moorhen, and black-crowned night heron) or shorebirds (i.e., represented by the wandering tattler) from ingestion measures for consumption of either epibenthic forage items (i.e., whole-body tissue samples of composite benthic macroinfauna, epibenthic crabs, tilapia, or bandtail goatfish) or incidental sediment related to lowest literature-derived NOAELs for ingestion doses in birds for combined effect endpoints of impaired growth or development, reproduction, and survival.

- No adverse effects on populations of piscivorous seabirds (i.e., represented by the sooty tern) from ingestion measures for consumption of epibenthic forage items (i.e., whole-body tissue concentrations of tilapia or bandtail goatfish) related to the lowest literature-derived NOAELs for ingestion doses in birds for combined effect endpoints of impaired growth or development, reproduction, and survival.

USEPA (1998; p. 43) notes the following for measures of effects: "Measures of effect are measurable changes in an attribute of an assessment endpoint or its surrogate in response to a stressor to which it is exposed (formerly measurement endpoints)." USEPA (1997; p. I-6) notes: "Sometimes, the assessment endpoint can be measured directly; usually, however, an assessment endpoint encompasses too many species or species that are difficult to evaluate (e.g., top-level predators). In these cases, the measurement endpoints [i.e., measures of effects; USEPA 1998] are different from the assessment endpoint, but can be used to make inferences about risks to the assessment endpoints. For example, measures of responses in particularly sensitive species and life stages might be used to infer responses in the remaining species and life stages in a specific community."

Measures of effects for the SRA are the following.

- Comparison of maximum measured concentrations for COPCs in harbor sediments to available low level Sediment Quality Benchmarks (SQB) represented by NOAA's Effects Range-Low values (ER-Ls) (Long et al. 1995).

- Site-specific measures of sediment toxicity determined from amphipod survival in whole sediments and echinoderm fertilization in sediment pore water.

- Comparison of maximum whole-body tissue concentrations for COPCs in wild-caught samples of target aquatic receptors (i.e., represented by composite benthic macroinfauna, epibenthic crabs, tilapia, and bandtail goatfish) to lowest no-observed-adverse-effect-levels (NOAELs) of whole-body tissue residues in appropriate receptors from the scientific literature for the lowest value for combined effect endpoints of growth or development, reproduction, and survival.

- Comparison of maximum estimated ingestion doses for COPCs for omnivorous waterbirds (i.e., represented by the Hawaiian stilt, Hawaiian coot, Hawaiian duck, Hawaiian moorhen, and black-crowned night heron) and shorebirds (i.e., represented by the wandering tattler) for 100% consumption of whole-body samples of wild-caught aquatic forage items (i.e., composite benthic macroinfauna, epibenthic crabs, tilapia, and bandtail goatfish) or incidental ingested sediment to lowest NOAEL ingestion doses from the scientific literature for the lowest value for combined effect endpoints of growth or development, reproduction, and survival in birds.

- Comparison of maximum estimated ingestion doses for COPCs for piscivorous seabirds (i.e., represented by the sooty tern) for 100% consumption of whole-body samples of wild-caught aquatic forage items (i.e., tilapia and bandtail goatfish) to minimum NOAEL ingestion doses from the scientific literature for the lowest value for effect endpoints of growth or development, reproduction, and survival in birds.

A receptor-specific summary of Assessment Endpoints and Measures of Effects for the SRA is presented in Table 2.5-1. The table includes information for the following items.

- Receptor class and/or specific receptors.
- Assessment Endpoint.
- Risk questions related to the Assessment Endpoint.
- Surrogate species or community for the Assessment Endpoint.
- Measures of Effects to address the Assessment Endpoint.
- Uncertainties associated with the Measures of Effects.
- Notes for related information, including indication for points at which COPCs are identified as needing to be carried forward or not to a subsequent BERA.

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