Restoration Plan and Environmental Assessment
for the
Tex Tin Corporation Superfund Site
Texas City, Galveston County, Texas

Prepared by:

Texas Natural Resource Conservation Commission
Texas General Land Office
Texas Parks and Wildlife Department
National Oceanic and Atmospheric Administration and
the United States Fish and Wildlife Service on behalf of the
U.S. Department of the Interior

July 9, 2001

1.0 INTRODUCTION AND SUMMARY

This Restoration Plan and Environmental Assessment (RP/EA) has been prepared by state and federal natural resource trustees to address natural resources and services injured or lost due to releases of hazardous substances from the Tex Tin Corporation Superfund Site ("Tex Tin Site" or "Site"). The designated natural resource trustee agencies involved in the development of this document are the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce, the Texas Natural Resource Conservation Commission (TNRCC), the Texas General Land Office (TGLO), the Texas Parks and Wildlife Department (TPWD), and the United States Fish and Wildlife Service (USFWS) on behalf of the U.S. Department of the Interior (DOI) (collectively, the "Trustees").

The trace metals aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver, tin, vanadium, and zinc and polycyclic aromatic hydrocarbons (PAHs) detected at the Site are hazardous substances covered by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 United States Code (U.S.C.) Sections 9601 *et seq.*), better known as Superfund. Owners and/or operators of facilities responsible for unauthorized releases of hazardous substances are liable under CERCLA for costs of cleaning up releases and the costs of restoring, replacing or acquiring the equivalent of natural resources injured, destroyed or lost as a result of the releases.

This RP/EA is intended to inform members of the public of the Trustees' assessment of the natural resource injuries and service losses described herein and the restoration actions which the Trustees propose to compensate the public for those injuries and losses. Comments received by the Trustees during the public comment period will be considered prior to finalizing this RP/EA. A summary of the comments received and the

Trustees' responses thereto will be included in the final RP/EA. This RP/EA also serves as an Environmental Assessment pursuant to the National Environmental Policy Act (NEPA), 42 U.S.C. Section 4321 *et seq.*, and regulations guiding its implementation at 40 Code of Federal Regulations (C.F.R.) Part 1500. Accordingly, this document addresses the purpose and need for the proposed restoration actions, the restoration alternatives considered, and the potential impact of restoration actions on the quality of the physical, biological, and cultural environment (Section 7.0, below).

1.1 Overview of the Site and Releases of Hazardous Subtances

The Site is located on approximately 3547 acres of land in Texas City, Galveston County, Texas (Figure 1). The Site is approximately 10 miles north of Galveston and adjacent to the southeastern quadrant of the intersection of State Highway 146 and Farm to Market Road 519. North and east of the Site, large petro-chemical and other industrial complexes exist. Waste disposal facilities and marshes are located to the south, southeast and southwest of the Site. Residential areas are found to the west and northwest.

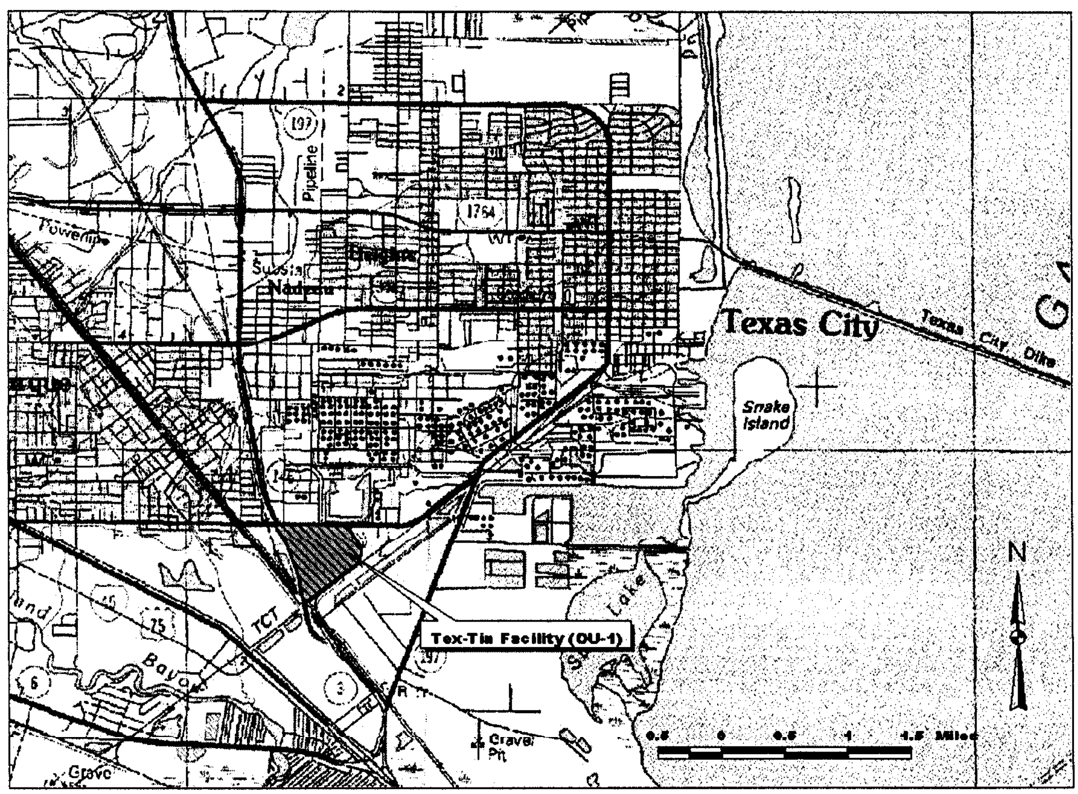

Figure 1. The Tex Tin Corporation Superfund Site, Galveston County, Texas City, Texas

The U.S. Government, acting through now defunct wartime agencies, commissioned the construction of a tin smelting plant at the Site in support of World War II activities. The plant was operated under government contract between 1941 and 1956. The Wah Chang Corporation bought the Site in 1957 and operated the tin smelter for 11 years. Teledyne Corporation purchased Wah Chang Corporation in 1967. In 1968, Teledyne sold the smelter to the Fred H. Lenway Corporation, which sold the eastern portion of the Site to Amoco Chemical Company in 1969. The Gulf Chemical and Metallurgical Company purchased the smelting plant from Lenway in 1970. In 1978, the Associated Metals and Minerals Corporation purchased Gulf Chemical. The portion of the Site controlled by Associated Metals and Minerals Corporation became the Tex Tin Corporation in 1985. Tex Tin Corporation operations continued at the Site into the early 1990s.

At various times, industrial activities at the Site have included tin ore processing, acid recovery operations, heavy metals recovery operations, copper washing operations using ammonia, secondary copper smelting, land filling of low-level radioactive materials, and still bottom and waste oil recovery. The Tex Tin smelter complex included a processing area, a small power-generation station, fuel oil tanks, acid tanks, five wastewater treatment ponds, several large abandoned acid ponds, a ferric chloride pond, and numerous slag piles and drums.

For the purposes of remediation, the Site was divided into four operable units (OU1 to OU4) (Figure 2). This RP/EA addresses natural resource injuries and service losses attributable to all four OUs, and the restoration project to compensate for such injuries and losses. OU1, OU2, OU3, and OU4 are summarized below, but will not be considered in this document except to the extent that the remedy chosen for OU4 interacts with the restoration project.

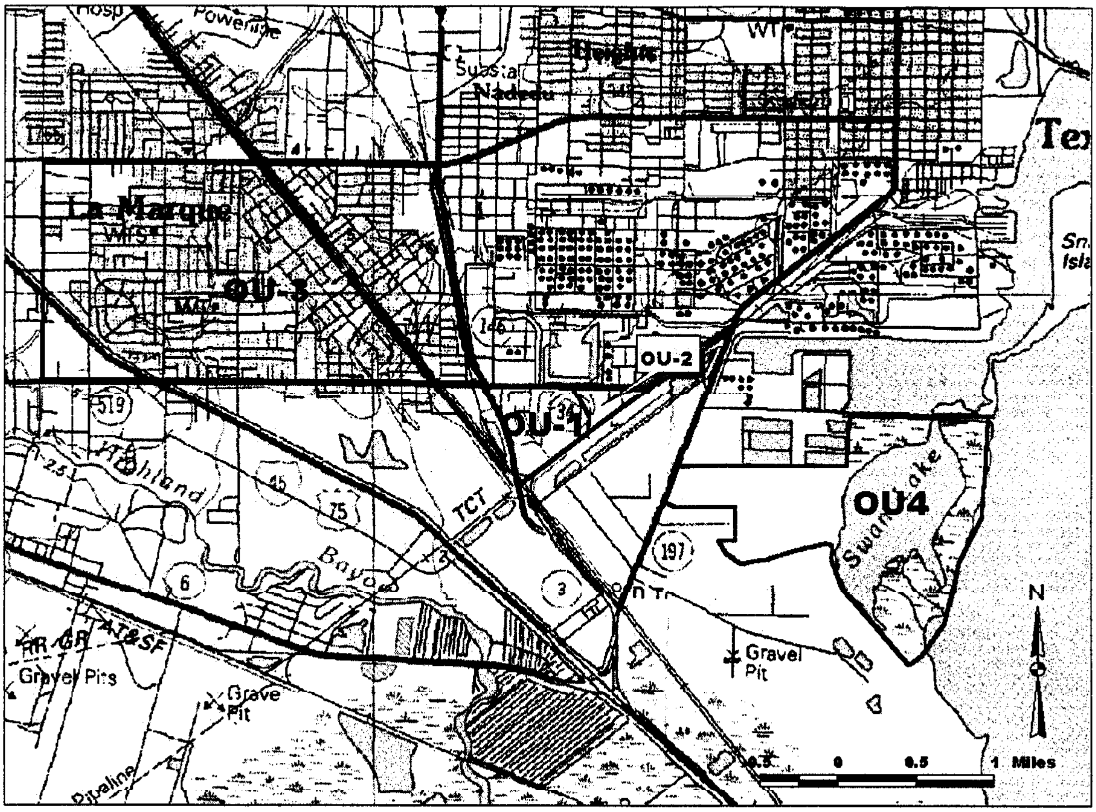

Figure 2. OU designations at the Tex Tin Corporation Superfund Site, Galveston County, Texas.

OU4 consists of the easternmost portion of a dredged canal known as the Wah Chang Ditch (WCD) (east of the hurricane levee), Swan Lake, and surrounding marsh habitats (Figure 3). The U.S. Environmental Protection Agency (EPA) conducted a Superfund remedial investigation (RI), baseline ecological risk assessment (BERA), and feasibility study (FS) for OU4, in close coordination with the Trustees.

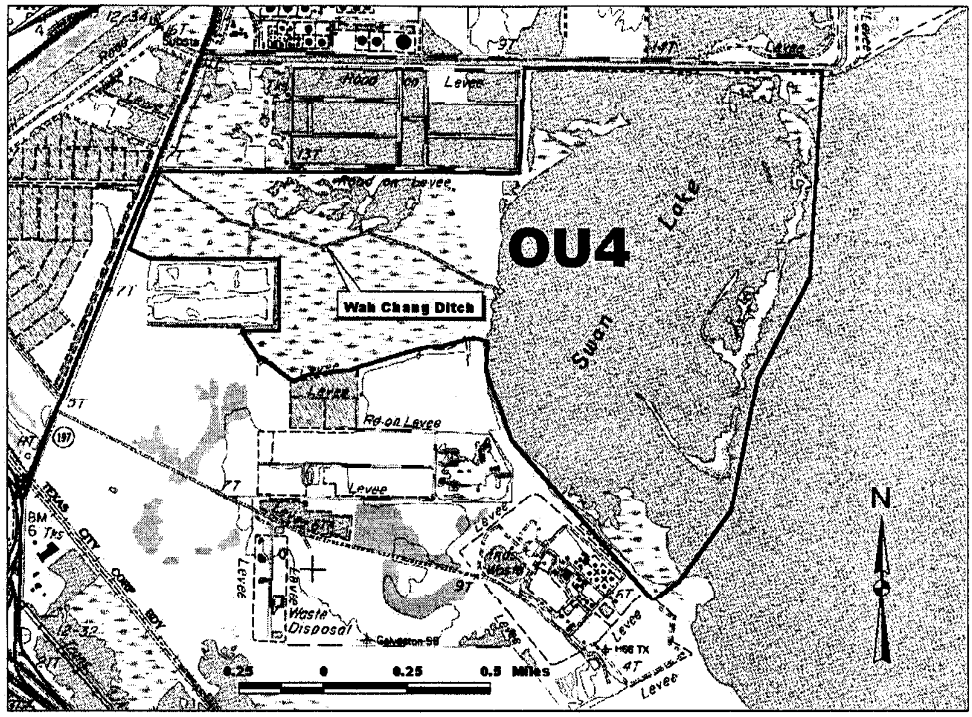

Figure 3. OU4, Tex Tin Corporation Superfund Site, Galveston County, Texas

Swan Lake, located in OU4, received acid smelter wastewater in the 1940s, 1950s, and 1960s via the WCD. Around 1971, water flow in the WCD was interrupted by a hurricane protection levee (HPL). Tin smelter storm water and treated effluent, as well as upstream contributions, collected in ponds inside the levees. Pond water continues to be periodically pumped over the levee, moving through a 2-mile canal to the Texas City Ship Channel thence to Galveston Bay. As a result, contamination, originating from the Site, has been detected or is predicted to occur in the WCD, the Texas City Ship Channel, Swan Lake, the adjacent marsh system, and West Galveston Bay. Subsequent to construction of the HPL, Site contaminants only reach the Swan Lake system by aerial deposition and through storm events, floods, and extreme tidal excursions.

Existing data indicate that trace metals are the primary contaminants at this Site. PAHs were frequently encountered; however, the levels of PAHs were not as high relative to levels of concern as the trace metals. Volatile and semivolatile organic compounds and polychlorinated biphenyls (PCBs) are also present but were infrequently detected and/or present in concentrations below levels of ecological concern.

The Trustees are responsible for evaluating potential injuries to natural resources and resource service losses resulting from releases of hazardous substances from the Site pursuant to Section 107(f) of CERCLA (42 U.S.C. Section 9607(f)), the Federal Water Pollution Control Act (33 U.S.C. Section 1251 *et seq.*) (also known as the Clean Water Act or CWA), and other applicable federal or state laws, including Subpart G of the National Oil and Hazardous Substances Contingency Plan (NCP) (40 C.F.R. Sections 300.600 through 300.615), and regulations at 43 C.F.R. Part 11 which are applicable to natural resource damage assessments (NRDA) under CERCLA. Payment of the cost of actions appropriate to restore, replace or acquire resources or resource services equivalent to those lost (collectively, "restoration actions") is the primary method for compensating the public for injuries to natural resources under these authorities. The goal of this process is to allow restoration actions, which will make the environment and public whole for resource injuries or losses that have occurred or will occur into the future, to be identified and implemented in an expeditious and cost-effective manner.

1.2 Natural Resource Injuries

Trace metals, particularly chromium, copper, lead, tin, and zinc, are the primary contaminants of concern at the Site. These hazardous substances were found in the sediments of the WCD, Swan Lake delta, and salt marsh. The Swan Lake ecosystem, part of the greater Galveston Bay ecosystem, is an important habitat for numerous recreational and commercial fish and shellfish species and an important source of organic production for the system. Trace metals do not degrade naturally in marine sediments and persist at injurious levels long after the primary source of pollution is removed. Benthic invertebrates, which form the basis of estuarine food webs, are especially susceptible to this contamination because they live and feed directly in the sediments. A wide variety of metals have been documented to cause a range of toxic responses in marine organisms, including mortality and reduced growth and reproduction.

Using data developed during the OU4's BERA and the remedial investigation/feasibility study (RI/FS), the Trustees were able to identify the types of habitats, their component resources, and the habitat or resources services with the greatest potential to have been injured by historic and ongoing releases of metals from the Site. These include subtidal unvegetated soft-bottom benthic habitats in the WCD, Swan Lake, and estuarine marsh habitats. Some animals living in these habitats, such as shellfish, fish, and birds, may have suffered lethal effects (increased mortality) or sublethal effects (reduced growth, reduced fecundity, etc.) as a result of exposure to metals.

1.3 Authority and Legal Requirements

The Trustees have prepared this RP/EA jointly. Each of these agencies is a designated natural resource trustee under Section 107(f) of CERCLA (42 U.S.C. Section 9607(f)). As a designated Trustee, each agency is authorized to act on behalf of the public to assess and recover natural resource damages where natural resources and resource services are injured, lost, or destroyed as a result of releases of hazardous substances designated by CERCLA.

1.3.1 Overview of CERCLA Natural Resource Damage Assessment Procedures

Damages recovered by Trustees for natural resource injuries or service losses due to hazardous substances releases must be used to restore, replace or acquire natural resources or services equivalent to those lost (42 U.S.C. Section 9607(f)(1)). The costs of restoration actions are a preferred measure of natural resource damages under CERCLA.

The goal of the injury assessment is to determine the effect of the hazardous substances from the Site on natural resources and services of the Site, thus, providing a factual basis for evaluating the need for, type of, and scale of restoration actions, including the extent to which considered restoration alternatives would provide ecological service benefits comparable to assessed losses. This RP/EA incorporates and presents the plan for restoring ecological services developed by the Trustees. It identifies and evaluates a reasonable range of restoration alternatives and identifies the preferred restoration alternatives. The Trustees have determined that the preferred restoration actions will fully compensate for ecological injuries and service losses until the system returns to baseline condition.

1.3.2 Restoration Under CERCLA

In general, restoration actions for natural resource injuries and service losses under CERCLA can be termed as primary or compensatory. Primary restoration is any action taken to enhance the return of injured natural resources and services to their baseline condition, *i.e.*, the condition or level that would have existed had the hazardous substance releases not occurred. Compensatory restoration actions compensate for resource injuries and services losses during the interim period, until recovery to baseline occurs.

Removal and remedial actions (collectively, "response actions") are conducted or overseen by EPA or state response agencies and focus on controlling exposure to released hazardous substances, by removing, neutralizing, or isolating them in order to protect human health and the environment from the threat of harm. Although response actions can reduce the need for restoration, the two types of actions are separate and distinct. Trustees may elect to rely on natural recovery as the best alternative for achieving primary restoration in situations where feasible or cost-effective primary restoration actions are not available, where response actions are sufficient to allow for recovery of injured resources, or where the injured resources can otherwise be expected to recover within a reasonable period of time without human intervention. EPA and the TNRCC evaluated a range of remedial actions for OU4 (EPA, 2000).

The Trustees have concluded that EPA's recommended remedial alternative (long-segmented breakwaters) should be sufficient to allow natural resources and services to return to their baseline condition without further primary restoration actions.

The scale of the required compensatory restoration depends both on the scale of the resource injuries and how quickly that resource and associated services return to baseline. Remedial actions that facilitate or speed resource recovery reduce interim losses and the compensatory restoration required to offset those losses. Resource injuries and service losses caused by implementation of remedial actions are also losses that may be compensated through appropriate restoration actions.

1.3.3 NEPA Compliance

Any restoration of natural resources under CERCLA must comply with the NEPA (42 U.S.C. Section 4321 *et seq.*) and the Council on Environmental Quality (CEQ) regulations implementing NEPA at 40 C.F.R. Part 1500. In compliance with NEPA and the CEQ regulations, this RP/EA summarizes the current environmental setting, describes the purpose and need for action, identifies alternative actions, assesses their applicability and environmental consequences, and summarizes Trustee actions taken to facilitate opportunities for public participation in the decision-making process. This information was used in making a threshold determination as to whether preparation of an Environmental Impact Statement (EIS) is required prior to the selection of the final restoration action (*i.e.*, Is the proposed action a major federal action that may significantly affect the quality of the human environment?). The EA integrated in this RP/EA determines that the proposed restoration action does not the meet the threshold requiring an EIS.

1.3.4 Public Participation

Public review of the RP/EA is an integral component of the restoration planning process. Through the public review process, the Trustees seek public comment on the analyses used to define and quantify natural resource injuries and service losses and the methods being proposed to restore injured natural resources or replace lost resource services. A draft version of this RP/EA was provided to the public with current information about the nature and extent of the natural resource injuries identified and restoration alternatives evaluated.

The draft version of this RP/EA was available to the public for a 30-day comment period which began June 1, 2001 and closed July 1, 2001. The notice of availability of the Draft RP/EA and notice of the comment period was published in 26 Tex. Reg. 3990 (Jun. 1, 2001). The Trustees received no public comments on the Draft RP/EA. Public review of the Draft RP/EA is consistent with all state and federal laws and regulations that apply to the natural resource damage assessment process, including the DOI regulations, NEPA, and the regulations implementing NEPA at 40 C.F.R. Part 1500.

Additional opportunities for public review will be provided in the event that significant changes to the RP/EA are required.

2.0 AFFECTED ENVIRONMENT

This chapter presents a brief description of the physical and biological environment affected or potentially affected by the releases of hazardous substances from the Site, as required by NEPA (42 U.S.C. Section 4321 *et seq.*). The physical environment includes Swan Lake, WCD, Swan Lake salt marsh, and Galveston Bay; however, existing data on contaminant concentrations indicate that injuries/service losses are confined to the vicinity of Swan Lake including the salt marsh and WCD. The biological environment includes a wide variety of finfish, shellfish, birds, benthos, and other organisms. The natural resources of Galveston Bay are of significant economic and cultural importance, such as travel, tourism, and commercial and recreational fishing. These activities depend on a healthy coastal ecosystem.

The area around the Site can be generally characterized as coastal plain, topographically flat, that extends east-southeast to Galveston Bay. Much of the area consists of marsh and slow moving coastal bayous. The primary surface water bodies on and surrounding the Site are man-made ponds and drainage ditches. Major natural water features close to the Site include Highland Bayou and Swan Lake, a sub-bay of West Galveston Bay.

The Swan Lake salt marsh, through which the WCD traverses, is situated west of Swan Lake and is bordered to the north by an industrial waste disposal facility, to the east by Route 197, hurricane protection levees, large petrochemical and other industrial facilities, and to the south by disturbed uplands and additional industrial and commercial development. Interspersed within the salt marsh are pockets of subtidal estuarine wetlands that are in hydrologic communication with the WCD. These areas appear to be continually submerged. Currently, the historic portion of the WCD originates along Route 197 and meanders through the Swan Lake salt marsh for approximately 1.1 miles to Swan Lake. The ditch is 10 feet deep and ranges from 15 to 30 feet wide.

Swan Lake is located two miles east of the Tex Tin smelting plant and is approximately one mile wide and one and a quarter miles long. As mentioned previously, the Wah Chang ditch drained through a salt marsh into Swan Lake during the 1940s, 1950s, and 1960s. The southwestern portion of the WCD below the hurricane protection levee drains the marsh immediately to the north. Swan Lake and Galveston Bay are separated by a series of small shell islands; however, the shell islands and the western and southern wetlands of Swan Lake are tidally influenced due to Campbell Bayou that connects Swan Lake with Galveston Bay.

The Texas Colonial Waterbird Society has designated the shell islands of Swan Lake as the Swan Lake Bird Rookery. This bird rookery serves as a breeding ground for the following species: gull-billed tern (*Gelochelidon nilotica*), Forster's tern (*Sterna forsteri*), black skimmer (*Rynchops nigra*), various gulls, various herons, and various egrets. Swan Lake waters are critical habitat for various species designated by the USFWS or the State of Texas as threatened or endangered including white-faced ibis and reddish egret. In addition, Pierce Marsh, a nearby intertidal marsh complex, is located on the Central Migratory Flyway within the area encompassed by the Texas Mid-Coast Initiative Area of the Gulf Coast Joint Venture of the North American Waterfowl Management Plan. It contains high priority populations of wintering ducks as well as shore and wading birds most commonly associated with coastal wetlands.

White shrimp (*Litopenaeus setiferus*) and brown shrimp (*Farfantepenaeus aztecus*) are economically important species found in the Galveston Bay system. Galveston Bay waters support species important for commercial and recreational usage and provide habitat for the following organisms: white shrimp, brown shrimp, blue crab (*Callinectes sapidus*), eastern oyster (*Crassostrea virginica*), spotted seatrout (*Cynoscion nebulosus*), sand seatrout (*Cynoscion arenarius*), Atlantic croaker (*Micropogonius undulatus*), red drum (*Scienops ocellatus*), black drum (*Pogonius cromis*), southern kingfish (*Menticirrhus americanus*), Gulf kingfish (*Menticirrhus littoralis*), sheepshead (*Argosargus probatocephalus*), southern flounder (*Paralichthyes leithostigma)*, striped mullet (*Mugil cephalus*), sea catfish (*Galeichthys felis*), Gulf menhaden (*Brevoortia patronus*), and gafftopsail catfish (*Bagre marinus*). In addition, numerous other estuarine and marine resources are found in Galveston Bay including bay anchovy *(Anchoa mitchilli*), sea catfish (*Arius felis*), silver perch (*Bairdiella chrysoura*), blue runner (*Caranx crysos*), jack crevalle (*Caranx hippos*), bull shark (*Carcharhinus leucas*), sheepshead minnow (*Cyprinodon variegatus*), gizzard shad (*Dorosoma cepedianum*), Gulf killifish (*Fundulus grandis*), code goby (*Gobiosoma robustum*), pinfish (*Lagodon rhombiodes*), spot (*Leiostomus xanthurus*), gray snapper (*Lutjanus griseus*), tarpon (*Megalops atlanticus*), silversides (*Menidia* spp.), Gulf flounder (*Paralichthys albigutta*), bluefish (*Pomatomus saltatrix*), Spanish mackerel (*Scomberomorus maculatus*), Florida pompano (*Trachinous carolinus*), bay squid (*Lolliguncula brevis*), Gulf stone crab (*Menippe adina*), hard clam (*Mercenaria mercenaria*), pink shrimp (*Penaeus duorarum*), grass shrimp (*Palaemonetes pugio*), and common rangia (*Rangia cuneata*).

Benthic organisms include annelid worms, small crustaceans (amphipods, isopods, copepods, juvenile decapods), molluscs, and other small bottom-dwellers in Swan Lake salt marshes and unvegetated subtidal sediments in Swan Lake or the WCD. Benthic organisms may be herbivores (eating algae or other live plant material), detritivores (feeding on decaying organic matter in surface sediments or sediment-bound nutrients and organic substances that are not generally available to epiphytic or pelagic organisms), carnivores (preying on other benthic organisms), or omnivores (a combination). Benthic organisms provide the nutritional base for developing stages of many finfish and shellfish and thus affect all trophic levels in the Swan Lake system. The activities of benthic organisms are important in conditioning these habitats and in decomposition and nutrient cycling that occurs in these areas. In sum, benthic communities provide important ecological services primarily related to food production, decomposition and energy cycling that affect nearly all organisms within an estuarine system. A potential adverse impact on benthic populations has the potential to impact biota in nearly all trophic levels of the Swan Lake system. The numerically dominant taxa in the Swan Lake study area include the polychaetes *Mediomastus californiensis*, *Laeonereis culveri*, *Streblospio benedicti*, and *Capitella capitata*, and the amphipod *Ampelisca abdita*. Oligochaetes and nemerteans are also important taxonomic groups.

The Swan Lake area is home to a variety of plant species which are typical of species found in estuarine wetlands including cordgrasses (*Spartina alterniflora* and *S. patens*), saltwort (*Batis maritima*), glass wort (*Salicornia virginica*), seashore saltgrass (*Distichlis spicata*), saltmarsh bulrush (*Scirpus maritimus*), sea oxeye (*Borrichia frutescens*), and marsh elder (*Iva frutescens*).

3.0 INJURY AND SERVICE LOSSES DUE TO RESPONSE ACTIONS AT THE SITE

Response actions (which include removal and remedial actions) are conducted by PRPs, EPA, or state response agencies and focus on controlling exposure to released hazardous substances, by removing, neutralizing or isolating them in order to protect human health and the environment from the threat of harm. Response actions are separate and distinct from the damage assessment process. However, at times, response actions can cause additional injuries to natural resources. When such injuries result from response actions, the additional injuries are included in the damage assessment (43 C.F.R. Section 11.15).
At the present time, there is a 1500-foot rock breakwater extending southward from Shoal Point (Snake Island) along the footprint of the barrier islands. Construction of a segmented breakwater or wave barrier would help restore the function of the barrier islands, mitigating the threat of erosion from contaminated areas behind the islands, and increasing natural sedimentation in the area. Due to the construction of a segmented breakwater or wave barrier, increased sedimentation is expected to continue over time, removing contaminated sediments from the biotic zone by gradually cutting off the exposure pathway, thereby preventing release and eliminating exposure to the ecological systems. Furthermore, wave barrier or breakwater construction will prevent erosion of Swan Lake and salt marsh sediments and encourage sediment deposition. Additionally, the Trustees anticipate that restoration actions would place dredge material over contaminated sediment during construction of compensatory marsh habitat. This action would accelerate contaminant burial in this ecosystem and isolate high concentrations of metals from trust resources.

Habitat injuries directly from response actions are expected to be limited to the physical covering of existing benthos organisms under the breakwater. No response action injuries are expected elsewhere in OU4 as sediment contamination would be ameliorated through natural process recovery (*i.e.*, sedimentation). Such action is only expected to have minimal ecological effects on the Swan Lake ecosystem because the response action will substantially decrease the release of hazardous contaminants, benefiting the natural resources in the system. Sedimentation is a natural process in estuaries that can be coped with by benthic organisms. Therefore, the Trustees have concluded that there is no compensable injury resulting from the anticipated response action.

4.0 INJURY AND SERVICE LOSS EVALUATION

This chapter describes the potential injuries and quantifies the potential ecological service losses caused by the releases of hazardous substances (primarily metals) from the Site. The section begins with an overview that describes the Trustees' assessment strategy. The remainder of the section presents the results of Trustee assessments for the specific resources affected by releases of trace metals from the Site, including the approaches used to determine potential injuries and quantify potential service losses.

4.1 Assessment Strategy

The goal of this assessment is to determine the nature and extent of injuries to natural resources and to quantify the resulting resource and service losses, thus providing a technical basis for evaluating the need for, type of, and scale of restoration actions. As described above in Section 1.3.1, this assessment process is guided by DOI's NRDA regulations under CERCLA (43 C.F.R. Part 11). For this Site, the Trustees have pursued an assessment approach that is closely linked to the RI/FS at OU4. This integration is advantageous because much of the data needed for the RI/FS is useful in evaluating injuries. The integrated approach permits data sharing, resulting in time and/or cost savings. Moreover, integration explicitly recognizes that RI/FS remediation decisions and NRDA primary restoration decisions are interdependent. Remedial decisions can affect the amount and type of primary restoration required at the Site. Thus, the integrated approach promotes efficiency in the overall process.

This assessment was designed for injury assessment and restoration planning to occur in parallel, an approach that is termed a "restoration-based approach." Under a restoration-based approach, the focus of the assessment is on quantifying the injuries and/or losses in natural resources and services in ways that facilitate identification and scaling of restoration alternatives that will provide to the public the same level, type, and quality of services that were lost. This restoration-based assessment approach is consistent with DOI regulations, which allow restoration planning to be included as part of the Assessment Plan phase where available data are sufficient to support concurrent development of assessment and restoration planning (43 C.F.R. Section 11.31).

This injury assessment process occurs in two stages: injury evaluation, and resource and service loss quantification. To evaluate potential injury to resources, the Trustees reviewed existing information, including: RI/FS data, BERA data, published and unpublished reports (from the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Texas Parks and Wildlife Department) and scientific literature (*e.g.*, Sipocz and Swafford, 1995; Park, 1995; Park and Presley, 1997; EPA, 1998; EPA, 2000). Based on information from these sources and with an understanding of the functioning of the Swan Lake ecosystem, the Trustees evaluated injury to natural resources. The Trustees considered several factors when making this evaluation, including, but not limited to:

- the natural resources and services of concern;
- the evidence indicating exposure, pathway, and injury;
- the mechanism by which injury occurred;
- the type, degree, spatial and temporal extent of injury; and
- the types of restoration actions that are appropriate and feasible.

For each resource category (either a group of organisms or a habitat type) potentially affected, the Trustees determined whether an injury is likely to occur or has occurred, identified the nature of the injury, and identified a pathway linking the injury to the incident. In order to undertake this effort, an understanding of the important contaminants is necessary. The evaluation of the potential contaminants of concern is described in the next section. Following the identification of these important contaminants, it is possible to evaluate those resources that could be adversely affected by those contaminants in OU4.

4.2 Contaminants of Concern

In the BERA process undertaken for the OU4, one of the early steps was to identify contaminants of concern (COCs). The Trustees participated in the RI/FS process to determine which contaminants pose risk to ecological receptors. This served as the basis for consideration, by the Trustees, of the potential for contaminants to cause injury to natural resources or losses of ecological services. The available data indicate that trace metals and PAHs are the COCs, based on exceedances of injury thresholds. These hazardous substances were found in subtidal and salt marsh sediments in OU4 and other areas where natural resources are impacted by releases of COCs from the Site.

The trace metals aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver, tin, vanadium, and zinc were found in the sediments at the Site in concentrations that are collectively high enough to potentially cause death or injury to trust resources. Chromium, copper, lead, tin, and zinc were found in the highest concentrations.

Metals differ from other potentially toxic contaminants in that they are naturally present in the environment. Most metals affect multiple systems and the targets for toxicity are specific biochemical processes and/or membranes of cells and organelles. The toxic effect usually involves an interaction between the free metal ion and the toxicological target (*e.g.*, the metabolism of the toxic metal may be similar to a metabolically related essential element).

Polycyclic aromatic hydrocarbons (PAHs) were found at the Site at concentrations high enough to potentially cause death or injury to trust resources. PAHs are persistent organic contaminants that tend to sorb to particulates and sediments at moderate concentrations. Locations where injury to sediment dwelling organisms due to PAH could occur are quite limited, *i.e.*, only at a station near Highway 197, where evidence of a historic oil spill was found; therefore, PAH contamination of the sediments was not evaluated during this assessment because the trace metal concentrations overwhelmingly contribute to hazardous substance injury at the Site. Assessment of injury caused by trace metals was sufficiently conservative in favor of the resources to account for any incremental injury due to PAHs.

4.3 Remedial Investigation and Ecological Risk Assessment Findings

COCs were discharged to the Swan Lake ecosystem through industrial activities at the Site. Data from a 1995 Texas A&M University study indicated that concentrations of numerous hazardous substances, primarily metals, in sediments of the Swan Lake ecosystem were likely causing injury to natural resources. Moreover, the depth profile of contaminant concentrations and the dynamic nature of this estuarine system indicate that resource injury has probably been ongoing for several decades and will continue into the future until sediment deposition isolates highly contaminated sediments below the sediment surface. These facts led the EPA, in coordination with the Trustees, to initiate ecological risk assessment investigations in OU4.

In June-July of 1997, EPA's Environmental Response Team Center (ERTC) conducted a site investigation to collect samples necessary to determine the ecological risk associated with OU4. Risk assessment investigations have included examining the nature and extent of contaminant distributions and concentrations, benthic invertebrate toxicity testing, analyzing benthic community structure, and modeling impacts to higher trophic levels through food web processes.

Baseline ecological risk assessment (BERA) activities included sampling sediments in (1) a salt marsh on Galveston Island (reference site), (2) Galveston Bay (reference site), (3) the historic portion of the WCD southeast of the hurricane protection levees, and (4) Swan Lake and associated salt marshes (Figure 4). The BERA sampling was designed to systematically characterize the study area and preferentially emphasize specific migration pathways and off-site receptor environments and habitats. In addition, two locations were selected as reference sites, *i.e.*, to be as similar as possible to the site in all aspects except contamination, for comparison to the contaminated sites. A total of 16 locations were sampled for sediment contaminants, benthic community, and sediment toxicity testing.

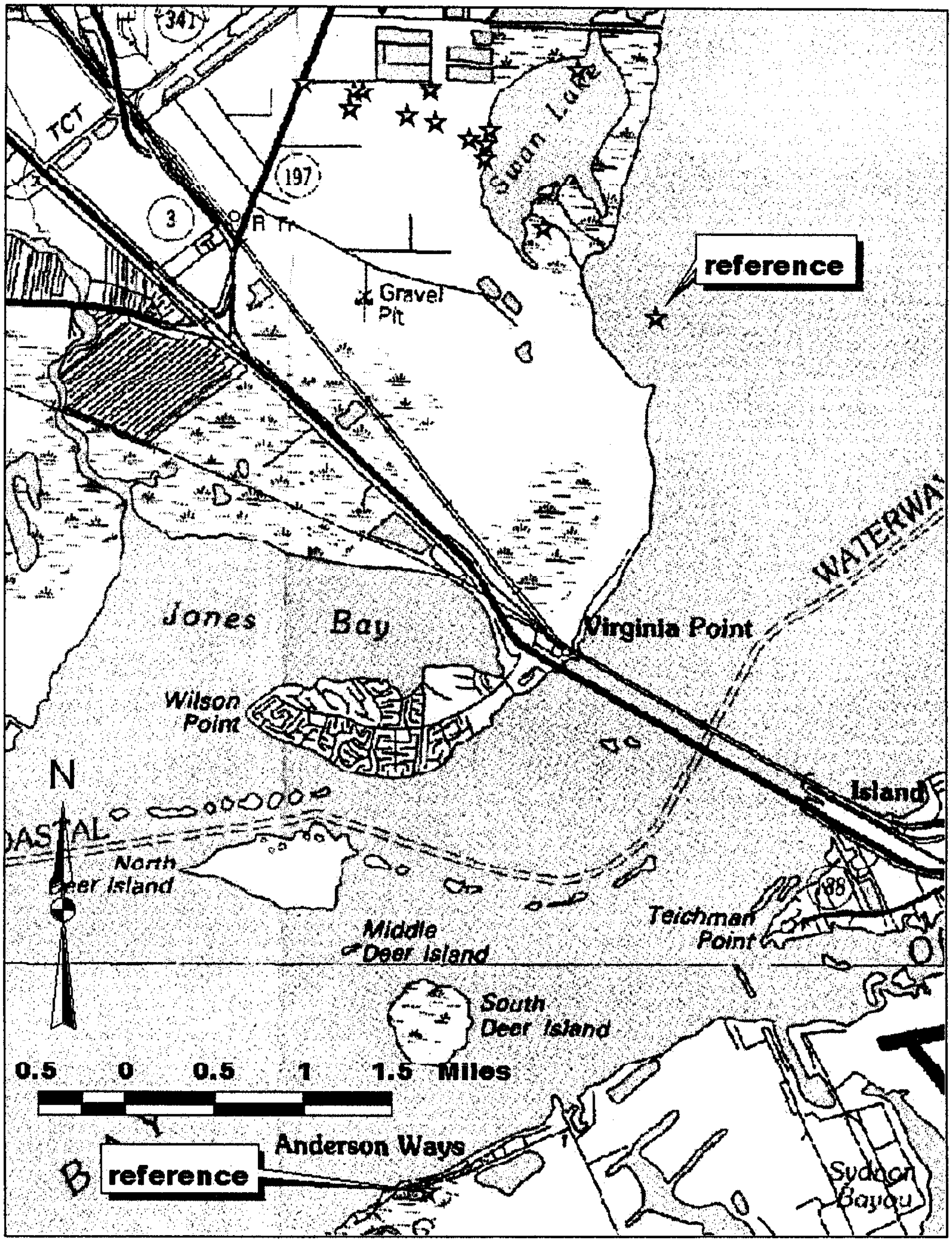

Figure 4. BERA station locations in the Galveston Bay System, Tex Tin Corporation Superfund Site, Galveston County, Texas.

Relatively high concentrations of chromium, copper, lead, tin, and zinc were detected in the western portion of Swan Lake marsh. The concentrations detected in the eastern portion of the marsh were somewhat lower, but still substantially higher than those observed in the reference marsh area. The trace metal concentrations were found to exceed the sediment risk screening level, particularly on the marsh surface.

The data suggest that the macroinvertebrate community is adversely affected at a number of locations as a result of exposure to contaminants. Contaminants considered to be potentially hazardous based on the results of the macroinvertebrate survey alone were identified on the basis of the analytical data. The results indicate that aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver, tin, zinc, and total PAHs may be partly responsible for the observed distribution and abundance of macroinvertebrates in the Swan Lake area.

The potential for toxicity of contaminants in sediment collected from the study area was determined by exposing amphipods (*Leptocheirus plumulosus*, and *Hyalella azteca)* and a polycheate *Neanthes arenaceodentata*, to a sediment-water microcosm in a laboratory setting. Collectively, significant mortality was observed in tests from sediments collected from the Swan Lake marsh, the farthest downstream site in the WCD, and near the mouth of the WCD in Swan Lake.

As discussed for the benthic macroinvertebrate survey, those contaminants considered to be a potential hazard based on the results of the toxicity testing alone were identified on the basis of analytical data. The toxicity and contaminant data were summarized and sorted with respect to increasing mortality. In all tests, the corresponding concentration of some contaminants followed an irregular, perceptible and statistically significant trend, with the lowest concentrations associated with the lowest mortality and elevated concentrations associated with higher mortality. The range of contaminant concentrations resulting in significant adverse effects was determined and compared to the range of concentrations that did not induce significant adverse effects. The results indicate that toxicity was typically associated with cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, tin, zinc, and total PAHs (EPA, 1997).

Results from the BERA documented significant mortality to benthic invertebrates caused by contaminated sediments primarily in two areas of the Swan Lake salt marsh north of the Wah Chang ditch, in the WCD itself, and in Swan Lake in the delta region where the WCD discharges. Benthic invertebrate community structure was adversely altered at roughly the same sampling locations. Food chain modeling indicates likely adverse impacts to upper trophic level mammals that feed from the aquatic food base of the Swan Lake ecosystem. These results are based on surface sediment concentrations alone; significantly greater concentrations of most of the contaminants exist at about one foot below the surface in sediments in the marsh and in Swan Lake. Erosion of this surficial sediment could expose more highly contaminated sediment, which would increase risk to benthic organisms. Conversely, sedimentation by uncontaminated material would further bury contaminated sediment.

More recently, in August of 1999, the ERTC, with assistance of the Texas Parks and Wildlife Department, conducted sampling in the study area (Figure 5) to better delineate the spatial extent of contamination of ecological concern. The study area was approximately 200 acres. A total of 101 sediment samples were collected and analyzed in the Swan Lake Salt Marsh Study area for chromium, copper, lead, tin, and zinc. Sediment samples were collected from Swan Lake, in the vicinity of the mouth of the WCD (the Wah Chang "delta"), from the WCD and several feeder streams south of the ditch, and from the Swan Lake salt marsh north of the WCD and south of the hurricane protection levee.

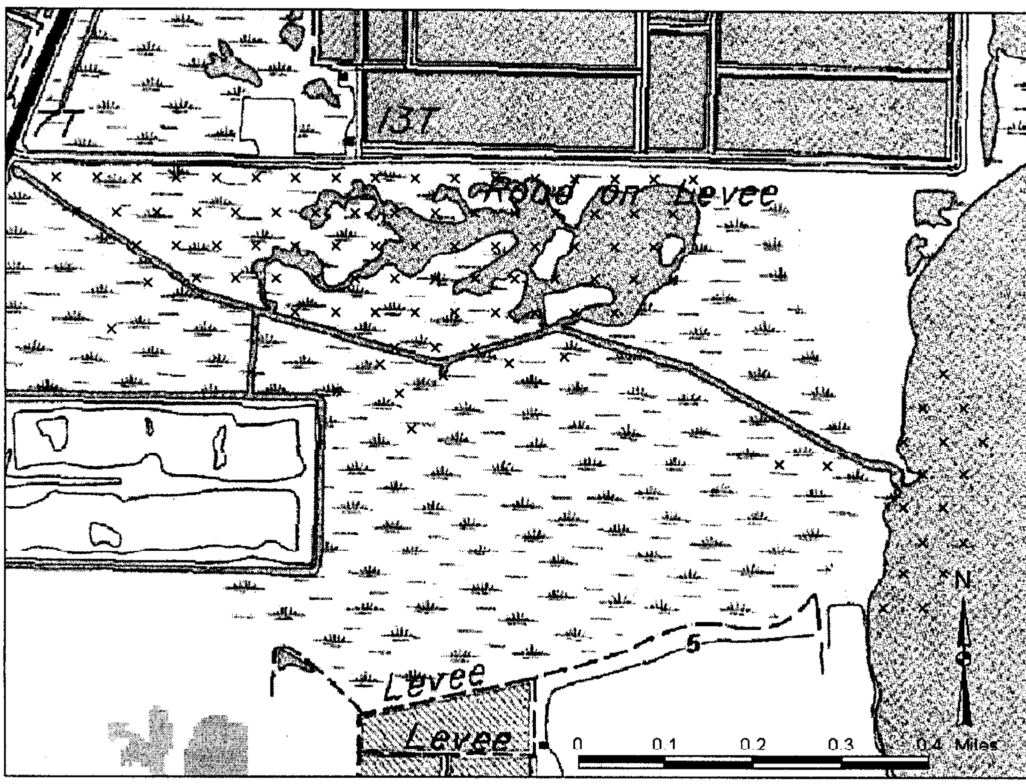

Figure 5. Station locations in the Study Area, Tex-Tin NPL Site OU-4, Galveston County, Texas.

The extent of metals contamination was estimated spatially, but no depth profiling was performed. All samples were collected from the upper 6 inches of surface sediment. Based on the BERA, benthic macroinvertebrates appear to be potentially at risk due to chromium, copper, lead, tin and zinc contamination in sediment. In addition, the analytical results showed some "hot spots" (elevated levels of metals) in sediments in the marshy area north of the WCD, in the WCD, and in the delta area of Swan Lake.

The presence of contaminants below the one-foot interval can be inferred from historical as well as analytical data; however, the presence of surface contaminants alone presents an unacceptable risk to ecological receptors.

4.4 Injury Determination and Quantification

Actual or potential injuries were evaluated using a benthic community survey, toxicity test results, and sediment quality guidelines. No criteria are presently available to evaluate the hazard of sediment contaminant concentrations that are comparable to the nationally promulgated ambient water quality criteria or Texas water quality standards. However, guidelines are available including the NOAA National Status and Trends Approach (Long *et al.*, 1995) and the Apparent Effects Threshold Approach (Buchman, 1999). Although neither of these approaches establishes criteria, they are useful for screening ecological risk or potential injury associated with contaminated sediment.

The injury assessment for benthos resulting from contamination used a reasonably conservative injury evaluation (RCIE) approach in identifying and quantifying natural resource injuries and services losses. This approach first focuses on existing scientific information, including site-specific information from response actions, as well as that derived from available scientific literature. Where sufficient to support technically sound and reasoned analyses, the RCIE approach allows resource injury determinations to be based on that information.

In considering this information, the participants sought to err on the side of conservatism, *i.e.*, in favor of finding 'resource injury' for an exposure level which at least one data or information source indicated was reasonably likely to result in an adverse effect.

The RCIE approach for benthos used analytical chemistry results for samples collected during the RI to determine the nature and extent of trace metals and PAH contamination in the Swan Lake system sediments. The next step in determining benthic injury was to develop contamination concentration benchmarks that are known or suspected injury thresholds for benthic resources based on RI/FS studies conducted at the Site and on the results of studies presented in the scientific literature.

To quantify interim service losses, Trustees determined that the mean effects range-median quotient (ER-MQ) would be used to estimate levels of benthos service reductions. For each ER-MQ range, service losses were estimated that approximated the reduction in ecological services provided by the benthic community in each habitat type. The ER-M for a particular contaminant is a number that represents the median concentration of available toxicity data screened by Trustees that the original investigators labeled as toxic. The ER-MQ is the concentration of a contaminant in the sediment divided by its corresponding ER-M. The mean ER-MQ is simply the mean of the individual contaminant ER-MQs at each location.

Long *et al.* (1998) showed the mean ER-MQ was a suitable predictor of severe toxicity to benthic organisms. Increasing mean ER-MQ generally resulted in an increase in the probability of severe toxicity at a given location. For this assessment, the Trustees determined that predicted severe toxicity was an appropriate line of evidence to estimate percent loss of benthos service. These predictions compared favorably with toxicity and numbers of benthic taxa observed in the BERA. For each range, the Trustees calculated a level of severity of the injury, which corresponds to the percent of services reduced, based on the type of endpoint affected and the degree of effect indicated, in the studies reviewed. For low levels of contamination, the reduction in services is relatively small. For higher concentrations, the percent of services lost is higher. Additional injury severity was "added" to account for recovery over time that has occurred prior to the studies and that was probably more severe in the past. Additionally, the Trustees relied on other available scientific literature, and their knowledge of and experience in Texas estuarine ecosystems.

Through habitat mapping, the Trustees determined the number of affected acres of benthos habitat at each of the injury thresholds. Table 4.1 below contains the different concentrations of contaminants, the corresponding level of service reduction determined by the Trustees, and the number of affected acres.

Six areas of injury were identified by the Trustees including: (1) the WCD subtidal habitat; (2) Swan Lake subtidal habitat near the WCD discharge; and (3-6) four subareas of salt marsh north of the WCD. The four subareas are delineated based upon the distribution of metals concentrations compared to the appropriate ER-M.

To develop percent Loss of Services (LOS) values, that accounted for injury due to several metals, the mean ER-M quotient (ER-MQ) was used. The BERA provided further lines of evidence of injury including: observed increased mortality as measured by the toxicity tests and reduced number of benthic taxa with increasing ER-MQ. Ultimately, percent LOS was determined from ER-MQ, trends in benthic community, toxicity test results and estimates of historical injury severity.

Table 4.1 - Loss of marsh benthos service vs. Mean ER-M Quotient

Mean ER-M Quotient	Loss of Service	Acres
0-0.33	0%	na
0.33-0.66	25%	31.5
0.66-1.0	50%	8.4
1.0 – 2.0	100%	2.6
2.0 – 2.75	100%	1.3

The WCD subtidal habitat injured was determined to be 5.97 acres and a 20% loss of ecological services was assessed. The Swan Lake subtidal habitat injured was determined to be 7.31 acres, and the injury represents a 20% loss of ecological services. The four marsh habitats injured were determined to be 31.5, 8.4, 2.6, and 1.3 acres, and injury values of 50%, 75%, 100%, and 100% loss of ecological services were calculated, respectively. Because contaminated sediment has been left on-site, future injury could occur; therefore, the duration of benthos and benthic habitat injury was considered to be from 1981 into perpetuity, under the RCIE approach.

5.0 RESTORATION ALTERNATIVES

The overall objective of the restoration planning process is to identify restoration alternatives that are appropriate to restore, rehabilitate, replace or acquire natural resources and their services equivalent to natural resources injured or lost as a result of releases of hazardous substances. These restoration actions make the public whole by providing compensation for injuries and losses to natural resources. The restoration planning process has two components: compensatory restoration and primary restoration. Compensatory restoration is any action taken to compensate for interim losses of natural resources and services, pending return of the resources and their services to baseline level. In contrast, primary restoration actions are actions designed to return resources and services to their baseline levels. Because the Trustees have concluded that EPA's anticipated remedial alternative for OU4 (construction of segmented breakwaters) should be sufficient to allow natural resources and services to return to their baseline condition without further primary restoration actions, the scope of this restoration plan is limited to compensatory restoration alternatives.

In accordance with NRDA regulations, the Trustees developed appropriate restoration alternatives and selected preferred alternatives to address resource injuries and losses of services. The Trustees first identified and evaluated general alternatives capable of serving as compensatory restoration for the injured natural resources and/or services. As part of the effort to develop general restoration alternatives, the Trustees consulted with local scientists and state agency personnel to get their perspective on the benefits and feasibility of various types of restoration alternatives. These efforts were important in assisting the Trustees in identifying projects that are potentially feasible, have strong net environmental benefits, and meet restoration requirements to compensate for injuries resulting from the Site.

Some compensatory alternatives considered by the Trustees would provide similar resources and/or services to those injured, while other alternatives would compensate by providing a comparable resource enhancement. The Trustees preferentially seek to restore injured natural resources in-kind (*e.g.*, create new marsh to compensate for lost marsh function), and in the geographical vicinity affected, while working to maximize ecosystem benefit, benefit to human uses of the environment (such as fisheries), and cost-effectiveness of restoration as a whole. However, in-kind restoration is not always possible or feasible, or may not otherwise fit the restoration selection criteria, and in those instances, enhancement or acquisition of alternative resources that provide similar ecological benefits may be appropriate. Finally, increased benefits and improved cost-effectiveness may often be obtained by addressing several injured resources and/or services or classes of injury with a single restoration project.

Table 5-1 contains the list of general restoration alternatives considered by the Trustees and identifies those selected as preferred, pursuant to the Trustees' evaluation of restoration alternatives in Section 5.3. The logic for selecting alternatives that provide different resources or services as compensation is described in detail in Section 5.2.

Table 5-1 - General Restoration Alternatives Considered for Each Injury

Injured Resource/Service	Compensatory Restoration Alternative[a]
Marsh	No Compensation
	Marsh Restoration
	Acquisition & preservation of marsh
Subtidal Benthic Habitat	No Compensation
	Marsh Restoration
	Oyster Reef Creation
	Subtidal Benthic Habitat Creation
	Acquisition & preservation of marsh

[a]Preferred Restoration Alternatives (identified below) are in bold

5.1 Selection Criteria

Once a reasonable range of restoration alternatives is developed, the NRDA regulations require the Trustees to identify preferred restoration alternatives based on certain criteria including the following:

- *The cost to carry out the alternative*: The benefits of a project relative to its cost are a major factor in evaluating restoration alternatives. In addition, the Trustees consider the total cost of the project. Factors that can affect and increase the costs of implementing the restoration alternatives may include project timing, access to the project Site (for example with heavy equipment), acquisition of state or federal permits, and acquisition of the land needed to complete a project and the potential liability from project construction. Although a monitoring program does increase the cost of an alternative, the presence of an adequate monitoring component is considered a positive attribute because documenting project performance is important.

- *The extent to which each alternative is expected to meet the Trustees' goals and objectives in compensating for interim losses*: The primary goal of any compensatory restoration project is to provide a level and quality of resources and services comparable to those lost. Thus, the ability of the restoration project to provide comparable resources and services is an important consideration. Specifically, the Trustees consider the potential relative productivity of restored habitat and whether the habitat is being created or enhanced. Habitats that would be constructed with or on contaminated sediments will provide fewer benefits and thus do not score as high in the evaluation process. If habitat is created from clean sediment overlying contaminated sediment, thus isolating the contaminated sediment, then habitat created would provide a similar level of services to a "clean" habitat. Additionally, the isolation of the contaminants would be a positive effect. Finally, future Site management issues and the opportunity for conservation easements are also considered because they can influence the extent that a restoration action meets objectives.

- *The likelihood of success of each alternative*: The Trustees consider technical factors that represent risk to either the success of project construction or the long-term viability of the habitats involved. For example, high rates of subsidence at a project Site are considered a risk to long-term existence of constructed habitats. Alternatives that are susceptible to future degradation or loss through contaminant releases or erosion are considered less viable. The Trustees also consider whether difficulties in project implementation are likely and whether long-term maintenance of project features is likely to be necessary and feasible. Sustainability of a given restoration action is a measure of the vulnerability of a given restoration action to natural or human-induced stresses following implementation and the need for future maintenance actions to achieve restoration objectives.

- *The extent to which each alternative will prevent future injury as a result of the release and will avoid collateral injury as a result of implementing the alternative*: For example, the possibility of the project site being contaminated is considered, as is the potential for use of contaminated dredged sediments in the project. The isolation of the contaminants under less contaminated material would be considered positively. Compatibility of the project with the surrounding land use and potential conflicts with any endangered species are also considered.

- *The extent to which each alternative benefits more than one natural resource or service*: This criterion addresses the interrelationships among natural resources and between natural resources and the services they provide. Projects that provide benefits to more than one resource and/or service yield more benefits. For example, certain types of marsh restoration projects could improve fish habitat such that anglers experience higher catch rates. Although recreational benefits are not explicitly evaluated in this RP/EA, the opportunities for a restoration alternative to provide these added benefits is considered a positive feature of the alternative.

- *The effect of each alternative on public health and safety*: Projects that would negatively affect public health or safety are not appropriate.

The regulations give the Trustees discretion to prioritize these criteria and to use additional criteria as appropriate. For this Site, the key criterion for the Trustees is the second in the list because it is the criterion that most clearly indicates whether the goal of making the public whole from losses resulting from the release is met. The Trustees also recognize the importance of public participation in the restoration planning process, as well as the acceptance of the projects by the community. Alternatives that are complementary with other community development plans/goals are considered more favorably. The Trustees also considered public access and recreational opportunities provided by a project as positive attributes.

NEPA and the DOI NRDA regulations require the Trustees to evaluate the "No Action" alternative, which for compensatory restoration equates to "No Compensation." Under this alternative, the Trustees would take no direct action to obtain compensation for interim losses, pending recovery, associated with the injured resource and/or service in question. Through the aforementioned reasonably conservative injury evaluation (RCIE) approach, the Trustees determined that compensation for losses of service is required for the six types of habitats (WCD subtidal unvegetated sediments, Swan Lake delta subtidal unvegetated sediments, and four marsh sediment habitats) for interim losses due to hazardous substance releases. While natural recovery would occur over varying time scales for the various injured resources, the interim losses suffered would not be compensated under the "no-action" alternative. Thus, although the Trustees have determined that natural recovery is expected to be appropriate as a primary restoration alternative for all injuries, the Trustees have determined that the "no action" alternative (*i.e.*, no compensatory restoration) is not preferred.

5.2 Evaluation of Restoration Alternatives

Based on a thorough evaluation of a number of factors, including the criteria listed above, the Trustees have selected preferred restoration alternatives for compensatory restoration of injured natural resources and/or services (Table 5-1). Information supporting the Trustees' selection of restoration alternatives is provided throughout the remainder of this Section.

5.2.1 Restoration Alternatives for Marsh Habitat Injuries – Action A

The Trustees considered four restoration alternatives for compensatory restoration for injuries to marsh habitat: Alternative 1: no action; Alternative 2: creation of oyster reefs; Alternative 3: acquisition and protection of existing marsh habitat; and Alternative 4: marsh restoration (*i.e.*, creation, enhancement),

<u>Alternative 1:</u> The "no action" alternative is eliminated because the Trustees must compensate for losses of public resources and services. No action would not provide any compensation. The injuries to marsh habitat caused by releases of hazardous substances from the Tex Tin Site (described above in Section 4) would continue, and the injured marsh habitat would not be restored. Therefore, Alternative 1 is not acceptable.

Alternative 2: Creation of oyster reef would provide services similar to marsh, but would not be in kind. Reef creation is highly beneficial and technically feasible and has a high probability of success. Oyster reefs have been successfully constructed at several locations in the Galveston Bay system. As discussed in Section 5.1, the Trustees' preference is for in-kind restoration where possible and otherwise consistent with restoration selection criteria. Creation of oyster reef as compensation for injuries to marsh habitat is not selected because it would not be in-kind restoration.

Alternative 3: Acquisition and preservation of existing marsh is a potential in-kind restoration action. This option is feasible and can, under certain circumstances, be highly beneficial. Acquisition and protection of existing marshes would have little negative impact compared to either creation or enhancement. However, if a particular marsh site had unique qualities, its location was especially valuable, and its destruction was imminent, benefits derived by exercising this option might increase substantially. No increase in service flows would occur through acquisition or protection alone. Therefore, unless a particular marsh site has unique characteristics or is in imminent danger of destruction, marsh acquisition would not be the preferred alternative.

Alternative 4: Several studies indicate that a marsh creation project would benefit the Galveston Bay ecosystem. Zimmerman *et al.* (1992) found that intertidal wetland and protected coves within Galveston Bay have greater numbers and biomass of juvenile and small fishes and invertebrates (shrimp, blue crabs, other crustaceans, bait fishes, commercial fishes, sport fishes, and benthic infauna) than do adjacent areas of open bay. This supports the hypothesis that the drowning and erosion of these habitats caused by human-induced subsidence (White *et al.* 1993) have negatively affected fishery and subsequently wildlife populations of Galveston Bay. The study cogently illustrated that protecting and restoring emergent wetland and sheltered waters would support the maintenance and restoration of the Galveston Bay ecosystem. Furthermore, fish and invertebrate sampling conducted in Swan Lake found that the wetlands and protected coves within the Swan Lake embayment are very productive (Sipocz and Swafford 1995). These types of wetlands and protected coves are among the areas, which if restored, have the best chance of achieving significant gains in abundance and biomass of fish and decapod fauna. Wetland restoration at nearby locations in the Virginia Point area of the Galveston Bay Ecosystem would result in similar gains.

Marsh restoration is consistent with the criteria used by the Trustees to evaluate restoration alternatives. It will provide an increased outflow of organic material that will generally benefit the Swan Lake ecosystem by providing a source of organic carbon (*i.e.*, an energy supply supporting the estuarine food web). Created or enhanced marsh will provide services benefiting a wide range of resources, including benthic invertebrate species that inhabit marshes and the bird and fish species that feed on them. By providing critical nursery habitat for shrimp, fish, and other aquatic species, and nesting and foraging habitat for birds and other wildlife, created or enhanced marsh will benefit recreational uses of the area by supporting increased populations of these species. Therefore, this alternative would have clear overall benefits to the environment. Marsh creation typically results in some impacts to existing habitats, such as subtidal sediments or terrestrial habitat, on which it is created. However created marshes will include 20-40% unvegetated open water bottoms (*i.e.*, channels, tidal creeks & swales) in which open water organisms can thrive.

Additionally it may be difficult to get permits necessary to implement marsh enhancement projects because permitting agencies are reluctant to approve projects where marsh currently exists. Furthermore, the Trustees are unaware of any particular, existing marshes in the Swan Lake are which are in imminent danger of destruction in order to justify marsh acquisition as an alternative. Federal and state laws already protect existing marsh in the Swan Lake system.

Marsh creation and enhancement projects typically have a high likelihood of success and tend to be very cost-effective to implement. In-kind restoration as creation or enhancement of marsh is highly beneficial and technically feasible. They are also consistent with state and federal policies and law. For these reasons, the Trustees determined that the preferred compensatory restoration action for marsh injury (Action A) is marsh restoration (Alternative 4) in area of Swan Lake. Size and location of Alternative 4 are discussed below.

5.2.2 Evaluation of Restoration Alternatives for Subtidal Benthic Habitat (WCD and Swan Lake Delta) Injuries – Action B

The Trustees considered five restoration alternatives for compensatory restoration for injuries to subtidal benthic habitat: Alternative 1: no action; Alternative 2: creation of subtidal benthic habitat; Alternative 3: creation of oyster reefs; Alternative 4: acquisition and protection of existing wetland habitat ; and Alternative 5: marsh restoration (*i.e.*, creation, enhancement).

Alternative 1: The Trustees' have determined that compensatory habitat for these losses must be provided. The no action alternative will not provide any compensatory services and the public's loss would remain. The injuries to subtidal benthic habitat caused by releases of hazardous substances from the Tex Tin Site (described above in Section 4) would continue, and the injured subtidal benthic habitat would not be restored. Therefore, Alternative 1 is not acceptable.

Alternative 2: Creation of subtidal benthic habitat is possible by grading down terrestrial habitat and allowing it to be flooded by seawater. This alternative is technically feasible, although the disposal of the large amount of removed soil could be problematic. It would closely replace the same ecological services as those lost due to injury. Although this alternative would represent in-kind restoration, which is normally preferred when feasible, it conflicts with current governmental policy. Land loss along the Gulf of Mexico coastal zone is a severe problem, with many square miles being lost each year. Implementation of this alternative could exacerbate this problem by directly converting land to open water. Additionally, marsh restoration or oyster reef creation would provide more benefits to the Swan Lake and Galveston Bay ecosystem than would creation of additional unvegetated subtidal benthic habitat. Therefore, creation of subtidal benthic habitat is not selected as the preferred restoration alternative for this injury category.

Alternative 3: Creation of an oyster reef as a restoration alternative fits the restoration criteria and policies. A created oyster reef would serve as a substrate for increased secondary productivity, would support fish, and would provide feeding areas for some bird species. If constructed appropriately, it could provide a lounging area for birds during low tides. Oyster reef creation would also have some very positive benefits to fish, other organisms, and recreational fishing. However, creation of marsh habitat will provide services that are more similar to those lost in the area of Swan Lake. Therefore, creation of oyster reef habitat is not selected as the preferred restoration alternative for this injury category.

Alternative 4: Acquisition and preservation of existing marsh is a potential in-kind restoration action. This option is feasible and can, under certain circumstances, be highly beneficial. Acquisition and protection of existing marshes would have little negative impact compared to either creation or enhancement. However, if a particular marsh site had unique qualities, its location was especially valuable, and its destruction was imminent, benefits derived by exercising this option might increase substantially. No increase in service flows would occur through acquisition or protection alone. Therefore, unless a particular marsh site has unique characteristics or is in imminent danger of destruction, marsh acquisition would not be the preferred alternative.

Alternative 5: The benefits and other features of marsh restoration have been discussed above. Although marsh restoration is not *per se* an in-kind restoration alternative for subtidal benthic habitat, it does provide most of the same services as subtidal benthic habitat, as well as additional services. Marsh restoration is also a much more productive habitat than unvegetated subtidal sediments. Furthermore, created marshes will include 20-40% unvegetated open water bottoms (*i.e.*, channels, tidal creeks, and swales). In addition, the Swan Lake ecosystem previously included substantial marsh habitat on its eastern and northern boundaries. Subsidence due to groundwater extraction and subsequent erosion destroyed these habitats in the 20th century. Conversion of portions of open water back to marsh habitat would restore the Swan Lake system to a more natural, productive state. For the reasons enumerated above, restoration of marsh (Alternative 5) was selected as appropriate compensation for injuries to subtidal benthic habitats (Action B) in the area of Swan Lake. Size and location of Alternative 5 are discussed below. Thus, the same restoration alternative (marsh restoration) was selected for both Action A (restoration for marsh habitat injuries) and Action B (restoration for subtidal benthic habitat injuries).