Office Of Oil Spill Prevention and Response

CALIFORNIA DEPARTMENT OF FISH AND GAME

TRANSMITTAL INFORMATION SHEET

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FROM: R. Ricker, OSPR Tel. 916-323-0635; FAX 916-324-8829 RGO

NOTE: Attached is a revised version of the earlier herring document, which was circulated to the attorneys and Doug Helton for their comments. Apart from various editorial corrections, the current version has some additional information in the exposure, injury, and restoration sections. The exposure section has more information regarding the reasonable assumption of persistent impacts not only to herring but to other organisms that would occur in the oiled band. The injury determination section more fully addresses issues of pre-existing "stressors" such as salinity and creosote (see attached recent news article in ESTUARY). And the restoration section now includes a revised discussion on the credit/debit assumptions for differences in the habitat quality, as well as a new section on "Acreage Scaling Factors". Note also that the data for the "egg scaling factor" have been modified to compare the 1996-97 season total for eggs/m2 at the SF waterfront spawning areas with total for eggs/m2 in spawning areas in eelgrass habitat within the bay. Consequently, the scaling factor changed from 17:1 to 15:1. I modified the text accordingly and provided more explanation for the balancing of credits and debits.

Please replace the earlier draft with this one. It is important that you provide your comments to me as soon as possible regarding the content and the information to redact should we propose to exchange this document with the RPs to help them understand our sense of the injury. At a minimum, I would expect to revise the headers, remove the footer, and remove any reference to Michael Welsh and Hagler Bailly regarding preparation of the HEA calculations.

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DRAFT

Impacts to Pacific herring and Potential Restoration Options

Background to the fishery:

Much of the following background information is contained in a report entitled the Final Environmental Document, Pacific Herring Commercial Fishing Regulations prepared by the California Department of Fish and Game (CDFG) in 1996. This report provides additional public use information about the fishery as well as general biological information about the species life history, distributions, population status, and habitat.

Pacific herring *(Clupea pallasi)* are an important ecological species as well as a valuable commercial and recreational resource. A large commercial fishery is supported in San Francisco Bay, particularly for roe that is exported to Japan. A smaller portion of the fishery relies on adult and juvenile herring that are caught and sold for bait or sold fresh or canned as food. The commercial roe fishery, which began in 1973, consists of two types of harvests (Spratt, 1981). In the first, rafts of *Macrocystis* are deployed where the herring are spawning and harvested with roe. This roe-laden algae is sold in Japan as "Kazunoko kombu". In the second type of harvest, spawning adults are caught mostly in gill nets but also in seine (for round-haul) nets, and the ovaries of the ripe females are taken and sold in Japan as "Kazunoko". Gonadal weight in ripe herring approaches 22% of body weight (Hay and Fulton, 1983).

In San Francisco Bay, the herring fishery has been managed by the CDFG since 1973. The population is still thriving, and it appears that effective management has kept harvest rates below levels that would be detrimental to persistence of the fishery. The recommended harvest rate by the CDFG is no more than 20% of spawning biomass (Final Environmental Document Pacific Herring Commercial Fishing Regulations). A limited entry program was established in 1977, and the number of herring permits issued for San Francisco Bay peaked at 430 permits in the 1982-84 seasons. Each year, the CDFG scientists monitor the number of fish returning to the bay, the amount and location of prominent spawns, and develop an index of abundance for the young-of-year fish following hatching.

San Francisco and Tomales Bays attract the largest spawning aggregations of herring in California (Spratt, 1976). The spawning in San Francisco Bay generally begins in November and continues through March (CDFG, 1991). Adult fish typically remain in deeper waters until spawning. The size of the spawning population has fluctuated through time, with the largest declines in biomass associated with *El Niño* conditions. Biomass estimates were first based only on intertidal surveys of spawning (D. Watters, pers. comm.). In 1978, however, the surveys were expanded to include the subtidal. This led to an immediate increase in biomass estimates from 1978 onwards. In 1992, the lowest biomass was documented since CDFG began their combined intertidal and subtidal surveys.

Juvenile fish abundance within San Francisco Bay may be correlated with recruitment to the adult spawning population two years later. However, data from a recent year revealed a strong discrepancy between actual recruitment and that expected based on the calculated index for young-of-year abundance (Oda and Wendell, 1990). Smaller young fish tend to be widely distributed in shallower habitats in South, Central and San Pablo Bays. As the young grow, they are found in deeper waters closer to the Golden Gate, and most emigrate from the bay between April and August (Herbold, Jassby, Moyle, 1992).

Although herring appear to be very adaptable to changing conditions in their spawning grounds, changes in certain ecological features and oceanographic conditions, which are not well understood, might explain past collapses that have characterized the history of herring fisheries (Doubleday, 1985). Fisheries such as those for Kazunoko have a direct affect on fish abundance. Another direct impact on fish abundance might also be expected for activities such as oil spill incidents that could expose significant amounts of spawning habitat, and consequently embryos, to spilled petroleum hydrocarbons. This would be especially true for incidents in which fish eggs are in direct contact with spilled oil and susceptible to deleterious effects (Kocan et al., 1996a; Kocan et al., 1996b).

Herring populations fluctuate widely from year to year because of variable year-class strengths. The populations generally are resilient such that fish numbers may be restored even where overfishing has greatly reduced a fishery (Blaxter, 1985; Ware, 1985). Oil spill incidents, however, may promote unforeseen problems that immediately (e.g., through developmental abnormalities or direct mortalities to embryos and larvae, or loss of weight) or subsequently (e.g., through reduced immune function and susceptibility to disease, genetic damages, or lowered reproductive success) impact the population in ways that are difficult to predict over the long term (Brown et al., 1996; Hose et al., 1996; Kocan et al., 1996a; Kocan et al., 1996b; Norcross et al., 1996).

Exposure:

Herring were not observed to be spawning at the time of the spill but began to spawn at a northern location in Richardson Bay on or about November 10, 1996. Prior to this time, the fish were in the bay but (typically) residing in deeper water. The fish were not seen spawning in the immediate vicinity of the San Francisco waterfront until January 1997. For purposes of this evaluation, the Trustees are not making a claim for exposure of adult fish through a contamination pathway extending into the water column. Rather, the claim for exposure is restricted to direct contact of eggs on spawning surfaces that were oiled as a result of the spill. The amount and locations of oiled spawning surfaces extend throughout the bay in three principal areas that were monitored by the CDFG: Richardson Bay, the San Francisco waterfront, and shoreline extending from Sausalito out past the Golden Gate Bridge. For purposes of this document, exposure calculations were limited to oiled surfaces on pilings and other hard, artificial surfaces that exist along the San Francisco waterfront.

Spawning areas have been well documented for the San Francisco Bay through years of fisheries monitoring and management by the CDFG. Artificial surfaces along the San Francisco waterfront, which may receive a significant portion of herring spawn during a season, have been quantified by CDFG personnel (D. Watters & John Ugoretz, pers. comm.) to aid in calculations of the total amount of eggs spawned and subsequent management of the herring fishery. The total surface area of artificial surfaces along the San Francisco waterfront (from Hunter's Point to San Francisco marina) that can serve as spawning habitat is just over **1,215, 680 m^2**. This assumes an average 6.7 m spawn depth and 100% availability for spawning on pilings and other hard artificial surfaces below the high water mark. Past annual observations of the CDFG confirm that exposed surfaces can become completely covered with eggs following a spawn. Field observations during the 1996-97 spawning season recorded approximately 75% of the waterfront habitat was covered with herring spawn.

Persistent oiling of pilings and other surfaces of the waterfront was obvious as black "bathtub rings" that were deposited between the high and low water marks following the spill incident. The maximum tidal amplitude in the immediate vicinity of the San Francisco waterfront shortly after the spill was 2.19 meters (based on NOAA reports for North Point, Pier 41), with an average range of 1.8 meters during the first ten days post spill. CDFG biologists observed bands of oil approximately 1.8 meters (roughly six feet) wide on piling surfaces in the immediate vicinity of the spill and multiple (2-4) 0.3 to 0.6 meter wide bands per piling away from the drydock at Pier 70. For purposes of this document, the Trustees used an average value of one (1) meter as a band width for the oily "bathtub ring" of affected spawning habitat. A one meter wide band represents 181,445 m^2 of oiled spawning habitat along the waterfront. This translates to **contamination of 15 percent of the total waterfront habitat potentially used for spawning.** The tidal range at the time of spawning in January 1997 was comparable to the tidal amplitude at the time of the spill.

The CDFG biologists who monitor the herring fishery in San Francisco Bay calculated a total area of 7,416,414 m^2 spawning habitat for the prominent spawns in the bay during the 1996-97 season. Based on this total area estimate, the **oiled waterfront habitat represents an impact of just over two (2) percent of the total spawning habitat** that was monitored in the bay.

CDFG biologists measured spawn densities and counted samples of eggs from various locations throughout the bay. These empirical data were used to estimate a total number of herring eggs spawned in San Francisco Bay during the past season, which totaled 2,956,369 millions of eggs. Based on this estimate of total eggs and data from hydrocoustic surveys of sizes of schooling fish, CDFG estimates a spawning biomass of approximately 89,000 tons, the third highest on record (Estuary, 1997). The herring spawn at the San Francisco waterfront during the 1996-97 season was the largest documented spawn for the entire bay. A fraction of the eggs spawned at the waterfront were observed to be deposited on the oiled waterfront surfaces. CDFG biologists sampled sites along the waterfront to calculate an estimated total of 1,657,055 millions of eggs for the entire waterfront area. A one meter wide oiled band is approximately 15 percent of the total 6.7 meter average depth for piling habitat that can be used for spawning. Fifteen percent of the estimated total eggs spawned along the waterfront, or eggs potentially deposited on oiled surfaces, is 246,900 millions of eggs. Based on the total egg count for the bay, the oiled waterfront habitat represents **direct exposure (i.e., physical contact with persistent oil) of just over eight (8) percent of the total eggs estimated to have been spawned in the bay.**

The Trustees believe that exposure to spilled oil of eight percent of all herring eggs deposited in the bay is a reasonable estimate because this figure is based on a one meter bandwidth of oiling, not the maximum tidal amplitude (over 2 meters) where oil is typically deposited in a "bathtub ring". Additionally, this value does not account for the expected exposure of herring eggs to spilled petroleum in other areas of the bay where habitat was documented as oiled and subsequently used by herring for spawning. It is also reasonable to assume that persistent oiling of this one meter wide band of piling habitat will reduce the quality of the habitat in future years, and lower or degrade resources services provided by the habitat through continuing petroleum exposure to not only herring and other fish but to a broad range of organisms including encrusting and mobile invertebrates, shellfish, and plants.

Injury Determination:

Types of Injuries. Fouling of piling surfaces with spilled petroleum represents an injury to the habitat by diminishing the habitat quality for use by numerous types of animals and plants. In addition, this document focuses on the injury to pacific herring caused by oiling of important waterfront spawning habitat. There are multiple types of impacts to eggs, larvae, and adult fish that have been reported in published studies of herring following exposure to petroleum hydrocarbons. Much of this research has resulted from the Exxon Valdez incident with spilled crude oil (Brown et al., 1996; Hose et al., 1996; Kocan et al., 1996a; Kocan et al., 1996b; Norcross et al., 1996). The types of injuries to herring that are being claimed for this incident are primarily embryonic developmental abnormalities that result in non-viable larvae following direct contact of eggs with oil on spawning surfaces. The percentage of developmental abnormalities that would result in non-viable fish larvae is expected to be between 90 to 100 percent (R. Kocan, pers. comm.). This is consistent with a previously published account of over 95% embryo-larval mortality for shortnose sturgeon embryos and larvae that were exposed to sediments contaminated with heavily weathered (over 40 years in a stream) petroleum hydrocarbons from coal tar (Kocan, Matta, & Salazar, 1996).

The Trustees acknowledge that chemical differences exist between crude oils, coal tar petroleum hydrocarbons, and intermediate fuel oil such as spilled in this incident. In spite of these differences, we do not believe that survival rates of herring larvae or other fish embryos following direct contact of eggs with any one of these products would differ substantially because all three types of products contain compounds that are harmful to fish and wildlife. For example, creosotes, which are derived from coal tar, are very high in unsubstituted (i.e., without alkanes attached to the parent molecule) polycyclic aromatic hydrocarbons (PAHs). Crude oils have a full range of PAHs that typically are substituted. The intermediate fuel oils (IFOs) or bunkers, which are blends of refinery residuals and diesels, contain a full range of PAHs that are similar to the parent crude oils.

Expected Duration of Injuries. The duration of injuries to the herring fishery is expected to extend over multiple years because of the persistence of heavy bunker C (IFO 180) when spilled in the environment and its continued presence on spawning surfaces. It is not clear how long the impact will last, but it is not unreasonable to assume a period of five years considering the persistent toxicity of weathered crude oil in some of the Exxon Valdez herring studies, and the observed toxicity for 40-year weathered coal-tar petroleum hydrocarbons (Kocan, Matta, & Salazar, 1996).

Potentially Confounding Factors in Injury Determination. There are undoubtedly numerous factors that influence the survival of herring embryos into adult fish. Some loss in viability can be attributed to natural causes such as desiccation or predation at the upper edge of the spawning habitat in the intertidal, extreme changes in salinity caused by either droughts or influxes of freshwater, and the presence of other contaminants in the environment. Each of these factors can act as an environmental stressor to reduce the fitness or chance of survival of herring embryos.

Most of the information on salinity and contaminant effects are based on laboratory studies, with little to no field data available to evaluate the cumulative interactions of multiple stressors simultaneously or quantitatively account for the effects pre-existing contaminants on herring embryos <u>in situ</u>. It is reasonable to assume that some of the herring embryos developing in habitats along the San Francisco waterfront are exposed to some level of stress from fluctuations in salinity that naturally occur following heavy rains such as experienced during the 1996-97 winter season and from pre-existing contaminants such as creosote. It is also reasonable to assume that the addition of another stressor, such as spilled and persistent petroleum, would only exacerbate conditions and further decrease chances for survival of organisms already in a potentially weakened or compromised state.

Predation: CDFG scientists have previously observed predation rates along the upper edge of the spawning habitat between 80 - 90 percent, much of which might be attributed to predation by gulls (Spratt, 1981). The Trustees are unaware of any estimates for the mortality of subtidal eggs, although predation certainly occurs in the subtidal, with various fish such as pile perch and sturgeon as well as invertebrate species probably accounting for significant egg mortality. Predation, however, is a natural process that represents a valuable ecological service, in which one organism serves as food for another organism. Contamination of eggs, which are directly deposited on oiled surfaces, represents a loss not only to herring recruitment but also a loss of clean food to other members of the ecosystem.

Salinity: Laboratory studies have revealed that high and low salinity water can affect egg and embryo viability, and that ideal salinity for herring egg fertilization and embryo development is between 12 and 20 parts per thousand (ppt). Below 8 ppt and above 24 ppt overall egg and embryo viability may drop (Estuary, 1997). The interpretation of salinity influence, however, is not simple. Fish typically osmoregulate or adapt to changes in salinity prior to spawning, and this may influence the ability of eggs and developing embryos to survive stress from sub-optimal salt conditions (Cherr, pers. comm.). Further work is needed to evaluate the significance of salinity as a stressor in field conditions.

Other Contaminants: The present evaluation of oil contamination of herring eggs and fouling of spawning habitat has focused on visible persistence of intermediate fuel oil on spawning surfaces. Some of the wood used in the construction of piers along the San Francisco waterfront was originally coated with creosote, which is toxic to aquatic organisms. Without additional investigation, however, it is unknown what level of impact would occur following exposure of herring embryos to heavily weathered creosote on artificial structures along the San Francisco waterfront. Additionally, many of the piers have concrete pilings that were not treated with creosote. In many instances of the creosote-treated wood pilings, however, there is a layer of marine fouling organisms covering the wood surfaces, and the herring eggs are not deposited directly on creosote treated wood. Further work is needed to evaluate the effects of reducing exposure to creosote by intervening layers of marine fouling organisms atop piling surfaces.

Restoration Options:

The Trustees identified various projects that appear to have a strong nexus with the injury to subtidal habitat and specifically with habitat that is used by herring for spawning. We are in the process of evaluating various restoration options to compensate for losses to herring that resulted from the spill of petroleum hydrocarbons. There has not been adequate time to investigate all of the options listed below or to determine cost estimates or scale projects to the degree of resource injury for each project concept. The Trustees are willing to discuss these and other alternatives that might be proposed by the responsible parties. Any projects that would require the addition of hard structures (e.g., reefs or additional pilings) are expected to be scrutinized closely by the Bay Conservation and Development Commission (BCDC). The following project concepts might be considered:

1) Construction of artificial reefs.
2) Fisheries management projects (e.g., buy back of herring permits).
3) Replacement of creosote pilings with concrete pilings; or sheathing impacted piling surfaces.
4) Creation or expansion of eelgrass beds.

Project Concept 4: Creation of Eelgrass Beds. At present, the Trustees evaluated the benefits of creating eelgrass beds within San Francisco Bay to provide additional spawning habitat and replace a comparable amount of eggs and other ecological services that were reduced or lost as a result of the spill. Although the proposed restoration project has been scaled to the injury based on the amount of eggs lost or contaminated following deposition on oiled surfaces, other ecological services provided by the oiled waterfront habitat were also reduced or lost. Creation or expansion of eelgrass habitat would provide additional ecological services beyond simply herring egg production.

The CDFG biologists involved in monitoring and managing the herring fishery provided data from the 1996-97 field season to compare total egg counts on piling surfaces used for spawning at the San Francisco waterfront and total egg counts for plant surfaces in eelgrass beds within the bay. A comparison of total egg counts per square meter from both types of habitats suggests that piling surfaces support approximately 15 times more herring eggs than surfaces within an equivalent area of eelgrass habitat (Table 1). This might indicate the need to create 15 times more eelgrass habitat than area of piling surfaces impacted to produce an equivalent amount of herring eggs, if all other variables were the same. On the basis of various Trustee considerations, we do not think that a simple multiplication by 15 is appropriate. Table 2 summarizes some of the assumptions used by the Trustees to account for differences in the quality of the two habitats and potential differences in the types and diversity of resource services produced in an eelgrass bed. The assumptions have been used to scale or calculate an appropriate acreage of eelgrass habitat for restoration.

Table 1.

Location	Total Area with Spawn	Average no. Total Eggs	Average no. Eggs/m²
Pilings at SF Waterfront covered with spawn (Compilation of data from two spawn dates)	909,862 m²	1.68×10^{12}	1,846,434
Eelgrass & other subtidal vegetation (Compilation of data from nine spawn dates)	7,284,753 m²	9.089×10^{11}	124,767
Ratio of egg production in pilings to eelgrass	Approximately 15: 1		

The Trustees used resource or habitat equivalency analysis (HEA) to equate the amount of habitat lost or injured with the size of eelgrass bed habitat proposed. The Trustees did not attempt to quantify the differences in total ecological service production between the two types of habitats (piling vs eelgrass). They acknowledged, however, possible ecological benefits of improved quality and diversity of resource services from an eelgrass habitat beyond those produced by a pier piling community in which many of the pilings were originally treated with creosote. A credit therefore was applied against the scaling factor that was identified on the basis of egg production alone.

<u>Acreage of Impact</u>: The total area estimated to have persistent oiling along the San Francisco waterfront, based on a one meter wide band, is 44.8 acres (=181,445 m²).

<u>Acreage of Proposed Eelgrass Habitat</u>: The Trustees are proposing the creation of 21.5 acres of eelgrass habitat to compensate for the loss of herring eggs and other ecological services provided by the oiled habitat along the San Francisco waterfront. Some of the data and assumptions that were used for calculating this acreage are presented in Table 2. Dr. Michael Welsh (Hagler Bailly Consulting, Inc.) performed

an equivalency analysis for the proposed herring spawning habitat restoration project, which used a model based on the concepts described by NOAA in a document entitled "Habitat Equivalency Analysis: An Overview", dated March 21, 1995.

HEA Model Assumptions: Dr. Welsh ran the model with two different types of assumptions concerning the percent of injury to herring eggs and the path of recovery. In one instance, we assume that the injury is 100% and persists at 100% loss for five years, at which point recovery is instantaneous. In the second instance, we assume that the injury is initially 100% and recovery is linear over a five year period, at which point there is no residual injury. Both assumptions include a 3% discount rate to arrive at present day (1997) habitat values. For purposes of this document, the Trustees used the assumption of linear recovery of 20 percent per year over five years, with no residual injury beyond five years.

Dr. Welsh also ran the model with two different types of assumptions for the relative quality of piling versus eelgrass habitats regarding service production. Empirical data from herring egg counts in the two types of habitats suggested approximately 15 times greater herring egg production on the pilings than within the eelgrass beds. The Trustees, however, felt that eelgrass habitat potentially could provide a greater diversity of ecological services, and higher quality services, than those provided by creosote-treated pilings. A credit therefore was applied for creation of habitat that would potentially provide additional ecological factors beyond simply replacing lost services from herring eggs. The Trustees did not believe that the differences in service returns between the two types of habitats would exceed an order of magnitude, therefore the credit was set at a maximum of ten (10). This credit was subtracted from the "herring egg scaling factor" of 15 to yield a much reduced overall scaling factor of five (5) when calculating the amounts of resource equivalents between piling and eelgrass habitats.

Table 2.

Explanation	Scaling Factor		Total
	pilings	*eelgrass*	
Acreage of oiled spawning habitat at SF Waterfront			44.8 acres
DEBIT FOR RESOURCE SERVICE CONVERSION Field Data: Total herring egg counts, on average, were 15 times greater on pilings than in equivalent areas of eelgrass habitat.	15 x		
CREDIT FOR RESOURCE SERVICE CONVERSION Assumption: The Trustees assume that eelgrass habitat is more desirable in general habitat quality and will potentially produce more diverse resource services than creosote piling habitat. Therefore, a credit is applied to compensate for these differences in resource services.		10x	
CREDIT/DEBIT SUMMARY Assumption: The Trustees assume simple arithmetic for calculating the total scaling factor based on credits and debits in service production between the piling and eelgrass habitats. This yields an acreage scaling factor of 5x in the equivalency analysis to account for differences in relative habitat quality and resource service production between piling and eelgrass habitats.	5x		
1997 PRESENT VALUE LOST ACRE YEARS (based on 100% initial injury, a linear recovery path over five years from 1997 to 2002, with no residual injury after 2002, and a 3% discount rate)			108.16
PRESENT VALUE CREDIT PER ACRE (based on restoration beginning in 2000, immediate completion of the project, service benefits at 80% into perpetuity, and a 3% discount rate)			5.03
1997 PRESENT VALUE RESTORED ACRE YEARS (based on present value of 108.16 injured acres divided by present value credit per acre of 5.03)			21.5 acres
TOTAL ESTIMATED PROJECT COST	$1.29 MILLION		

Acreage Scaling Factors: A scaling factor of five for the creation of new habitat for lost habitat is consistent with other examples of acreage scaling factors (also known as mitigation ratios) that have been widely used by various state and federal agencies to calculate levels of compensatory habitat replacement or restoration. The California Department of Fish and Game (CDFG) began using these ratios in the early 1980s to compensate for temporary and permanent impacts to habitats and natural resources caused by human disturbances to the environment, with higher ratios typically applied for more permanent losses. There are three primary reasons behind the use of these scaling factors or ratios:

1) Artificially created habitat generally is not as productive as naturally created habitat, and generally some resource services are lost when one habitat type is converted to the newly created habitat.
2) Artificially created habitat requires time to reach maturity, which results in a temporal loss of ecological services to the ecosystem.

3) Artificially created habitat has an associated failure rate that must be considered when trying to achieve a final goal of a specified acreage restored.

In the present project concept, there is potential difficulty associated with the creation of a functional eelgrass bed in San Francisco Bay and considerable uncertainty about the timing and level of replacement of lost resource services. This difficulty and uncertainty would further justify use of a higher scaling factor when creating acres of eelgrass habitat.

Cost of Proposed Eelgrass Habitat: **The estimated total cost for the proposed creation of 21.5 acres of eelgrass habitat is 1.29 million dollars.** This value is based on an estimate of $60,000 per acre of habitat created. The Trustees consulted with two firms that have considerable experience creating eelgrass habitat in California. We identified a site in Richardson Bay as a possible location for the restoration project because eelgrass currently grows in this location and herring spawn in the existing eelgrass beds. The general elements considered in this cost estimate are provided in Table 3.

Table 3.

Task	Cost per Acre	Cost for Project
Planning and General Management (includes costs for correspondence, bid preparation, coordination of personnel, and preparation of a restoration project plan)		7,000
Site Preparation (includes installation of transplant lines and demarcation of underwater orientation grids; DOES NOT INCLUDE COSTS FOR FILL MATERIAL IF NEEDED)	10,000	
Planting (includes collection of donor plants, preparation of planting units, and planting and anchoring transplants)	40,000	
Monitoring over five years (includes monitoring reports for 0, 3, 6, 12, 24, 36, 48, 60 months)	5,000	
10% Contingency Fund (covers costs of replanting and other unforeseen activities)	5,000	
APPROXIMATE TOTAL COST PER ACRE	$60,000	

Other potential costs: Eelgrass growth typically is limited on the upper edge of its habitat by desiccation in the intertidal and on the lower edge of its habitat by light levels. Eelgrass habitat creation usually is most successful in areas near existing eelgrass beds where water quality is suitable for plant growth and donor plants can be readily obtained. In these instances, new habitat generally is created by using fill materials to raise the seafloor to a depth at which light levels will support plant growth. The present estimates do not include any costs for fill material, which in one project in Southern California was nearly $10 per cubic yard. The Trustees did not factor in costs for fill because it is possible that fill material can be obtained at no charge if coordinated with a dredging operation from some other area of the bay.

Literature Cited:
TO BE SUPPLIED