March 13, 2009

INJURY ASSESSMENT FOR SALT MARSHES, SAND BEACHES, AND TIDAL FLATS AFFECTED BY THE M/V *COSCO BUSAN* OIL SPILL HABITAT EQUIVALENCY ANALYSIS (HEA) INPUTS

HABITAT WORKING GROUP COMMENTS SUBMITTED ON BEHALF OF THE RESPONSIBLE PARTY

Following the September 24/25, 2008 meeting, the Trustees and Responsible Party have compiled literature, reviewed data, and in some instances conducted additional field studies to take the necessary steps to determine exposure, pathway, and to estimate direct or indirect injury in exposed areas where a pathway exists. On February 20, 2009 the Trustees provided a Habitat Equivalency Analysis (HEA), without the input values to the RP. Restoration proposals were provided on February 25. The input values were provided on March 4. The following are the RP comments to the HEA. We believe the key major issues to resolution of the habitat injury assessment are:

1. There is an implicit conclusion in the HEA prepared by the Trustees that any exposure to oil equals injury. "Very Light" Exposure is by far the largest oil category in the Trustees Assessment and results in the vast majority of restoration requirements, although evidence of injury in Very Lightly Oiled shorelines has not been demonstrated. In past spills similar to the COSCO BUSAN spill, the Trustees concluded that exposure to very light oiling or light oiling did not result in injury. Under the OPA NRDA regulations, exposure does not equal injury and the Trustees are obligated to prove that exposure to very light and light oiling caused injury.

2. The Trustees selected studies from large spills of fuel and crude oil, and used these studies to extrapolate injury in this case. The large spills which the Trustees selected are not appropriate analogues in that the extent and degree of oiling in those spills was much greater than that observed in the Cosco Busan spill. The assigned categories of oil used for HEA purposes are not congruent with the categorization of oiled shorelines from most if not all previous spills that have been referenced by the Trustees to judge expected recovery. These two scales need to be harmonized for purposes of injury assessment, loss of services, and expected recovery times. The Trustees excluded studies from smaller, more comparable spills, without explanation or justification.

3. The Trustees assume that if any oil was found on a beach, the entire beach was oiled to the same extent as the area on which oil was found. The Trustees also assume that if a marsh had any amount of oil in it, then all adjoining mudflats were also exposed and affected by oil. This assumption has no basis in reality, and the RP does not accept this method as valid or reliable. Oil and its effects cannot be in many places at the same time. Using this method results in a vastly overstated number of acres oiled being attributed to the Cosco Busan spill.

4. The Trustees' assumptions regarding loss of service and duration of loss of service are overstated. For example, the Trustees assume that light or moderate oiling of a marsh results in a complete loss of service and that it takes years for the marsh to recover to full service. This is

inconsistent with all the cited studies of marsh that was not completely oiled, and has not been documented by the Trustees in this case.

We also have a number of comments relative to the restoration projects and the assumed credits they are assumed to offer by the Trustees. As part of a cooperative process, the following general comments are offered in response to the exposure and injury assessment approach, HEA input variables, and habitat restoration project details provided to representatives of the Responsible Party on February 20, 2009.

DETERMINATION OF EXPOSED AREA

- The overall approach to assignment of injury by the Trustees is one that assumes all exposure results in injury. Determining exposure, pathway, and a subsequent adverse change to a natural resource or service as a result of the discharge are separate steps in the process. Exposure does not necessarily result in a pathway or injury. There is no measurable or observable evidence of injury in very lightly oiled shorelines, and in many instances other relatively low shoreline oiling categories. Most of the shorelines designated as "Very Lightly Oiled" were documented to have less than 1% oil distribution maximum oiling or were assumed to be exposed because of oiling in adjacent habitats. This is in contrast to a previous long-term oil spill on the outer coast, the Luchenbach spill, where continually lightly oiled beaches over many years were not included by the Trustees in the DARP published for that incident.

- The assessment method used by the Trustees assumes that the intertidal zone from the highest high tide to the lowest low tide was exposed at the same level as the stranded band of oil for rip-rap and sand shorelines and one oiling category lower than the oiled band for rocky shorelines. Not all portions of the intertidal zone are exposed by many shoreline oiling scenarios. Oil stranded during the highest tides may not be subsequently re-mixed in the intertidal zone. This assumption results in a vast overall overestimation of exposed acres and is not an appropriate exposure determination method.

Proposed Approach: The assessment should eliminate "Very Lightly" exposed shorelines from the injury determination due to lack of injury (and in many instances exposure) evidence. If we accept the assumption that the entire intertidal zone is oiled equally as the oiled zone as a measure of conservatism in the HEA, further reduction in oiling category assignment of unoiled portions of the intertidal zone is required to more accurately reflect the injury data to which they are compared.

DEGREE OF INJURY

- The assumption that the intertidal zone, from the highest high tide to the lowest low tide, was exposed at the same level or one oiling category lower than the oiled band for injury assessment purposes substantially overstates the degree of injury. Inferences drawn from spills with standardized methods of assigning Heavy, Moderate, Light, and Very Light oiling categories are not comparable and have far more oil per unit area than used in the currently proposed Habitat Equivalency Analysis as described above. As an example, using the average volume of oil per acre for SCAT categories calculated from band width, distribution, and thickness, the amount of oil that spilled would have had to be over 165,000 gallons to affect the total acres in the Trustees Habitat Equivalency Analysis (excluding eelgrass exposure assumptions). Only 53,000 gallons spilled. Unified Command estimated up to 30% evaporation in the first five days, overflights identified fugitive oil that was swept offshore, and over 19,000 gallons were recovered on the water, which means less than 30,000 gallons were available to strand on shorelines. The Trustees assumptions of SCAT exposure for injury inferences require far more oil than was available.

- The on-site eelgrass study cited in support of service loss for some habitats examined macroinvertebrates in eelgrass and sand communities in exposed and reference sites. The study data did not result in statistically significant differences between oiled and reference sample location means for nearly all organisms on sand or in eelgrass. The statistical analyses in the study appear to have analyzed the replicate samples at each location as independent samples, a statistical error known as pseudoreplication. Pseudoreplication increases the effect of a few sample locations by artificially increasing their sample size in the analyses. Since greater numbers of replicates were collected at two reference sites that had higher abundances than other reference sites, this further magnifies the effect of pseudoreplication on the statistical analyses by increasing the sample sizes of only those sites with high abundance. Statements regarding large increases or decreases in abundance between sites or sampling periods have no meaning when they are not statistically significant and within the normal sample variation.

- Considering seawall and rip-rap to be ecologically equivalent to rocky intertidal substantially overstates overall rocky intertidal service (Discounted Service Acre Years (DSAYs) lost and restoration acres required since most injury acres within the rocky intertidal habitat category are seawall and rip-rap. Seawall and rip-rap consists of 50% of the oiled intertidal zone in the bay and 86% of all rocky intertidal habitats directly oiled according the Trustees exposure summary table. Considering natural rocky intertidal restoration or enhancement to be less valuable than services provided by seawall and rip-rap substantially overcompensates for possible injury.

- We have included a number of specific comments on service loss within the Habitat Equivalency Analysis Input spreadsheet (attached).

Proposed Approach

The assumption that a band of oil will equally oil the entire tidal zone should be accompanied by a reduction in the SCAT oiling category of several levels in order to be more consistent with the levels of oil on shorelines in the cited injury studies. Adjacent habitats not visibly oiled should not be rated with SCAT exposure categories in the HEA if no oil was observed on them. Referring to these habitats as "adjacent to oiled beaches" does not resolve the problem as long as the injury inferences are gathered from sources where visible oil was present (not adjacent). At a minimum, "Very Light", "Adjacent to Light" and "Adjacent to Very Light" should be removed from injury assessment due to lack of evidence of injury and in many instances, exposure. This method has not yet been accepted in the ATHOS as the DARP and Consent Decree have just been made available for public comment. The relative value of a restoration project for rocky intertidal in the Habitat Equivalency Analysis should be 1.0 or greater considering the majority of injured rocky intertidal habitat is rip-rap and seawall. Review and consider specific comments in Habitat Equivalency Analysis Input spreadsheet (attached).

RECOVERY

- As mentioned, injury inferences are drawn from spills with standardized methods of assigning Heavy, Moderate, Light, and Very Light oiling categories that in most cases have far more oil per unit area than used in the currently proposed Habitat Equivalency Analysis as described above. As such, recovery projections of habitats in various oil categories from other spills are not comparable and are misleading.

- Even with the overstated oiling categories, the literature cited for marsh and other habitats with less than 100% oil distribution suggest faster recovery in some categories than those predicted in this case (e.g., Pezeshki and DeLaune, 1993, Smith et al., 1981)

- We continue to believe quick and simple field studies requested by the Responsible Party in September 2008 would be helpful to verify the Trustees' assumptions. The Trustees cite literature studies in support of their assumptions. The literature studies report injury in other (dissimilar) cases such as above-ground mortality, loss of age classes of organisms, loss of biomass and reduced vegetation cover after 1 year. If that is correct, then we should be able to readily detect the more pronounced loss assumptions used by the Trustees.

Proposed Approach

The assumption for the model that a band of oil will equally oil the entire tidal zone should be accompanied by a reduction in the oiling category of several levels for HEA recovery inferences. Review and consider specific comments and compromises in Habitat Equivalency Analysis Input spreadsheet (attached). Immediately conduct field surveys to determine whether assumptions by Trustees regarding continuing injury are accurate. Such field surveys can be easily accomplished in a short period of time with little additional expense.

RESTORATION

As discussed, we believe injury has been substantially overstated. Therefore, we believe that the restoration recommended vastly overcompensates for the scale of the injury. In addition, we believe that the scale of some of the projects are considerably larger than similar projects that also rated high for other selection criteria, even considering the Trustees' representation that the smaller sized projects result in higher per acre costs.

Some of the proposed projects may involve contaminated sediments that require increased transportation and disposal costs and increase the risk of exposure to workers and public health. The RP was not responsible for the contamination which exists at these sites, and it is not appropriate to ask the RP to assume liability and pay to mitigate contamination that it did not create. To the extent these sites are owned by the United States or the State of California, they should be fully responsible for the costs of mitigation and proper disposal of any contaminated wastes.

Comments Regarding Project Selection

Project selection guidelines under OPA list the following criteria:

1. *Cost to carry out the alternative;*
2. *Extent to which each alternative is expected to meet the Trustees' goals and objectives in returning the injured natural resources and services to baseline and/or compensating for interim losses;*
3. *Likelihood of success of each alternative;*
4. *Extent to which each alternative will prevent future injury as a result of the incident, and avoid collateral injury as a result of implementing the alternative;*
5. *Extent to which each alternative benefits more than one natural resource and/or service; and*
6. *Effect of each alternative on public health and safety.*

We offer the following comments relative to the selection criteria.

- Multiple related projects throughout the bay for each injury category substantially increases the overall cost of restoration and appears to run counter to the selection guidelines.

- One of the objectives of restoration is to compensate for interim losses sooner rather than later since services are discounted over time. The Trustees assume that restoration activities will initially result in increased injury (lost DSAYs) as we discuss in more detail under "Habitat Equivalency Analysis." Baseline services at an unrestored mitigation site are assumed to be lost for up to three years as a result of the mitigation itself. Selecting restoration projects that result in increased overall injury (for the first 3 years) is counter to the selection criteria of preventing future injury if other (less damaging) mitigation projects exist. In essence, the Responsible Party is held liable for construction injuries at the mitigation site. Under this assumption, projects that do not involve invasive restoration are favored and should be given preference since they do not result in additional lost DSAYs during the post construction period, and credits begin accruing immediately.

Comments Regarding Projects Not Selected

- The State Coastal Conservancy Invasive Spartina Control for marsh was estimated to cost $790,000 through September 2009 and in need of funding until 2012 for complete eradication on approximately 1,500 acres. The cost per acre is much lower than the selected projects. This project would not result in additional lost DSAYs from the outset to three years and would accrue benefits in the first year.

- Revegetation and Grading for Quartermaster Reach Wetland Restoration, a 6 acre project (2-3 acres of saltmarsh), was less expensive per acre than the projects selected by the Trustees (estimated $400,000 total costs).

- The Bolinas Lagoon project was ranked high and was less expensive per acre than projects selected. This project is less invasive than selected projects and would also not result in additional lost DSAYs.

- A 7.0 acre Sandy Beach project with a ranking of 1 at Ocean Beach was estimated to cost 10 times less per acre than the selected Radio Beach project (Estimated cost $400,000).

- A 300 acre dune project at Drakes Estero cost substantially less per acre than selected projects.

- A Rocky Intertidal project at Berkeley North Basin to improve habitat to 4 acres appears to have substantial cost benefit over selected projects (estimated Costs $1,000,000). This project could also start accruing benefits right away.

- The Duxbury Reef project aimed at reducing visitor impacts to over 20 acres of rocky intertidal ($50,000 USD) also appears to have substantial cost benefit over selected projects. This and other rocky intertidal projects had high rankings and were significantly lower in cost ($150,000 per acre or less) than selected projects.

- The non-native oyster eradication project will benefit the entire bay and is estimated to cost $60,000.

Comments Regarding Selected Projects

- The Hoffman Marsh project description we received from the restoration group (1/28/2009) indicated 40 to 50 acres of tidal wetland restoration for $2.5 M USD. The Trustees have asked for $1.39 M for only 6.5 acres at Hoffman Marsh, which appears to underestimate the acreage credit and/or overestimate costs.

- The long term benefit of removing a toxic threat to the public and ecology as well as financial liability of the threat appears not to be credited as part of the services of the restored marsh.

- Oyster shell projects in the 1/29/2009 restoration worksheet were estimated to cost $240 to $290 K USD for 1 acre of reef and an additional one acre of benefit, substantially less than the estimated Rocky Intertidal costs per acre for the selected projects. Our conversations with Mr. Todd Barber, Chairman of the The ReefBall Foundation, indicated oyster reef balls are small, weighing only 35 lbs and costing approximately $35 USD each to construct (personal communication, Todd Barber, 2/27/2009). Placement of several hundred on several acres should cost substantially less than predicted by the Trustees. Since the Trustees assume rip-rap and seawall to be equivalent to rocky intertidal for injury assessment purposes, it would be valid to create either as a restoration project in place of oyster reef balls.

- The Muir Dune Project was previously estimated to cost $87,000 and is now estimated to be $138,750 for 1.6 acres.
- We did not see a Limantour Dune project of 2.5 acres in our previous restoration tables. The Limantour Dune project may be a small part of the 300 acre project estimated to cost $3.78 M USD (1/29/2009). The cost per acre is high relative to the overall cost.

Proposed Approach– Further evaluation of project costs and credits pending HEA considerations below.

HABITAT EQUIVALENCY ANALYSIS

- The Trustees approach to HEA assumes a mitigation applicant continues to accrue debit (lost DSAYs) from the construction at the mitigation site. In other words, if a mitigation site provides an estimated 25% service in its impaired state, the mitigation applicant is held responsible for the lost DSAYs of disturbing the site further in order to enhance it. The site is assumed to drop from 25% service to zero during mitigation construction and slowly recovering from that point. By the time a mitigation site begins to accrue positive DSAYs over 25% service, the value of the mitigation has been substantially discounted by time. Assuming an initial loss in service for removing already existing contaminated sediment (baseline) at a restoration site also is not logical. Priority should be given to projects that do not add to the lost DSAYs
- The Trustees assume that enhancement and mitigation sites require longer to recover from enhancement and mitigation activities than they do from oil spills. While we believe this may be true in some cases, the assumption of 8 years for a sandy beach to provide full service after beach enhancement is 7 years longer than beaches required to recover following the Sea Empress Oil spill, which involved substantially heavier oiling and was a much larger spill than the Cosco Busan spill. Many species offset dynamic physical disruption by benefiting from pelagic larval supply or long shore and near shore immigration of many life stages (i.e. fast recovery). The assumption that a marsh does not provide full services after enhancement for 25 years is far longer than oil spill recovery from even the heaviest oiling categories. Most literature suggests full function of created and enhanced marshes within ten to fifteen years.
- The assumption that a marsh or rocky intertidal restoration site can only provide 83% of full service after maximum site development relative to the natural habitats is not supported and substantially overestimates the required DSAYs. Most of the oiled rocky intertidal habitat was rip-rap and seawall. A natural rocky intertidal enhancement project should provide more than 100% of services relative to those provided by seawalls and rip-rap.
- The assumption that the enhanced or restored marshes will only provide 83% of function relative to affected marshes is also not appropriate. The health and service of affected marshes was impaired prior to the spill. In other words, 100% baseline services at the injured sites are lower than 100% services at less impaired sites. Most importantly, most of what is considered marsh impact in the HEA is actually derived from mud flat exposure. Marshes are more productive and the relative value of a marsh to a mud flat is higher.
- The assumption that an enhanced sand beach will only provide 85% of services relative to impacted beach is also not justified. There is no evidence that a restored sand beach does not function at the same levels of existing beaches.

Proposed Approach

Consistent with other mitigation approaches, we should not accrue additional lost DSAYs for mitigation site construction. Rocky intertidal mitigation should be considered equally or more valuable than rocky intertidal injury since most rocky intertidal injury occurred on seawall and rip-rap. We should assume marsh enhancement benefit is equal in service to the affected habitats being considered equivalent to marsh (mud flats). The time for a restoration project to reach full service should be lowered to reasonable literature reported limits for each category. Review and consider specific comments and compromises in Habitat Equivalency Analysis Input spreadsheet (attached).

The comments on injury and recovery affect the restoration outcome as shown in the Table below.

Table: HEA results using Trustees Assumptions and Revisions.

Habitat	Trustees Injury and Credit Assumptions	Suggested Injury and Credit Revisions
Marsh (acres)	7.1	>0.1 *
Sand (acres)	11.6	1.4 **
Rocky (acres)	6.9	0.4 *

* Most restoration requirements using Trustees assumptions are derived from assumption of many acres of Very Light oiled tide flats, rip-rap, and seawall.

** Most restoration requirements in Trustees Sandy Beach Assessment are derived by assuming entire tide zone is oiled equally as oiled band, and from the assumption of many acres of Very Light oiled sand beaches.

For settlement purposes, the Responsible Party proposes one or more of the following restoration projects previously identified by the Trustees with a ranking of 1 that are more cost-effective than the projects proposed by the Trustees. They also satisfy the Trustees's assumptions of acres required, are less invasive, do not involve potential human health issues from contaminated soils, and avoid additional lost DSAYs the Trustees assume are associated with the collateral injury of habitat disruption during mitigation construction.

Table: Restoration Projects from Draft Habitat Restoration list received 1/28/09

Project	**Description**	**Acres**
Quartermaster Reach Wetland - Marsh	Daylighting a small stream and enhancing 6 acres of habitat	6 acres total- 2 to 3 acres marsh.
Ocean Beach - Sandy	Invasive plant removal and dune enhancement	up to 7
Duxbury Reef – Rocky Intertidal	Informational Buoys and protection of intertidal areas	20+
Non-Native Oyster eradication - Rocky Intertidal	Non-Native Oyster eradication	Entire Bay

Attachment: General comments on specific input variables below (blue):

HABITAT EQUIVALENCY ANALYSIS (HEA) INPUTS

Table 2. Trustees HEA inputs and justifications for Salt Marsh, Sand Beach, and Tidal Flat service categories RP comments in blue

Salt Marsh + Heavy Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present

T= 0; 0% 25%
 	
Evidence does not support 100% loss of service.
	Heavy oiling smothered vegetation and fauna using the habitat, rendering it unsuitable for use by fish, invertebrates, and wildlife
	
	- 60% of heavily oiled marsh lengths had >50% oil cover/coat; 40% had 11-50% (all in the oiled band)
	This means oil cover was not complete. Partial oil cover does not result in 100% loss of photosynthesis. (See study listed under Moderate Oiled Marsh). If photosynthesis is part of the service of a marsh, service loss in these areas cannot be 100%. We also sampled numerous organisms in these areas, all of which were live. The marsh service of shoreline stabilization was also not impacted.
	- Oiling occurred from the outer vegetation fringe to several meters towards the interior, affecting the predominant fauna utilizing the edges and channel borders of this habitat, as well as those crossing this interface to use different areas at different tidal levels for feeding and protection
	- Crustacea and gastropods are the dominant epifauna in salt marshes (Josselyn, 1983). These species are motile and cross from marsh to tidal flat/channel to feed, increasing their exposure to the oiled marsh fringe as mentioned above.
	
	Salt marshes in San Francisco Bay (SFB) are dominated by surface feeders (Neira et al., 2005), exposed to the oil on the vegetation and marsh surface during feeding. Marsh vegetation is also impacted by oil coating of leaf surfaces, resulting in reduced photosynthesis and tissue death.
	
	- Laboratory and field studies of wetlands with 50-100% coating or oil application rate of 1.5-2 L/m^2 showed:
	  - 100% reduction in *Spartina* photosynthesis for week 1 for Mexican crude oil (Pezeshki and DeLaune, 1993)
	  - Photosynthesis decreased by 63-80% of controls for 7-14 days after heavy oiling of *Spartina* with S. Louisiana crude (Smith et al., 1981)
	  - *Spartina* dead biomass = 250% and live biomass = 70% of control at 3 weeks after oiling with No. 6 fuel oil (Alexander and Webb, 1983)

	- All fish in the tidal creek of the field oiling experiment with weathered S. Louisiana crude died by day 9 (Bender et al., 1977) Marshes have many services; habitat, shoreline stabilization, biomass production export among others. A relatively narrow band of oil of several meters with 11% to greater than 50% coat is not 100% loss of services. A marsh converted to an impervious concrete surface is 100% loss of services. Organisms collected for tissue samples from these locations were all live and no reported mortality of other organisms
T= 2 mo; 0% 25% Evidence from other spills does not indicate 100% service loss.	End of active cleanup and associated disturbances in salt marsh areas - Cleanup methods included cutting (at one location) and natural recovery; Most areas remained coated with oil that was still tacky, thus continued to be unsuitable for use Oil in the salt marshes was bioavailable to fauna from initial spill, as well as due to apparent 're-oiling' event in early January 2008 that resulted in re-exposure of PAHs to fauna in East Bay fauna - *Geukensia* mussels collected from heavily oiled Stege marshes on 15-20 November 2007 contained up to 60.5 ppm total PAHs; Mussels collected 19 December 2007 contained 4.3 and 7.3 ppm total PAHs; collections on 30 January 2008 contained 53.3 ppm; All samples matched to *Cosco Busan* oil - PAHs in mussels exhibit a range of lipophilic affinities, thus elimination of the variety of PAHs in fuel oil are variable. Elimination constants for PAHs (summarized in Meador et al., 1995) range on the order of ~2 days for the lower MW compounds (phananthrene/anthracene) to up to ~30 days for the higher MW compounds (fluoranthene/benzo-a-pyrene). Further, depuration kinetics of PAHs generally indicate a biphasic component to elimination (rapid initial depuration with an asymptotic depuration of the residual), thus body burdens of impacted mussels directly after the spill likely were significantly higher than those determined in the subsequent sampling events. - Total PAHs in mussel tissues greatly exceeded 6 and 9 mg/kg, levels at which 100% lysosomal destabilization is predicted to occur, based on data from Hwang et al. (2002; 2008) for field and laboratory studies of oysters, respectively; embryo viability is predicted to be very low at these levels (Moore et al., 2004; 2006); bay mussels have a single massive spawn in late fall and/or winter (Shaw et al., 1988) and *Geukensia* spawns from early summer to early fall (Cohen, 2005), so the total PAH levels in tissues likely reduced spawn viability No recovery of affected fauna during winter non-reproductive period - Laboratory and field studies of wetlands with 50-100% coating showed: - Live aboveground biomass of *Spartina* plugs oiled with No. 6 fuel oil = 20% of control after 49 days (Pezeshki et al., 1995)

	- Dead biomass of heavily oiled *Spartina* = 145% of control sites in field tests with No. 6 fuel oil after 5 months (Alexander and Webb, 1983) - Amphipods = 30% of control and Chironomids = 8% of control at week 20 in field oiling experiment in *Spartina* marsh with weathered S. Louisiana crude oil (Bender et al., 1977) - Number of live stems/plot and live biomass = 30% of control at 15 weeks after heavy oiling of *Spartina* with S. Louisiana crude (Lindau et al., 1999) - Heavily oiled fringing *Spartina* at the Chalk Point oil spill in the Patuxent River, MD had stem counts = 20% and stem height = 103% of unoiled reference sites 3 months post spill (Michel et al., 2002)
T= 1 yr; 50% 75% The inferences from the literature are what the Responsible Party suggested the group verify with anniversary studies since they should have been easily measurable given the assumptions to the right. We do not expect detectable differences in oiled and unoiled marshes or in organism age class distribution after one year based on site data and studies of similar spills. The Chalk Point spill is not	Laboratory and field studies of wetlands with 50-100% coating showed impacts to vegetation and fauna after one year: - Number of live *Spartina* stems/plot = 75% and biomass = 80% of controls 1 year after oiling with S. Louisiana crude (Lindau et al., 1999) - *Spartina* standing crop = 40% of control after 1 year in field oiling experiment with weathered S. Louisiana crude oil (Bender et al., 1977) - No. 6 fuel oil spill in Galveston Bay resulted in mortality of aboveground vegetation with 100% oil cover; 7 months post-spill, live aboveground biomass = 44% of pre-spill; belowground biomass = 84% of pre-spill (Webb et al., 1981) - Percent cover for *Salicornia* that was heavily oiled and trampled was reduced compared to controls at 1 year (Hoff et al., 1993) - *Carex* heavily oiled by IFO 380 spill, with no cleanup or trampling, was the same as control after 1 year (Challenger et al., 2008) - 7 months after a spill of 250,000 gal No. 6 fuel oil in Chesapeake Bay, *Littorina* were 40% of control, with evidence of both redistribution and recruitment (skewed size class); also *Spartina* had reduced flowering (Hershner and Moore, 1977) - Within 1 year after a No. 6 fuel oil spill in the Potomac River, heavily oiled *Spartina* marshes had greatly reduced populations of *Geukensia* (~20% of controls) and juvenile *Littorina* (~10% of controls). Age class distributions of *Littorina* remained altered for 2 years (Krebs and Tanner, 1981) - Heavily oiled fringing *Spartina* at the Chalk Point oil spill in the Patuxent River, MD had stem counts = 72% and stem height = 120% of unoiled reference sites 1 year post spill (Michel et al., 2002) Shore crabs have life spans up to 4 years, and gastropods have life spans up to >10 years; Recovery reflects the time to restore to pre-spill age class distributions of these long-lived key species (by recruitment and immigration) This would have been simple to study as the RP suggested in September

comparable to the Cosco Busan Oiled marshes. The marsh we essentially buried and the response excavated large areas in an attempt to drain deeply pooled oil from the marsh.	
T= 5 yr; 100% T = 3 yr, 100% Comparison with other spills not similar. Squamish BC study with Env. Canada (Challenger, Sergy, and Graham 2008) found no evidence of ongoing injury after 1-2 years with no trampling in more heavily oiled marsh than CB	Full recovery is expected after 5 years - At the *Amoco Cadiz* spill in France, heavily oiled marshes with no cleanup disturbances recovered in less than 5 years (Baca et al., 1987) - Sell et al. (1995) summary of heavily oiled salt mashes found that initial colonization (i.e., the initial settlement or migration of macroscopic opportunists into the impacted site) of biota was observed to occur during the first year and that within 5 years of the contamination event, the marshes were within the recovery phase or were completely recovered. Shore crabs, gastropods, and amphipods would have recovered to their pre-spill age class distributions

Salt Marsh + Moderate Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present

T= 0; 50%
 	
Accept
	Moderate oiling smothered vegetation and fauna using the habitat, rendering it unsuitable for use by fish, invertebrates, and wildlife
	
	- 25% of moderately oiled marsh lengths had 11-50% oil cover/coat; 75% had 1-10% (all in the oiled band)
	- Crustacea and gastropods are the dominant epifauna in salt marshes (Josselyn, 1983); These species are motile and cross from marsh to tidal flat/channel to feed, increasing their exposure to the oiled marsh fringe
	- Oiling occurred from the outer vegetation fringe to several meters towards the interior, affecting the predominant fauna utilizing the edges and channel borders of this habitat, as well as those crossing this interface to use different areas at different tidal levels for feeding and protection
	
	Salt marshes in SFB are dominated by surface feeders (Neira et al., 2005), exposed to the oil on the vegetation and marsh surface during feeding. Marsh vegetation is also impacted by oil coating of leaf surfaces, resulting in reduced photosynthesis and tissue death.
	
	- Laboratory and field studies of wetlands with moderate oiling showed:
	  - In lab tests with Mexican crude oil on *Spartina*, partial oil cover resulted in photosynthesis reduced to 53-71% of control, but recovering by week 4 (Pezeshki and DeLaune, 1993)
	  - Photosynthesis decreased by 63-80% of controls for 7-14 days after both moderate and heavy oiling of *Spartina* with S. Louisiana crude (Smith et al., 1981)

T= 2 mo; 50% Accept	End of active cleanup and associated disturbances in salt marsh areas - Cleanup methods included natural recovery; most vegetation remained coated with oil that was still tacky and thus continued to present hazards to inhabitants. - No recovery of affected fauna during winter non-reproductive period - Laboratory and field studies of wetlands with moderate oiling showed: - Dead biomass of moderately oiled *Spartina* = 130% of control sites in field tests with No. 6 fuel oil after 5 months; live biomass showed no differences (Alexander and Webb, 1983)
T= 1 yr; 75% 100%	- Laboratory and field studies of wetlands with moderate oiling on the vegetation showed: - Number of live *Spartina* stems/plot = 75% of control and biomass = 80% of control 1 year after oiling with S. Louisiana crude (Lindau et al., 1999)

Studies in BC in moderately oiled marshes found no differences in stem density, height, biomass, soil PAH, and tissue body burden.	- *Spartina* standing crop = 40% of control after 1 year in field oiling experiment with weathered S. Louisiana crude oil (Bender et al., 1977) - 7 months after a spill of 250,000 gal No. 6 fuel oil in Chesapeake Bay, *Littorina* were 40% of control, with evidence of both redistribution and recruitment (skewed size class); also *Spartina* had reduced flowering (Hershner and Moore, 1977) - No. 6 fuel oil spill in Galveston Bay resulted in mortality of aboveground vegetation with 100% oil cover; 7 months post-spill, live aboveground biomass = 44% of pre-spill; belowground biomass = 84% of pre-spill (Webb et al., 1981) - Moderately oiled fringing *Spartina* at the Chalk Point oil spill in the Patuxent River, MD had stem counts = 33% and stem height = 82% of unoiled reference sites 1 year post spill (Michel et al., 2002) - *Carex* Moderately oiled by bunker fuel (IFO 380) spill, with no cleanup or trampling, was the same as control after 1 year (Challenger et al., 2008). Biomass, density, height, soil PAH, tissue PAH. - -PAHs in mussels exhibit a range of lipophilic affinities, thus elimination of the variety of PAHs in fuel oil are variable. Elimination constants for PAHs (summarized in Meador et al., 1995) range on the order of ~2 days for the lower MW compounds (phananthrene/anthracene) to up to ~30 days for the higher MW compounds (fluoranthene/benzo-a-pyrene). Further, depuration kinetics of PAHs generally indicate a biphasic component to elimination (rapid initial depuration with an asymptotic depuration of the residual), thus body burdens of impacted mussels directly after the spill likely were significantly higher than those determined in the subsequent sampling events. - Total PAHs in mussel tissues greatly exceeded 6 and 9 mg/kg, levels at which 100% lysosomal destabilization is predicted to occur, based on data from Hwang et al. (2002; 2008) for field and laboratory studies of oysters, respectively; embryo viability is predicted to be very low at these levels (Moore et al., 2004; 2006); bay mussels have a single massive spawn in late fall and/or winter (Shaw et al., 1988) and *Geukensia* spawns from early summer to early fall (Cohen, 2005), so the total PAH levels in tissues likely reduced spawn viability
T= 3 yr; 100% Accept	Full recovery is expected after 3 years because moderately oiled marshes and biota are expected to recover more quickly than heavily oiled marshes - At the *Amoco Cadiz* spill in France, heavily oiled marshes with no cleanup disturbances recovered in less than 5 years (Baca et al., 1987) - Sell et al. (1995) summary of heavily oiled salt mashes found that initial colonization (i.e., the initial settlement or migration of macroscopic opportunists into the impacted site) of biota was observed to occur during the first year and that within 60 months of the contamination event, the marshes were within the recovery phase or were completely recovered.

	Shore crabs have life spans up to 4 years; gastropods have life spans up to >10 years. Recovery reflects the time to restore age class distributions (by recruitment and immigration) This would have been simple to study as the RP suggested in September.

Salt Marsh + Light Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 50% 75%	Light oiling predominantly adhered to vegetation and/or sediment surface - ~80% of the salt marsh length with light oiling had 1-10% oil cover/coat and ~20% had 11-50% cover/coat (all in the oiled band) - Crustacea and gastropods are the dominant epifauna in salt marshes (Josselyn, 1983); These species are motile and cross from marsh to tidal flat/channel to feed, increasing their exposure to the oiled marsh fringe - Oiling occurred from the outer vegetation fringe to several meters towards the interior, affecting the predominant fauna utilizing the edges and channel borders of this habitat, as well as those crossing this interface to use different areas at different tidal levels for feeding and protection Salt marshes in SFB are dominated by surface feeders (Neira et al., 2005), exposed to the oil on the vegetation and marsh surface during feeding - There are very few laboratory and field studies of wetlands with light oiling. It is assumed that impacts to vegetation are limited and of short duration as described below at one year. The only study of which we are aware in light and very light oiling (Challenger, Sergy, and Graham 2008) indicate no detectable differences in sediment and vegetation indices and no discernable effects in subsequent growing seasons. - However, given the presence of tacky oil interspersed throughout the vegetation at the edges and channel borders, impacts to fauna within the oil footprint and motile species that must cross the oiled marsh fringe (such as *Rallidae*s) are expected to be common and widespread
T= 2 mo; 50% 75%	No cleanup methods were employed in lightly oiled marshes, thus removal and weathering of residual oil would be due to natural attenuation. - Most impacted areas remained oiled, thus continued to be unsuitable for use. Residual oil remained "tacky" for several months following the spill and re-oiling events introduced less weathered oil into the marsh as well. - In field experiment with application of 0.0375 L/m^2 of No. 5 fuel oil, many *Littorina* were killed initially; at 3 months oiled areas = 20% of control (3/m^2 in oiled versus 16/m^2) (Lee et al., 1981) No recovery of affected fauna during winter non-reproductive period
T= 1 yr; 75% T= 1 yr 100%	Vegetation assumed fully recovered; however, biota are assumed to be still recovering: - *S. alterniflora* lightly oiled with IFO 180 from the *Julie N* spill had the

No. 5 Fuel oil not similar. No. 5 is a blend of No. 6 and diesel oil and is substantially more acutely toxic. There is no evidence of injury from on-site or from other similar study of injury.	same stem density and stem height as unoiled controls one year later (Michel et al., 1998) - In field experiment with application of 0.0375 L/m^2 of No. 5 fuel oil, at 6 months, *Littorina* in oiled areas = 3% of control (1/m^2 in oiled versus 33/m^2) (Lee et al., 1981) - *Carex* Lightly oiled by bunker fuel (IFO 380) spill, with no cleanup or trampling, was the same as control after 3 months, 7 months, and 1 year (Challenger et al., 2008). Biomass, density, height, soil PAH, tissue PAH.
T= 3 yr; 100% Accept	Shore crabs have life spans up to 4 years; gastropods have life spans up to >10 years. Recovery reflects the time to restore age class distributions (by recruitment and immigration)

Salt Marsh + Very Light Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 75% 100% No evidence of injury or service loss	Very light oiling mostly occurred as tarballs or patches of oiled wrack both along the fringe and in the interior of the marsh - Most of the very lightly oiled marsh segments had <1% oil coat/cover or tarballs (all in the oiled band) - Crustacea and gastropods are the dominant epifauna in salt marshes (Josselyn, 1983); These species are motile and cross from marsh to tidal flat/channel to feed, increasing their exposure to the oiled marsh fringe - Salt marshes in SFB are dominated by surface feeders (Neira et al., 2005), exposed to the oil on the vegetation and marsh surface during feeding - There are no laboratory and field studies of wetlands with very light oiling - It is assumed that impacts to vegetation are limited and of short duration; however, significant but intermittent impacts to motile fauna are anticipated due to distribution of tarballs and wrack.
T= 2 mo; 75% No evidence of service loss	No cleanup methods were employed in very lightly oiled marshes, thus removal and weathering of residual oil was due to natural attenuation. - The impacted areas remained oiled, thus continued to present a hazard to resident fauna - No recovery of affected fauna during winter non-reproductive period
T= 1 yr; 100% Accept	Vegetation assumed fully recovered Fauna assumed fully recovered to their pre-spill abundance and age class distributions

Tidal Flats + Adjacent to Heavy Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 75% No evidence of exposure for this category over the vast majority of acres. While some exposure occurred, there is also no evidence of injury. Unless observed with oil such that it can be categorized by SCAT as H, M, L, VL, these habitats should be excluded.	Oil moving across intertidal flats would foul fauna and reduce the use of the flats habitat by fish, invertebrates, and wildlife - The only tidal flat adjacent to heavily oiled shorelines was in Keil Cove where the adjacent beach had a band of oil 237 m long and 3-m wide with 80% cover; cleanup included removal of oiled gravel using a barge for support - We believe this acreage is already included in the eelgrass assessment. - Studies of the adjacent eelgrass in Keil Cove showed significant impacts to fauna, with observations of numerous slow-moving or dead caprellids in the field 2-10 days post spill (Kitting and Chen, 2009). - No significant differences resulted and no corroboration of any dead or dying organisms is found for any other location. - Dominant species on tidal flats include mollusks (*Gemma, Nutricola, Venerupis, Cryptomya)*, oligachaetes, amphipods, harpacticoid copepods, and polychaetes (Brusati, 2004; Neira et al., 2005) - Many of these species are suspension feeders and surface deposit feeders, making them susceptible to exposure to oil films on the surface and oil suspended in the water column - Biofilms on tidal flats accounts for 45-59% of the total diet of western sandpipers (Kuwae et al., 2008) and likely for similar sandpipers, who winter in SFB in large numbers; oil moving across the tidal flats with the rise and fall of the tide would significantly affect the microphytobenthos and benthic bacteria that secrete the mucilaginous matrix of biofilms - Oil may affect them. There is no evidence presented.

T= 2 mo; 75%
 	
No evidence of exposure for this category over the vast majority of acres. While some exposure occurred, there is also no evidence of injury. Unless observed with oil such that it
	End of active cleanup and associated disturbances
	
	- Oil was still moving across tidal flats and potentially affecting epifauna due to continued re-oiling events
	  - Studies of the adjacent eelgrass in Keil Cove showed ~97% loss of normally common caprellids by December 2007 (Kitting and Chen, 2009) Reference study sites had greater variability that 97%. There were no significant differences in nearly all organisms between oiled and reference sites in the study.
	  - Evidence of oil uptake by filter-feeding bivalves; *Mytilus* on adjacent shoreline in Keil Cove had 14.7 ppm total PAHs on 7 December 2007
	
	- PAHs in mussels exhibit a range of lipophilic affinities, thus elimination of the variety of PAHs in fuel oil are variable. Elimination constants for PAHs (summarized in Meador et al., 1995) range on the order of ~2 days

can be categorized by SCAT as H, M, L, VL, these habitats should be excluded.	for the lower MW compounds (phananthrene/anthracene) to up to ~30 days for the higher MW compounds (fluoranthene/benzo-a-pyrene). Further, depuration kinetics of PAHs generally indicate a biphasic component to elimination (rapid initial depuration with an asymptotic depuration of the residual), thus body burdens of impacted mussels directly after the spill likely were significantly higher than those determined in the subsequent sampling events.
T= 7 mo; 90% No evidence	Tarball stranding and re-oiling events continued into May 2007 - Recovery based on assumption that most of the affected species would have successfully reproduced; this is confirmed by the eelgrass studies that showed invertebrate densities increasing at oiled sites in April and May 2008 (Kitting and Chen, 2009) All sites, including reference, showed increase spring densities. There were no significant differences between sites. Tarball presence is evidence of possible exposure and not injury.
T= 1 yr; 100% Accept	Recovery based on assumption that most of the affected species have annual life histories and would have returned to pre-spill abundances

<u>Tidal Flats + Adjacent to Moderate Oiling</u>

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 75% 100% Same comments as above. No evidence of any injuries has been presented for tidal flats. In most cases, no tangible evidence of exposure exists.	Oil moving across intertidal flats would foul fauna and reduce the use of the flats habitat by fish, invertebrates, and wildlife - Most of the tidal flats adjacent to moderately oiled shorelines were located on the south side of Brooks Island and along the Albany shoreline along Richland Inner Harbor from Ford Channel to Point Isabel - Studies of eelgrass beds adjacent to moderately oiled shorelines (e.g., Keller Beach) showed ~90% loss of normally common caprellids by December 2007 (Kitting and Chen, 2009) - Dominant species on tidal flats include mollusks (*Gemma, Nutricola, Venerupis, Cryptomya)*, oligachaetes, amphipods, harpacticoid copepods, and polychaetes (Brusati, 2004; Neira et al., 2005) - Many of these species are suspension feeders and surface deposit feeders, making them susceptible to exposure to oil films on the surface and oil suspended in the water column - Biofilms on tidal flats accounts for 45-59% of the total diet of western sandpipers (Kuwae et al., 2008) and likely for similar sandpipers, who winter in SFB in large numbers; oil moving across the tidal flats with the rise and fall of the tide would significantly affect the microphytobenthos and benthic bacteria that secrete the mucilaginous matrix of biofilms

T= 2 mo; 85%
100%
	End of active cleanup and associated disturbances
	
	- Tissue samples indicate ongoing oil exposure
	  - *Cryptomya* clam tissues collected 19 December 2007 from two tidal flat locations on south Brooks Island contained total PAHs of 7.5 and 12.2 ppm; on 30-31 January 2008, values were 9.4 and 13.0 ppm, by March 2008, the concentration had dropped to 1.6 ppm, all matching *Cosco Busan* source oil, indicating oil exposure to infauna
	  - Two *Mytilus* samples from the south shore of Brooks Island in December 2007 contained 16.6 ppm total PAHs (Match); in January 2008, two samples contained 11.4 and 128.7 ppm (Match); by March, two samples contained 1.0 (Probable Match/Mix) and 20.3 ppm (Match)

T= 7 mo; 95% 100%	Tarball stranding and re-oiling events continued into May 2007 - Tissue samples indicate decreasing oil exposure - One *Mytilus* sample from the south shore of Brooks Island collected on 24 June 2008 contained 1.0 ppm total PAHs which fingerprinted as Probable Match/Mix, indicating a very low level of oil from the *Cosco Busan* remained - Recovery based on assumption that most of the affected species would

	have successfully reproduced; this is confirmed by the eelgrass studies that showed invertebrate densities increasing at oiled sites in April and May 2008 (Kitting and Chen, 2009)
T= 1 yr; 100% Accept	Recovery based on assumption that most of the affected species have annual life histories and would have returned to pre-spill abundances

Tidal Flats + Adjacent to Light Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 90% 100% See previous comments	Oil moving across intertidal flats would foul fauna and reduce the use of the flats habitat by fish, invertebrates, and wildlife - Most of the tidal flats adjacent to lightly oiled shorelines were located in Albany Bay between Point Isabel and Golden Gate Fields, smaller flats on either side of the Berkeley Marina, and the western end of Emeryville Crescent - Studies of eelgrass beds adjacent to lightly oiled shorelines (e.g., Emeryville) reported observations of numerous slow-moving or dead caprellids in the field 2-10 days post spill (Kitting and Chen, 2009) - Dominant species on tidal flats include mollusks (*Gemma, Nutricola, Venerupis, Cryptomya)*, oligachaetes, amphipods, harpacticoid copepods, and polychaetes (Brusati, 2004; Neira et al., 2005) - Many of these species are suspension feeders and surface deposit feeders, making them susceptible to exposure to oil films on the surface and oil suspended in the water column - Biofilms on tidal flats accounts for 45-59% of the total diet of western sandpipers (Kuwae et al., 2008) and likely for similar sandpipers, who winter in SFB in large numbers; oil moving across the tidal flats with the rise and fall of the tide would significantly affect the microphytobenthos and benthic bacteria that secrete the mucilaginous matrix of biofilms

T= 7 mo; 95%
100%
	Tarball stranding and re-oiling events continued into May 2007
	
	- Tissue samples indicate decreasing oil exposure
	  - In Albany Bay, *Geukensia* mussels contained 25.9 ppm total PAHs on 30 January 2008 (Match) and 4.6 ppm (No Match) on 26 March 2008
	  - In Emeryville, Mytilus mussels contained 20.6 ppm total PAHs on 20 December (Match), 11.6 ppm on 30 January 2008 (Match), and 1.5 ppm (No Match) on 26 March 2008
	- Recovery based on assumption that most of the affected species would have successfully reproduced; this is confirmed by the eelgrass studies that showed invertebrate densities increasing at oiled sites in April and May 2008 (Kitting and Chen, 2009)

T= 1 yr; 100% 100%	Recovery based on assumption that most of the affected species have annual life histories and would have returned to pre-spill abundances

Tidal Flats + Adjacent to Very Light Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 95% 100% There is no evidence of injury on very lightly oiled shorelines; hence, there can be no evidence of injury on habitats adjacent to very lightly oiled shorelines.	Oil moving across intertidal flats would foul fauna and reduce the use of the flats habitat by fish, invertebrates, and wildlife - Most of the tidal flats adjacent to very lightly oiled shorelines were located on the north side of Brooks Island, between Berkeley Marina and Emeryville Crescent, in South Bay near Alameda, and most of Bolinas Lagoon - Studies of eelgrass beds adjacent to very lightly oiled shorelines (e.g., Crown Beach) reported high abundances of caprellids before and during the spill, then a 47% drop 19 days post spill (Kitting and Chen, 2009) - Dominant species on tidal flats include mollusks (*Gemma, Nutricola, Venerupis, Cryptomya)*, oligachaetes, amphipods, harpacticoid copepods, and polychaetes (Brusati, 2004; Neira et al., 2005) - Many of these species are suspension feeders and surface deposit feeders, making them susceptible to exposure to oil films on the surface and oil suspended in the water column - Biofilms on tidal flats accounts for 45-59% of the total diet of western sandpipers (Kuwae et al., 2008) and likely for similar sandpipers, who winter in SFB in large numbers; oil moving across the tidal flats with the rise and fall of the tide would significantly affect the microphytobenthos and benthic bacteria that secrete the mucilaginous matrix of biofilms
T= 2 mo; 95% 100%	End of active cleanup and associated disturbances - Assume end of oil remobilization in very lightly oiled areas - *Cryptomya* clam tissues collected in Bolinas Lagoon on 11 December 2007 contained 4.7 ppm total PAHs (Match), indicating exposure to infauna on the tidal flats - *Mytilus* mussel tissues collected from the shoreline in Bolinas Lagoon on 28 November 2007 contained 2.1 ppm total PAHs (No Match); samples collected 30 January 2008 contained 0.4 and 0.6 ppm (No Match)
T= 7 mo; 100% 100%	Recovery based on assumption that affected species have would have returned to pre-spill abundances

Sand Beach + Heavy Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 0% The Trustees use the terms "affected" and "exposed" interchangeably. The entire ITZ may have been exposed. Whether or not there was injury is a different question.	Heavy oiling smothered/fouled fauna using the habitat, rendering it unsuitable for use by fish, invertebrates, and wildlife - Most of the heavily oiled sand beaches had 11-50% oil cover within the oiled band only; 7% had >90% oil cover (all in the oiled band) - Although the Trustees consider the entire area to be 100% covered with heavy oiling, including areas outside the oiled band. The entire intertidal zone on sand beaches may have been exposed by the oil - Entire intertidal zone up to the oiled band at the high-tide line was impacted as the oil washed across the entire zone; Oil was mixed into the surf zone by wave action, and stranded on the beach face during falling tides - de la Huz et al. (2005) found significant reductions in numbers of species at all 4 tidal zones (from swash to dry) on sand beaches 8 months after the *Prestige* heavy fuel oil spill - Sand lance avoided low levels of oil contaminated sand (113-116 ppm) compared to clean sand (Pinto et al., 1984) All interstitial invertebrate species in spill area or cleanup zone severely affected because of heavily oiled wrack and removal of wrack during cleanup - Beach wrack is inhabited by a wide variety of insect and other arthropod species. Coleopteran beetles and flies (Diptera) are the most abundant, with 35 and 11 species respectively being found in one study. Other groups include mites, spiders, pseudoscorpions, centipedes, isopod crustaceans, hymenopterids (wasps), and orthopterids (Lavoie 1984) - Chan (1977) reported no organisms in oiled beach wrack nor in the oil-soaked sand 9 days after a 1,500-3,000 barrel spill of emulsified crude oil in the Florida Keys
T= 2 mo; 0% Some services likely present at two months even with ongoing disturbance.	End of active cleanup, associated disturbances, and wrack removal - Cleanup methods included predominantly manual removal of oiled sand and wrack removal; however, there was extensive trenching and sediment relocation at Rodeo Beach - Dominant species on sand beaches include amphipods and flies (<1 year life span), Coleopteran beetles (2 year life span), isopods (*Excirolana* with a 2-3 year life span), *Emerita* (<1 year life span); - In a study of the Ixtoc I spill on Texas beaches, the heaviest oiled transect showed a statistically significant reduction (86%) in total intertidal benthic

	invertebrate population densities between pre-spill and 1 month post-spill sampling periods (Thebeau et al., 1981)
T= 7 mo; 50% 75% Sea Empress studies reported no evidence of ongoing injury at 9 months post spill in heavily oiled beaches, an oiling category with much more oil than the CB.	BeachWatch wrack monitoring data indicates no lag in wrack accumulations; however, invertebrate community structures remain altered following wrack removal more than 6 months following removal (J. Dugan, Pers. Comm.) Tarball stranding and re-oiling events continued into May 2007 - PAH concentrations in mussels samples from adjacent to interior beaches indicated a return to ambient levels by March-June 2008, depending on location - Studies of the large crude oil spill from the *Sea Empress* in Wales showed that Crustacea on sand beaches were severely depleted 3 to 6 months post-spill (Moore, 1998) - Abundance of macrofauna dominated by amphipods, isopods, and polychaetes were reduced (often by 20-50%) 6 months after the *Prestige* spill of a heavy fuel oil off Spain (Junoy et al., 2005); the number of species on heavily oiled beaches before the spill was 15-20 versus 10-16 after the spill - A common nemertean was present on 22% of the beaches affected by the *Prestige* oil spill 6 months after the spill, whereas it was present on 61% of the beaches after 18 months (Herrara-Bachiller et al., 2008)
T= 1 yr; 80% 100%	Based on life histories of dominant species (1-3 years), recovery is estimated at 80% after 1 year - Meiofauna on sandy shorelines showed no impacts 9 months after the *Sea Empress* spill in Wales (Moore et al., 1997) - Macroinfauna abundance in sand beaches affected by the *Prestige* spill showed evidence of recovery 18 months post-spill, with isopods and polychaetes mostly recovered; species richness also increased (Castellanos et al., 2007) - Beaches were still heavily oiled 18 months after the spill in the Prestige. In the Sea Empress, no evidence of injury was found after 9 months. Both of these spills resulted in orders of magnitude more oil per square meter on sandy beaches than in the Cosco Busan.
T= 3 yr; 100% Accept	Based on life histories of dominant species (1-3 years), recovery is estimated at 100% in 3 years - Full recovery of sand beach fauna was predicted to take 31 months in experimental oiled-sediment field studies in the Strait of Juan de Fuca, WA (Vanderhorst et al., 1981) - Macrofauna at the heavily oiled beaches at the *Prestige* spill site were not fully recovered after 3 years (Castellanos et al., 2007)

Sand Beach + Moderate Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 0% 40% We have photos of organisms on moderately oiled beaches that are alive. Wrack that is not oiled remains. There cannot be 100% service loss on beaches with only 1-10% cover.	Moderate oiling smothered/fouled fauna using the habitat, rendering it unsuitable for use by fish, invertebrates, and wildlife - 57% of the moderately oiled sand beaches had 1-10% oil cover; 43% had 11-50% oil cover (all in the oiled band) The entire intertidal zone on sand beaches was affected by the oil - Entire intertidal zone up to the oiled band at the high-tide line was impacted as the oil washed across the entire zone; Oil was mixed into the surf zone by wave action, and stranded on the beach face during falling tides - de la Huz et al. (2005) found significant reductions in numbers of species at all 4 tidal zones (from swash to dry) on sand beaches 8 months after the *Prestige* heavy fuel oil spill - Sand lance avoided low levels of oil contaminated sand (113-116 ppm) compared to clean sand (Pinto et al., 1984) All interstitial invertebrate species in spill area or cleanup zone severely affected because of heavily oiled wrack and removal of wrack during cleanup - Beach wrack is inhabited by a wide variety of insect and other arthropod species. Coleopteran beetles and flies (Diptera) are the most abundant, with 35 and 11 species respectively being found in one study. Other groups include mites, spiders, pseudoscorpions, centipedes, isopod crustaceans, hymenopterids (wasps), and orthopterids (Lavoie 1984) - Interstitial detritus as a major food source for these species results in chronic exposure to oil due to unremoved oil permeation. - Chan (1977) reported no organisms in oiled beach wrack nor in the oil-soaked sand 9 days after a 1,500-3,000 barrel spill of emulsified crude oil in the Florida Keys
T= 2 mo; 0% 40%	End of active cleanup, associated disturbances, and wrack removal - Cleanup methods included predominantly manual removal of oiled sand and wrack; however, there was extensive trenching and sediment relocation at Rodeo Beach - Dominant species on sand beaches include amphipods and flies (<1 year life span), Coleopteran beetles (2 year life span), isopods (*Excirolana* with a 2-3 year life span), *Emerita* (<1 year life span); chronic exposure to oil

	would have continuing effects because of their feeding behaviors and association with beach wrack where oil also tends to accumulate - In a study of the Ixtoc I spill in Texas, four out of seven transects showed a decrease of at least 50% in total benthic invertebrate population densities between pre-spill and 1 month post-spill sampling periods for intertidal and shallow subtidal habitats (Thebeau et al., 1981) January 2008 storm resulted in significant re-oiling event across much of East Bay resulting in re-exposure of PAHs to fauna. Several *Mytilus* samples collected from Stege, Emeryville, Albany and Brooks Island in 30-31 January 2008 had PAH concentrations approximately equal, and in several instances up to an order of magnitude higher, than samples collected at the same sites in 20-21 December 2007.
T= 6 mo; 75% 100%	BeachWatch wrack monitoring data indicates no lag in wrack accumulations; however, invertebrate community structures remain altered following wrack removal more than 6 months following removal (J. Dugan, Pers. Comm.) Tarball stranding and re-oiling events along the outer coast sand beaches continued into April 2007 Tarball stranding events have been occurring for decades. What is the initial level of baseline service loss? If very light oiling results in 25% service loss, than the baseline condition of the beach should be 75%. - Mussel and clam samples showed that PAH concentrations in tissues had returned to background levels by March-June 2008 - Studies of the large crude oil spill from the *Sea Empress* in Wales showed that amphipods and Crustacea on sand beaches were severely depleted 3 to 6 months post-spill (Moore, 1998) - The number of species on "lightly" oiled beaches (similar to moderate for the *Cosco Busan*) before the *Prestige* spill of a heavy fuel oil off Spain was 15-20 versus 11-16 (6 months after the spill); abundances at 6 months were also reduced by up to 75% (Junoy et al., 2005)
T= 1 yr; 80% 100%	Based on life histories of dominant species (1-3 years), recovery is estimated at 80% after 1 year - Meiofauna on sandy shorelines showed no impacts 9 months after the *Sea Empress* spill in Wales (Moore et al., 1997)
T= 3 yr; 100% 100%	Based on life histories of dominant species (1-3 years), recovery is estimated at 100%

Sand Beach + Light Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 50% 75% Over 70% of lightly oiled beaches had less than 1% oil cover. It is not rational to conclude that less than 1% of the beach with tarballs can result in the loss of 50% of all organisms and/or services on the beach. There is no evidence of service loss on lightly oiled beaches. The assumption of 75% is very conservative.	Light oiling would foul fauna and reduce the use of the beach habitat by fish, invertebrates, and wildlife - 71% of the lightly oiled sand beaches had <1% oil cover; 18% had 1-10% oil cover; 11% had 10-50% oil cover (all in the oiled band) - Beach wrack is inhabited by a wide variety of insect and other arthropod species. Coleopteran beetles and flies (Diptera) are the most abundant, with 35 and 11 species respectively being found in one study. Other groups include mites, spiders, pseudoscorpions, centipedes, isopod crustaceans, hymenopterids (wasps), and orthopterids (Lavoie 1984); all of these fauna would be affected by even light oiling of the wrack - Mole crabs collected from the south end of Rodeo Beach 10 days post-spill contained elevated PAHs matched to *Cosco Busan* source oil The entire intertidal zone on sand beaches was affected by the oil - Entire intertidal zone up to the oiled band at the high-tide line was impacted as the oil washed across the entire zone; Oil was mixed into the surf zone by wave action, and stranded on the beach face during falling tides - de la Huz et al. (2005) found significant reductions in numbers of species at all 4 tidal zones (from swash to dry) on sand beaches 8 months after the *Prestige* heavy fuel oil spill, even on lightly oiled beaches - The burial with oil of adjacent beaches within many hundreds of miles of coastline in the Prestige oil spill is not consistent with the COSCO BUSAN. This widespread heavy oil exposure may affect neighboring beach recruitment and species abundance, even in the beach itself was lightly oiled, unlike in the Cosco Busan.
T= 2 mo; 50% 100%, this assumption follows from a lack of evidence of injury at time zero, although we are willing to consider some service loss for settlement purposes.	End of active cleanup, associated disturbances, and wrack removal - Cleanup methods included manual removal of tarballs and oiled wrack - Dominant species on sand beaches include amphipods and flies (<1 year life span), Coleopteran beetles (2 year life span), isopods (*Excirolana* with a 2-3 year life span), *Emerita* (<1 year life span); chronic exposure to oil would have continuing effects because of their feeding behaviors and association with beach wrack where oil also tends to accumulate - Bay mussel tissues collected adjacent to lightly oiled Muir Beach on 20 November 2007 contained 16.1 ppm total PAHs; mussels adjacent to lightly oiled beaches in the Emeryville Crescent on 30 January 2008 contained 11.5 ppm and adjacent to lightly oiled beaches on Brooks Island contained 11.4 ppm (all matched to *Cosco Busan* oil), indicating on-going exposure to oil

	- January 2008 storm resulted in significant re-oiling event across much of East Bay resulting in re-exposure of PAHs to fauna. Several *Mytilus* samples collected from Stege, Emeryville, Albany and Brooks Island in 30-31 January 2008 had PAH concentrations approximately equal, and in several instances up to an order of magnitude higher, than samples collected in the same vicinities in 20-21 December 2007. - In experiments sand lance avoided low levels of oil contaminated sand (113-116 ppm) compared to clean sand (Pinto et al., 1984)
T= 7 mo; 90% 100%	BeachWatch wrack monitoring data indicates no lag in wrack accumulations; however, invertebrate community structures remain altered following wrack removal more than 6 months following removal (J. Dugan, Pers. Comm.) Tarball stranding and re-oiling events continued into May 2008 - Studies of lightly oiled and low intensity-cleaned sand beaches 8 months after the Prestige heavy fuel oil spill in Spain showed 40-47% reductions in number of species and large reductions in macrofauna abundance in the upper intertidal zone (de la Huz et al., 2005) - Bay mussel tissues collected adjacent to lightly oiled beaches in March 2008 contained low levels of PAHs that did not match Cosco Busan oil - Meiofauna on sandy shorelines showed no impacts 9 months after the Sea Empress spill in Wales (Moore et al., 1997) Recovery based on assumption that most species would have recovered except for the longer-lived isopods and beetles
T= 1 yr; 100% 100%	Based on life histories of dominant species (1 year), recovery is estimated at 100% after 1 year

Sand Beach + Very Light Oiling

Post-Spill Time/Services Present	Summary of Basis for Assignment of Services Present
T= 0; 75% 100% No evidence of injury and in many cases, no evidence of exposure.	Very light oiling would foul fauna and reduce the use of the beach habitat by fish, invertebrates, and wildlife Many of the very lightly oiled beaches are important habitat for wintering western snowy plover, federally listed as threatened - ~75% of the lightly oiled sand beaches had <1% oil cover; 25% had 1-10% oil cover (all in the oiled band) The entire intertidal zone on sand beaches was affected by the oil - Entire intertidal zone up to the oiled band at the high-tide line was impacted as the oil washed across the entire zone; Oil was mixed into the surf zone by wave action, and stranded on the beach face during falling tides
T= 2 mo; 75% 100%	End of active cleanup, associated disturbances, and wrack removal - Cleanup methods included mostly manual removal of tarballs and oiled wrack - Dominant species on sand beaches include amphipods and flies (<1 year life span), Coleopteran beetles (2 year life span), isopods (*Excirolana* with a 2-3 year life span), *Emerita* (<1 year life span); chronic exposure to oil would have continuing effects because of their feeding behaviors and association with beach wrack where oil also tends to accumulate
T= 7 mo; 95% 100%	Tarball stranding and re-oiling events continued into May 2007 - Recovery based on assumption that most species would have recovered except for the longer-lived isopods and beetles - Meiofauna on sandy shorelines showed no impacts 9 months after the *Sea Empress* spill in Wales (Moore et al., 1997)
T= 1 yr; 100% 100%	Based on life histories of dominant species (1 year), recovery is estimated at 100% after 1 year

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Table 1. Trustees original HEA Inputs in BLACK. Trustees Revisions to HEA Inputs in RED
RP NMO = Not Measurable or Observable, No evidence

Services Present for SALT MARSH

Very Light	Light	Moderate	Heavy
0 / 75% NMO	0 / 50% 75%	0 / 50%	0 / 0% 25%
2 mo / 75% NMO	2 mo / 50%75%	2 mo / 50%	2 mo / 0%25%
1 yr / 100%	1 yr / 75%100%	1 yr / 75%100%	1 yr / 50%75%
	3 yr / 100%	3 yr/ 100%	5 yr / 100%

Services Present for TIDAL FLATS (adjacent to..)

Very Light	Light	Moderate	Heavy
0 / 95%NMO	0 / 85% 90%NMO	0 / 75%NMO	0 / 75%
2 mo / 95%NMO	7 mo / 90% 95%NMO	2 mo / 75% 85% NMO	2 mo / 75%
7 mo / 100%NMO	1 yr / 100%	7 mo / 85% 95% NMO	7 mo / 85% 90%
		1 yr / 100%	1 yr / 100%

Services Present for SAND BEACHES

Very Light	Light	Moderate	Heavy
0 / 50% 75% NMO	0 / 50%75%	0 / 0%40%	0 / 0%
2 mo / 50% 75% NMO	2 mo / 50%75%	2 mo / 0% 40%	2 mo / 0%
7 mo / 90% 95% NMO	7 mo / 80% 90% 100%	6 mo / 25% 75% 100%	7 mo / 25% 50% 75%
1 yr / 100%	1 yr / 100%	1 yr / 80%100%	1 yr / 75% 80% 100%
		3 yr / 100%	3 yr / 100%