FINAL REPORT

SHORELINE INJURY ASSESSMENT

M/T ATHOS 1 OIL SPILL

Prepared by:

Shoreline Assessment Team

21 March 2007

PREFACE

This report was prepared by the Shoreline Assessment Team for the *M/T Athos* oil spill. Membership included the following agencies and individuals:

Delaware Department of Natural Resources and Environmental Control – Rob Hossler
New Jersey Department of Environmental Protection – David Bean
Pennsylvania Department of Environmental Protection – Alan Everett
Pennsylvania Department of Conservation and Natural Resources – Autumn Sabo
National Oceanic and Atmospheric Administration – Jim Hoff and Kate Clark
U.S. Fish and Wildlife Service – Al Rizzo
Research Planning, Inc. – Jacqueline Michel and Heidi Hinkeldey Dunagan
Polaris Applied Sciences, Inc. – Greg Challenger

TABLE OF CONTENTS

LIST OF APPENDICES

EXECUTIVE SUMMARY

On November 26, 2004, the tanker *M/T Athos 1* struck several submerged objects while preparing to dock at the CITGO refinery in Paulsboro, NJ, resulting in the release of an estimated 265,000 gallons of Bachaquero Venezuelan crude oil into the Delaware River. Shoreline Cleanup Assessment Team (SCAT) survey data collected to support the response and cleanup were a key source of information for assessing shoreline injury. These data were processed through several data quality checks and updated where necessary. Based on the revised SCAT data, it was determined that the spill resulted in the oiling of 279 miles of shoreline along the mainstem of the river and oiling of six tributaries.

The oiled shoreline was grouped into four habitat types: seawalls, sand/mud substrates, coarse substrates, and marshes. The SCAT oiling data were used to develop four exposure categories for each of these habitats: very light, light, moderate, and heavy. The oiled tributaries were treated as entire systems where open water, shoreline habitats (i.e. isolated wetlands), an oiled wetland fringe along the shoreline, and associated tidal flats were assigned an appropriate oiling category based on aerial observations of the extent and thickness of sheens, shoreline oiling from SCAT surveys, and other ground observations.

On moderately and heavily oiled habitats, the injured area was extended beyond the footprint of the oil band as described during the SCAT surveys for two reasons: 1) the use of high-pressure, hot-water flushing in the Spring of 2005 on many of the seawalls and coarse habitats exposed the lower intertidal zone to both oil and hot-water during cleanup; and 2) the lower intertidal zones were observed being chronically exposed to oil that was released from adjacent moderately and heavily oiled shorelines through the summer of 2005. Thus, the shoreline assessment includes injuries to the entire intertidal zone to mean low water along the river mainstem. The methods to estimate the area of exposure for each habitat are described in detail in the report. Table ES-1 shows the number of acres across all three states by oiling level and habitat type.

TABLE ES-1. Total estimated area (acres) of exposed habitat across all states.

Habitat Type	Oiling Level	Shoreline (Acres)	Lower Intertidal Zone (acres)*	Tidal Flat (acres)**	Total By Habitat (acres)	Percent of Total Oiling
Seawalls	Very Light	8.66			8.66	0.50%
	Light	17.72			17.72	1.02%
	Moderate	30.46			30.46	1.76%
	Heavy	2.54			2.54	0.15%
Subtotals		**59.38**			**59.38**	**3.43%**
Sand/Mud Substrate	Very Light	7.39	55.69	677.43	740.51	42.83%
	Light	9.98	26.94	279.54	316.46	18.30%
	Moderate	9.94		205.48	215.42	12.46%
	Heavy	8.24		135.20	143.44	8.30%
Subtotals		**35.55**	**82.63**	**1297.65**	**1415.83**	**81.89%**
Coarse Substrate	Very Light	16.23			16.23	0.94%
	Light	66.08			66.08	3.82%
	Moderate	36.91			36.91	2.13%
	Heavy	18.01			18.01	1.04%

TABLE ES-1. Cont.

Subtotals		**137.23**			**137.23**	**7.94%**
Marsh	Very Light	51.83			51.83	3.00%
	Light	40.89			40.89	2.36%
	Moderate	17.22			17.22	1.00%
	Heavy	6.53			6.53	0.38%
Subtotals		**116.47**			**116.47**	**6.74%**
TOTAL MAINSTEM HABITATS					**1728.91**	**100%**
Tributaries	Very Light	583.25			583.25	30.71%
	Light	1216.08			1216.08	64.03%
	Moderate	99.90			99.90	5.26%
	Heavy	0			0	0
Subtotals		**1899.23**			**1899.23**	**100%**
TOTAL OILED TRIBUTARIES					**1899.23**	**100%**

* Lower ITZ values were only shown separately for the sand/mud substrate because they represented the majority of the injury for the sand/mud substrate category.

** Tidal flat acreage under the sand beach habitat includes flats from both sand beach and marsh habitat categories.

A Habitat Equivalency Analysis (HEA) model was used to calculate the initial loss of services and the recovery rate for services for all habitat and oiling categories, expressed in discounted service-acre years (DSAYs). The spilled oil was a heavy, viscous oil that contained relatively low polynuclear aromatic hydrocarbons (PAH). Thus it posed little chemical toxicity. However, the oil posed significant physical impacts associated with smothering and fouling where the oil initially stranded onshore and during chronic re-oiling as residual oil was re-mobilized throughout 2005. The initial injury and recovery rates developed for the *M/T Athos 1* spill were based on the type and timing of cleanup methods used on the different shoreline types and oiling degree, visual observations during site visits in July and September 2005, the results of chemical analysis of the oil and sediment samples, vegetative conditions, and the life histories of fauna associated with the intertidal and shallow subtidal habitats of the Delaware estuary, as well as published studies of past spills. Table ES-2 shows the number of DSAYs calculated for each habitat type by oiling degree.

The injury was quantified using metrics that can be used to scale appropriate compensatory restoration options, the next step of the Natural Resource Damage Assessment.

TABLE ES-2. Total number of DSAYs calculated for each habitat by oiling degree.

Habitat	**Very Light Acres**	**DSAYs**	**Light Acres**	**DSAYs**	**Moderate Acres**	**DSAYs**	**Heavy Acres**	**DSAYs**	**Total Acres Per Habitat**	**Total DSAYs Per Habitat**
Seawalls	8.7	0.3	17.7	2.0	30.5	25.9	2.5	2.2	59.4	30.3
Sand/Mud	740.5	443.0	316.5	204.2	215.4	278.1	143.4	191.9	1415.8	1117.2
Coarse	16.2	5.5	66.1	42.6	36.9	52.7	18.0	25.9	137.2	126.8
Marsh	51.8	11.5	40.9	22.5	17.2	16.7	6.5	9.3	116.5	60.0
Tributaries	583.3	108.2	1216.1	375.3	99.9	40.1	0.0	0.0	1899.2	523.5
Total DSAYs		**639.4**		**747.7**		**413.2**		**229.2**		**1857.8**

SHORELINE INJURY ASSESSMENT: *M/TATHOS 1* OIL SPILL

1.0 INTRODUCTION

1.1 Background

On the evening of November 26, 2004, the tanker *M/T Athos 1* began leaking oil into the Delaware River while it executed a berthing maneuver in route to its terminal, the CITGO asphalt refinery in Paulsboro, New Jersey. The U.S. Coast Guard estimated that 265,000 gallons of a heavy Venezuelan crude oil were released from the tanker into the river (Preassessment Data Report, 2005). The spill affected a variety of natural resources, including intertidal habitats, wildlife, and aquatic resources.

Under the Oil Pollution Act, the states of Delaware and New Jersey, the Commonwealth of Pennsylvania, the U.S. Fish and Wildlife Service on behalf of the Department of the Interior, and the National Oceanic and Atmospheric Administration on behalf of the Department of Commerce (collectively referred to as the Trustees), are responsible for assessing natural resource injuries resulting from this incident. The Trustees have worked cooperatively with representatives of the responsible party (Tsakos Shipping and Trading S.A) to assess potential shoreline injuries through a Shoreline Assessment Team Technical Working Group (SAT). This report describes the methodology, data collection, and findings on the spatial and temporal extent of injury to the shoreline. The draft maps included in the appendices show the degree of oiling for the impacted shoreline segments as well as the Environmental Sensitivity Index (ESI) shoreline types for Delaware, New Jersey, and Pennsylvania (NOAA, 1996). Research Planning, Inc. (RPI) provided technical assistance to the Trustees; Polaris Applied Sciences, Inc. is the technical representative for Tsakos Shipping and Trading S.A.

The overall goal of the Shoreline Assessment is to quantify the nature and extent of injury to shoreline natural resources, including intertidal habitats and communities, and to identify appropriate options to restore those resources and/or associated services to baseline or pre-spill conditions. Data and surveys conducted during the cleanup phases of the response of the spill were used to determine the degree and geographic extent of oiling by habitat type, including injuries resulting from shoreline cleanup activities (e.g., manual removal of oiled sediments and small debris, high-pressure hot-water flushing of riprap, large debris, seawalls, and gravel, vegetation cutting, etc.). Cleanup activities shifted to the maintenance and monitoring phase on 1 June 2005; maintenance consisted of oiled boom and snare replacement, and state and U.S. Coast Guard representatives monitored the impact area for changes in oiling condition that might trigger the need for additional response actions. The basis for the assumption of injury to shoreline resources include the field observations and measurements made during the cleanup phase, as well as oil spill case histories, and literature values. The Habitat Equivalency Analysis (HEA) model approach was used to quantify injuries by habitat type and scale appropriate restoration projects. Field observations were used to develop HEA model inputs.

1.2 Oil Characteristics

Two samples of the oil from hold No. 7 center (the source oil) were analyzed for physical properties and chemical characteristics, with the following results:

Density: 0.973 and 0.978 grams per milliliter; fresh water is 1.00 and oceanic sea water is 1.025 g/ml. Therefore, the oil is lighter than both fresh water and sea water.

Viscosity: greater than 5,000 centiStokes (cSt) at 100°F and at ambient water temperature greater than 50,000 cSt, meaning that the oil's viscosity is similar to cold honey;

Composition: the oil is a heavily biodegraded crude oil, depleted in lower molecular weight hydrocarbons and n-alkanes. The concentrations of compounds of acute and chronic toxicity are low: monoaromatic hydrocarbons (e.g., benzene, toluene) comprise 0.02% and polynuclear aromatic hydrocarbons (PAH) comprise 0.6% (Michel et al., 2004; Donlan et al., 2005).

Based on these oil characteristics, the spilled oil is likely to have limited acute mortality resulting from exposure to the dissolved fractions in the water column, but significant physical impacts associated with smothering and fouling are possible. Also, this heavy oil will weather slowly and be highly persistent in the environment, as has been observed since the spill.

1.3 Cleanup Methods

The cleanup was divided into two phases: 1) gross oil removal using mostly manual methods from December 2005 to January 2006; and 2) shoreline cleanup using manual removal of patties and tarmats in previously cleaned areas as they were exposed, high-pressure, hot-water flushing of riprap, bulkheads, and seawalls using hotsy-type units, and oiled debris removal extended from February-May 2006. An estimated 90 percent of the hard substrates that were oiled (seawalls, riprap, bulkheads) were treated with hotsy washing (Ploen, pers. comm., 2006) because it was the only way to remove the oil.

The "hotsy" units consist of a heater and a hand-held sprayer, and the volume of water was generally less than 3.5 gallons per minute. It is important to note that the volume of water used in high-pressure, hot-water flushing with a hotsy is very different than the 500 gallons per minute of 140°F water supplied by the "omni-barge" during the *Exxon Valdez* oil spill. Thus, the likely impacts of wash water flowing across the lower intertidal zone, while significant, were not on the order of what was found for treated shorelines in Prince William Sound (Lees et al., 1996).

When active cleanup was terminated along a shoreline segment, sorbents were deployed, where necessary, to recover any oil that was mobilized, particularly during the warmer summer months. Oil droplets and sheens were frequently observed during site visits by the SAT on June 7 and September 22, 2005 along the mainstem of the river in the areas that were moderately and heavily oiled. There was also evidence of remobilization of oil that was submerged in the nearshore subtidal areas.

1.4 Habitat Equivalency Analysis

Natural resource trustees are authorized to act on behalf of the public to protect the resources of the nation's environment. Under the Oil Pollution Act of 1990, trustee agencies determine the damage claims to be filed against parties responsible for injuries to natural resources resulting from discharges of oil; *injury* is defined as "an observable or measurable adverse change in a natural resource or impairment of a natural resource service." Claims can be made for *primary* restoration (actions taken to directly restore the injured resources) and *compensatory* restoration (actions taken to replace the interim loss of resources from the time of injury until the resources recover to baseline conditions). For injuries resulting from oil spills, shoreline cleanup is a key part of the primary restoration actions that are taken. Often, there are few additional actions that can be taken to restore the injured resources, thus the injury assessment is based on the loss of services during the natural recovery period. Habitat equivalency analysis (HEA) is a methodology used to determine compensation for such resource injuries. The principal concept underlying the HEA method is lost habitat resources/services can be compensated through habitat replacement projects providing additional resources/services of the same type (NOAA, 2000a).

Under the HEA method, trustees determine the injury using metrics that can be used to scale appropriate compensatory restoration options. The size of a restoration action is scaled to ensure that the present discounted value of project gains equals the present discounted value of interim losses. That is, the proposed restoration action should provide services of the same type and quality, and of comparable value as those lost due to injury (NOAA, 2000a). The selection of the metric(s) to quantify the injury and scale restoration options is key to the successful application of the HEA method. Therefore, the SAT carefully considered the ecological services provided by the shoreline habitats that were injured as result of the *M/T Athos 1* oil spill. The full list of services and functions considered can be found in Appendix A. Food-web support and habitat usage were common ecological services among all habitat types, and these ecological services were considered to be the most valuable.

Under the HEA method, the injuries are quantified in terms of the percent loss of ecological services (compared to pre-spill baseline levels) and the rate at which the lost services recover over time. Figure 1 shows a hypothetical curve of the reduction in services for a habitat after an incident and the expected rate of natural recovery. The inputs into such curves for each injured habitat are: 1) the percent loss in services immediately after the incident; and 2) the percent of baseline services at key points in time after the injury. For example, the ecological services as measured by habitat usage and food-web support to birds for a moderately oiled sand beach might be reduced to 0 percent of baseline during the period from the spill to when shoreline cleanup was terminated, because birds would have avoided oiled areas, as well as been disturbed by cleanup activities, and their preferred prey items would be reduced in abundance. Recovery would be a function of the rate of oil degradation and the life history of key intertidal biota on which the birds feed. By the end of the first reproductive period, the services might be predicted as 50 percent of baseline; by the end of the second year, services might be predicted to have returned to 80 percent of baseline; full recovery might be predicted to occur at the end of the third year of reproduction. The injury is then quantified using a term called a discounted-service-acre-year. The injury is discounted each year after the spill at a standard rate to express future quantities in present terms. For the above example, if the injured area was 1 acre, the estimated injury would be 1.2 discounted service-acres-years (DSAYs), as shown in Table 1.

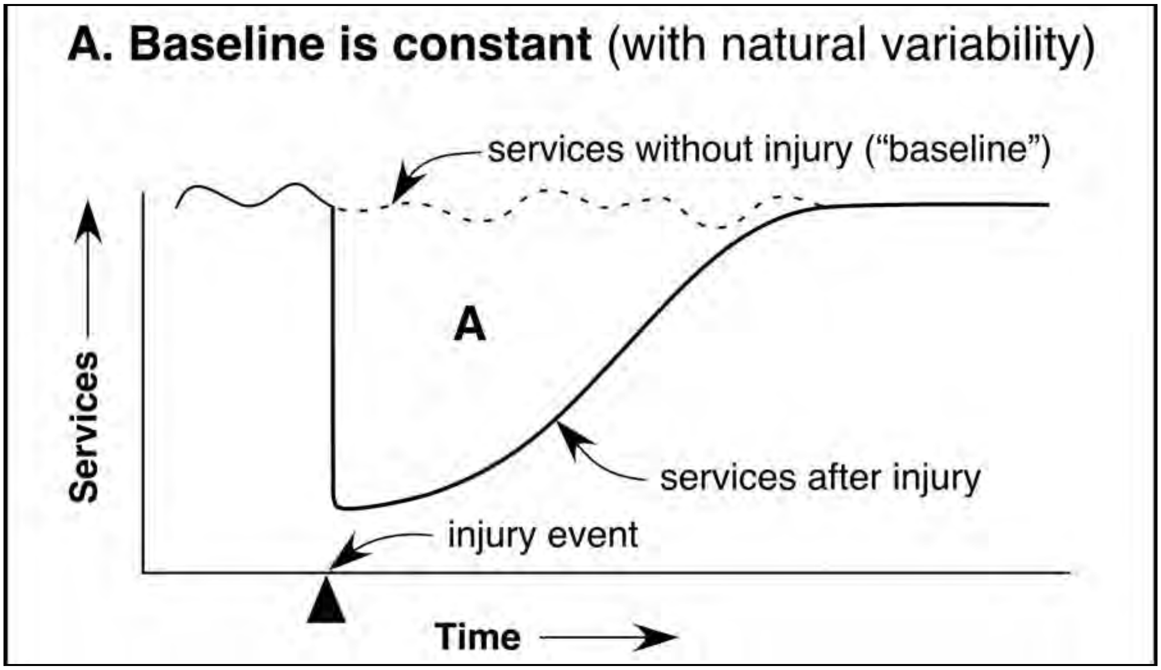

FIGURE 1. Hypothetical curve showing the lost services after an oil spill and the expected rate of natural recovery, for habitats where the baseline is constant, though undergoing natural variability.

TABLE 1. Hypothetical injury calculated for 1.0 acre of moderately oiled sand beach habitat.

Years Post Spill	Year	Average Percent Service Loss	Discount Factor[1]	Discounted Ave. Percent Services Lost[2]	Discounted Service Acre Years Lost[3]
0	2003	75%	1.000	75%	0.750
1	2004	35%	0.971	34%	0.340
2	2005	10%	0.943	9%	0.094
3	2006	0%	0.915	0%	0.000
Total Discounted Service Acre Years Lost					**1.184**

[1] the standard discount rate, 3 percent
[2] (discount factor) * (average percent service loss)
[3] (acres injured (1.0)) * (discounted average percent services lost)

2.0 METHODS FOR DETERMINING INJURY CATEGORIES AND AREAS

2.1 Mapping the Distribution of Oil

Estimates of the spatial extent of oiling to mainstem Delaware River habitats and associated tributaries were developed through the following multi-step process:

a) Oil Distribution Mapping - Field observations of shoreline oiling from SCAT surveys incorporated into a GIS were used to identify exposed shoreline areas and estimate the degree of oiling (e.g., very light, light, moderate, or heavy);
b) Implementation of Quality Assurance Checks - A series of quality control checks were implemented to confirm the accuracy of data used for shoreline damage assessment purposes;
c) Determination of Shoreline Habitat Types - Using Geographical Information System (GIS) software, oiled shoreline areas were classified by habitat type to better characterize potential oiling impacts and recovery trajectories; and
d) Estimation of the Area of Exposure - Information generated from the previous steps, combined with data about tidal heights, oil band width, and other data were used to calculate areas of exposure for each combination of habitat type and oiling degree.

Data from Shoreline Cleanup Assessment Team (SCAT) surveys collected during the response and cleanup efforts were used to determine the geographic extent of shoreline oiling. Multi-agency teams collected data on the degree of oiling and the habitat type, with most surveys completed within two weeks after the spill, so there was little risk of mis-identification of oil from the *M/T Athos 1* with other spill sources. The shoreline was divided into segments. For each segment, field observations were recorded onto standard forms including width of the oiled band, percent oil coverage in the band, oil thickness, and shoreline type. The SCAT data were entered into an Access™ database daily by the *M/T Athos I* Environmental Unit (EU). These data were used to create summaries of the degree of oiling for each segment.

An ArcInfo™ spatial database was created by the EU to provide GIS maps of the degree of oiling for each shoreline segment. For shoreline injury assessment purposes, the SCAT data were translated into oiling categories based on guidance provided in the NOAA (2000b) Shoreline Assessment Manual. Consistent with that guidance, the oiling categories used for shoreline damage assessment purposes include very light, light, moderate, or heavy (VL, L, M, or H). Areas that were surveyed but had no oil were labeled as “clean.” Areas with no oiling category indicate that the shoreline was not surveyed and no observations exist for that area. The EU replaced meters with feet (ft) within the oiling category guidance provided by the National Oceanic and Atmospheric Administration (NOAA) Shoreline Assessment Manual to provide a better understanding of the relative oiling levels for exposed shorelines specific to this spill. The definition of three oiling categories were modified for injury assessment, as identified below:

1) "Light oiling" changed to "moderate oiling" for <0.5 ft width and 91-100% coverage;
2) "Moderate oiling" changed to "heavy oiling" for >0.5–3ft width and 91-100% coverage; and
3) "Moderate oiling" changed to "heavy oiling" for >3–6 ft width and 51-90% coverage.

These oiling category changes were made to better reflect likely impacts to intertidal habitats, which would not be captured adequately by measurements of the width and coverage of the oiled band at the shoreline. It was determined that, even where the oiled band on the shoreline was very narrow (less than 3 ft), most of the intertidal communities and services within that oiled band would be significantly affected where the oil covered more than 50 % of the area in the band.

Oiling categories were assigned within each shoreline segment based on the width, percent cover of oil, and oil thickness observed on the shoreline by the SCAT teams (Table 2). For the shoreline injury assessment, the heaviest oiling was selected from among the SCAT observations on different dates, and so represent the maximum oiling observed within each segment.

TABLE 2. Shoreline oiling categories based on the oiled band width, percent oil cover, and oil thickness in the oiled band.

Shoreline Oiling Width	% Oiling within Shoreline Oiling Width	Oil Thickness	Oiling Category
<0.5 feet	<1%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Very Light
		>.1-1.0 cm (cover)	Light
		>1 cm (thick or pooled)	Light
	1-10%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Very Light
		>.1-1.0 cm (cover)	Light
		>1 cm (thick or pooled)	Light
	11-50%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Very Light
		>.1-1.0 cm (cover)	Light
		>1 cm (thick or pooled)	Light
	51-90%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Light
		>.1-1.0 cm (cover)	Moderate
		>1 cm (thick or pooled)	Moderate
	91-100%	<.01 cm (film)	Light
		>.01-.1 cm (coat)	Moderate
		>.1-1.0 cm (cover)	Moderate
		>1 cm (thick or pooled)	Heavy
>0.5-3 feet	<1%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Very Light
		>.1-1.0 cm (cover)	Light
		>1 cm (thick or pooled)	Light

TABLE 2. Cont.

>0.5-3 feet			
	1-10%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Very Light
		>.1-1.0 cm (cover)	Light
		>1 cm (thick or pooled)	Light
	11-50%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Light
		>.1-1.0 cm (cover)	Moderate
		>1 cm (thick or pooled)	Moderate
	51-90%	<.01 cm (film)	Light
		>.01-.1 cm (coat)	Moderate
		>.1-1.0 cm (cover)	Moderate
		>1 cm (thick or pooled)	Heavy
	91-100%	<.01 cm (film)	Light
		>.01-.1 cm (coat)	Moderate
		>.1-1.0 cm (cover)	Heavy
		>1 cm (thick or pooled)	Heavy
>3-6 feet	<1%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Very Light
		.1-1.0 cm (cover)	Light
		>1 cm (thick or pooled)	Light
	1-10%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Light
		>.1-1.0 cm (cover)	Moderate
		>1 cm (thick or pooled)	Moderate
	11-50%	<.01 cm (film)	Light
		>.01-.1 cm (coat)	Moderate
		.1-1.0 cm (cover)	Moderate
		>1 cm (thick or pooled)	Heavy
	51-90%	<.01 cm (film)	Light
		>.01-.1 cm (coat)	Moderate
		>.1-1.0 cm (cover)	Heavy
		>1 cm (thick or pooled)	Heavy
	91-100%	<.01 cm (film)	Light
		>.01-.1 cm (coat)	Moderate
		>.1-1.0 cm (cover)	Heavy
		>1 cm (thick or pooled)	Heavy

TABLE 2. Cont.

>6 feet	<1%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Very Light
		>.1-1.0 cm (cover)	Light
		>1 cm (thick or pooled)	Light
	1-10%	<.01 cm (film)	Very Light
		>.01-.1 cm (coat)	Light
		>.1-1.0 cm (cover)	Moderate
		>1 cm (thick or pooled)	Moderate
	11-50%	<.01 cm (film)	Light
		>.01-.1 cm (coat)	Moderate
		>.1-1.0 cm (cover)	Moderate
		>1 cm (thick or pooled)	Heavy
	51-90%	<.01 cm (film)	Light
		>.01-.1 cm (coat)	Moderate
		>.1-1.0 cm (cover)	Heavy
		>1 cm (thick or pooled)	Heavy
	91-100%	<.01 cm (film)	Light
		>.01-.1 cm (coat)	Moderate
		>.1-1.0 cm (cover)	Heavy
		>1 cm (thick or pooled)	Heavy

2.2 Review of the SCAT/ESI Data

To check for errors and evaluate the accuracy of the Access database and the GIS data, the following tasks were completed:

1.) A manual check of the SCAT forms and Access database against the GIS data by incorporating the GPS coordinates from the SCAT forms as a data layer within the GIS.
2.) A manual check of approximately 30% of the records in the Access database against the original SCAT forms.
3.) A manual check of the blank records in the Access database against the SCAT forms to verify that all data that may affect oiling level assignments were entered.
4.) A manual check of those records from #2 in the Access database against the GIS data.
5.) An automated check to assign the maximum oiling level to all records within the GIS.
6.) Review of possible mislabeled ESI classifications.

Overall, these reviews and associated edits confirmed the accuracy of data used for shoreline injury assessment purposes. Edits made in response to the review of the SCAT forms, Access database, and GIS data are documented in Appendix B. In addition to the checks identified above, the SAT reviewed draft shoreline oiling maps and made changes to the oiling exposure in locations they or SCAT members within their respective agencies observed. Changes were made digitally within the GIS database. The justification for each change is listed under the "RPIChange" column in the attribute table of the GIS data.

2.3 Determining Shoreline Habitat Types

The next step in determining the shoreline injury was to review the shoreline habitat types used in the GIS data. The shoreline classification data originated from the ESI Atlas for Delaware, New Jersey, and Pennsylvania (NOAA, 1996) and include:

1A Exposed rocky shores/rocky banks
1B Exposed man-made structures
2A Exposed wave-cut platforms in rock
3 Fine to medium-grained sand beaches
Coarse-grained sand beaches
Mixed sand and gravel beaches
6A Gravel beaches
6B Riprap
7 Exposed tidal flats
8A Natural banks
8B Sheltered man-made structures
9A Sheltered tidal flats
10A Salt and brackish-water marshes

Shoreline types that provide similar services were grouped together into six habitat categories: seawalls, sand beaches, coarse substrate, mainstem fringing marshes, tributary creeks, and lower intertidal zone buffer areas, as follows:

a) <u>Seawalls</u> – sheltered manmade structures (ESI=8B), exposed man-made structures (ESI=1B).

b) <u>Sand/Mud substrates</u>– fine- to medium-grained sand beaches (ESI=3), coarse-grained sand beaches (ESI=4), mixed sand and gravel beaches (ESI=5), associated exposed and sheltered tidal flats (ESI=7 and 9A), and natural banks (8A).

c) <u>Coarse substrates</u> – gravel beaches (ESI=6A), riprap (ESI=6B), exposed wave-cut platform in rock (ESI=2A), and exposed rocky shores/rocky banks (ESI=1A).

d) <u>Mainstem fringing marshes</u> – salt, brackish, and freshwater marshes (ESI=10A) along the Delaware River, and associated tidal flats (ESI=7 and 9A).

e) <u>Tributary creeks</u> – Six oiled creeks in NJ were treated as an entire system where open water, shoreline habitats (i.e. isolated wetlands), an oiled wetland fringe along the shoreline, and associated tidal flats (ESI=7 and 9A) were assigned an appropriate oiling category based on aerial observations of the extent and thickness of sheens, shoreline oiling from SCAT surveys, and other ground observations.

f) Lower intertidal zone buffer areas - The lower intertidal zone (ITZ) is treated as a separate injury category, and injury was calculated using methods described in Section 2.4.

Figure 2 shows the percentage of shoreline oiling for the first four habitat classifications identified above (seawalls, sand/mud substrates, coarse substrates, and marshes). Tributary creeks and lower intertidal zone buffer areas are not included in the figure calculations. Of the seawall habitat category, 98% of the shoreline is made up of exposed seawalls. Mixed sand and gravel beaches comprise the majority of the sand/mud substrate category (63%), while riprap is the largest contributor to the coarse substrate category (98%). These data were helpful in determining the appropriate methodology used to calculate the intertidal area of impact for each habitat category.

Some shorelines consisted of a combination of more than one habitat type (i.e., sand beach occurring seaward of a salt marsh). When two habitat types were present along the mainstem of the Delaware River, it was assumed that the oil was distributed evenly between the shoreline types, unless the SCAT data indicated otherwise.

The SCAT data reflect the geographic extent of direct impacts from the final footprint of the stranded oil on the shoreline. However, both the temporary stranding of oil at low tide immediately following the spill and the chronic release of oil from the heavy and moderately oiled shorelines would have contributed to injury on the lower ITZ. Furthermore, moderately and heavily oiled shorelines often underwent intensive cleanup, including the use of high-pressure, hot-water flushing, and the runoff would have impacted the lower ITZ. Therefore, the lower ITZ (below the footprint of the stranded oil) along moderately and heavily oiled shorelines was treated as a separate injury category, and the injury to the lower ITZ of sand beach/flat, coarse substrate, and mainstem fringing marshes was calculated using methods that are discussed below. For most past NRDA cases, the shoreline injury assessment focused on the oil footprint as recorded by the SCAT data. However, during the *T/B Bouchard 120* spill of a heavy fuel oil in Buzzards Bay, Massachusetts, while the SAT followed the traditional approach of quantifying injury in the oil footprint, it was recognized that there were significant impacts to the lower intertidal zone from both the oil and cleanup efforts. Thus the lower intertidal zone impacts were included in the Aquatics injury assessment, separate from the Shoreline injury assessment. This split of the intertidal zone injury into two different assessment methods was not efficient, and eventually it was decided to combine all of the intertidal injury during the restoration scaling efforts. Because the *M/T Athos 1* spill conditions were somewhat similar to the *T/B Bouchard 120* spill, it was decided that the SAT should consider all intertidal habitat injuries. For the present calculations, the lower ITZ areas were included in the appropriate habitat category, but the ITZ values were shown in a separate column in the tables in Section 3.0.

2.4 Estimating the Area of Exposure

The combination of habitat type and oiling level was used to determine the exposure categories. Twenty-five exposure categories were identified initially, of which:

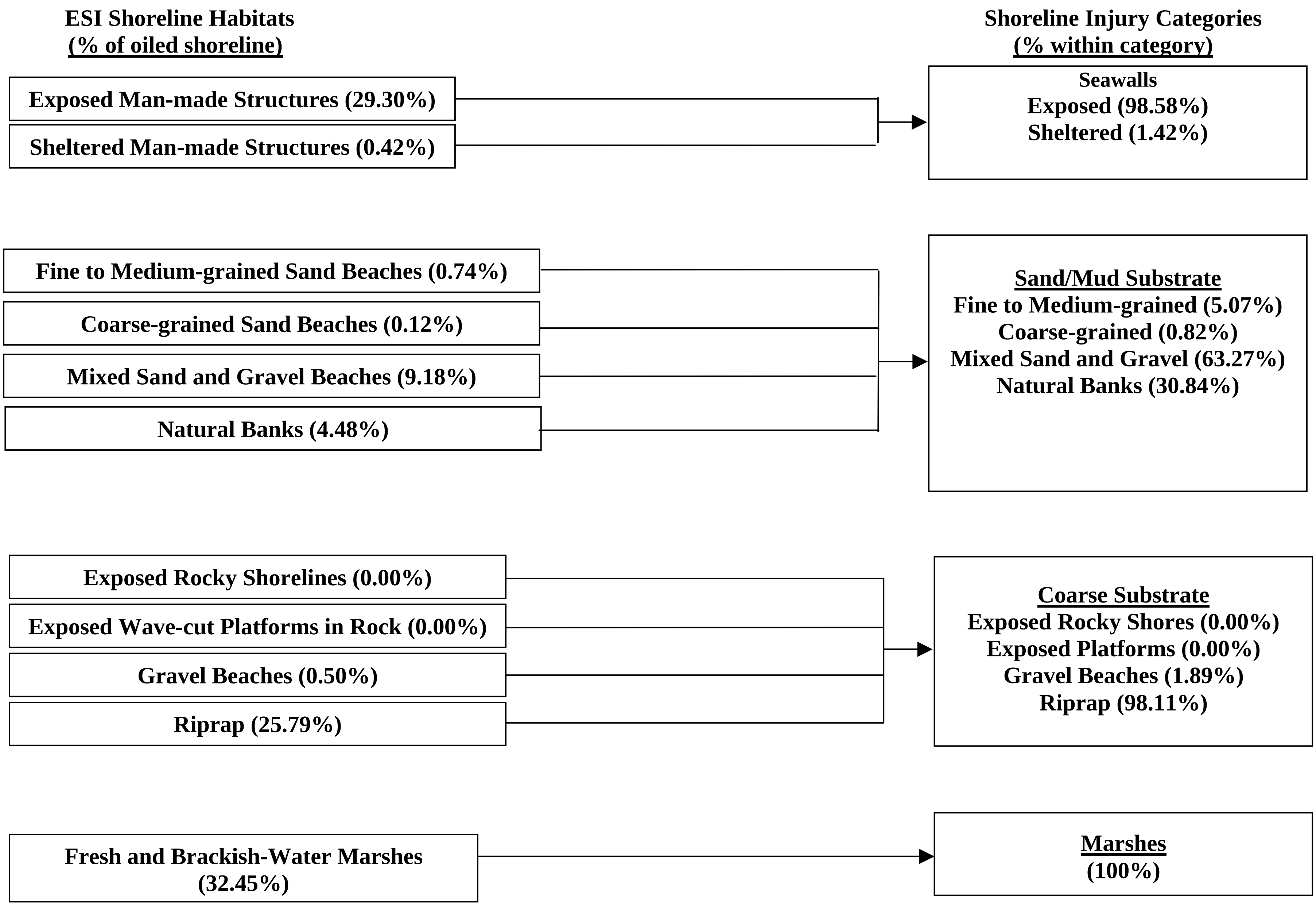

FIGURE 2. Distribution of shoreline types and injury categories as percent of total shoreline length oiled, excluding tidal flats which are represented as polygons and not included in the linear shoreline lengths.

- 16 categories included the four habitat types (Figure 2) at each of the four oiling levels,
- 3 categories included the tributary creeks at three oiling levels (VL, L, and M; there were no heavily oiled tributaries).
- 2 categories included the lower ITZ for sand beaches/flats (2 oiling levels, VL and L),
- 2 categories included the tidal flats seaward of mainstem fringing marshes (2 oiling levels, VL and L), and
- 2 categories that included the sand flats fringing Tinicum Island and Fort Mifflin that were observed to be moderately or heavily oiled during the SCAT surveys.

The area of exposure was estimated separately for each habitat type, as there were variations in the methodology depending on the ESI classification. The parameters included in the oiled area calculations were spring tide height, oiled band width, the area of tidal flats, and segment length. Once the area of exposure was determined for each habitat, the sand flat areas were combined with other sand/mud habitats (as indicated in Fig. 2), resulting in sixteen final injury categories.

2.4.1 Spring Tide Height

The spring tide height was used to estimate the width of the intertidal zone for shoreline types that were vertical (seawalls) or could be assumed to have a uniform slope (riprap). The spring tidal range was estimated using the predicted tide tables for December 2004, from the NOAA CO-OPS website (http://www.co-ops.nos.noaa.gov/tide_pred.html). The tidal range from 50 tidal stations, located in Delaware Bay, Delaware River and inside the tributaries, was obtained from the maximum and minimum tide levels across all days within the month. The tidal range was then attached to the GPS coordinates for each tidal station and incorporated as a point data layer into a GIS. Using an Inverse Distance Weighting algorithm, a tidal range surface was interpolated from the various points along the river and tributaries. The interpolated surface was then divided into 1 ft intervals, and these breaks were used to assign a tidal range to all shoreline segments. Three ranges were estimated along the shoreline: 6 ft, 7 ft, and 8 ft (Appendix C, map index). The tidal range of 8 ft occurred in Delaware Bay and decreased to 7 ft and then 6 ft as the range was measured in the Delaware River and further upstream, respectively. Shoreline oiling does not currently fall within the 8 ft zones (within Delaware Bay); therefore, this value was not used in the area calculations.

2.4.2 Oiled Band Width

Many SCAT forms contained information on the width of the oiled band, but this information was not available for all oiled segments. Thus, some assumptions and extrapolations were necessary. For all oiled shorelines in the mainstem of the Delaware River, widths recorded on each SCAT form distinguished by oiling category were averaged together to produce a mean width for each oiling level: very light (3.57 ft), light (7.55 ft), moderate (8.11 ft), and heavy (13.36 ft). These averages are based on all widths in the database for each oiling category with the exception of widths greater than 30 ft (11 total records). The majority of these unusually large widths included tidal flats and so were unlikely to reflect "typical" shoreline oil band widths. Excluding these outlier records provided a more conservative basis for estimating oil band width for segments at which such data were not recorded.

Trustees from DE, NJ, and PA measured the width of representative sand beach and coarse substrate shorelines within each states' boundaries. The field measurements were necessary in order to determine the area of the entire ITZ that would have been impacted on the moderately and heavily oiled beaches due to cleanup activities and oil runoff. Figure 3 shows the individual widths collected during the field visits by state. The sand beach category (which included sand beach and mixed sand and gravel) had an average width of 53 ft. The widths for coarse substrate were averaged based on the type of habitat within this category, for example, gravel shorelines, which are included under the coarse substrate category, had an average width of 45 ft. Riprap, also included under the coarse substrate category, was assumed to have an average width of 22 ft (assumed to have an average slope of 1:3 with a tidal range of 7 ft) and 18 ft (average slope of 1:3 with a tidal range of 6 ft). Some of the riprap in the area is old and the slope of the structure has been degraded to resemble the structure of a gravel shoreline. Therefore, the width of the riprap and the width of gravel beaches were averaged to determine a more appropriate average width for riprap (34 ft for riprap shoreline within the 7ft tidal range; 32 ft for riprap shoreline within the 6 ft tidal range).

When multiple habitats were present (e.g., a marsh in front of a sand beach), the tidal zone or width (depending on the habitat) was divided in half and applied to the two shoreline habitats equally. The stranded oil could have affected both habitats because of tidal changes, as well as run-off during cleanup operations. Due to the lack of detailed data available from the SCAT surveys on double shorelines, it was assumed that both habitats were affected.

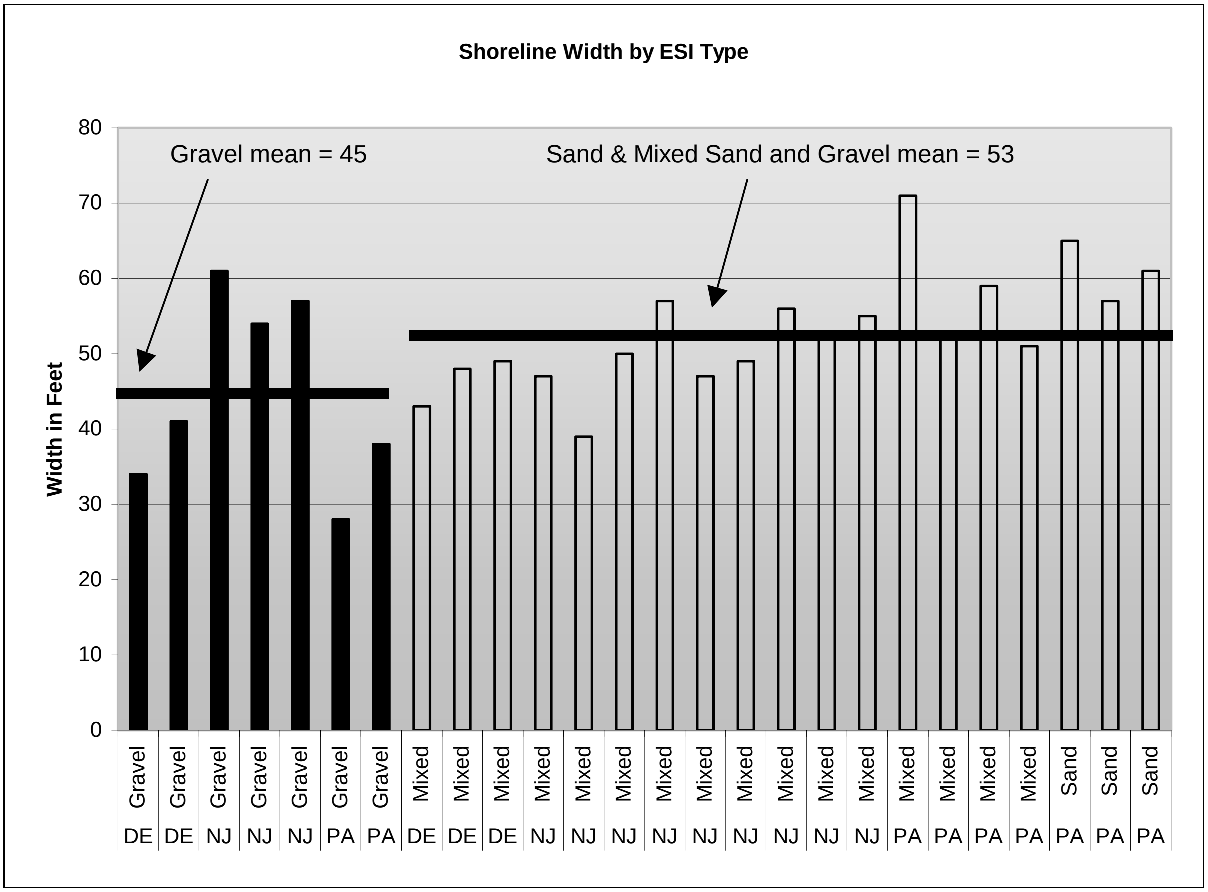

FIGURE 3. Widths of sand beach, mixed sand and gravel, and gravel as measured for DE, NJ, and PA. The mean of the widths is shown above the bars.

2.4.3 Tidal Flats

Data for polygonal tidal flats were obtained from each state and incorporated into the GIS data in combination with the ESI polygonal tidal flats. The sources for each state are as follows:

1.) Delaware: U.S. Fish and Wildlife Service, National Wetlands Inventory Polygon Data
2.) Pennsylvania: PA DE River Coastal Zone National Wetland Inventory maps
3.) New Jersey: New Jersey Department of Environmental Protection, Wetland Polygons (http://www.nj.gov/dep/gis/download.htm); 1995 tidal flats mapped during the *Jahre Spray* spill; USGS topographic maps

2.4.4 Segment Length

To calculate the total shoreline areas injured by the exposure category, the total length of shoreline within each exposure category was calculated. The length of oiled shoreline was obtained by overlaying the ESI habitats onto the maximum oiling maps and generating lengths using a GIS application. The results are shown in Table 4. The total length of shoreline surveyed was 556 miles, and the length of oiled shoreline was 279 miles (this number does not include tributary creeks; the length of shoreline with tributary creeks was 376 miles). This length (279 miles) differs from the total number of miles in Table 4 because of the shoreline segments that have two habitat types present along the mainstem. The lengths of these double shorelines are included twice in Table 3 to account for both habitats.

TABLE 3. Length in miles of shoreline habitat by oiling degree. The numbers do not include the length of oiled shoreline in tributary creeks.

Habitat	Very Light	Light	Moderate	Heavy	Total (miles)
Seawalls	12.69	24.00	37.43	3.87	77.99
Sand/Mud Substrate	17.64	11.35	10.23	5.61	44.84
Coarse Substrate	37.23	18.19	9.17	4.63	69.23
Marsh	70.06	19.72	4.26	1.62	95.65
Total (miles)	**137.62**	**73.26**	**61.09**	**15.73**	**287.71**

2.4.5 Area Calculations

The total area of each exposure category was determined using the following methods.

Seawalls

The area for each exposure category for seawalls was calculated using the length of the segment and the spring tidal range, according to the following formula:

A (Area) = L (Length of segment) * R (Spring tidal range)

Figure 4 illustrates a cross sectional view of a hypothetical seawall shoreline and the measurements used in calculating the area. Although the oil formed a band along the high tide line, it was determined that the entire ITZ was impacted through intensive cleanup methods and oil runoff.

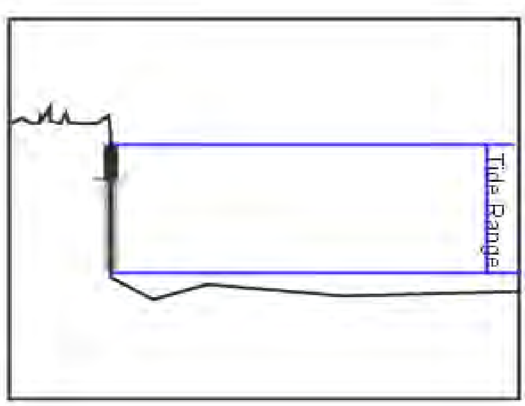

FIGURE 4. Cross-sectional view of hypothetical seawall shoreline. The oiled area is in heavy black, and the impacted ITZ is in gray.

Sand Beaches/Flats

Sand beach area calculations included multiple steps. First, shoreline oiling was calculated for each sand beach using the length of that segment and the average width of the oil band for each oiling degree as described above, as shown in the following formula:

SA (shoreline area) = L (segment length) * W (average oil band width for each oiling degree)

Next, the area of the lower ITZ was calculated for each sand beach segment using the length of that segment and the mean width of the sand beach, as calculated by the state Trustees during a field survey (see Fig. 5). The shoreline area calculated above was subtracted from the ITZ area calculation to avoid double counting (i.e., the sand beach widths measured by the Trustees include the portion of the upper shoreline where oil bands were observed), as shown in the following formula:

ITZ (intertidal zone area) = L (segment length) * W (field survey shoreline width) - SA

The lower ITZ area was assigned an oiling category two levels below the oiled shoreline area. That is, if the exposure category for the original shoreline oiling was heavy, the oiled area calculated for the lower ITZ was assigned a light oiling level because, in general, the percent cover of the oil was 1-10% and the band width was > 6 ft, which is defined as light in Table 2. If the exposure category for the original shoreline oiling was moderate, the oiled area calculated for the lower ITZ was assigned a very light oiling level because, in general, the percent cover of the oil was <1% and the band width was > 6 ft, which is defined as very light in Table 2. If the exposure category for the original shoreline oiling was light or very light, no oiled area was calculated for the lower ITZ because the amount of oil being mobilized from this level of oiling was considered to be very small. Figure 5 shows a cross sectional view of a hypothetical beach habitat and the measurements used in calculating the shoreline and ITZ areas.

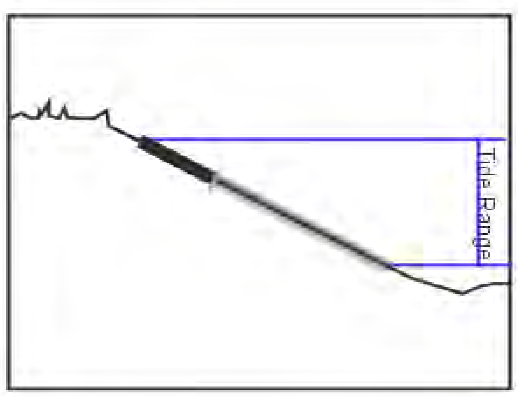

FIGURE 5. Cross-sectional view of hypothetical beach shoreline. The oiled shoreline area is in heavy black, and the impacted lower ITZ is in gray.

The area of oiled polygonal sand tidal flats was calculated from the dimensions of each digital polygon (with the exception of marsh tidal flats, see marsh calculations below). As for the ITZ calculations above, each flat was assigned an oiling category two levels below that assigned to the adjacent landward habitat. That is, if the exposure category for the landward shoreline oiling was heavy, the oiled area calculated for the polygonal tidal flat was assigned a light oiling level. If the exposure category for the landward shoreline oiling was moderate, the oiled area calculated for the polygonal tidal flat was assigned a very light oiling level. If the exposure category for the original shoreline oiling was light or very light, no oiled area was calculated for the tidal flat. This methodology was applied to all tidal flats with the exception of the tidal flats surrounding Tinicum Island and the tidal flats seaward of Fort Mifflin. These flats were assigned a heavy, moderate, or light oiling level based on SCAT surveys and forms.

If the polygonal tidal flat was located immediately seaward of a sand beach shoreline, the area of the lower ITZ, as calculated above, was subtracted from the area of the tidal flat. Figure 6 illustrates a cross sectional view of a hypothetical beach shoreline with an associated polygonal flat and the measurements used in calculating the area.

With very narrow or narrow bands of oil (<3 ft) contributing to moderate and heavy oiling shoreline assignments, there were concerns that tidal flats were assigned an injury category that may have overestimated the damage. The SAT reviewed the SCAT data within the Access database to determine that 12.3% of segments that had an oil band width of <3 ft were assigned a heavy or moderate oiling. Of this 12.3%, only one segment was determined to have a heavy oiling assignment; the remaining were moderately oiled. Approximately 2.3% of these records were examined in greater detail and tidal flats were not found to lie seaward of any of these segments. Nonetheless, to account for the possibility that the degree of injury to adjacent tidal flats would be reduced for the small minority of segments (approximately 10%) that were moderately oiled by bands <3 ft, the injury of the tidal flats in the very light oiling category of sand/mud substrates was reduced by a corresponding 10%.

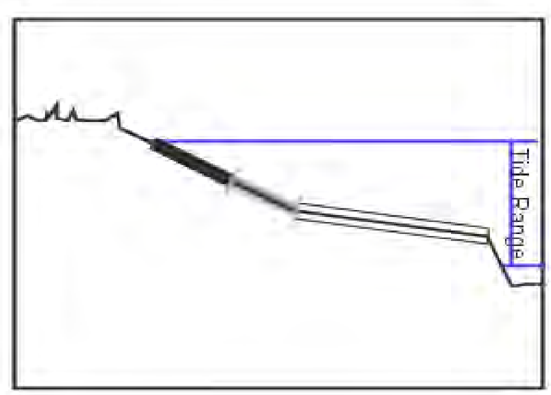

FIGURE 6. Cross-sectional view of hypothetical beach shoreline with an associated polygonal tidal flat. Oiled shoreline area is in heavy black, lower ITZ is in gray, and the oiled flat is represented by the black and white-striped box.

Coarse Substrate

The area for each exposure category for coarse substrates was calculated using the length of the segment and the average width of oiling by category from SCAT forms, according to the following formula:

Very light oiling: A (area) = L (segment length) * W (average oil band width for VL oiling)

Other oiling categories: A (area) = L (segment length) * W (shoreline width from field survey)

The shoreline width was used for light, moderate, and heavily oiled shorelines because clean-up activities (e.g., high-pressure, hot-water flushing) that took place in the heavier oiled areas would have affected the entire ITZ on the shoreline. Figure 7 illustrates a cross sectional view of a hypothetical coarse substrate shoreline and the measurements used in calculating area.

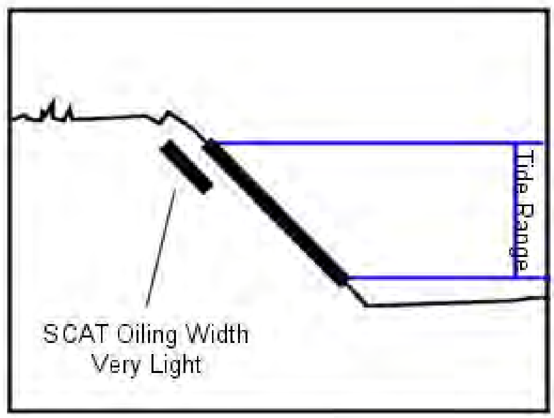

FIGURE 7. Cross-sectional view of hypothetical coarse substrate shoreline. The oiled area is in heavy black. The small oiled area represents the SCAT width used for very light oiling and the large oiled area represents the oiled area calculated from the entire shoreline width for other oiling categories.

Mainstem Fringing Marshes

The area for each exposure category for mainstem fringing marshes was calculated using the length of that segment and the average width of oiling by category from SCAT forms, as in the following formula:

A (area) = L (segment length) * W (average oil band width for each oiling degree)

Figure 8 illustrates a cross sectional view of a hypothetical fringing marsh shoreline and the measurements used in calculating the area.

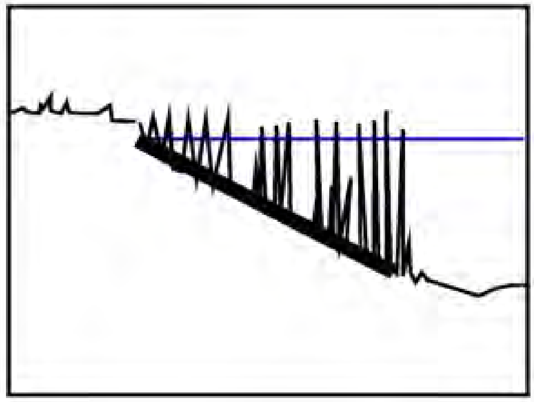

FIGURE 8. Cross-sectional view of hypothetical fringing marsh shoreline. Shoreline oiled area is the heavy black line beneath the marsh vegetation.

Most of the fringing marshes along the mainstem of the Delaware River were fronted by tidal flats, which were included in the GIS data layer. Therefore, the area of the polygonal tidal flats seaward of the oiled marshes was used to determine the area of the lower ITZ area adjacent to marshes that would have been injured, and this value was added in to the total area of injury for sand beach/flats. For each flat, if the exposure category for the landward shoreline oiling was heavy, the oiled area calculated for the polygonal tidal flat was assigned a light oiling level. If the exposure category for the landward shoreline oiling was moderate, the oiled area calculated for the polygonal tidal flat was assigned a very light oiling level. If the exposure category for the original shoreline oiling was light or very light, no oiled area was calculated for the tidal flat. Figure 9 illustrates a cross sectional view of a hypothetical fringing marsh shoreline with associated polygonal flat and the measurements used in calculating area. The only exceptions were the flats on the south side of Tinicum Island and fronting Fort Mifflin, which were assigned the oiling category assigned during the SCAT surveys.

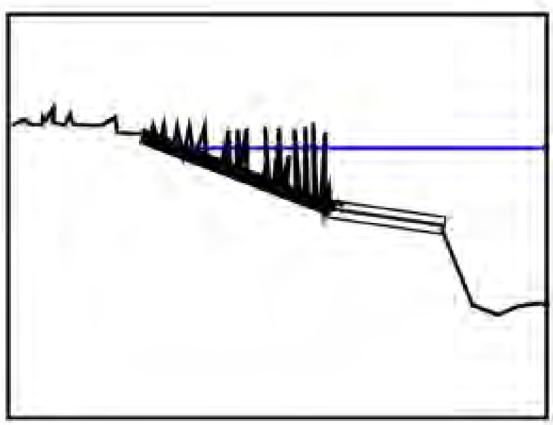

FIGURE 9. Cross-sectional view of hypothetical fringing marsh shoreline with associated polygonal tidal flat. Shoreline oiled area is in heavy black below the marsh vegetation, and the oiled flat is the black and white-striped box.

Tributary Creeks

Six tributary creeks (Big and Little Timber Creek, Woodbury Creek, Mantua Creek, Raccoon Creek, Old Canal, and Oldmans Creek) in NJ were closest to the release and exposed to extensive and persistent slicks. They also have extensive wetlands, intertidal flats, and shallow benthic habitats. Because of the extent, amount, and duration of slicks in these shallow, sensitive habitats, they were treated as whole ecosystems that were affected by the persistent slicks. It was agreed that the SAT would address injuries to these tributary creeks, and the Aquatics TWG would address injuries to aquatic and benthic resources in the mainstem river and bay.

Each state provided guidance on the upstream extent of oiling and degree of oiling if the oiling differed from what was initially classified in the GIS oiling database. Also, the observations from aerial surveys on the extent and degree of floating oil were reviewed. The moderate oiling category consisted of moderate oil along the shoreline based on SCAT surveys and observations of black oil slicks on the water during aerial surveys. The light oiling category consisted of light to very light shoreline oiling based on SCAT surveys and aerial observations of extensive dull to rainbow sheens on the water. The very light category was based on aerial observations of the presence of extensive rainbow to silver sheens on the water.

Using these data, the tributary area of exposure was digitized. The tributaries required photo-interpretation using the 2002 Digital Orthophoto Quarter Quadrangles to outline the exposed areas in each tributary, which included areas of annual vegetation and small patches of perennial vegetation. It was determined, based on aerial and ground observations, that there was no extensive oiling of the other tributaries in the river and bay. A 5 ft shoreline buffer was included for each tributary to account for oil that likely stranded on the shoreline and/or penetrated into the fringing wetland vegetation. The area calculated for impacted tributary creeks was treated separately from the mainstem of the Delaware River.

3.0 RESULTS

3.1 Estimate of Impacted Shoreline

Table 4 lists the oiling degree and area of oiling (in acres) for the seven tributary creeks in New Jersey. Zones were established when oiling degrees changed within a tributary. The total area potentially exposed from the tributary creeks was 1,899 acres.

The oiling maps and habitat classification maps can be found in Appendices C and D, respectively. Table 5 shows the total area calculated in each exposure category, for all states combined. The total estimated area of exposed habitat within the mainstem of the Delaware River as a result of the oil spill was 1,729 acres. The total areas calculated for each individual state are found in Appendix E.

TABLE 4. The number of acres impacted by oil from the six tributary creeks in New Jersey.

Tributary Creek	Zone	Oiling Level	Area (acres)
Big Timber Creek	**1:** Mouth to I-295	Light	198.95
Big Timber Creek	**2:** I-295 to NJ Turnpike	Very Light	55.38
Little Timber Creek	**3:** Mouth to Rt 130	Very Light	21.83
Subtotal (acres)			**276.17**
Woodbury Creek	**1:** Mouth to I-295	Light	147.40
Subtotal (acres)			**147.40**
Mantua Creek	**1:** Mouth to 1st RR bridge	Light	65.06
	2: 1st RR bridge to NJ Turnpike	Very Light	404.80
Subtotal (acres)			**469.86**
Old Canal	**1:** Mouth to I-295	Very Light	101.23
Subtotal (acres)			**101.23**
Raccoon Creek	**1:** Mouth to Rt. 130	Moderate	99.90
	2: Rt 130 to I-295	Light	492.83
	3: I-295 to Kings HWY	Light	251.74
Subtotal (acres)			**844.47**
Oldmans Creek	**1:** Mouth to Rt. 130	Light	60.10
Subtotal (acres)			**60.10**
TOTAL OILED TRIBUTARIES			**1899.23**

TABLE 5. Total estimated area (acres) of exposed habitat across all states.

Habitat Type	Oiling Level	Shoreline (Acres)	Lower Intertidal Zone (acres)*	Tidal Flat (acres)**	Total By Habitat (acres)	Percent of Total Oiling
Seawalls	Very Light	8.66			8.66	0.50%
	Light	17.72			17.72	1.02%
	Moderate	30.46			30.46	1.76%
	Heavy	2.54			2.54	0.15%
Subtotals		**59.38**			**59.38**	**3.43%**
Sand/Mud Substrate	Very Light	7.39	55.69	677.43	740.51	42.83%
	Light	9.98	26.94	279.54	316.46	18.30%
	Moderate	9.94		205.48	215.42	12.46%
	Heavy	8.24		135.20	143.44	8.30%
Subtotals		**35.55**	**82.63**	**1297.65**	**1415.83**	**81.89%**
Coarse Substrate	Very Light	16.23			16.23	0.94%
	Light	66.08			66.08	3.82%
	Moderate	36.91			36.91	2.13%
	Heavy	18.01			18.01	1.04%
Subtotals		**137.23**			**137.23**	**7.94%**
Marsh	Very Light	51.83			51.83	3.00%
	Light	40.89			40.89	2.36%
	Moderate	17.22			17.22	1.00%
	Heavy	6.53			6.53	0.38%
Subtotals		**116.47**			**116.47**	**6.74%**
TOTAL MAINSTEM HABITATS					**1728.91**	**100%**
Tributaries	Very Light	583.25			583.25	30.71%
	Light	1216.08			1216.08	64.03%
	Moderate	99.90			99.90	5.26%
	Heavy	0			0	0
Subtotals		**1899.23**			**1899.23**	**100%**
TOTAL OILED TRIBUTARIES					**1899.23**	**100%**

* Lower ITZ values were only shown separately for the sand/mud substrate because they represented the majority of the injury for the sand/mud substrate category.

** Tidal flat acreage under the sand beach habitat includes flats from both sand beach and marsh habitat categories.

4.0 ASSESSMENT OF INJURY AND RECOVERY FOR INJURED HABITATS

4.1 Introduction

Determining the degree of initial injury and rate of recovery for shorelines is a complex process. The shoreline type, health and composition of intertidal habitats, oil type, amount of oiling, exposure to natural removal processes, and duration of oiling can all affect the recovery of ecological services on an oiled shoreline. There are very few studies available that follow the full recovery of a coarse substrate, sand beach, or marsh shoreline, particularly for riverine settings. The recovery rates developed for the *M/T Athos 1* spill focused on the visual observations of oiling, the results of chemical analysis of the oil and sediment samples, vegetative conditions, and the life histories of fauna associated with the intertidal and shallow subtidal habitats of the Delaware estuary (see summary table and references in Appendix G), as well as published studies of past spills. The percent of baseline services at key points in time were used to create the recovery curves for each injury category. These time inflections include:

1) Time – Initial service losses, immediately after the spill on 28 November 2004.
2) 0.5 yr after spill – Representing the termination of cleanup activities (end of May 2005), start of recovery process.
3) 1 yr after spill – The end of the first growing season.
4) 2 yrs after spill – The end of the second growing season.
5) 3 yrs after spill – The end of the third growing season.
6) 4 yrs after the spill – The end of the fourth growing season.
7) 5 yrs after the spill – The end of the fifth growing season.

The impacted areas along the mainstem and tributary creeks were surveyed twice, on June 7 and September 22, 2005, by members of the SAT to assess oiling conditions and habitat recovery. Site-specific observations were made on oiling conditions as the amount and extent of residual oil (e.g., on the sides and undersides of gravel and riprap) and re-oiling of surface sediments and vegetation. General observations were made on habitat recovery in terms of vegetative vigor, algal cover on coarse substrates, and relative abundance of epibiota. In developing the inputs to the HEA injury assessment, estimates of lost services were based on observations of oil persistence (as coat on hard substrates) and continuing exposure of intertidal habitats to oil re-mobilized as sheens and oil droplets during the September 2005 field visit and the coating/fouling properties of this type of oil, rather than the toxicity associated with PAHs bound to sediments. Since these observations document the persistence of oil in the intertidal zone at a time period 10 months after the spill, the injury to moderately and heavily oiled shorelines was extended for longer than one year for all shoreline categories. The oil is expected to have low chemical toxicity but chronic physical effects from fouling and coating because of its persistence and re-mobilization during the natural recovery processes through 2005.

The following sections describe the impact and recovery using the HEA methodology for five injury categories: seawalls, sand/mud substrates, coarse substrate, marsh, and tributaries. Note that the lower intertidal zone category, which was treated as a separate injury category for determining the area of exposure has been incorporated into the sand/mud substrate for injury assessment.

4.2 Seawalls

Approximately 59 acres of seawalls were oiled and affected by cleanup operations, with the majority of the habitat observed as moderately oiled (30 acres). Oil attached to the dry, rough surface of the seawalls along the Delaware River and persisted in a band above the high tide line. Shoreline cleanup consisted of high-pressure, hot-water flushing of the oiled band. Because of the persistence of this oil, even narrow bands of oil on seawalls (often classified as light oiling) were treated with high-pressure, hot-water flushing (Ploen, pers. comm., 2006). Multiple sprays were required to meet the cleanup endpoints. The effluent from the flushing flowed down the seawall surface, affecting the entire intertidal zone of the seawall. As a vertical, impermeable structure, even small amounts of hot water would affect the entire intertidal zone.

Few resources are affected during a seawall injury, as animals that attach to the substrate in fresh to brackish settings are sparse in abundance, particularly in such an urban setting as the Delaware River. Seawalls support algal biomass and therefore contribute to primary production. A loss of production may occur with the oiling of macroalgae, and the detachment of insects and invertebrates removes a source of prey for fish that may feed along the seawalls.

Table 6 shows the HEA inputs for ecological service losses for oiled seawalls and the number of DSAYs accumulated from the number of acres injured for all states combined. The DSAYs accumulated from the number of acres injured by state are in Appendix F. The loss of services for very lightly oiled seawalls was estimated to be at 5% of baseline (95% services present). Very light oiling ranged from trace oil in a band less than 6 ft wide to up to 50% oil in a band less than 0.5 ft wide. Few of these areas were subject to cleanup efforts. With this small amount of oil and no additional impacts from cleanup, the loss of services was estimated to have been minor. The majority of the oil was removed by natural weathering processes within the first year after the spill. It was assumed that the lightly oiled seawalls would recover in the same amount of time as the very lightly oiled seawalls but with a slighter larger initial loss of services (15%). Very light and light oiling could have removed some habitats as suitable settling locations for invertebrates, however the majority of the seawalls would be functioning normally.

The moderately and heavily oiled seawalls were estimated to have 0% services present immediately following the spill and until 6 months after the spill because of the initial oiling and the effects of high-pressure, hot-water flushing cleanup operations that were completed by May 2005. Moderately and heavily oiled shorelines were characterized with an oil band up to 6 ft in width and an oil cover up to 90% or 100%, for moderate and heavy oiling, respectively.

Seawalls that were moderately or heavily oiled would have experienced a much higher loss of primary production as well as a loss of invertebrates that depend on the algae for food. One year following the spill, the loss of services was estimated to be at 15% of baseline (85% services present), reflecting the rapid recruitment of short-lived species. Because both moderately and heavily oiled seawalls were mostly treated with high-pressure, hot-water flushing in the spring of 2005, they have the same loss of services and recovery rates. Services on moderately and heavily oiled seawalls were estimated to have recovered by two years following the spill. Injury to seawalls was calculated as 30.3 DSAYs across all states. Figure 10 shows the recovery over time for very lightly, lightly, moderately, and heavily oiled seawalls.

TABLE 6. Recovery rate and total number of DSAYs lost for oiled seawalls (all states combined).

Oiling Degree	Acres	Services Present Post Spill			
		0.5 yr	1 yr	2 yr	DSAYS
Very Light	8.66	0.95	1		0.32
Light	17.72	0.85	1		1.97
Moderate	30.46	0	0.85	1	25.87
Heavy	2.54	0	0.85	1	2.16
Total	**59.38**				**30.32**

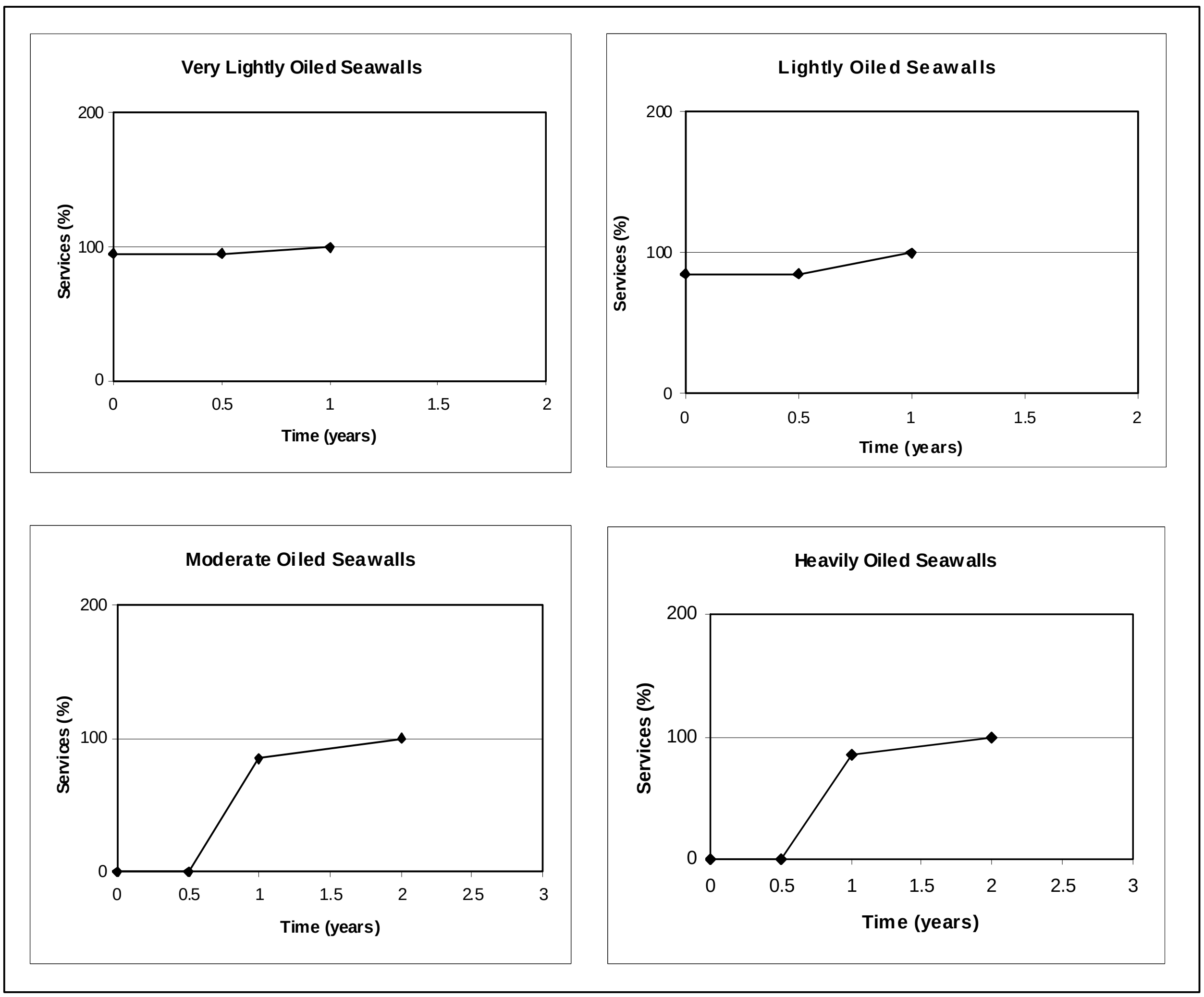

FIGURE 10. Assumed recovery of services over time for very lightly, lightly, moderately, and heavily oiled seawalls.

4.3 Sand/Mud Substrates

Approximately 1,416 acres of sand/mud substrates were estimated to have been exposed to oil at some point following the spill. As shown in Figure 2, this category includes sand beaches, mixed sand and gravel beaches, and sandy and muddy tidal flats. On beaches, the viscous oil coated the sediments, particularly the gravel, and penetrated in to the sandy sediments where accumulations were heavy. Cleanup on sandy shorelines in 2005 included removal of tarmats as they were exposed on previously cleaned shorelines; tarmat removal continued until at least May 2005. In spite of aggressive cleanup efforts that included both manual removal of oiled sediments and high-pressure, hot-water flushing of the coarser gravel sediments, small tarballs that readily spread into sheens continued to be released from oiled beaches throughout 2005, as observed in the July and September 2005 site surveys. Furthermore, as late as September 2005, oil droplets and larger deposits of oil were observed in the sandy and muddy intertidal sediments at multiple locations along heavily oiled shorelines in PA (for example, see Fig. 11). At every sandy shoreline segment visited in July and September 2005 that was moderately or heavily oiled, the SAT observed tacky oil droplets adhered to pebbles and cobbles, small tarballs with sheen halos on the sand, and oil droplets released from the sediments when they were disturbed.

This category also includes tidal flats where oil stranded directly on the flat during the spill (i.e., south side of Tinicum Island, Figure 12A, and in front of Fort Mifflin) and those flats fronting moderately and heavily oiled shorelines, where the oil initially floated over the flats, but were chronically exposed to oil being released from adjacent shorelines. Figure 12B shows the small tarballs and associated sheens stranded on the tidal flat on the east side of Tinicum Island on 22 September 2005. Tarballs and sheens were observed on tidal flats during both site visits in 2005. This chronic oil exposure continued to affect the fauna and users of these habitats at least towards the end of 2005. Very lightly oiled tidal flats represent 677 acres, or 43% of the total acreage in this habitat category (Table 5).

Sand/mud substrates provide important habitat for epifauna and infauna (see Appendix G). Macrofauna, such as shellfish, worms, and snails can be found on and in the sediments on sand/mud substrates in high abundance. Meiofauna colonize the interstitial spaces among the sand grains of the intertidal zone. Meiofauna contribute to the food chain by converting the energy content of dead seaweed and wrack into forms available for larger animals such as birds and fish (Basson et al., 1977). Birds and fish use the sand/mud habitats to feed. The initial smothering of epifauna and chronic oil exposures at least through 2005 are likely to impact the amount of food available for birds and fish. Food-web support is the primary services considered in evaluating injury for these habitats.

Table 7 shows the HEA inputs for oiled sand/mud substrates and the number of DSAYs calculated from the number of acres exposed for all states combined. Appendix F shows the number of DSAYs calculated for individual states. The loss of services for very lightly and lightly oiled sand/mud substrates was estimated to be 50% of baseline (50% services present) for the first 6 months after the spill. This category is dominated by tidal flats fronting heavily and moderately oiled shorelines that were constantly being exposed to oil slicks, droplets, and sheens being released from the shoreline until cleanup activities were terminated. Very light and light oiling of flats would reduce use by birds and have fouling impacts to intertidal biota because of the chronic exposure to oil being released from adjacent shorelines, thus they are assigned similar injury and recovery inputs. One year following the spill, the loss of services for very lightly and lightly oiled sand/mud substrates was estimated to be at 25% of baseline (75% services present), based on the observations of oil droplets and sheens on all such tidal flats visited in September 2005, and the relatively short life history of most species associated with these habitats in the lower Delaware River. By the third year following the spill, services were expected to have recovered, assuming that the stranded oil would have weathered enough to prevent significant releases after year two, which would allow affected resources to recover by year three.

Moderately and heavily oiled sand/mud substrates were estimated to have had 100% loss of services (0% services present) 6 months after the spill. The stranded oil would have directly smothered and killed intertidal organisms; however, the constant release of oil exposed all intertidal organisms to the smothering effects. Furthermore, the intensity of cleanup required to remove the viscous, persistent oil would have affected any remaining organisms and restricted use until cleanup activities were terminated. Thus, both oiling categories were assigned similar injury and recovery inputs. These two categories were estimated to recover within three years as the lighter oil categories were, however, the services were estimated to take a longer time to return in the interim years (see Table 7).

Injury to the 1,416 acres of sand/mud substrates that were oiled as a result of the spill was calculated as 1,117 DSAYs across all states. Figure 13 shows the recovery curves for each of the oiling categories for this habitat type.

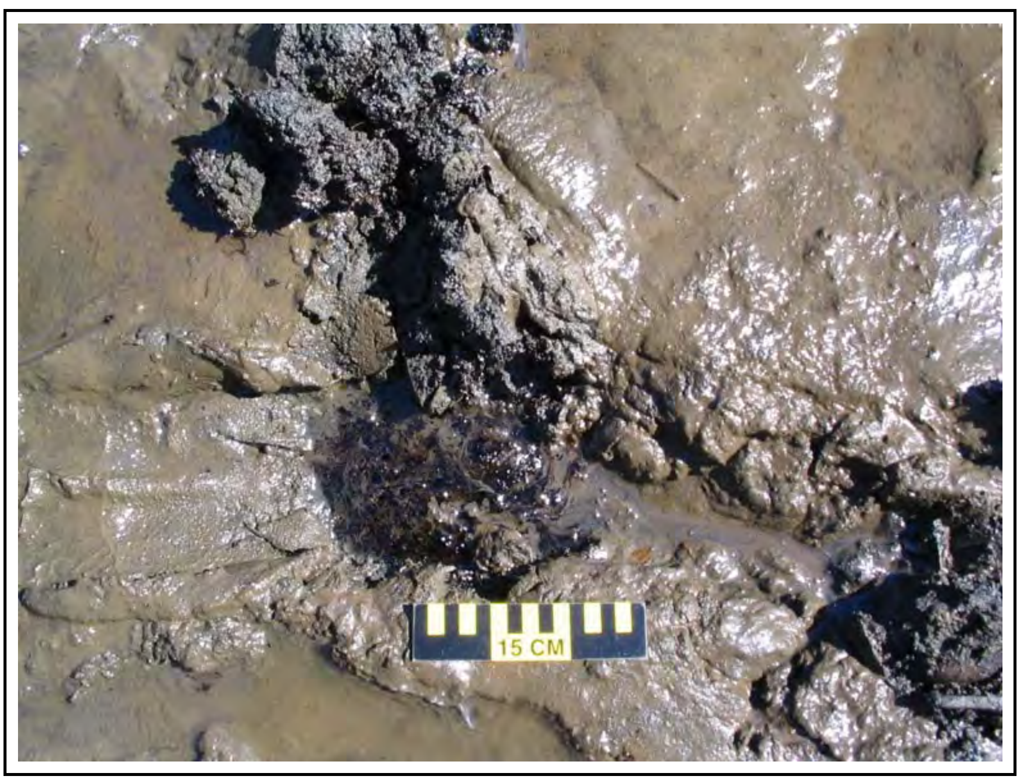

FIGURE 11. Oil in muddy tidal flat sediments along segment PA-5 indicating the persistence of oil from the *M/V Athos 1* spill, 22 September 2005, ten months after the spill.

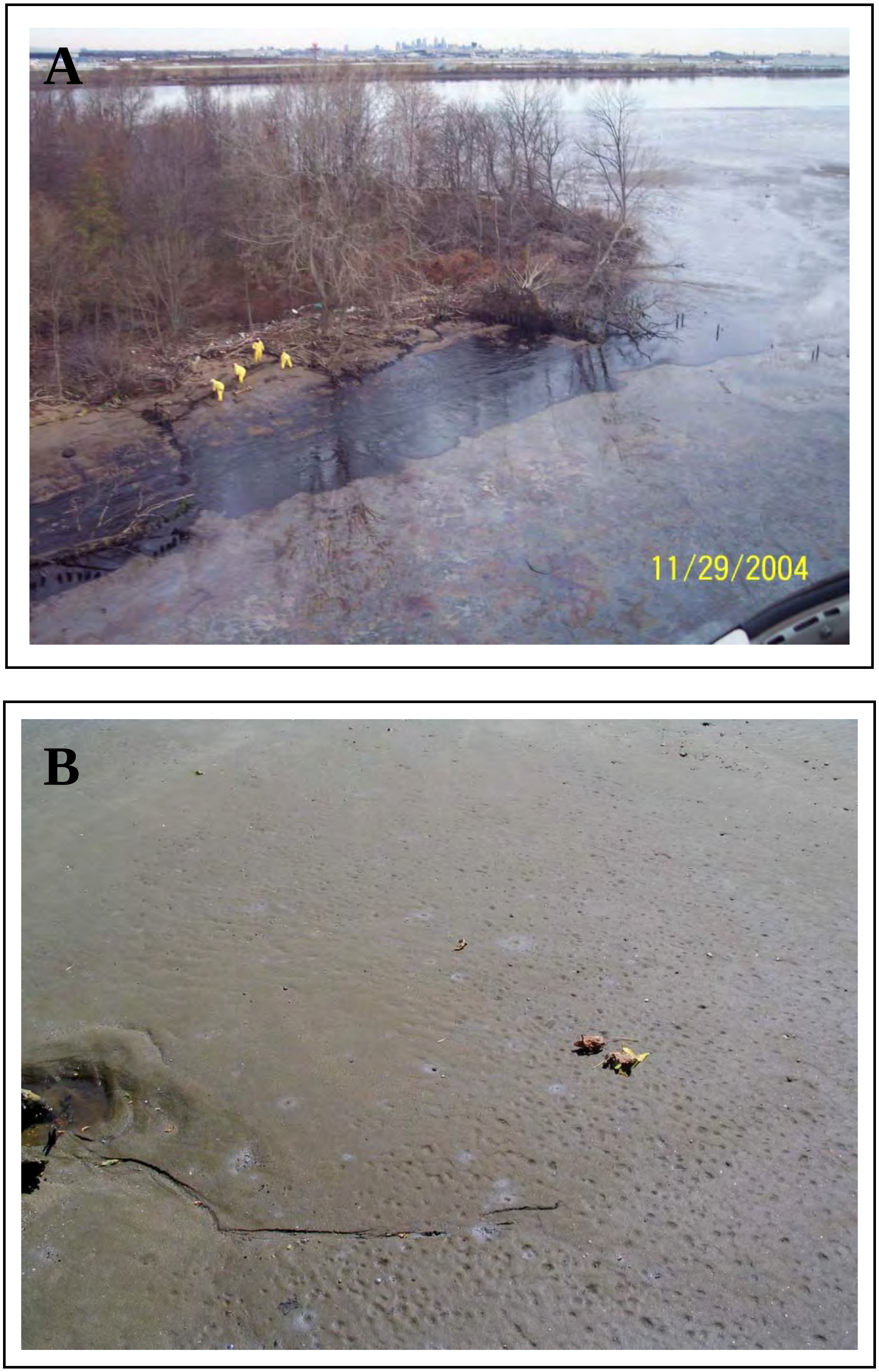

FIGURE 12. A. Heavy oil stranded on the south side of Tinicum Island on 29 November 2004. Note the lighter oiling of the flat below the footprint of the stranded oil.
B. Chronic re-oiling of sand flats on Tinicum Island observed on 22 September 2005, occurring as oil droplets surrounded by a halo of sheen on the sediment.

TABLE 7. Estimated recovery rate and total number of DSAYs lost for oiled sand/mud substrates (all states combined).

Oiling Degree	Acres	Services Present Post Spill				
		0.5 yr	**1 yr**	**2 yr**	**3 yr**	**DSAYs**
Very light	740.51	0.5	0.75	0.95	1	443.02
Light	316.46	0.5	0.75	0.9	1	204.24
Moderate	215.42	0	0.5	0.8	1	278.06
Heavy	143.44	0	0.5	0.75	1	191.91
Total	**1415.83**					**1117.24**

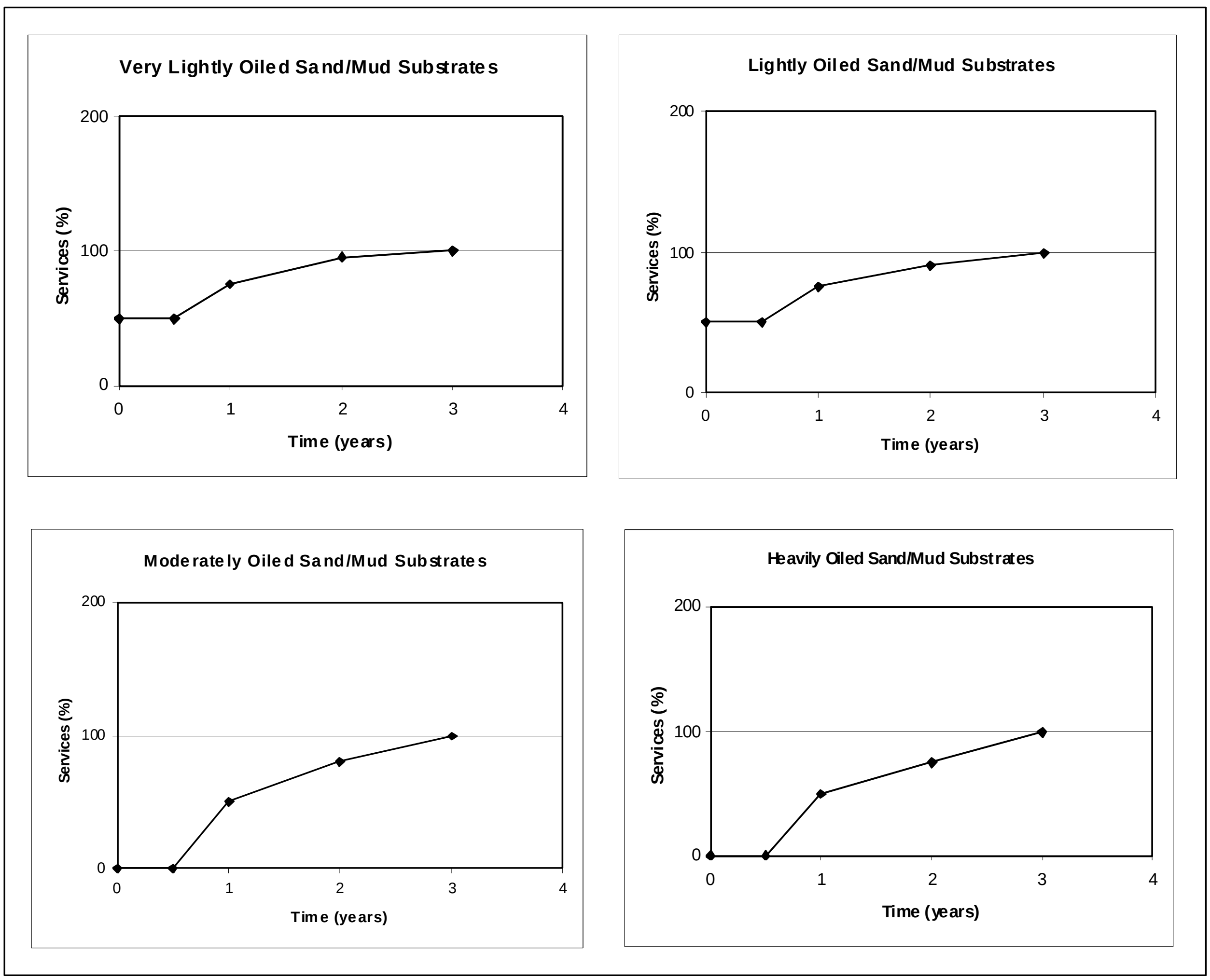

FIGURE 13. Assumed recovery of services over time for very lightly, lightly, moderately, and heavily oiled sand/mud substrates.

4.4 Coarse Substrate

Approximately 137 acres of coarse substrate were oiled as a result of the spill, with the majority consisting of light oiling (66 acres). This habitat was dominated by riprap. At the surface, oil adhered to the rough surfaces on the riprap for all oiling categories; at depth, oil adhered where the oiling was moderate or heavy. Cleanup of riprap proved to be very difficult because the oil was highly adhesive and often heavily coated not just the rock surface but also many sides. Most riprap underwent intensive high-pressure, hot-water flushing, even on shorelines considered to be lightly oiled (Ploen, pers. comm., 2006), but even this technique was not effective at removing oil that had coated the riprap below the surface layer. Where possible, the riprap blocks on the surface were turned over to attempt cleaning of all sides, but deeper blocks remained heavily oiled. On 5 May 2005, the Unified Command conducted field inspections to observe the how the cleanup was progressing, to see what some of the shorelines looked like, and discuss varying endpoints. According to the 6 May 2005 posting to ResponseLink, the consensus was stated as "In general, it was felt that most sites would be OK with surface cleaning of rip-rap rocks and that oil underneath would need to be left." Thus, the oil that penetrated into the riprap structures on moderately and heavily oiled segments was not removed, and it likely was the source of the chronic release of oil droplets during the summer of 2005. In September 2005, tarry oil layers on the clasts and oil droplets in the underlying sediments were observed in all heavily oiled riprap areas visited (see examples in Fig. 14). Release of the oil remaining in the riprap and other coarse sediments is likely a source of the oil droplets and sheens observed on the adjacent intertidal habitats in April and September 2005.

Coarse substrate provides habitat to species including algae, snails, blue mussels, crabs, fishes, and shorebirds. The ESI atlases show important striped bass spawning areas are adjacent to riprap areas in the mainstem of the river (NOAA, 1996).

Determining the impacts to an oiled shoreline and the recovery time requires an understanding of the degree of oiling, cleanup methods used, chronic oil exposure after cleanup, and the life histories of the associated fauna and flora. Observing the recovery of the lower trophic levels (e.g., algae, snails, mussels) can provide an estimation of recovery for some of the higher trophic levels (e.g., birds). Using this method to determine the recovery time for an oiled coarse substrate takes into account the food web interactions as well as the services the habitat provides.

The heavy crude oil coated the upper intertidal zone of sheltered coarse substrate shorelines and the splash zone of exposed shorelines. Any oil remaining after cleanup dries, cracks, and is removed by natural processes within a few years (Michel and Hayes, 1993). Some species will not survive being smothered with oil as Chan (1977) found after crude oil coated a rocky platform shoreline in the Florida Keys, where gastropods decreased slightly in abundance and many empty shells were found in the rocky zone. However, many more survived the oiling, indicated from the growth of the shell past the oil-stained portion of the shell. Several studies have been conducted on the recovery of flora and fauna of rocky and coarse substrates after oil contamination. Peterson (2001) reported a reduction in the dominant algae as well as limpets, barnacles and periwinkles on the intertidal rocky shore after the *Exxon Valdez* spill. However, within 2-3 years following the spill, the epibiotic populations on the oiled shoreline began to resemble those present on reference sites.

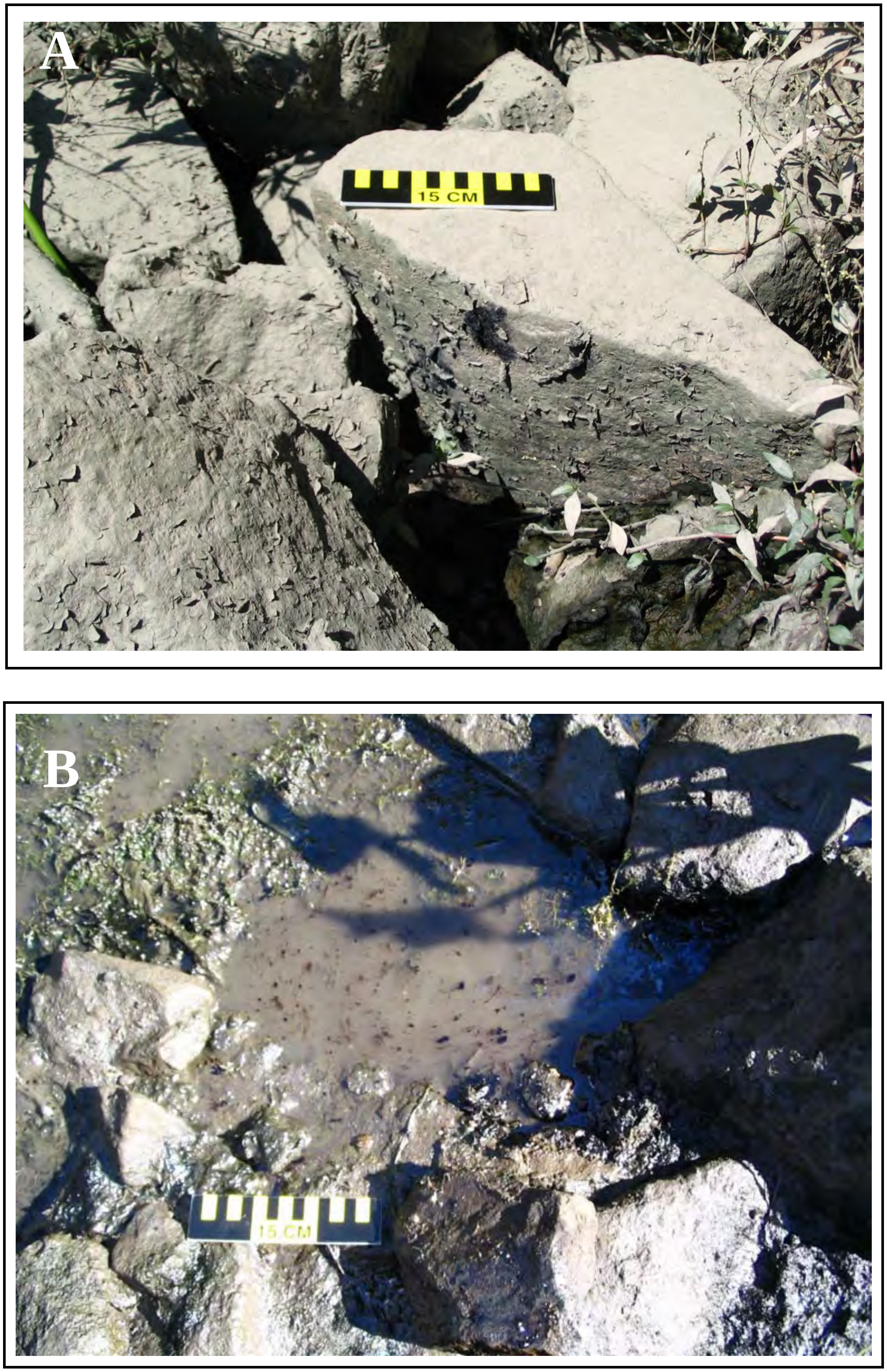

FIGURE 14. A. Tarry residue on riprap on heavily oiled shorelines on 22 September 2005. The tarry layer is partially covered by algal growth but also exposed as the tarry residue dries and peals off. **B.** Oil in the sediments underneath heavily oiled coarse substrates on 22 September 2005.

Recovery is also dependent on the type of cleanup effort that was used to remove the oil. Coarse substrates that undergo intrusive cleanup, such as mechanical cleaning (i.e., stripped of oily gravel), and are replaced with clean sediment or pressure-washed, have shown much slower rates of recovery than coarse substrates that were cleaned through natural recovery. Rolan and Gallagher (1991) found that biological communities that were not mechanically cleaned recovered within one year even though weathered oil still existed, while biological communities in the mechanically cleaned rocky shores had not recovered after nine years following the spill. At the *Exxon Valdez* spill in Prince William Sound, Alaska, where rocky shores were treated with large volumes of high-pressure, hot-water flushing, the period of recovery lasted around 2-3 years even at the most disturbed sites, when species abundances across sites that received varying amounts of oil and treatment—or no oil at all—were generally comparable (Hoff and Shigenaka, 1999). After studying the results of recovery from twelve different oil spills, Sell et al. (1995) summarized that biotic recolonization on heavily oiled rocky shores with no cleanup treatment could occur between 0.5 and 1.5 years; recolonization was seen between 1 and 3 years from rocky shores that were treated. This synthesis study also suggests that recovery can be visibly progressing between 1-3 years for shorelines that were not treated and 1-10 years for shorelines that had been intensively treated. In the upper Delaware estuary, where most of the heavy oiling occurred, recovery rates are expected to be faster, reflecting the relatively short life histories of the intertidal fauna in this fluvial setting and the fact that 98% of coarse habitats affected by the spill were composed of degraded riprap structures with abundant deep voids and undersides of rock that could provide some refuge from treatment effects and recruitment sources to speed recovery. Also, the shoreline treatment consisted mostly of high-pressure, hot-water flushing using hotsy units that supplied relatively small amounts of hot water to the immediate spray area.

Table 8 presents the number of injured acres, the recovery rate in years following the spill, and the total number of DSAYs that were lost as a result of the spill across all states. The total number of DSAYs that were lost within each individual state can be found in Appendix F. Very lightly oiled coarse substrate was estimated to have a 25% loss of services as compared to baseline (75% services present) six months after the spill occurred, a 15% loss after one year, a 5% loss after two years, and complete recovery three years following the spill. For lightly oiled coarse substrates, the injury was estimated as a loss of 50% of services as compared to baseline (50% services present) 6 months after the spill, a 25% loss after one year, a 10% loss after two years, and full recovery after three years. These recovery estimates were based on direct smothering effects of the oil and the short life history of fauna associated with these mostly man-made habitats.

Heavy and moderately oiled coarse substrates were estimated have a 100% loss of services until six months after the spill. All these habitats underwent high-pressure, hot-water flushing during cleanup. All associated fauna would have been completely smothered in oil and were likely to have experienced high mortality from both the oil and subsequent cleanup. The habitat would not have been available for shorebirds to use for loafing or feeding until cleanup activities were terminated. Lost services were estimated to be at 50% of baseline at one year following the spill, reflecting both the recovery of some services after the initial impacts and on-going impacts resulting from persistent oil on the riprap blocks and chronic exposures to oil being released during 2005. At every moderately or heavily oiled shoreline segment visited during the September 2005 survey, oil droplets were observed stranded on the sediment surface. The droplets were sticky to the touch and surrounded by a halo of rainbow sheen, indicating that the oil was still fresh enough to spread. This chronic release of oil through September 2005 was considered to be a significant source of fouling and impact to intertidal communities. Lost services were estimated to be 25% at two years and 10% by the third year. Moderately oiled coarse substrate shorelines were estimated to be fully recovered after four years. The SAT determined that the heavily oiled coarse substrate would likely have minor injuries extending out to five years after the spill. This decision was based on the review of the persistence of the *Presidente Rivera* spill for more than 10 years along the Delaware River shoreline (Dave Bean, NJDEP, pers. comm., 2006). Therefore, the services present were slightly increased from 0.9 to 0.99% four years after the spill occurred to account for the injury from persistent, lingering oil underneath coarse substrates.

Injury to the 137 acres of coarse substrates that were oiled as a result of the spill was calculated as 127 DSAYs across all states (Table 8). Figure 15 shows the recovery curves for each of the oiling categories for this habitat type.

TABLE 8. Estimated recovery rate and total number of DSAYs lost for oiled coarse substrates (all states combined).

Oiling Degree	Acres	Services Present Post Spill						
		0.5 yr	1 yr	2 yr	3 yr	4yr	5yr	DSAYs
Very light	16.23	0.75	0.85	0.95	1			5.53
Light	66.08	0.5	0.75	0.9	1			42.65
Moderate	36.91	0	0.5	0.75	0.9	1		52.76
Heavy	18.01	0	0.5	0.75	0.9	0.99	1	25.90
Total	**137.23**							**126.84**

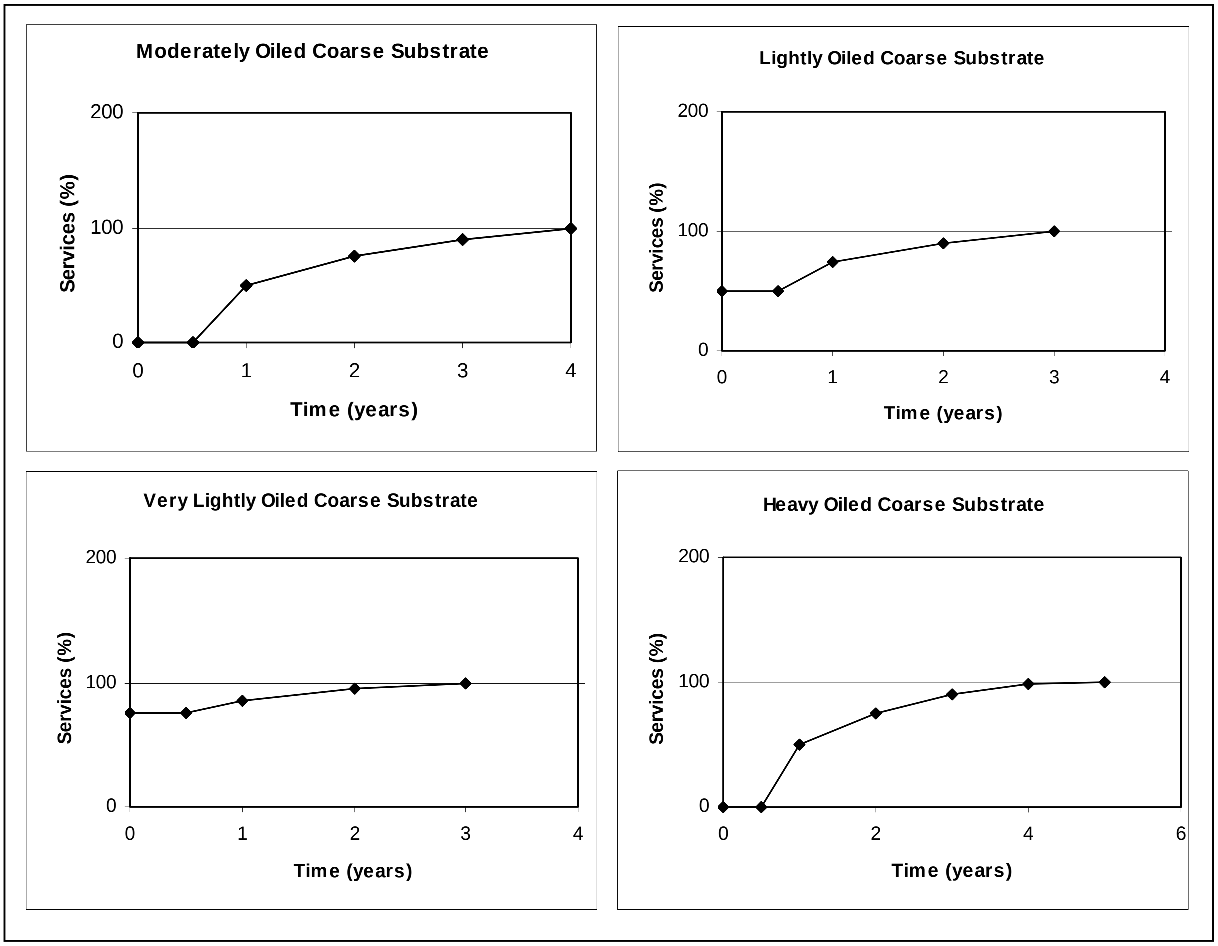

FIGURE 15. Assumed recovery of services over time for very lightly, lightly, moderately, and heavily oiled coarse substrates.

4.5 Marsh

The spill affected approximately 116 acres of marsh along the Delaware river and bay, with 80% described as very light or light oiling. Oil that stranded in the marshes mostly coated the intertidal vegetation and debris; some oil did strand on and persist on the sediments along the moderately and heavily oiled segments. Figure 16 shows examples of oiled marshes during the spill. Along shoreline segments delineated as moderately and heavily oiled, oil droplets were observed adhered onto marsh vegetation and released from marsh soils when disturbed in September 2005, indicating on-going oil exposure to both epifauna and infauna in these habitats. However, the oil in the marsh soils was mostly observed in the surface sediments; there was little evidence that the oil had penetrated deeply into the marsh soils.

Marsh vegetation represents a broad range of ecological services and functions related to primary production, habitat structure, food chain support, sediment/shoreline stabilization, and fish and shellfish production. Marshes are important nursery grounds for shellfish, fish, and birds (Burns et al., 2000). The common snapping turtle and midland painted turtle can also be found using the marsh as a protective habitat in which to forage. Marsh vegetation is important for populations of fish and crustaceans that inhabit marshes, many species of which are key prey items for larger fish and birds. Wading birds, such as clapper rails, willets, and egrets, depend on the prey within the marsh and the plant cover for protection.

The spill occurred when the marshes were in senescence and it was not possible to discern any significant impacts to intertidal marsh vegetation in 2005. During the September 2005 site visit, there was no evidence of die-back or sublethal effects on vegetation; in fact, all the vegetation appeared healthy even though oil spots were found on the vegetation. There were little cleanup efforts in marshes, other than oily debris removal. Therefore, impacts to this habitat type are estimated based primarily on the direct smothering impacts of the oil on associated fauna during the spill, the persistence of oil in surficial sediments in the more heavily oiled areas, the chronic exposure to oil being released from adjacent habitats, and the life histories of associated fauna.

Table 9 presents the number of injured acres of marsh habitat, the recovery rate in years following the spill, and the number of DSAYs lost for each oiling category across all states. The DSAYs lost within each individual state can be found in Appendix F. Very lightly oiled marsh was estimated to have lost 25% of services as compared to baseline (75% services present) six months after the spill occurred, as a result of the oil coating of the vegetation. After one year, services would have recovered to 95% of pre-spill conditions, reflecting the return of most associated fauna. Full recovery was expected within two years post-spill. Lightly oiled marshes followed a similar pattern but had an estimated 50% of services lost as compared to baseline and 25% lost one year after the spill.

For moderately and heavily oiled marshes, services losses were estimated to be 100% for the first six months, until new vegetation emerged to replace oiled vegetation. Oil would have smothered most organisms within the oil band and wildlife would not have been able to use the area for feeding. Moderately oiled marshes were estimated to have 25% loss of services (75% services present) one year after the spill, 5% loss of services (95% services present) after two years, and recovered after three years. Heavily oiled marshes were estimated to have a 50% loss of services one year after the spill, 25% loss of services after two years (75% services present), 10% loss of services (90% services present) after three years, and recovered after four years. Injury to the 116 acres of marshes that were oiled as a result of the spill was calculated as 60 DSAYs across all states. Figure 17 shows the recovery curves for each of the oiling categories for this habitat type.

FIGURE 16. **A.** Oiled marsh in Pennsylvania, near the airport, taken on 29 November 2004. **B.** Oiled marsh at PA-4, on 3 December 2004. Much of the vegetation had already died back, although *Phragmites* was still standing at the time of the spill.

TABLE 9. Estimated recovery rate and total number of DSAYs created from oiled marsh (all states combined).

Oiling Degree	Acres	Services Present Post Spill					
		0.5 yr	1 yr	2 yr	3 yr	4yr	DSAYS
Very light	51.83	0.75	0.95	1			11.47
Light	40.89	0.5	0.75	1			22.54
Moderate	17.22	0	0.75	0.95	1		16.68
Heavy	6.53	0	0.5	0.75	0.9	1	9.33
Total	**116.47**						**60.02**

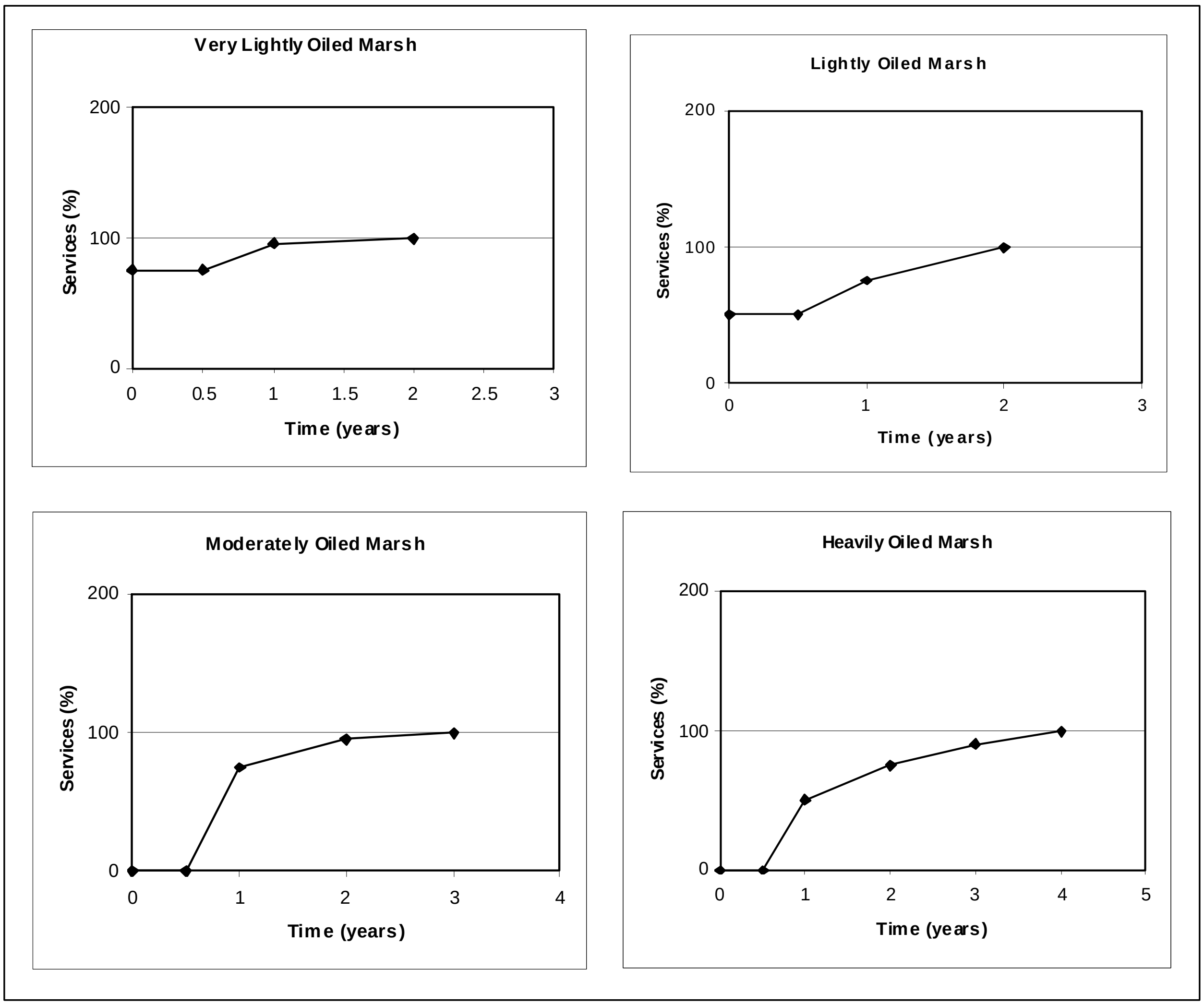

FIGURE 17. Estimated recovery of services over time for very lightly, lightly, moderately, and heavily oiled marsh.

4.6 Tributaries

Approximately 1,899 acres of shorelines, extensive wetlands, intertidal flats, and shallow benthic habitats in six tributaries in New Jersey were oiled as a result of the spill. The majority of tributaries were lightly oiled (1,216 acres), which was described as extensive dull to rainbow sheens on the water within the tributaries.

Various aquatic and benthic resources inhabit the tributaries including fish, invertebrates, crabs, terrapins, and birds. Oil slicks that stranded on the intertidal areas likely coated the habitat and any organisms using the shoreline. Shoreline habitats were temporarily unavailable for feeding or loafing for diamondback terrapins, wading birds and shorebirds. Oil sheens and slicks on the water surface would have impacted water quality and reduced the use of these habitats by wildlife such as birds and aquatic mammals. The shallow benthic habitats that are commonly used by fish and crabs for feeding, protection from predators, and spawning were also likely affected by floating oil, naturally dispersed oil, and submerged oil. Because some of the oil became submerged, there was concern that the submerged oil may have contaminated the benthic resources at the mouths of these tributaries by attaching to particulate matter in the water column, becoming heavier and sinking in these low-energy habitats. In that situation, both smothering effects and chronic toxicity effects from PAHs could impact sediment biota.

Table 10 shows the number of injured acres of habitat within the tributaries, the recovery rate in years following the spill, and the number of DSAYs lost as a result of the spill. The initial service losses in the tributaries extended for the first three months following the spill, when floating oil was persistently observed throughout the tributaries. The floating oil had fouling and coating impacts to the shoreline, water-surface, and upper water-column resources. The tributaries have low dilution and flushing rates, thus oil in these systems would affect a significant percentage of the resources present. Moderately oiled tributaries were estimated to have a service loss of 65% as compared to baseline (35% services present). These areas had black oil slicks on the surface and moderate shoreline oiling that would have been a source of chronic releases of oil. Lightly oiled tributaries were estimated to have a service loss of 50% due to the light and very light shoreline oiling and the presence of extensive oil sheen. Very lightly oiled tributaries were estimated to have a service loss of 25% because of the presence of oil sheen on the water surface.

During the Preassessment Phase, subtidal sediment samples were collected in Woodbury Creek, Big Timber Creek, and Mantua Creek (three from each tributary). One sample from Woodbury Creek measured 12.9 ppm NS&T PAHs, and several other samples from Big Timber Creek and Woodbury Creek were above adverse ecological effect thresholds (Shellenbarger Jones et al. 2006).[1] The Aquatics Technical Working Group designed and implemented a sediment sampling and analysis plan to better characterize potential longer term ecological risks associated with PAH concentrations in subtidal sediments within portions of the Delaware River (Donlan et al.,

---

[1] NS&T PAHs include 18 primary PAHs and was the basis for toxicity estimates by the Aquatic Technical Working Group. Adverse ecological effects thresholds were developed based on estimated background concentrations and historical matched sediment chemistry-toxicity data (Shellenbarger Jones et al. 2006). The analytical laboratory also provided a total PAH concentration which included alkylated congeners of the parent PAHs, among other compounds.

2005). During the September 2005 sampling program (i.e., approximately 10 months after the spill), two samples were collected each from the mouths of Mantua Creek and Raccoon Creek. An initial screening of all samples was conducted using ultraviolet fluorescence spectroscopy, and one sample from Mantua Creek was selected for detailed characterization of the PAHs using Gas Chromatography/Mass Spectrometry (GC/MS), along with 19 samples from the mainstem of the Delaware River. From the 20 samples with detailed characterization, a relationship between screening PAH and total NS&T PAH concentrations was determined, and total NS&T PAH concentrations were estimated for each sample. The samples from Mantua Creek had total NS&T PAH values of 2.4 and 3.8 parts per million (ppm), with the higher sample having a petroleum odor. The Raccoon Creek samples had estimated NS&T PAH values of 0.8 and 0.6 ppm. The September 2005 samples from the tributaries were all below thresholds at which adverse ecological effects may begin to be detected in Delaware River sediments.

The tributaries are important fish natal habitat. In recent research by Rice et al. (2000), mostly motivated by the *Exxon Valdez* oil spill, they found that:

1.) "PAH are released from oil films and droplets at progressively slower rates with increasing molecular weight leading to greater persistence of larger PAH;
2.) Eggs from demersally spawning fish species accumulate dissolved PAH released from oiled sediments, even when the oil is heavily weathered; and
3.) PAH accumulated from aqueous concentrations of < 1 ppb can lead to adverse sequelae appearing at random over an exposed individual's lifespan. These adverse effects likely result from genetic damage acquire during early embryogenesis in response to PAH exposure."

Based on these results, it is possible that the shallow subtidal habitats in the tributaries could be sites of some chronic exposure and injury, which has not been specifically included in this assessment. While the samples in the tributaries are limited, the results of the Preassessment Phase and September 2005 sediment analyses are generally consistent with a finding of moderate impacts in the tributaries immediately following the spill, but recovery within 1 year. Additionally, no oil was observed along the shorelines or released from subtidal sediments during the 2005 site visits. Therefore, all oiled tributaries were assumed to have completely recovered within 1 year.

Injury to the 1,899 acres of tributaries oiled as a result of the spill was calculated as 524 DSAYs. Figure 18 shows the recovery curves for the oiling categories for this habitat type.

TABLE 10. Estimated recovery rate and total number of DSAYs created from the oiled tributaries in NJ.

Oiling Degree	Acres	Services Present Post Spill		
		0.25 yr	1 yr	DSAYS
Very light	583.25	0.75	1	108.16
Light	1216.08	0.5	1	375.29
Moderate	99.9	0.35	1	40.08
Heavy	0			0.00
Total	**1899.23**			**523.53**

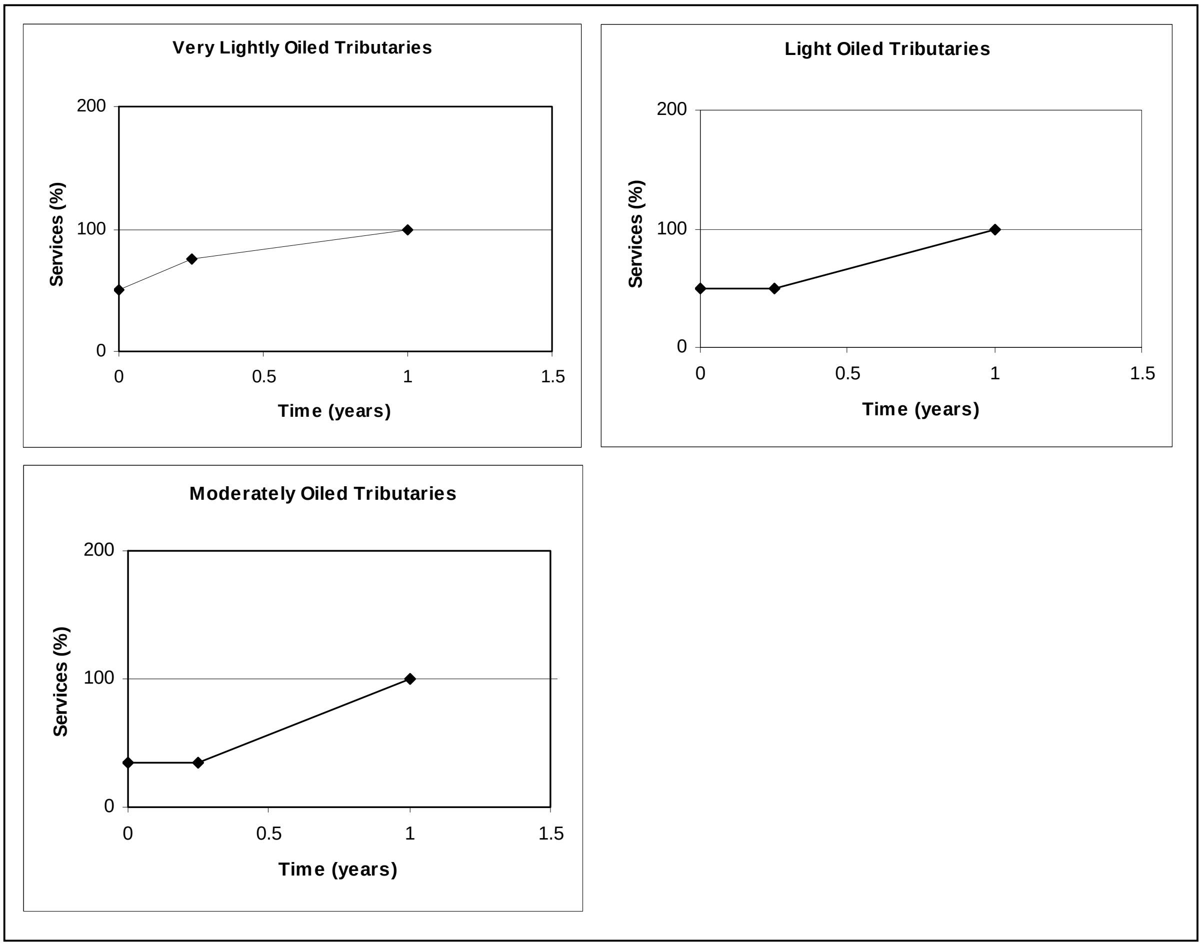

FIGURE 18. Assumed recovery of services over time for very lightly, lightly, and moderately oiled tributaries. There were no heavily oiled tributaries.

5.0 REFERENCES

Basson, P.A., J.E. Burchard, J.T. Hardy, A.R.G. Price. 1977. Biotopes of Western Arabian Gulf. Aramco Department of Loss Prevention and Environmental Affairs. Dhahran, Saudi Arabia. 284 pp.

Chan, E.I. 1977. Oil pollution and tropical littoral communities: biological effects of the 1975 Florida Keys oil spill. Proc. 1977 Oil Spill Conf., American Petroleum Institute, Washington, D.C., pp. 539-542.

Donlan, M., A. Shellenbarger, and D. MacDonald. 2005. Preliminary evaluation of PAH-related ecological effects on Delaware River subtidal sediments collected for the Athos Natural Resource Damage Assessment. Submitted to the Athos NRD Aquatic TWG. 18 pp.

Donlan, M.C., A. Shellenbarger Jones, and D.D. MacDonald. 2005. Proposed Aquatic Sediment Sampling and Analysis Design. Prepared for the Aquatic Technical Work Group for ATHOS I Spill. Prepared by Industrial Economics, Incorporated, Cambridge, Massachusetts and MacDonald Environmental Sciences Ltd., Nanaimo, British Columbia.

Grimes, B.G., M.T. Huish, J.H. Kerby, and D. Morgan. 1989. Species Profile: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic) -- Atlantic Marsh Fiddler. US Fish and Wildlife Service Biol. Rep 82 (11.114). US Army Corps of Engineers, TR EL-82-4. 18 pp.

Hanna, R.G.M. 1995. An approach to evaluate the application of the vulnerability index for oil spills in tropical Red Sea environments. Spill Science & Technology Bulletin 2(2/3): 171-186.

Hoff, R. and G. Shigenaka. 1999. Lessons learned from ten years of post-Exxon Valdez monitoring of intertidal shorelines. Proc. 1999 International Oil Spill Conference., American Petroleum Institute, Washington, D.C. 8 pp

Industrial Economics, Inc. 2005. Sediment collection field data report, M*/T Athos* oil spill, Delaware River. Industrial Economics, Inc. Cambridge, MA. 28 pp.

Lees, D.C., J.P. Houghton, and W.B. Driskell. 1996. Short-term effects of several types of shoreline treatment on rocky intertidal biota in Prince William Sound. Proc. of the Exxon Valdez Oil Spill Symposium, American Fisheries Society, Bethesda, Maryland, pp. 329-348.

Michel, J. and M.O. Hayes. 1993. Persistence and weathering of Exxon Valdez oil in the intertidal zone–3.5 years later: Proc. 1993 Intl. Oil Spill Conf., American Petroleum Institute, Washington, D.C., pp. 279-286.

NOAA (National Oceanographic and Atmospheric Administration). 1996. Coastal resource atlas: Delaware, New Jersey, and Pennsylvania. National Ocean Service, Office of Response and Restoration, Seattle, WA.

NOAA (National Oceanographic and Atmospheric Administration). 2000a. Habitat Equivalency Analysis: An Overview. Damage Assessment and Restoration Program, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, 23 pp.

NOAA (National Oceanographic and Atmospheric Administration). 2000b. Shoreline Assessment Manual, Third Edition. HAZMAT Report No. 2000-1, Hazardous Materials Response and Assessment Division, NOAA, Seattle, WA. 57 pp. + appendices.

Peterson, C. H. 2001. The “Exxon Valdez” Oil Spill in Alaska: Acute, Indirect and Chronic Effects on the Ecosystem. Advances in Marine Biology 39. Academic Press Ltd.

Ploen, Mark, Qualitech, Inc. 2006. Personal communication. 27 October 2006.

Rice, S.D., J.W. Short, R.A. Heintz, M.G. Carls, and A. Moles. 2000. Life history consequences of oil pollution in fish natal habitat. In: Peter Catania (ed.), Energy 2000: The Beginning of a New Millennium. Technomic Publishing Co., Lancaster, England, p. 1210-1215

Rolan, R.G. and R. Gallagher. 1991. Recovery of intertidal biotic communities at Sullom Voe following the Esso Bernicia oil spill of 1978. Proc. 1991 Oil Spill Conf., American Petroleum Institute, Washington, D.C., pp. 461-465.

Sell, D., L. Conway, T. Clark, G.B. Picken, J.M. Baker, G.M. Dunnet, A.D. McIntyre, and R.B. Clark. 1995. Scientific criteria to optimize oil spill cleanup. Proc. 1995 International Oil Spill Conf., American Petroleum Institute, pp. 595-610.

Shellenbarger Jones, A., M.C. Donlan, D.D. MacDonald, J. Hoff, and J. Steinbacher. 2006. Preliminary Aquatic Injury Quantification: Options and Initial Recommendations. Prepared for the Aquatic Technical Work Group for ATHOS I Spill. Prepared by Industrial Economics, Incorporated, Cambridge, Massachusetts, MacDonald Environmental Sciences Ltd., Nanaimo, British Columbia, and NOAA Damage Assessment Center, Silver Spring, Maryland.

Stern, D. 1995. Copepods. Pages 33-42 in L.E. Dove and R.M. Nyman, eds. Living Resources of the Delaware Estuary. The Delaware Estuary Program.

APPENDIX A

ECOLOGICAL SERVICES TABLES

TABLE 1. Ecological services and functions that have been attributed to salt and brackish marsh habitats.

Ecological Services	Function	Examples of Metrics	Consideration given for Injury Quantification
Primary production	Production of plant material that forms the base of the primary food web and the detrital food web. Much of salt marsh production is exported to adjacent habitats as detritus.	Above-ground biomass Below-ground biomass Stem density Species composition, richness, diversity, evenness	
Habitat for biota	Marshes serve as physical habitat for a variety of organisms including birds (herons, egrets, yellowlegs, etc.), mammals, insects, fish and a suite of invertebrates. The type and density of the vegetation is often the primary determinant of which species are served.	Canopy architecture of vegetation Above-ground biomass Species composition, richness, diversity, evenness Degree of usage by birds, mammals, etc.	
Food web support	Related to primary productivity but encompasses the entire system including invertebrates that are food for higher trophic levels that may only spend minor amounts of time in the wetland.	Density and biomass of living vegetation, infauna and epifauna Macrophyte and benthic algae detritus Species composition, richness, diversity, evenness Degree of use by higher trophic levels	
Fish and shellfish production	Marsh edge and ponds are important nursery areas for fish and shellfish Dense shellfish provide microhabitat for a diverse assemblage of organisms that contribute to overall system productivity and species composition.	Density Species composition Diversity, Evenness Biomass Population demographics Size class distributions	
Sediment/shore-line stabilization	Marsh vegetation serves to stabilize the soil and prevent erosion during normal tides, wave action or storm events	Shoreline change rates	

TABLE 1. Cont.

Water Filtration	The physical removal of particles and nutrients from water flowing through the wetlands.	Water quality metrics (turbidity)	
Nutrient removal/transformation	Nutrients can be removed and converted to plant material within the wetland and thereby reduce the occurrence of algal blooms and the resulting anoxic conditions in the bay.	Water quality metrics (nutrients)	
Sediment/toxicant retention	Sediments can be filtered out in the wetland rather than being transported to the bay. Toxicants can be transported adhering to sediment particles rather than dissolved in the water and these will be removed as well. Wetlands encourage redox reactions around plant roots that can detoxify many compounds	Sediment chemistry metrics	
Soil development and biogeochemical cycling	The soil is a living system that converts chemicals from one form to another and supports the growth of higher plants through biogeochemical cycling and the breakdown of detritus.	Soil and pore water nutrient concentrations Soil organic matter content Nitrogen fixation/Denitrification rates	
Storm Surge Protection	The presence of wetland habitat serves as a buffer between the bay and other habitats. Wetland vegetation can absorb wave energy and reduce the impacts to habitats further inland.	Reduction of storm surge height and velocity	
Slow runoff from upland	Marsh surface absorbs runoff from upland, vegetation also slows flow allowing more runoff to be absorbed	Water quality metrics (nutrients)	

TABLE 2. Ecological services and functions that have been attributed to tributary freshwater marsh habitats.

Ecological Services	Function	Examples of Metrics	Consideration given for Injury Quantification
Primary production	Production of plant material that forms the base of the primary food web and the detrital food web. Much of freshwater marsh production is exported to adjacent habitats as detritus.	Above-ground biomass Below-ground biomass Stem density Species composition, richness, diversity, evenness	
Habitat for biota	Marshes serve as physical habitat for a variety of organisms including birds (herons, egrets, geese, swans, ducks, etc.), mammals, insects, fish and a suite of invertebrates. The type and density of the vegetation is often the primary determinant of which species are served.	Canopy architecture of vegetation Above-ground biomass Species composition, richness, diversity, evenness Degree of usage by birds, mammals, etc.	
Food web support	Related to primary productivity but encompasses the entire system including invertebrates that are food for higher trophic levels that may only spend minor amounts of time in the wetland.	Density and biomass of living vegetation, infauna and epifauna Macrophyte and benthic algae detritus Species composition, richness, diversity, evenness Degree of use by higher trophic levels	
Fish and shellfish production	Marsh edge and ponds are important nursery areas for fish and shellfish Dense shellfish provide microhabitat for a diverse assemblage of organisms that contribute to overall system productivity and species composition.	Density Species composition Diversity, Evenness Biomass Population demographics Size class distributions	
Sediment/shore-line stabilization	Marsh vegetation serves to stabilize the soil and prevent erosion during normal tides or storm events	Shoreline change rates	

TABLE 2. Cont.

Water Filtration	The physical removal of particles and nutrients from water flowing through the wetlands.	Water quality metrics (turbidity)	
Nutrient removal/transformation	Nutrients can be removed and converted to plant material within the wetland and thereby reduce the occurrence of algal blooms and the resulting anoxic conditions in the bay.	Water quality metrics (nutrients)	
Sediment/toxicant retention	Sediments can be filtered out in the wetland rather than being transported to the river. Toxicants can be transported adhering to sediment particles rather than dissolved in the water and these will be removed as well. Wetlands encourage redox reactions around plant roots that can detoxify many compounds	Sediment chemistry metrics	
Soil development and biogeochemical cycling	The soil is a living system that converts chemicals from one form to another and supports the growth of higher plants through biogeochemical cycling and the breakdown of detritus.	Soil and pore water nutrient concentrations Soil organic matter content Nitrogen fixation/Denitrification rates	
Storm Surge Protection	The presence of wetland habitat serves as a buffer between the river and other habitats. Wetland vegetation can absorb wave energy and reduce the impacts to habitats further inland.	Reduction of storm surge height and velocity	
Slow runoff from upland	Marsh surface absorbs runoff from upland, vegetation also slows flow allowing more runoff to be absorbed	Water quality metrics (nutrients)	

TABLE 3. Ecological services and functions that have been attributed to coarse substrate (gravel beaches, exposed wave-cut platform in rock, and riprap habitats).

Ecological Services	Function	Examples of Metrics	Consideration given for Injury Quantification
Primary production	Gravel shorelines serve as a substrate for algal colonization that forms the base of some grazing food webs. Rock ledge or boulders (more stable substrates) support higher algal biomass and consequently higher primary production. Some rocky shore production is exported to adjacent habitats	Above-ground plant biomass Macroalgae biomass for rock ledge/boulder shores	
Food web support	Rock and gravel shorelines support algal growth by providing attachments substrates. Many species of sessile invertebrates also attach to rocky substrates. Both the attached algae and invertebrates provide habitat for some smaller algae and invertebrates. They support a different assemblage of organisms, most of which are only found on rocky shores (habitat specialists).	Invertebrate biomass and density Species composition, richness, diversity and evenness Recruitment and larval production Algal and invertebrate growth rates Attached macrophytes/algae, percent cover and biomass Hydrocarbon bioaccumulation Degree of use by higher trophic levels	
Fish and shellfish production	Dense shellfish provide microhabitat for a diverse assemblage of organisms that contribute to overall system productivity and species composition	Species biomass and density Species composition, richness, diversity, evenness Species size class distributions	
Habitat usage	These shorelines are used by a variety of invertebrates, birds, mammals and other organisms for roosting.	Bird densities Bird species composition, diversity, evenness	

TABLE 3. Cont.

Filtration of water (filter feeders)	Water is filtered by the filter feeders such as barnacles, amphipods, bivalves, tunicates, hydroids, sponges, polychaetes, brittle stars, etc. Water percolating through the gravel or underlying sand can be filtered prior to re-entering the bay. The particles may then be used by benthic epifauna and infauna.	Water turbidity Phytoplankton chlorophyll-*a* Phytoplankton Primary Productivity	
Biogeochemical and sedimentary processes	Biogeochemical process can occur within the pore water that can result in chemical transformation including denitrification and the breakdown of organic matter.	Denitrification Water column nutrients Sediment organic matter, nutrients	
Shoreline protection	Armoring of the shoreline provides protection during severe storm events.	Shoreline change rates	
Storm Surge Protection	Gravel berms can reduce storm surge impacts.	Height of storm berms	

TABLE 4. Ecological services and functions that have been attributed to sand beach habitats (sand beaches, mixed sand and gravel beaches, and sand flats)

Ecological Services	Function	Examples of Metrics	Consideration given for Injury Quantification
Food web support	Sand beaches provide habitat for many invertebrates that derive nutrition from particulates and detritus brought in on tides and waves. These organisms serve as food for higher trophic levels particularly birds and fish.	Microalgae primary production Microalgae chlorophyll-*a* Infaunal/epifaunal biomass and density Species composition. richness, diversity and evenness Invertebrate re-colonization rate Hydrocarbon bioaccumulation Degree of use by higher trophic levels	
Habitat usage	Habitat for invertebrates and other organisms, particularly birds. Several species of sandpiper use sandy beaches.	Bird densities Bird species composition, diversity, richness and evenness Behavioral studies Hydrocarbon bioaccumulation	
Fish and shellfish production	Dense shellfish provide microhabitat for a diverse assemblage of organisms that contribute to overall system productivity and species composition	Species abundance and density Species composition and richness Species size class distribution Standing crop or density	
Biogeochemical cycling and sedimentary processes	Biogeochemical process can occur within the pore water that can result in chemical transformation including denitrification and the breakdown of organic matter.	Denitrification Water column nutrients Sediment organic matter, nutrients	
Filtration of water (filter feeders)	Water is filtered by filter feeders such as barnacles, amphipods, bivalves, etc. Water percolating through the sand is filtered prior to re-entering the bay. The particles may then be used by benthic epifauna and infauna.	Water turbidity Phytoplankton chlorophyll-*a*	
Storm Surge Protection	Storm damage prevention and flood control.		

TABLE 5. Ecological services and functions that have been attributed to seawalls (exposed and sheltered man-made structures).

Ecological Services	Function	Examples of Metrics	Consideration given for Injury Quantification
Primary production	Seawalls can serve as a substrate for algal colonization that forms the base of some grazing food webs.	Above-ground plant biomass Macroalgae biomass for seawalls	
Food web support	Seawall shorelines support algal growth by providing attachments substrates. Many species of sessile invertebrates also attach to seawalls. Both the attached algae and invertebrates provide habitat for some smaller algae and invertebrates.	Invertebrate biomass and density Species composition, richness, diversity and evenness Recruitment and larval production Algal and invertebrate growth rates Attached macrophytes/algae, percent cover and biomass Hydrocarbon bioaccumulation Degree of use by higher trophic levels	
Habitat usage	These shorelines are used by a variety of invertebrates and fish for feeding	Fish species composition, diversity, evenness	
Shoreline protection	Armoring of the shoreline provides protection during severe storm events.	Shoreline change rates	
Storm Surge Protection	Seawalls can reduce storm surge impacts.	Height of seawalls	

Source Literature

Bliven, S. and Barr, B.W., 1987. Areas of Critical Environmental concern. Massachusetts coastal zone management office, Boston, MA.

Peterson, C., pers. comm., 2004. University of North Carolina, Institute of Marine Science Beaufort, NC.

Price, J.H., Irvine, D.E.G, and Farnham, W.F. (eds.), 1980. The shore environment, volume 1: Methods. Academic Press, New York, New York, 945 pp.

Price, J.H., Irvine, D.E.G, and Farnham, W.F. (eds.), 1980. The shore environment, volume 2: Ecosystems. Academic Press, New York, New York, 945 pp.

Strange, E, H. Galbraith, S. Bickel, D. Mills, D. Beltman, and J. Lipton, 2002. Determining Ecological Equivalence in Service-to-Service Scaling of Salt Marsh Restoration. *Environmental Management* 29:290-300.

Thayer, G.W. (ed.), 1992. Restoring the nation’s marine environment. A Maryland Sea Grant Book, College Park, Maryland, 716 pp.

Massachusetts Office of Coastal Zone Management, Boston, MA. February 1994. Guidelines for Barrier Beach Management

APPENDIX B

ACCESS AND GIS DATABASE REVIEWS AND CHANGES

Manual Review

The first manual review of the Access database was to incorporate all GPS coordinates collected during the SCAT surveys into the GIS database as a separate data layer. Arcs labeled with segment IDs and zones were created between the GPS coordinates to connect the “start” and “stop” endpoints from the SCAT forms. An on-screen assessment was then completed, comparing the GPS arcs with their assigned segment names/zone IDs (from the Access database) to the shoreline segment names/zone IDs recorded within the GIS. With the exception of a few areas, the majority of the segment names/zone IDs in the GIS data matched the Access data. After contacting the Environmental Unit staff on some of the problem areas, it was determined that the Access database and the GIS database were never intended to be linked during their production, so this limited the ability to conduct detailed comparisons or assign the data in Access to the GIS shoreline except via GPS coordinates. A second issue that complicated the linking of the Access records to the GIS data was that each record in Access could consist of many segments in the GIS data.

To evaluate the accuracy of the data in the Access database, a random sample of 129 records (approximately 30%) of the 426 records in the database were manually checked against the SCAT forms, focusing on errors that would affect the shoreline oiling determinations. Any changes made to the Access table were noted in a column that was added to the database titled “RPIChange”. During the review of the SCAT data within the Access table, it was observed that a number of records (122) had blank fields where information was missing. Records that had missing data under the headings of ESI, Width, Surface Oil Distribution I, Surface Oil Thickness I, and Oil Category were checked against the original SCAT forms and missing data were entered into the Access database if the information was available on the SCAT form. The table below lists the discrepancies found or changes that were made to the Access table during these reviews as well as the number of changes that were made. Table 1 lists all findings and changes to the Access database in greater detail.

Most discrepancies that were noted but not changed (Table 2) were segment names that differed between the SCAT forms and the Access database. This was usually the result of the SCAT team not recording the correct segment on the SCAT form while in the field or the segment divisions changing slightly after the SCAT had been completed. Using the GPS points, the correct location was verified from the SCAT form, when possible, to confirm that the oiling listed on the SCAT form was placed on the appropriate shoreline. However, no changes or edits were made in Access because the database had the correct segment recorded, and naming discrepancies would not affect the shoreline injury analyses. From the 187 records reviewed, only 20 changes were made to the Access database (note that there was an overlap of records checked for accuracy in the first review and records checked for blank fields in the second review).

The GIS data were then reviewed for geographical and oiling accuracy as compared to the SCAT maps and GPS locational data recorded on the SCAT form and in the Access database. Only three records, out of the 135 reviewed, were manually changed after comparing the spatial data to the SCAT forms and Access database (Table 3).

Automated Review

It was observed during the GIS database review that neither of the maximum oiling fields in the attribute table, “Max_Oil” or Scat_MxOil”, contained the correct maximum oiling level for all of the records listed in the shoreline oiling shapefile. RPI wrote an automated script that checked the maximum oiling level encountered in the "Oiling" field and in the individual dates of oiling against both the "Max_Oil" and "Scat_MxOil" fields. Sixty-one discrepancies were identified and appropriate actions taken (Table 4). A new field, "RPIMax_Oil", was created to store the new maximum oiling. This field can be updated by the SAT if they find incorrect oiling levels assigned to certain segments during their upcoming review. Table 5 shows the oiled segments with the new field that contains the maximum oiling level.

ESI Data Review

Several ESI classifications in the spatial data were evaluated based on initial reviews by the SAT. The following issues were reviewed:

- Tinicum Island shoreline was classified in the GIS as marsh, although the habitat is predominantly sand beach on the east side (New Jersey side), and some areas on the Pennsylvania side. The SCAT forms were reviewed and the ESI habitats were changed to the sand beach classifications. The majority of Tinicum Island shoreline is now classified as sand beach on both east and west sides.

- Some shorelines along the main river channel were classified as vegetated bluffs. The SCAT forms were used to update the shoreline classification in these areas. All vegetated bluffs found along the tributaries were changed to natural banks or riprap based on the SCAT forms.

- Concerns were also raised as to the lack of double shorelines or shorelines referencing tidal flats. Polygonal tidal flats provided by the wetland coverages for each state were added to the GIS data since they were not included in the original SCAT GIS data. The original SCAT GIS data does include a significant number of double shoreline types.

- NJ flats: flats that were mapped in 1995 during a previous spill (Jahre Spray) were incorporated into the tidal flat data at the request of the NJ Trustees. Tidal flats were filled in using flats from USGS topographic maps in areas where breaks in the tidal flat data occurred because of state boundaries.

- PA flats: five flats included in the National Wetlands Inventory dataset but not in the ESI habitat classifications were added to the ESI data at the request of PA Trustees.

A new field, RPI_ESI, was added to the GIS database to store the updated ESI attributes. Table 6 indicates the actions taken. Table 7 shows the segments and edit descriptions.

TABLE 1. Detailed edits, discrepancies, or notes associated with the review of the Access database and the GIS spatial data against the SCAT datasheets.

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
839	116	02-Dec-04	PA-5	C	VL	Add oil cat using Matrix 1	
395	190	03-Dec-04	NJ-8	B3	VL	Add oil cat using Matrix 1	
885	165	02-Dec-04	PA-4	J	L	Add oil cat using Matrix 1	
841	116	02-Dec-04	PA-5	C	L	Add oil cat using Matrix 1	GIS max oiling matches db
249	231	07-Dec-04	DE-9	Silver Run Creek	VL	Add oil cat using Matrix 1	
394	189	03-Dec-04	NJ-8	B2	VL	Add oil cat using Matrix 1	
772	49	29-Nov-04	PA-5	D	VL	Add oil cat using Matrix 1	
465	294	13-Dec-04	PA-3	C	L	Add oil cat using Matrix 1 & 2	
393	188	03-Dec-04	NJ-8	A2	VL	Add Surface Oil Dist. & oil cat using Matrix 1	
392	187	03-Dec-04	NJ-8	A1	VL	Add Surface Oil Dist. & oil cat using Matrix 1 & Add Subsurface oil Penetration	
252	233	07-Dec-04	NJ-3	Woodbury Creek	VL	Add width	
843	112	02-Dec-04	PA-6	B	VL	Added ESI, Changed Second Shore from 6B	
271	264	09-Dec-04	NJ-5	Old Canal	VL	Checked no change	
64	12	29-Nov-04	NJ-3	F	H	Checked no change	
282	259	09-Dec-04	DE-10	Smyrna River	VL	Checked no change	
896	339	11-Feb-05	DBRA	Delaware Bay Response Area		Checked no change	
469	266	09-Dec-04	PA-8	B	VL	Checked no change	
258	244	08-Dec-04	DE-9	Black Bird Creek	VL	Checked no change	
248	232	07-Dec-04	DE-9	Appoqunimink	VL	Checked no change	
305	288	13-Dec-04	NJ-3		NO	Checked no change	
270	263	09-Dec-04	NJ-5	Old Canal	VL	Checked no change	
837	114	02-Dec-04	PA-5	A	M	Checked no change	
95	27	29-Nov-04	NJ-4	A		Checked no change	
92	26	29-Nov-04	NJ-4	A	VL	Checked no change	
894	337	11-Feb-05	DBRA	Delaware Bay Response Area	NO	Checked no change	

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
842	111	02-Dec-04	PA-6	A	VL	Checked no change	
22	205	04-Dec-04	DE-5	A	VL	Checked no change	
133	181	03-Dec-04	NJ-6	E		Checked no change	
862	317	16-Dec-04	DE-7	A1	L	Checked no change	
848	195	03-Dec-04	PA-3	E	U	Checked no change	
74	86	30-Nov-04	NJ-3	H	U	Checked no change	
863	318	16-Dec-04	DE-7	A2	L	Checked no change	
864	319	16-Dec-04	DE-7	A3	VL	Checked no change	
866	321	16-Dec-04	DE-8	B	L	Checked no change	
19	204	04-Dec-04	DE-2	D	L	Checked no change	
870	324	16-Dec-04	NJ-11			Checked no change	
840	117	02-Dec-04	PA-5	D	VL	Checked no change	
420	272	10-Dec-04	DE-1		L	Checked no change	
415	199	04-Dec-04	DE-1	J-1	M	Checked no change	
419	271	10-Dec-04	DE-1		VL	Checked no change	
16	201	04-Dec-04	DE-2	A	M	Checked no change	
26	207	04-Dec-04	DE-7	B	VL	Checked no change	
414	198	04-Dec-04	DE-1	I	L	Checked no change	
416	199	04-Dec-04	DE-1	J-2	M	Checked no change	
325	134	02-Dec-04	NJ-4	B	M	Checked no change; matches SCAT form	GIS max oiling matches db
865	320	16-Dec-04	DE-8	A	L	Checked no change; matches SCAT form	GIS max oiling matches db
884	98	30-Nov-04	NJ-5	D	NO	Checked no change; matches SCAT form	GIS max oiling matches db
106	23	29-Nov-04	NJ-4	D		Checked no change; matches SCAT form	no oiling category, could not assess
424	274	10-Dec-04	DE-1	Downstream tide gate	VL	Checked no change; matches SCAT form	GIS max oiling matches db
78	15	29-Nov-04	NJ-3	I		Checked no change; matches SCAT form	no oiling category, could not assess
422	273	10-Dec-04	DE-1	Downstream point	VL	Checked no change; matches SCAT form	GIS max oiling matches db

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
87		29-Nov-04	NJ-3	K	U	Could not find; No SCAT ID and No NJ3-K	
51	121	02-Dec-04	NJ-3	A	M	Db lists surface oil distribution as 30, scat form lists it as 15; changed db to 15	GIS Max oiling matches db
58	10	29-Nov-04	NJ-3	D	M	Db lists surface oil type but this is NOT listed on the scat sheet; no change made; doesn't affect oiling degree	Not sure; area gps segment covers is NJ-3 Zone E and has no oil value. Small section at end is Zone D and oil Cat of M.; Leave as is, cannot decipher
374	236	07-Dec-04	NJ-12	Money Island off Bay View Rd.	NO	Matches SCAT form	GIS Max oiling matches db
88	90	30-Nov-04	NJ-3	K	H	Matches SCAT form	unsure if oiling is in correct spot, probably okay
454	305	14-Dec-04	PA-7	H	L	Matches SCAT form	GIS Max oiling matches db
373	235	07-Dec-04	NJ-12	Raybins Beach to Fishing Cr./Egg Isl.	NO	Matches SCAT form	GIS Max oiling matches db
83	88	30-Nov-04	NJ-3	J	M	Matches SCAT form	GIS Max oiling matches db
82	16	29-Nov-04	NJ-3	J	L	Matches SCAT form	GIS Max oiling matches db
375	236	07-Dec-04	NJ-12	Gandy Beach (Del Bay Rd to South Cove Rd)	NO	Matches SCAT form	GIS Max oiling matches db
451	302	14-Dec-04	PA-7	K	M	Matches SCAT form	GIS max oiling matches db
46	120	02-Dec-04	NJ-2	C	VL	Matches SCAT form	No GPS location, was not checked
371	179	03-Dec-04	NJ-6	C	VL	Matches SCAT form	NO; GPS Segment at NJ-6 Zone A not Zone C and all oiling categories are Light, no VL listed for any date at that location; Okay- segment name discrepancy
376	237	07-Dec-04	NJ-12	Cedar Lake @ Rt. 553	NO	Matches SCAT form	GIS Max oiling matches db
786	57	30-Nov-04	PA-2	H	M	Matches SCAT form	GIS max oiling matches db
366	313	15-Dec-04	NJ-4	F	M	Matches SCAT form	GIS Max oiling matches db
850	197	03-Dec-04	PA-4	J	M	Matches SCAT form	No GPS location, was not checked
788	50	30-Nov-04	PA-2	A	M	Matches SCAT form	GIS Max oiling matches db
886	165	02-Dec-04	PA-4	J	VL	Matches SCAT form	NO; oiling VL not included in any of the oiling dates; Okay

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
349	309	14-Dec-04	NJ-4	D	L	Matches SCAT form	GIS max oiling matches db
101	21	29-Nov-04	NJ-4	D	VL	Matches SCAT form	GIS max oiling matches db
846	192	03-Dec-04	PA-3	B	M	Matches SCAT form	GIS max oiling matches db
845	191	03-Dec-04	PA-3	A	M	Matches SCAT form	Max oil field not populated correctly; will be fixed during automatic checks
844	194	03-Dec-04	PA-3	D	M	Matches SCAT form	GIS max oiling matches db
853	228	06-Dec-04	PA-5	Darby Creek	NO	Matches SCAT form	GIS Max oiling matches db
869	322	16-Dec-04	NJ-11		NO	Matches SCAT form	GIS max oiling matches db
878	333	07-Jan-05	NJ-3	Rest of island	M	Matches SCAT form	GIS Max oiling matches db
390	186	03-Dec-04	NJ-7	B	L	Matches SCAT form	No GPS location, was not checked
388	185	03-Dec-04	NJ-7	A	L	Matches SCAT form	GIS Max oiling matches db
17	202	04-Dec-04	DE-2	B	L	Matches SCAT form	GIS Max oiling matches db
873	328	27-Dec-04	NJ-3	G-H	VL	Matches SCAT form	GIS max oiling matches db
55	9	29-Nov-04	NJ-3	C	M	Matches SCAT form	GIS max oiling matches db
872	327	27-Dec-04	NJ-3	B-C	VL	Matches SCAT form	GIS max oiling matches db
57	123	02-Dec-04	NJ-3	C	L	Matches SCAT form	GIS max oiling matches db
387	184	03-Dec-04	NJ-7	C		Matches SCAT form	No GPS location, was not checked
386	184	03-Dec-04	NJ-7	C	VL	Matches SCAT form	GIS Max oiling matches db
61	81	30-Nov-04	NJ-3	D	H	Matches SCAT form	GIS Max oiling matches db, but shore segment names do not match; okay
62	11	29-Nov-04	NJ-3	E		Matches SCAT form	No oiling category, could not assess
77	128	02-Dec-04	NJ-3	H	L	Matches SCAT form	GIS Max oiling matches db
399	219	04-Dec-04	NJ-11	D	NO	Matches SCAT form	GIS Max oiling matches db
21	221	05-Dec-04	DE-4		NO	Matches SCAT form	GIS max oiling matches db
384	214	04-Dec-04	NJ-10		NO	Matches SCAT form	GIS Max oiling matches db
459	255	09-Dec-04	NJ-4	Site 5		Matches SCAT form	No oiling category, could not assess
778	44	29-Nov-04	PA-7	A	H	Matches SCAT form	GIS max oiling matches db
779	60	30-Nov-04	PA-1	B	L	Matches SCAT Form	GIS Max oiling matches db
71	85	30-Nov-04	NJ-3	G	M	Matches SCAT form	GIS max oiling matches db
781	59	30-Nov-04	PA-1	A	NO	Matches SCAT Form	GIS max oiling matches db
73	14	29-Nov-04	NJ-3	H	L	Matches SCAT form	GIS max oiling matches db

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
782	58	30-Nov-04	PA-2	I	M	Matches SCAT Form	GIS Max oiling matches db, but GPS segment is approx 7 miles long, portion at PA2-I is at one end of gps segment and matches oiling; Okay
783	54	30-Nov-04	PA-2	E	VL	Matches SCAT form	GIS Max oiling matches db
29	2	29-Nov-04	NJ-1	B	NO	Matches SCAT form	GIS max oiling matches db
76	86	30-Nov-04	NJ-3	H	M	Matches SCAT form	GIS max oiling matches db
377	237	07-Dec-04	NJ-12	Cedar Cr. Mouth & Del. Bay @ Paris Rd.	NO	Matches SCAT form	GIS Max oiling matches db
63	82	30-Nov-04	NJ-3	E	H	Matches SCAT form	GIS Max oiling matches db
816	70	30-Nov-04	PA-7	D	M	Matches SCAT form	GIS Max oiling matches db
774	48	29-Nov-04	PA-5	C	L	Matches SCAT form	GIS Max oiling matches db
250	230	07-Dec-04	DE-9	Main Stem DE River	VL	Matches SCAT form	No GPS location, was not checked
822	160	02-Dec-04	PA-4	F	H	Matches SCAT form	GIS Max oiling matches db
331	137	02-Dec-04	NJ-4	D	M	Matches SCAT form	GIS Max oiling matches db
801	67	30-Nov-04	PA-7	C	H	Matches SCAT form	GIS max oiling matches db
260	245	08-Dec-04	DE-9	Cedar Swamp	NO	Matches SCAT form	No GPS location, was not checked
802	68	30-Nov-04	PA-7	C	M	Matches SCAT form	GIS max oiling matches db
262	247	08-Dec-04	NJ-5	Oldmans Creek	NO	Matches SCAT form	GIS max oiling matches db
328	136	02-Dec-04	NJ-4	C	M	Matches SCAT form	GIS Max oiling matches db
431	105	01-Dec-04	NJ-1	E	H	Matches SCAT form	GIS Max oiling matches db, but shore segment listed as NJ-1 Zone C not Zone E; Okay- segment name discrepancy
327	135	02-Dec-04	NJ-4	B	M	Matches SCAT form	GIS Max oiling matches db
266	262	09-Dec-04	NJ-5	Old Canal	VL	Matches SCAT form	GIS Segment ID is NJ-4 Zone E, not NJ-5 old canal; Area matches SCAT map; GIS max oiling for location matches db; Okay- segment name discrepancy
346	307	14-Dec-04	NJ-4	C	L	Matches SCAT form	GIS Max oiling matches db
268	262	09-Dec-04	NJ-5	Old Canal	VL	Matches SCAT form	GIS Segment ID is NJ-4 Zone E, not NJ-5 old canal; Area matches SCAT map; GIS max oiling for location matches db; Okay- segment name discrepancy
763	40	29-Nov-04	PA-4	F	M	Matches SCAT form	GIS Max oiling matches db

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
324	133	02-Dec-04	NJ-4	A	H	Matches SCAT form	GPS Segment includes NJ-4 Zone A & Zone B. GIS max oiling matches db; Okay- segment name discrepancy
281	260	09-Dec-04	DE-10	Woodland	VL	Matches SCAT form	GIS Max oiling matches db
418	200	04-Dec-04	DE-1	J-4	L	Matches SCAT form	GIS Max oiling matches db, but shore segment listed as DE-1 Zone H not DE-1 Zone J4; Okay-segment name discrepancy
322	132	02-Dec-04	NJ-4	A	H	Matches SCAT form	GIS Max oiling matches db
805	73	30-Nov-04	PA-7	E	M	Matches SCAT form	GIS Max oiling matches db
880	334	13-Jan-05	NJ-3		M	Matches SCAT form	GIS max oiling matches db
769	35	29-Nov-04	PA-4	A	L	Matches SCAT form	GIS max oiling matches db
813	72	30-Nov-04	PA-7	E	L	Matches SCAT form	GIS Max oiling matches db
814	71	30-Nov-04	PA-7	D	M	Matches SCAT form	GIS Max oiling matches db, but gps segment covers PA-7 Zone D and Zone E; Okay- segment name discrepancy
306	289	13-Dec-04	NJ-3		VL	Matches SCAT form	GIS Max oiling matches db
770	43	29-Nov-04	PA-4	I	M	Matches SCAT form	GIS Max oiling matches db, but shore segment listed as PA-4 Zone J & Zone I; Okay- segment name discrepancy
315	306	14-Dec-04	NJ-4	C	L	Matches SCAT form	GIS Max oiling matches db
417	200	04-Dec-04	DE-1	J-3	M	Matches SCAT form	GIS Max oiling matches db, but shore segment listed as DE-1 Zone H not DE-1 Zone J3; Okay-segment name discrepancy
122	150	02-Dec-04	NJ-5	D	VL	Matches SCAT form	Not sure; GPS segment Zone D is located at shore segment Zone C, Zone C does not match oiling of zone D. Shore location of Zone D matches this record; Okay- segment name discrepancy
107	18	29-Nov-04	NJ-4	E	M	Matches SCAT form	GIS max oiling matches db
108	18	29-Nov-04	NJ-4	E	L	Matches SCAT form	GIS Max oiling matches db
244	227	06-Dec-04	DE-5	C & D Canal	NO	Matches SCAT form	No GPS location, was not checked
110	19	29-Nov-04	NJ-4	E	NO	Matches SCAT form	GIS max oiling matches db
28	109	02-Dec-04	NJ-1	A	NO	Matches SCAT form	No GPS location, was not checked

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
113	145	02-Dec-04	NJ-5	A	L	Matches SCAT form	Half of shore segment oiling matched, other half oiling did not match; Okay- segment name discrepancy
343	143	02-Dec-04	NJ-4	CI	M	Matches SCAT form	GIS Max oiling matches db, but shore segment listed as NJ-4 Zone D not Zone B; Okay- segment name discrepancy
838	115	02-Dec-04	PA-5	B	H/M	Matches SCAT form	NO; correct area of shore, but listed only as M, no H, reason for H/M is b/c thickness was pooled and coat.; okay- but H/M will affect widths
342	143	02-Dec-04	NJ-4	CI	M	Matches SCAT form	GIS Max oiling matches db, but shore segment listed as NJ-4 Zone D not Zone A; Okay- segment name discrepancy
341	142	02-Dec-04	NJ-4	E	M	Matches SCAT form	GIS Max oiling matches db, but there are no oiling values for any of the dates in the GIS; Okay- segment name discrepancy
339	141	02-Dec-04	NJ-4	E	M	Matches SCAT form	GIS Max oiling matches db
759	31	29-Nov-04	PA-3	C	M	Matches SCAT form	GIS max oiling matches db
332	138	02-Dec-04	NJ-4	D	M	Matches SCAT form	GIS Max oiling matches db
121	149	02-Dec-04	NJ-5	C	VL	Matches SCAT form	GIS max oiling matches db
243	226	06-Dec-04	DE-5	Branch Canal	NO	Matches SCAT form	GIS max oiling matches db
123	212	04-Dec-04	NJ-5	D	VL	Matches SCAT form	GIS Max oiling matches db
833	159	02-Dec-04	PA-4	E	M	Matches SCAT form	GIS Max oiling matches db
443	296	14-Dec-04	PA-7	P	VL	Matches SCAT form	GIS max oiling matches db
126	210	04-Dec-04	NJ-5	D	L	Matches SCAT form	GIS Max oiling matches db
127	209	04-Dec-04	NJ-5	D	L	Matches SCAT form	GIS Max oiling matches db
891	99	01-Dec-04	NJ-1	A	VL	Matches SCAT form	No; GIS oiling indicates Clean; was changed to reflect VL
438	281	12-Dec-04	NJ-12	Beach - East side of Delaware Bay	NO	Matches SCAT form	GIS Max oiling matches db
437	280	12-Dec-04	NJ-12	Beach - East side of Delaware Bay	NO	Matches SCAT form	GIS Max oiling matches db
134	178	03-Dec-04	NJ-6	F	VL	Matches SCAT form	GIS max oiling matches db

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
436	279	12-Dec-04	NJ-12	Beach - East side of Delaware Bay	NO	Matches SCAT form	GIS Max oiling matches db
825	164	02-Dec-04	PA-4	I	M	Matches SCAT form	GIS Max oiling matches db, but shore segment names do not; okay
435	278	12-Dec-04	NJ-12	Beach - East side of Delaware Bay	NO	Matches SCAT form	GIS Max oiling matches db
30	110	02-Dec-04	NJ-1	B	NO	Matches SCAT form	GIS max oiling matches db
120	97	30-Nov-04	NJ-5	C	L	Matches SCAT form	GIS Max oiling matches db
292	277	11-Dec-04	DE-5	Branch Canal	VL	SCAT does NOT list surface oil type OR thickness unless it is in the hand written notes which are illegible; scat form scanned in as de-7 instead of de-5; no change made	GIS max oiling matches db
291	276	11-Dec-04	DE-5	C&D Canal CD-1	VL	SCAT does NOT list surface oil type unless it is in the hand written notes which are illegible; scat form scanned in as de-7 instead of de-5; no change made	
91	92	30-Nov-04	NJ-4	A	H	SCAT form calls this segment NJ-3 not NJ-4 but okay	GIS max oiling matches db
462	258	09-Dec-04	NJ-4	Site 8		SCAT form lists ESI as freshwater marsh, db lists ESI as 10C, changed to 10B	
461	257	09-Dec-04	NJ-4	Site 7		SCAT form lists ESI as freshwater marsh, db lists ESI as 10C, changed to 10B	
460	256	09-Dec-04	NJ-4	Site 6		SCAT form lists ESI as freshwater marsh, db lists ESI as 10C, changed to 10B	
458	254	09-Dec-04	NJ-3	Site 4		SCAT form lists ESI as freshwater marsh, db lists ESI as 10C, changed to 10B	

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
457	253	09-Dec-04	NJ-3	Site 3		SCAT form lists ESI as freshwater marsh, db lists ESI as 10C, changed to 10B	
456	252	09-Dec-04	NJ-3	Site 2		SCAT form lists ESI as freshwater marsh, db lists ESI as 10C, changed to 10B	
455	251	09-Dec-04	NJ-3	Site 1		SCAT form lists ESI as freshwater marsh, db lists ESI as 10C, changed to 10B	
408	172	03-Dec-04	DE-1	F-1	M	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db
413	175	03-Dec-04	DE-1	H	M	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS Max oiling matches db, but shore segment listed as DE-1 Zone H not DE-2 Zone H; Okay-segment name discrepancy
412	174	03-Dec-04	DE-1	G-2	L	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db
409	172	03-Dec-04	DE-1	F-2	L	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS Max oiling matches db, but shore segment listed as DE-1 Zone F not DE-2 Zone F; Okay-segment name discrepancy
407	173	03-Dec-04	DE-1	F-3	M	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db
406	168	03-Dec-04	DE-1	Mid Zone	M	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db
405	171	03-Dec-04	DE-1	Oil on Debris	M	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	NO; GPS segment at DE-1 Zone E not DE-2 Zone E; Oiling for location Does not match; GIS had L, was changed to M in GIS
404	170	03-Dec-04	DE-1	Mainly on Veg.	M	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db

Count	SCAT ID	Date	Segment ID	Zone ID	Oil Category	RPIChange	RPI_GISCheck
403	169	03-Dec-04	DE-1	Oiled Rack	M	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db
402	168	03-Dec-04	DE-1	Lower Zone	L	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db
401	167	03-Dec-04	DE-1	B	M	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db
400	166	03-Dec-04	DE-1	A	L	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db
411	174	03-Dec-04	DE-1	G-1	M	Scat form segment entered as DE-2 not DE-1 on SCAT Sheet; Is DE-1 in GIS; not changed	GIS max oiling matches db

TABLE 2. Manual review of the Access database after comparing the data to the original SCAT forms.

Count (Access Record changes)	Action
1	Added width measurement
1	Edited surface oil distribution number
2	Added surface oil distribution data & oil category
8	Added / edited ESI data
8	Added oil category data
18	Discrepancies noted but no changes made; will not affect analyses
149	Checked no change; matches SCAT form

TABLE 3. Manual review of GIS database after comparing the digital data to the Access database and SCAT forms:

Count (Access Record Changes)	Action
3	Incorrect oiling level assigned; fixed manually or were fixed during automatic check (see below)
5	Could not assess (no oiling category or no GPS location)
7	Discrepancies noted but could not decipher from SCAT forms or SCAT maps; no changes made
17	Segment name discrepancy but GIS maximum oiling matches Access; no changes made
103	GIS maximum oiling matches SCAT/ Access database

TABLE 4. Comparison of oiling fields ("Oiling" and dates of oiling) in the GIS data to the existing oiling maximum fields ("Max_Oil" & Scat_MxOil):

Count (GIS Segment Changes)	Action
7	New maximum oiling level based on edits in tasks 1 through 4. "RPIMax_Oil" updated to match the edits.
8	Oiling level lower in the maximum fields than in the oiling fields. "RPIMax_Oil" updated to match the oiling fields.
12	Oiling blank or lower in the oiling fields than in the maximum fields. "RPIMax_Oil" updated to match the maximum fields.
34	Max_Oil, Scat_MxOil, or both blank. "RPIMax_Oil" updated to match the maximum oiling from the oiling fields or non-blank maximum fields.

TABLE 5. Records of oiled segments from the GIS attribute table with discrepancies in the maximum oiling level field. These records can be located in the GIS data based on the RPI_ID field.

New maximum oiling level based on RPI's edits in tasks 1 through 4. "RPIMax_Oil" updated to match the edits.						
RPI_ID	**scat_id**	**Zone_ID**	**Max_Oil**	**Scat_MxOil**	**RPIMax_Oil**	**RPI_NOTES**
535	DE-1	E	LIGHT	DE-1 LIGHT	MEDIUM	Oiling - Based on SCAT
503	NJ-1	C	CLEAN	NJ-1 CLEAN	VERY LIGHT	Oiling - Changed based on SCAT map
514	NJ-1	C	CLEAN	NJ-1 CLEAN	VERY LIGHT	Oiling - Changed based on SCAT map
532	NJ-1	C	CLEAN	NJ-1 CLEAN	VERY LIGHT	Oiling - Changed based on SCAT map
4212	NJ-1	C	CLEAN	NJ-1 CLEAN	VERY LIGHT	Oiling - Based on SCAT
4790	NJ-1	C	CLEAN	NJ-1 CLEAN	VERY LIGHT	Oiling - Changed based on SCAT map
4791	NJ-1	C	CLEAN	NJ-1 CLEAN	VERY LIGHT	Oiling - Changed based on SCAT map
Oiling lower in the maximum fields than in the oiling fields. "RPIMax_Oil" updated to match the oiling fields.						
RPI_ID	**scat_id**	**Zone_ID**	**Max_Oil**	**Scat_MxOil**	**RPIMax_Oil**	**RPI_NOTES**
4720	NJ-6	B	VERY LIGHT	NJ-6 VERY LIGHT	LIGHT	Oiling - Max_Oil VERY LIGHT
4151	PA-3	A	LIGHT	PA-3 LIGHT	MEDIUM	Oiling - Max_Oil LIGHT
4351	PA-3	A	LIGHT	PA-3 LIGHT	MEDIUM	Oiling - Max_Oil LIGHT
4353	PA-3	A	LIGHT	PA-3 LIGHT	MEDIUM	Oiling - Max_Oil LIGHT
4697	PA-3	A	LIGHT	PA-3 LIGHT	MEDIUM	Oiling - Max_Oil LIGHT
4777	PA-3	A	LIGHT	PA-3 LIGHT	MEDIUM	Oiling - Max_Oil LIGHT
4779	PA-3	A	LIGHT	PA-3 LIGHT	MEDIUM	Oiling - Max_Oil LIGHT
4780	PA-3	A	LIGHT	PA-3 LIGHT	HEAVY	Oiling - Max_Oil LIGHT
Max_Oil, Scat_MxOil, or both blank. "RPIMax_Oil" updated to match the maximum oiling from the oiling fields or non-blank maximum fields.						
RPI_ID	**scat_id**	**Zone_ID**	**Max_Oil**	**Scat_MxOil**	**RPIMax_Oil**	**RPI_NOTES**
3942	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
3943	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
3944	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
3949	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
3956	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
3970	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank

3979	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
3980	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
3992	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
3994	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
4004	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
4005	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
5385	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
5386	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
5389	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
5390	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
5393	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
5395	DBRA		CLEAN		CLEAN	Oiling - Scat_MxOil blank
4590	NJ-8	A1		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil Blank
1352	NJ-8	A2		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil blank
1427	NJ-8	A2		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil blank
1346	NJ-8	A3		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil blank
5418	NJ-8	A3		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil Blank
1314	NJ-8	B1		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil blank
5419	NJ-8	B1		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil Blank
1269	NJ-8	B2		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil blank
1283	NJ-8	B2		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil blank
1285	NJ-8	B2		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil blank
1303	NJ-8	B2		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil blank
5420	NJ-8	B2		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil Blank
1232	NJ-8	B3		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil blank
4451	NJ-8	B3		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil Blank
5421	NJ-8	B3		NJ-8 VERY LIGHT	VERY LIGHT	Oiling - Max_Oil Blank
4682					LIGHT	Oiling - Max_Oil Blank & Scat_MxOil blank

Oiling blank or lower in the oiling fields than in the maximum fields. "RPIMax_Oil" updated to match the maximum fields.

RPI_ID	scat_id	Zone_ID	Max_Oil	Scat_MxOil	RPIMax_Oil	RPI_NOTES
5381	DE-1	H	MEDIUM	DE-1 MEDIUM	MEDIUM	Oiling - LIGHT from RPI Script
5382	DE-1	H	MEDIUM	DE-1 MEDIUM	MEDIUM	Oiling - LIGHT from RPI Script

4736	NJ-3	A	MEDIUM	NJ-3 MEDIUM	MEDIUM	Oiling - Blank from RPI Script
5370	NJ-3	A	MEDIUM	NJ-3 MEDIUM	MEDIUM	Oiling - Blank from RPI Script
5371	NJ-3	A	MEDIUM	NJ-3 MEDIUM	MEDIUM	Oiling - Blank from RPI Script
813	NJ-4	C	CLEAN	NJ-4 CLEAN	CLEAN	Oiling - Blank from RPI Script
4406	NJ-4	E	MEDIUM	NJ-4 MEDIUM	MEDIUM	Oiling - Blank from RPI Script
4476	NJ-4	E	LIGHT	NJ-4 LIGHT	LIGHT	Oiling - Blank from RPI Script
4776	NJ-4	E	MEDIUM	NJ-4 MEDIUM	MEDIUM	Oiling - Blank from RPI Script
4404	NJ-5	C	VERY LIGHT	NJ-5 VERY LIGHT	VERY LIGHT	Oiling - Blank from RPI Script
890	NJ-5	D	CLEAN	NJ-5 CLEAN	CLEAN	Oiling - Blank from RPI Script
4236	NJ-5	D	CLEAN	NJ-5 CLEAN	CLEAN	Oiling - Blank from RPI Script

TABLE 6. ESI edits for the GIS data (task 6 from above):

Count (GIS Segment Changes)	Action
44	Tinicum Island segments updated with ESI from the SCAT forms.
171	Vegetated bluff segments on the main river channel updated with ESI from the SCAT forms or adjacent ESI classifications.

TABLE 7. Records of ESI segments from the GIS attribute table with discrepancies in the ESI field. These records can be located in the GIS data based on the RPI_ID field.

Tinicum Island ESI updates.					
RPI_ID	**scat_id**	**Zone_ID**	**ESI**	**RPI_ESI**	**RPI_NOTES**
4506	PA-7	A	10A	3	ESI - Changed to 3 based on SCAT
4507	PA-7	A	10A	3	ESI - Changed to 3 based on SCAT
5396	PA-7	A	10A	3	ESI - Changed to 3 based on SCAT
5411	PA-7	A	10A	3	ESI - Changed to 3 based on SCAT
5397	PA-7	B	10A	3	ESI - Changed to 3 based on SCAT
5398	PA-7	B	10A	3	ESI - Changed to 3 based on SCAT
4196	PA-7	C	10A	3	ESI - Changed to 3 based on SCAT
4197	PA-7	C	10A	3	ESI - Changed to 3 based on SCAT
4198	PA-7	C	10A	3	ESI - Changed to 3 based on SCAT
5363	PA-7	C	10A	3	ESI - Changed to 3 based on SCAT
5399	PA-7	C	10A	3	ESI - Changed to 3 based on SCAT
4194	PA-7	D	10A	3	ESI - Changed to 3 based on SCAT
4195	PA-7	D	10A	3	ESI - Changed to 3 based on SCAT
5364	PA-7	D	10A	3	ESI - Changed to 3 based on SCAT
5400	PA-7	D	10A	3	ESI - Changed to 3 based on SCAT
4742	PA-7	E	10A	3	ESI - Changed to 3 based on SCAT
5402	PA-7	E	10A	3	ESI - Changed to 3 based on SCAT
772	PA-7	F	10A	5	ESI - Changed to 5 based on SCAT
4193	PA-7	F	10A	5	ESI - Changed to 5 based on SCAT
4743	PA-7	F	10A	5	ESI - Changed to 5 based on SCAT
4744	PA-7	F	10A	5	ESI - Changed to 5 based on SCAT
4192	PA-7	G	10A	3	ESI - Changed to 3 based on SCAT
4745	PA-7	H	10A	3	ESI - Changed to 3 based on SCAT
5359	PA-7	H	10A	5	ESI - Changed to 5 based on SCAT
5360	PA-7	H	10A	3	ESI - Changed to 3 based on SCAT
5361	PA-7	H	10A	5	ESI - Changed to 5 based on SCAT
4516	PA-7	I	10A	5	ESI - Changed to 5 based on SCAT
4517	PA-7	I	10A	5	ESI - Changed to 5 based on SCAT
4515	PA-7	J	10A	6A	ESI - Changed to 6A based on SCAT
4511	PA-7	K	10A	5	ESI - Changed to 5 based on SCAT
5404	PA-7	K	10A	5	ESI - Changed to 5 based on SCAT
5405	PA-7	L	10A	5	ESI - Changed to 5 based on SCAT
5406	PA-7	L	10A	5	ESI - Changed to 5 based on SCAT
4510	PA-7	M	10A	5	ESI - Changed to 5 based on SCAT
5407	PA-7	M	10A	5	ESI - Changed to 5 based on SCAT
5408	PA-7	M	10A	5	ESI - Changed to 5 based on SCAT
5362	PA-7	N	10A	5	ESI - Changed to 5 based on SCAT
5409	PA-7	N	10A	5	ESI - Changed to 5 based on SCAT
4508	PA-7	O	10A	5	ESI - Changed to 5 based on SCAT
4509	PA-7	O	10A	5	ESI - Changed to 5 based on SCAT
4512	PA-7	O	10A	5	ESI - Changed to 5 based on SCAT

4513	PA-7	O	10A	5	ESI - Changed to 5 based on SCAT
4514	PA-7	O	10A	5	ESI - Changed to 5 based on SCAT
5410	PA-7	O	10A	5	ESI - Changed to 5 based on SCAT
Vegetated Bluff ESI updates.					
RPI_ID	**scat_id**	**Zone_ID**	**ESI**	**RPI_ESI**	**RPI_NOTES**
546	NJ-1	A	8A	1B	ESI - based on SCAT
547	NJ-1	A	8A	1B	ESI - based on SCAT
4159	NJ-1	A	8A	1B	ESI - based on SCAT
535	NJ-1	C	8A	5	ESI - Based on SCAT
4605	NJ-1	C	8A	5	ESI - based on SCAT
4606	NJ-1	C	8A	5	ESI - based on SCAT
4607	NJ-1	C	8A	5	ESI - based on SCAT
4608	NJ-1	C	8A	5	ESI - based on SCAT
4609	NJ-1	C	8A	5	ESI - based on SCAT
4610	NJ-1	C	8A	5	ESI - based on SCAT
4611	NJ-1	C	8A	5	ESI - based on SCAT
4613	NJ-1	C	8A	5	ESI - based on SCAT
4627	NJ-3	C	8A	5	ESI - based on SCAT
4628	NJ-3	C	8A	5	ESI - based on SCAT
4723	NJ-3	C	8A	5	ESI - based on SCAT
4736	NJ-3	C	8A	5	ESI - based on SCAT
4737	NJ-3	C	8A	5	ESI - based on SCAT
5368	NJ-3	C	8A	5	ESI - based on SCAT
5369	NJ-3	C	8A	5	ESI - based on SCAT
5437	NJ-3	C	8A	5	ESI - based on SCAT
5438	NJ-3	C	8A	5	ESI - based on SCAT
5439	NJ-3	C	8A	5	ESI - based on SCAT
5440	NJ-3	C	8A	5	ESI - based on SCAT
4162	NJ-3	H	8A	5	ESI - based on SCAT
5445	NJ-3	H	8A	5	ESI - based on SCAT
5447	NJ-3	H	8A	5	ESI - based on SCAT
5448	NJ-3	I	8A	5	ESI - based on SCAT
5449	NJ-3	I	8A	5	ESI - based on SCAT
4163	NJ-3	J	8A	5	ESI - based on SCAT
4164	NJ-3	J	8A	5	ESI - based on SCAT
5450	NJ-3	J	8A	5	ESI - based on SCAT
4639	NJ-3	K	8A	5	ESI - based on SCAT
4905	NJ-3	K	8A	5	ESI - based on SCAT
5451	NJ-3	K	8A	5	ESI - based on SCAT
4640	NJ-3	L	8A	5	ESI - based on SCAT
4641	NJ-3	L	8A	5	ESI - based on SCAT
4906	NJ-3	L	8A	5	ESI - based on SCAT
4907	NJ-3	L	8A	5	ESI - based on SCAT
4908	NJ-3	L	8A	5	ESI - based on SCAT
5452	NJ-3	L	8A	5	ESI - based on SCAT

4338	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4339	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4340	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4341	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4342	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4345	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4346	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4497	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4498	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4499	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4655	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4656	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4657	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4658	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4911	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
4912	NJ-3	WOODBURY	8A	10A	ESI - based on SCAT
5446	NJ-3	WOODBURY	8A	5	ESI - based on SCAT
799	NJ-4	B	8A	10A	ESI - based on adjacent segment
813	NJ-4	C	8A	10A	ESI - based on SCAT
4171	NJ-4	C	8A	10A	ESI - based on SCAT
4172	NJ-4	C	8A	10A	ESI - based on SCAT
815	NJ-4	D	8A/10A	10A	ESI - based on SCAT
825	NJ-4	D	8A	10A	ESI - based on SCAT
4179	NJ-4	D	8A	10A	ESI - based on SCAT
4766	NJ-4	D	8A	10A	ESI - based on SCAT
4767	NJ-4	D	8A	10A	ESI - based on SCAT
870	NJ-4	E	8A	1A	ESI - based on SCAT
4411	NJ-4	E	8A	1A	ESI - based on SCAT
4413	NJ-4	E	8A	1A	ESI - based on SCAT
4476	NJ-4	E	8A	1B	ESI - based on SCAT
496	PA-1	B	8A	1B	ESI - based on SCAT
499	PA-1	B	8A	1B	ESI - based on SCAT
4148	PA-4	B	8A	5	ESI - based on SCAT
4149	PA-4	C	8A	5	ESI - based on SCAT
4872	PA-4	D	8A	5	ESI - based on SCAT
4873	PA-4	D	8A	5	ESI - based on SCAT
4146	PA-5	D	8A	6A	ESI - based on SCAT
783			8A	10A	ESI - based on SCAT
4913			8A	10A	ESI - based on SCAT
4914			8A	10A	ESI - based on SCAT

APPENDIX C

MAXIMUM OILING MAPS

APPENDIX D

SHORELINE CLASSIFICATION MAPS

APPENDIX E

STATE TABLES –TOTAL ESTIMATED AREA OF EXPOSED SHORELINE

TABLE E-1. Total estimated area (acres) of exposed shoreline for each habitat type in Delaware.

Habitat Type	Oiling Level	Shoreline (Acres)	Lower Intertidal Zone (acres)*	Tidal Flat (acres)**	Total By Habitat (Acres)	Percent of Total Oiling
Seawalls	Very Light	1.75			1.75	1.46%
	Light	1.07			1.07	0.89%
	Moderate	0.00			0.00	0.00%
	Heavy	0.00			0.00	0.00%
Subtotals		**2.82**			**2.82**	**2.35%**
Sand/Mud Substrate	Very Light	0.95	4.09	45.34	50.38	41.92%
	Light	0.22	0.00	0.00	0.22	0.18%
	Moderate	0.66		0.00	0.66	0.55%
	Heavy	0.00		0.00	0.00	0.00%
Subtotals		**1.83**	**4.09**	**45.34**	**51.26**	**42.66%**
Coarse Substrate	Very Light	12.80			12.80	10.65%
	Light	14.02			14.02	11.67%
	Moderate	4.94			4.94	4.11%
	Heavy	0.00			0.00	0.00%
Subtotals		**31.76**			**31.76**	**26.43%**
Marsh	Very Light	20.48			20.48	17.04%
	Light	13.77			13.77	11.46%
	Moderate	0.08			0.08	0.07%
	Heavy	0.00			0.00	0.00%
Subtotals		**34.33**			**34.33**	**28.57%**
TOTAL MAINSTEM HABITATS					**120.17**	**100%**
Tributaries	Very Light	0.00			0.00	0.00%
	Light	0.00			0.00	0.00%
	Moderate	0.00			0.00	0.00%
	Heavy	0.00			0.00	0.00%
Subtotals		**0.00**			**0.00**	0.00%
TOTAL OILED TRIBUTARIES					**0.00**	**0.00%**

* Lower ITZ values were only shown separately for the sand/mud substrate because they represented the majority of the injury for the sand/mud substrate category.

** Tidal flat acreage under the sand beach habitat includes flats from both sand beach and marsh habitat categories.

TABLE E-2. Total estimated area (acres) of exposed shoreline for each habitat type in New Jersey.

Habitat Type	Oiling Level	Shoreline (Acres)	Lower Intertidal Zone (acres)*	Tidal Flat (acres)**	Total By Habitat (acres)	Percent of Total Oiling
Seawalls	Very Light	5.33			5.33	0.68%
	Light	9.30			9.30	1.19%
	Moderate	3.60			3.60	0.46%
	Heavy	1.23			1.23	0.16%
Subtotals		**19.46**			**19.46**	**2.48%**
Sand/Mud Substrate	Very Light	6.33	33.24	489.91	529.48	67.61%
	Light	8.26	16.99	132.40	157.65	20.13%
	Moderate	5.97		0.00	5.97	0.76%
	Heavy	5.07		0.00	5.07	0.65%
Subtotals		**25.63**	**50.23**	**622.31**	**698.17**	**89.14%**
Coarse Substrate	Very Light	3.12			3.12	0.40%
	Light	26.96			26.96	3.44%
	Moderate	11.34			11.34	1.45%
	Heavy	5.21			5.21	0.67%
Subtotals		**46.63**			**46.63**	**5.95%**
Marsh	Very Light	9.64			9.64	1.23%
	Light	3.88			3.88	0.50%
	Moderate	3.32			3.32	0.42%
	Heavy	2.09			2.09	0.27%
Subtotals		**18.93**			**18.93**	**2.42%**
TOTAL MAINSTEM HABITATS					**783.19**	**100%**
Tributaries	Very Light	583.25			583.25	30.71%
	Light	1216.08			1216.08	64.03%
	Moderate	99.90			99.90	5.26%
	Heavy	0			0	0
Subtotals		**1899.23**			**1899.23**	**100%**
TOTAL OILED TRIBUTARIES					**1899.23**	**100%**

* Lower ITZ values were only shown separately for the sand/mud substrate because they represented the majority of the injury for the sand/mud substrate category.

** Tidal flat acreage under the sand beach habitat includes flats from both sand beach and marsh habitat categories.

TABLE E-3. Total estimated area (acres) of exposed shoreline for each habitat type in Pennsylvania.

Habitat Type	Oiling Level	Shoreline (Acres)	Lower Intertidal Zone (acres)*	Tidal Flat (acres)**	Total By Habitat (acres)	Percent of Total Oiling
Seawalls	Very Light	1.58			1.58	0.19%
	Light	7.35			7.35	0.89%
	Moderate	26.86			26.86	3.25%
	Heavy	1.31			1.31	0.16%
Subtotals		**37.10**			**37.10**	**4.49%**
Sand/Mud Substrates	Very Light	0.11	18.36	142.18	160.65	19.46%
	Light	1.50	9.95	147.14	158.59	19.21%
	Moderate	3.32		205.48	208.80	25.29%
	Heavy	3.17		135.20	138.37	16.76%
Subtotals		**8.10**	**28.31**	**630.00**	**666.41**	**80.72%**
Coarse Substrate	Very Light	0.31			0.31	0.04%
	Light	25.09			25.09	3.04%
	Moderate	20.63			20.63	2.50%
	Heavy	12.81			12.81	1.55%
Subtotals		**58.84**			**58.84**	**7.13%**
Marsh	Very Light	21.71			21.71	2.63%
	Light	23.24			23.24	2.81%
	Moderate	13.81			13.81	1.67%
	Heavy	4.44			4.44	0.54%
Subtotals		**63.20**			**63.20**	**7.66%**
TOTAL MAINSTEM HABITATS					**825.55**	**100%**
Tributaries	Very Light	0.00			0.00	0.00%
	Light	0.00			0.00	0.00%
	Moderate	0.00			0.00	0.00%
	Heavy	0.00			0.00	0.00%
Subtotals		**0.00**			**0.00**	0.00%
TOTAL OILED TRIBUTARIES					**0.00**	**0.00%**

* Lower ITZ values were only shown separately for the sand/mud substrate because they represented the majority of the injury for the sand/mud substrate category.

****** Tidal flat acreage under the sand beach habitat includes flats from both sand beach and marsh habitat categories.

APPENDIX F

STATE TABLES- RECOVERY RATE AND TOTAL NUMBER OF DSAYs LOST

SEAWALLS

TABLE F-1. Recovery rate and total number of DSAYs lost for oiled seawalls in Delaware (DE).

Oiling Degree	Acres	Services Present Post Spill			
		0.5 yr	**1 yr**	**2 yr**	**DSAYS**
Very Light	1.75	0.95	1		0.06
Light	1.07	0.85	1		0.12
Moderate	0	0	0.85	1	0.00
Heavy	0	0	0.85	1	0.00
Total	**2.82**				**0.18**

TABLE F-2. Recovery rate and total number of DSAYs lost for oiled seawalls in New Jersey (NJ).

Oiling Degree	Acres	Services Present Post Spill			
		0.5 yr	**1 yr**	**2 yr**	**DSAYS**
Very Light	5.33	0.95	1		0.20
Light	9.3	0.85	1		1.03
Moderate	3.6	0	0.85	1	3.06
Heavy	1.23	0	0.85	1	1.04
Total	**19.46**				**5.33**

TABLE F-3. Recovery rate and total number of DSAYs lost for oiled seawalls in Pennsylvania (PA).

Oiling Degree	Acres	Services Present Post Spill			
		0.5 yr	**1 yr**	**2 yr**	**DSAYS**
Very Light	1.58	0.95	1		0.06
Light	7.35	0.85	1		0.82
Moderate	26.86	0	0.85	1	22.81
Heavy	1.31	0	0.85	1	1.11
Total	**37.1**				**24.80**

SAND/MUD SUBSTRATES

TABLE F-4. Estimated recovery rate and total number of DSAYs lost for oiled sand/mud substrates in DE.

Oiling Degree	Acres	Services Present Post Spill				
		0.5 yr	1 yr	2 yr	3 yr	DSAYs
Very light	50.38	0.5	0.75	0.95	1	30.14
Light	0.22	0.5	0.75	0.9	1	0.14
Moderate	0.66	0	0.5	0.8	1	0.85
Heavy	0	0	0.5	0.75	1	0.00
Total	**51.26**					**31.13**

TABLE F-5. Estimated recovery rate and total number of DSAYs lost for oiled sand/mud substrates in NJ.

Oiling Degree	Acres	Services Present Post Spill				
		0.5 yr	1 yr	2 yr	3 yr	DSAYs
Very light	529.48	0.5	0.75	0.95	1	316.77
Light	157.65	0.5	0.75	0.9	1	101.75
Moderate	5.97	0	0.5	0.8	1	7.71
Heavy	5.07	0	0.5	0.75	1	6.78
Total	**698.17**					**433.00**

TABLE F-6. Estimated recovery rate and total number of DSAYs lost for oiled sand/mud substrates in PA.

Oiling Degree	Acres	Services Present Post Spill				
		0.5 yr	1 yr	2 yr	3 yr	DSAYs
Very light	160.65	0.5	0.75	0.95	1	96.11
Light	158.59	0.5	0.75	0.9	1	102.35
Moderate	208.8	0	0.5	0.8	1	269.52
Heavy	138.37	0	0.5	0.75	1	185.13
Total	**666.41**					**653.11**

COARSE SUBSTRATES

TABLE F-7. Estimated recovery rate and total number of DSAYs lost for oiled coarse substrates in DE.

Oiling Degree	Acres	Services Present Post Spill						
		0.5 yr	1 yr	2 yr	3 yr	4yr	5yr	DSAYs
Very light	12.68	0.75	0.85	0.95	1			4.32
Light	14.02	0.5	0.75	0.9	1			9.05
Moderate	4.94	0	0.5	0.75	0.9	1		7.06
Heavy	0	0	0.5	0.75	0.9	0.99	1	0.00
Total	**31.64**							**20.43**

TABLE F-8. Estimated recovery rate and total number of DSAYs lost for oiled coarse substrates in NJ.

Oiling Degree	Acres	Services Present Post Spill						
		0.5 yr	1 yr	2 yr	3 yr	4yr	5yr	DSAYs
Very light	3.12	0.75	0.85	0.95	1			1.06
Light	26.96	0.5	0.75	0.9	1			17.40
Moderate	11.34	0	0.5	0.75	0.9	1		16.21
Heavy	5.21	0	0.5	0.75	0.9	0.99	1	7.49
Total	**46.63**							**42.17**

TABLE F-9. Estimated recovery rate and total number of DSAYs lost for oiled coarse substrates in PA.

Oiling Degree	Acres	Services Present Post Spill						
		0.5 yr	1 yr	2 yr	3 yr	4yr	5yr	DSAYs
Very light	0.31	0.75	0.85	0.95	1			0.11
Light	25.09	0.5	0.75	0.9	1			16.19
Moderate	20.63	0	0.5	0.75	0.9	1		29.49
Heavy	12.81	0	0.5	0.75	0.9	0.99	1	18.43
Total	**58.84**							**64.21**

MARSHES

TABLE F-10. Estimated recovery rate and total number of DSAYs created from oiled marsh in DE.

Oiling Degree	Acres	Services Present Post Spill					
		0.5 yr	1 yr	2 yr	3 yr	4yr	DSAYS
Very light	20.48	0.75	0.95	1			4.53
Light	13.77	0.5	0.75	1			7.59
Moderate	0.08	0	0.75	0.95	1		0.08
Heavy	0	0	0.5	0.75	0.9	1	0.00
Total	**34.33**						**12.20**

TABLE F-11. Estimated recovery rate and total number of DSAYs created from oiled marsh in NJ.

Oiling Degree	Acres	Services Present Post Spill					
		0.5 yr	1 yr	2 yr	3 yr	4yr	DSAYS
Very light	9.64	0.75	0.95	1			2.13
Light	3.88	0.5	0.75	1			2.14
Moderate	3.32	0	0.75	0.95	1		3.22
Heavy	2.09	0	0.5	0.75	0.9	1	2.99
Total	**18.93**						**10.48**

TABLE F-12. Estimated recovery rate and total number of DSAYs created from oiled marsh in PA.

Oiling Degree	Acres	Services Present Post Spill					
		0.5 yr	1 yr	2 yr	3 yr	4yr	DSAYS
Very light	21.71	0.75	0.95	1			4.81
Light	23.24	0.5	0.75	1			12.81
Moderate	13.81	0	0.75	0.95	1		13.38
Heavy	4.44	0	0.5	0.75	0.9	1	6.35
Total	**63.2**						**37.34**

APPENDIX G

LIFE HISTORY SUMMARY OF DELAWARE BAY FAUNA

Common Name	Scientific Name	Life Span	Habitat Type	Seasonality	Breeding Period	Reproductive Age	Food Sources	Sources
Zooplankton								
Copepods	*Halicyclops fosteri*	Weeks to Months	Estuarine waters with the salinity in the 2 to 6 ppt range	Most abundant mainly in spring and summer	All year		Phytoplankton	19
Copepods	*Eurytemora affinis,*	Weeks to Months	Estuarine waters with the salinity in the 1 to 10 ppt range	Most abundant mainly in fall, winter, and spring	All year		Phytoplankton	19
Copepods	*Acartia tonsa*	Weeks to Months	Estuarine waters with the salinity in the 5- to 20 ppt range	Most abundant mainly in winter and spring	All year		Phytoplankton	19
Copepods	*Axartia hudsonica*	Weeks to Months	Estuarine waters with the salinity in the 5- to 20 ppt range	Most abundant mainly in summer and fall	All year		Phytoplankton	19
Copepods	*Pseudodiaptomus pelagicus*	Weeks to Months	Estuarine waters with the salinity in the 15- to 20 ppt range	Most abundant mainly in summer and fall	All year		Phytoplankton	19
Copepods	*Oithona colcarva*	Weeks to Months	Estuarine waters with the salinity in the 15- to 30 ppt range	Most abundant mainly in summer and fall	All year		Phytoplankton	19
Insects								
Damselflies	*Enallagma*	Weeks to Months	Wetland habitats	Present all year, flight period May to August				19

Insects

Benthic Macroinvertebrates								
Aquatic Earthworm	*Limnodrilus*		Mud/sand bottom in freshwater	Present all year			Organic particulate matter	19
Midge larvae	*Chironomus*		Mud/sand bottom in freshwater				Small particulate organic matter	19
Crustaceans								
Amphipod	*Gammarus sp.*	<1 year	Shallow water areas		Feb-Oct			28
Blue crab	*Callinectes sapidus*	3 years	Shallow waters in spring, summer, and fall and deeper waters in winter	Shallow waters (< 4 meters) in spring, summer and fall, and in the deeper channels in winter	Peak spawning late July to early August	18 Months	Detritovore and scavenger, plans, small inverts, fish and other crabs	19,22
Horseshoe crab	*Limulus polyphemus*	14-19 yr	Sandy beaches for spawning. Adults and juveniles are subtidal.	Present all year	Spawning begins late April and peaks between mid-May to mid-June	11 yr.	Larvae feed on nematodes, nereis, and polychaetes, juveniles and adults feed on marine worms, shellfish, razor clams, softshell clams	19,12
Mysid	*Mysidopsis sp.*	6 to 8 months	Sandy bottom with salinity of 1 ppt.	Present all year	Late winter through summer	30 days	Algae, plankton, detritus	19,18
Fiddler crabs	*Uca spp.*	1 to 1.5 yrs	Tidal flats and banks in intertidal intermediate marsh zone	Present throughout the year		1 year.	Particulate organic matter in muddy substrates.	19,23,9
Grass shrimp	*Palaemonetes*	6 to 13	Shallow tidal	Present	February to	1.5 to 2 months	Epiphytic	19,24

	spp.	months	streams and quiet embayment shorelines	throughout the year	October		plants, meiofauana, infauna, zooplankton, algae, detritus	
Bivalves								
Eastern elliptio	*Elliptio Complanata*	Approx. 10-15 yrs	any permanent body of water, in canals and reservoirs with quiet water and muddy bottom, as well as in large rivers with strong current and heavy gravel and rocks	Present throughout the year	April - August			30
Asiatic clam	*Corbicula fluminea*	7 yrs	Stream pools on fine, clean sand and coarse substrate	Present throughout the year	Spring to fall	2-4 months		29
Ribbed mussels	*Geukensia mdissa*	15 years	Intertidal zone on peat, roots and bridge pilings	Present throughout the year	June to August	2 years		19,8
Eastern oyster	*Crassostrea virginica*	Up to 20 years	Shallow subtidal hard substrates with a salinity range of 5-30 ppt	Present throughout the year	Spawning July and August	2 yr.	Suspension feeder, phytoplankton, bacteria, detritus	19
Gastropods								
Coffee-bean snails	*Melampus bidentatus*		High marsh	Present throughout the year				19
Mud snails	*Ilyanassa obsoleta*		Low intertidal mud/sand flats	Present throughout the year				19
Fish								
Striped bass	*Morone saxatilis*	Over 20 years	Throughout the Delaware River and Bay ssytem	Present throughout the year	Spawning April through	Male 4 years, female 8-9 years.	Fish, worms, squid	19

					June.			
Oyster toadfish	*Opsanus tau*	8 years	Hard substrate areas with salinity of 10-30 ppt	Present throughout the year	Spawn May to September		A variety of crustaceans, mollusks, and polychaetes.	19
Hogchoker	*Trinectes maculatus*		Present in salinities ranging from 0 to 35.5 ppt	Present all year but most abundant late spring to early fall.	Spawn May to September	70 millimeters		19
Bluefish	*Pomatomus saltatrix*	12 yrs	Typically in salinities higher than 15 ppt	Adults most abundant in April and May. Juveniles are present June to November	Spawn offshore from June to August	2 yr	Atlantic menhaden, yellow perch, weakfish, shrim, squid, blue crab, and annelid worms.	19,15
Carp	*Cyprinus carpio*	20 years	Shallow island backchannels and mudflats in spring through fall, and deeper water overwinter	Present all year	Late spring to early August	Males 3 to 10 yrs, females 4 to 16 years	Filamentous algae, snails, annelids, midge larvae, zooplankton, phytoplankton and plant material	19
Brown bullhead catfish	*Ameiurus nebulosus*	12 years	Demersal in shallow warmwater areas with slow moving current and abundant aquatic vegetation and sand to mud bottoms	Present all year	Late spring and summer	2 to 3 years	Omnivorous	19,7
Channel catfish	*Icatlurus punctatus*	15 to 20 years	Large rivers with low gradients, in deep pools with submerged cover	All year	Late spring and summer	4 to 5 years	Omnivorous	19,7
White catfish	*Ameiurus catus*	11 years	River channels	All year	Summer	3-4	Omnivorous	19,7

			and streams with sluggish water and in estuaries with salinities up to 8 ppt					
Spot	*Leiostomus xanthurus*	5 years	Lower salinity areas with mud an detrital bottoms	Early spring to fall	December to March	2 years	Neomysis, copepods, and polycheates	19
Atlantic croaker	*Micropagonias undulatus*	2 – 4 years	Young of year occupy soft substrates while adulst occur near oyster beds	Early spring to fall	October to February	2 years	Neomysis, copepods, and polycheates	19
Black drum	*Pogonias cromis*	43 years	Low or now current usually over mud bottoms	Early spring to fall	May to June	5 years	Benthic invertebrates, copepods, amphipods, annelids, mollusks, decapods.	19
American eel	*Anguilla rostrata*	10 to 22 years	Larger eels in deeper waters and juveniles in tidal marshes, harbors, barrier beach ponds coastal rivers, creeks, and streams	Present throughout the year	Fall migration to offshore spawning areas	Females 12-22 yr, Males 10-15 yr	Crustaceans, bivalves, and polycheates in the estuary and insects and fish in freshwater	19
Alewife	*Alosa pseudoharengus*	May exceed 10 years	Spawning in low currents	April to October	April and May	3 to 8 yrs	Fish, zooplankton, insects, and fish eggs	19,5
Blueback herring	*Alosa aestivalis*	Average 7-8 years	Spawning in fast currents over hard substrate	April to October	Spawn late April through early June	3 to 8 yrs	Fish, zooplankton, insects, and fish eggs	19,5
Brackish water killifish		1 to 3 years	Shallow nearshore and marsh surface habitats.	Present throughout the year	April to September	1 yr	Omnivorous	19
Freshwater marsh		1 to 3	May be associated	Present	May to	1 year	Benthic	19

killifish		years	with all bottom types.	throughout the year	August		invertebrates: insect larvae, amphipods, copepods, ostracods, and small gastropods	
Atlantic menhaden	*Brevoortia tyrannus*	7 to 8 years		All year	Spawn offshore year round	3 yr	Phytoplankton and zooplankton	19
White perch	*Morone americana*	19 yr	Areas of 0 to 300 ppt salinity.	All year	Spawn in freshwater April to June above RM 80 in the mainstem and in all larger tributaries.	Males 2 to 3 yrs, Females 3 to 4 yrs.	Zooplankton, benthic organisms and fish, shrimp, and crab	19,3
Yellow perch	*Perca flavescens*	13 years	Slow moving nearshore habitats with varying cover	Present all year	Migrate February to March, Spawn March or April in freshwater	Males 1 to 3 years, Females 3 to 4 years	Fish, crawfish, tadpoles and small frogs	19,17
American shad	*Alosa sapidissma*	7-11 years		March to-November	Spawing April and May	Males 3 to 5 years, Females 4 to 6 years	Small crustaceans	19,11,25
Shortnose sturgeon	*Acipenser brevirostrum*	67 years	Deepest water available, typical navigation channels	April to October	March and April above Trenton	7 to 10 years	Molluscs, oligocheates, and arthropods	19,4
Atlantic sturgeon	*Acipenser oxyrhynchus*	60 years	Mainstem estuary	Adults April – October, Juveniles All year	Spawning April – June	5 to 30 years	Benthic invertebrates, small fish.	19,11
Largemouth bass	*Micropterus salmoides*	Up to 16 years	Slow flowing water with some	Present all year	Spawning April to		Crayfish, frogs, fish,	19,13

			aquatic vegetation and sand, gravel or hard clay bottoms		June		insects, and small animals	
Smallmouth bass	*Micropterus dolomieui*	6 to 14 years	Fast flowing water with gravel-rubble bottom	Present all year	Spawning May to June		Crayfish, fish, and large insects	19,27
Black crappie	*Pomoxis nigromaculatus*	7 years	Slow flowing water with some aquatic vegetation and sand, gravel or hard clay bottoms	Present all year	Spawning April to June	2 years	Small crustaceans, insects, and small fish	19.1
Bluegill	*Lepomis macrochirus*	4 to 6 years	Slow flowing water with some aquatic vegetation and sand, gravel or hard clay bottoms	Present all year	Spawning May to September		Small insects, insect larvae, fish eggs and fry	19,16
Redbreast sunfish	*Lepomis auritus*		Slow flowing water with some aquatic vegetation and sand, gravel or hard clay bottoms	Present all year	Spawning June to August		Small insects, insect larvae, fish eggs, fry, small molluscs	19
Pumpkinseed	*Lepomis gibbosus*		Slow flowing water with some aquatic vegetation and sand, gravel or hard clay bottoms	Present all year	Spawning May to August		Small insects, insect larvae, fish eggs, fry, small molluscs	19
Chain pickerel	*Esox niger*	8 to 10 years	Shallow water with abundant vegetation over a mud bottom	Present all year	Spawning February to April		Fish	19,20
Weakfish	*Cynoscion regalis*	12-19 years	Throughout the estuary	Spring and summer	Peak spawning Mid-May to mid-June	1 to 2 years	Herring and killifish	19,14

Reptiles								
Diamondback terrapins	*Malaclemys terrapin*		*Spartina* salt marshes	Active April to October and hibernate November to March	Nesting June through mid-July. Eggs hatch 2 months later	Females 6 to 7 years, Males 3 years	Salt marsh snail, fiddler crab, mud snails, hermit crabs, and mussels	19
Snapping turtle	*Chelydra serpentine*	30 years	Ponds with muddy bottoms or streams with overhanging banks	Present all year	Mating April and May, egg-laying from May to mid July, hatching mid-August to early October			19.2
Eastern mud turtle	*Kinosternon subrubrum subrubrum*		Shallow vegetated habitats	Present all year	Mid June			19
Spotted turtle	*Clemmys guttata*		Shallow bodies of water such as marshes, swamps, etc.	Present all year	Mating in early spring, hatching in August	7 to 14 years	Algae, aquatic plants, water lily seeds, worms, molluscs, crustaceans, insects, amphibian eggs and larvae	19,10
Red-bellied turtle	*Pseudemys rubriventris*	40 to 55 years	Relative deep waterbodies with soft bottom.	Present all year	Hatching late August to October	15 to 20 years	Aquatic plants	19,25
Plants								
Common reed	*Phragmites australis*	Perennial	freshwater and brackish tidal wetlands		Flowering July to September			21

Pickerelweed	*Pontederia cordata*	Perennial	Shallow fresh water		Flowering June to October			
Waterhemp ragweed	*Amaranthus cannabinus*	Perennial	Coastal salt or brackish marsh	Present all year	Flowering June to October.			21
Walter's barnyard-grass	*Echinochloa walteri*	Annual	Tidal and nontidal fresh marshes, alkaline marshes, swamp and shallow waters		Flowering June through October			21
Wright's spike rush	*Eleocharis obtuse var peasei*	Annual	Fresh shores, marshes disturbed places	Present all year	Flowering summer to fall			6
Little-spike spike-rush	*Eleocharis parvula*		Slat and brackish marshes (regularly and irregularly flooded zones); wet inland saline soils		Flowering July to October			21
Multiflowered mud-plantain	*Heteranthera multiflora*	Annual	Roadside ditches, pond edges	Present all year	Flowering July to November			
Bugleweed	*Lycopus rubellus*	Perennial	Irregularly flooded tidal fresh marshes, nontidal marshes, wet meadows, forested wetlands		Flowers June to October			21
Shrubby camphor-weed	*Pluchea odorata*	Annual	Irregularly flooded salt and brackish marshes, interdunal wet swales and nontidal marshes		Flowers August to October			21
Long-lobed arrowhead	*Sagittaria calycina var. spongiosa*							21
Subulate arrowhead	*Sagittaria subulata*	Perennial	Brackish and tidal fresh waters,		Flowers May to			21

			intertidal mod flats and regularly flooded marshes		September			
Indian wild rice	*Zinzania aquatica*	Annual	Tidal fresh marshes and slightly brackish marshes, stream borders, shallow waters, and nontidal marshes		Flowers May to October.			21

Source Literature

1. Adams, R. 2000. "Pomoxis nigromaculatus" (On-line), Animal Diversity Web. Accessed August 24, 2005 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Pomoxis_nigromaculatus.html

2. Bosch, A. 2003. "Chelydra serpentina" (On-line), Animal Diversity Web. Accessed August 24, 2005 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Chelydra_serpentina.html

3. Chesapeake Bay Program. "White Perch" (On-line) Accessed August 24, 2005, at http://www.chesapeakebay.net/info/white_perch.cfm

4. Crance, J.H. 1986. Habitat suitability index models and instream flow suitability curves: shortnose sturgeon. U.S. Fish and Wildlife Service Biological Report 82(10.129). 31 pp.

5. Fay, C.W., Neves, R.J., Pardue, G.B. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic)- Alewife/blueback herring. U.S. Fish and Wildlife Service report FWS/OBS-82/11.9. U.S. Army Corps of Engineers, TR EL-82-4. 25 pp.

6. Flora of North America (On-line) http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=242415648

7. Florida Fish and Wildlife Conservation Commission, 2005, "Catfish" Accessed August 24, 2005 at http://www.floridafisheries.com/fishes/catfish.html.

8. Franz, D.R., 2001. Recruitment, Survivorship, and Age Structure of a New York Ribbed Mussel Population (Geukensia demissa) in Relation to Shore Level – A Nine Year Study. Estuaries 24: 319-327

9. Grimes, B.G., M.T. Huish, J.H. Kerby, and D. Morgan. Species Profile: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic) -- Atlantic Marsh Fiddler. US Fish and Wildlife Service Biol. Rep 82 (11.114). US Army Corps of Engineers, TR EL-82-4. 18 pp., 1989.

10. Harding, J. 2002. "Clemmys guttata" (On-line), Animal Diversity Web. Accessed August 24, 2005 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Clemmys_guttata.html.

11. Hazardous Materials Response and Assessment Division, 1996, "Sensitivity of Coastal Environments and Wildlife to Spilled Oil, Delaware, New Jersey, Pensylvania, A Coastal Atlas.

12. Maryland Department of Natural Resources. 2005. Species profile for *Limulus polyphemus*. Available: http://www.dnr.state.md.us/education/horseshoecrab/species.html

13. Maryland Department of Natural Resources. 2005. Largemouth Bass *Micropterus salmoides*. Available: http://www.dnr.state.md.us/education/lgmouthbass/lgmouth.html

14. Maryland Department of Natural Resources. 2004. Weakfish *Cynoscion regalis*. Available: http://www.dnr.state.md.us/education/weakfish/weakfish.shtml

15. Massachusetts Division of Fisheries. 2005. Species profile for bluefish. Available: http://www.mass.gov/dfwele/dmf/recreationalfishing/bluefish.htm

16. Parr, C. 2002. "Lepomis macrochirus" (On-line), Animal Diversity Web. Accessed August 24, 2005 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Lepomis_macrochirus.html.

17. Piavis, P. 1999, "Yellow Perch" (On-line) Maryland Department of Natural Resources, Accessed August 24, 2005 at http://www.dnr.state.md.us/fisheries/education/yellowperch/yperch.html

18. Reed Mariculture. "Mysidopsis bahia" Accessed August 24, 2005 at http://www.reed-mariculture.com/zooplankton/mysidshrimp/mysidopsisbahia.asp

19. Stern, D.. 1995. Copepods. Pages 33-42 *in* L.E. Dove and R.M. Nyman, eds. Living Resources of the Delaware Estuary. The Delaware Estuary Program.

20. Stiener, L. 2005, "Pennsylvania Fishes" Pennsylvania Boat and Fish Commission, 190pp. Accessed August 24, 2005 at http://sites.state.pa.us/PA_Exec/Fish_Boat/pafish/fishhtms/chapindx.htm

21. Tiner, R. 1993. Field Guide to Coastal Wetland Plants of the Southeastern United States. University of Massechusetts Press, Amherst, Mass.328 pp

22. Van Den Avyle, M.J. and D.L. Fowler. 1984. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South-Atlantic)- Blue crab. U.S. Fish and Wildlife Service report FWS/OBS-82/11.9. U.S. Army Corps of Engineers, TR EL-82-4. 16 pp.

23. Virginia Tech Species Information. 1996. "Atlantic Marsh fiddler crab". Accessed August 24, 2005 at http://fwie.fw.vt.edu/WWW/macsis/lists/M070000.htm

24. Virginia Tech Species Information. 2005. Grass Shrimp profile (*Palaemontes vulgaris*). Available: http://fwie.fw.vt.edu/WWW/macsis/lists/M070010.htm

25. Virginia Tech Species Information. 1996. "Species Turtle, Red-bellied, Plymouth" (On-line). Accessed August 24, 2005 at http://fwie.fw.vt.edu/WWW/esis/lists/e155001.htm.

26. Weiss-Glanz, L.S., J.G. Stanley, and J. R. Moring,. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)- American shad. U.S. Fish and Wildlife Service FWS/OBS-82/11.59. U.S. Army Corps of Engineers, TR EL-82-4. 16 pp.

27. Whitlock, J. 2004. "Micropterus dolomieu" (On-line), Animal Diversity Web. Accessed August 24, 2005 at http://animaldiversity.ummz.umich.edu/site/accounts/information/Micropterus_dolomieu.html.

28. Everett, A. 2006. Personal communication. Pennsylvania Department of Environmental Protection.

29. Gulf States Marine Fisheries Commission. 2005. Fact Sheet: *Corbicula fluminea* (Muller, 1774). Available online: http://nis.gsmfc.org/nis_factsheet.php?toc_id=128. Accessed: February 20, 2006.

30. Ortmann, A. E. 1919. A Monograph of the Naiades of Pennsylvania. Part III. Mem. Carn. Mus. 8: 1-384.