Operational Science Advisory Team (OSAT-2)
Gulf Coast Incident Management Team

SUMMARY REPORT FOR FATE AND EFFECTS OF REMNANT OIL IN THE BEACH ENVIRONMENT

Prepared for
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Deepwater Horizon MC252

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OPERATIONAL SCIENCE ADVISORY TEAM

SUMMARY REPORT FOR FATE AND EFFECTS OF REMNANT OIL REMAINING IN THE BEACH ENVRIONMENT

EXECUTIVE SUMMARY

The purpose of this report is to provide the Federal On-Scene Coordinator (FOSC) for the Deepwater Horizon MC252 Spill of National Significance with a risk-based Net Environmental Benefits Analysis (NEBA) associated with removing remnant oil from the near shore, surf zone, and shoreline sandy beach areas. This report was produced by primarily relying on data collected along the shoreline prior to the OSAT-2 effort. These data, however, were supplemented with laboratory and modeling information and certain supplemental data acquired during the course of the study. While no single source of information used by OSAT is conclusive, the multiple lines of evidence obtained informed the conclusions.

The massive shoreline cleanup effort along the impacted Gulf Coast removed much of the stranded oil residue. Three types of located oil residue are particularly challenging, or potentially damaging to the environment if removed. The three types of oil residue include: supratidal buried oil (SBO), small surface residue balls (SSRBs), and submerged oil mats (SOM). To evaluate the decision to either continue removing oil residue or leave it in place, answers were sought for three questions:

a. Are there human health concerns in leaving the three types of oil residue in place?

b. If no further action is taken aside from monitoring and maintenance, what are the potential effects of the three types of oil residue to the environment?

c. Does the Net Environmental Benefit Analysis (NEBA) justify a decision to remove the three types of oil residue or to leave it in place?

This report focused on four case study beach areas with sensitive habitats that are representative of oiling conditions across the Gulf: Fort Pickens, FL; Bon Secour, AL; Petit Bois, MS; and Grand Isle, LA. The conclusions of the report, however, are applicable to all oiled beach environment across the Gulf.

A NEBA was used to compare potential impacts of oil remaining in the environment to potential impacts of further treatment. Toxicology and risk assessment specialists examined the environmental risk of the remaining oil for specific groups of aquatic and wildlife resources. A summary of the NEBA endpoints is shown in figure 1. The first highlighted column, “Summed Effects Assessment”, represents the overall risk from oil residue to individual resources. The risk associated with cleanup beyond established “No Further Treatment” guidelines is labeled as “Further Cleanup Impact” in the NEBA matrix. The general results of the comparison are summarized in the NEBA matrix (figure 1) with specific key findings presented below.

Key Findings:

1. Recently collected weathered oil samples showed 86-98 percent depletion of total polycyclic aromatic hydrocarbons (PAHs).

2. Risk of leaching from supratidal buried oil into groundwater is minimal due to the combined effects of weathering, biodegradation, and the location of the buried oil.

3. In most locations, models predict PAH concentrations in supratidal buried oil will decrease to 20% of current levels within 5 years. However, there are isolated conditions where PAH concentrations are predicted to persist substantially longer.

4. Calculated potential cancer and non-cancer health effects from short and long-term exposures are below U.S. Environmental Protection Agency (USEPA) acceptable health-based risk and hazard levels.

5. Aquatic and wildlife resources would likely experience a greater threat from further cleanup beyond established guidelines than from the oil that still remains on the beaches.

6. Two particular routes of exposure posed potentially elevated risks to aquatic and wildlife resources:

    a. Ingestion of SSRBs by adult, subsurface-probing shore birds. Further study of the feeding habits of these birds in the presence of SSRBs will provide information to further evaluate risk.

    b. Contact between buried oil and sea turtle eggs and hatchlings. This is due to the combination of their endangered status, the possibility of buried oil interfering with nesting turtles, and that eggs could be in direct contact with residual oil. Active monitoring of turtle nesting and knowledge supratidal buried oil (such as location, thickness, and consistency) can be used to develop mitigation strategies.

NEBA MATRIX						
ROUTE OF EXPOSURE	**RESOURCE AT RISK**					
	Aquatic Invertebrates & Fish					
	Inherent Oil Toxicity	**Oil Spatial Distribution**	**Exposure Likelihood**	**Summed Effects Assessment**		**Further Cleanup Impact**
Supratidal Buried Oil contact (adult)	LOW	LOW	N/A	N/A		LOW
Submerged Oil Mat aquatic contact	MED	LOW	LOW	LOW		LOW
SSRB ingestion (adult)	MED	MED	N/A	N/A		LOW
SSRB contact (young)	MED	MED	LOW	LOW		LOW
Supratidal Buried Oil contact (eggs/young)	MED	LOW	N/A	N/A		LOW
	Sea Turtles					
	Inherent Oil Toxicity	**Oil Spatial Distribution**	**Exposure Likelihood**	**Summed Effects Assessment**		**Further Cleanup Impact**
Supratidal Buried Oil contact (adult)	MED	LOW	LOW	LOW		LOW - HIGH
Submerged Oil Mat aquatic contact	MED	LOW	LOW	LOW		LOW
SSRB ingestion (adult)	HIGH	MED	N/A	N/A		LOW - HIGH
SSRB contact (young)	LOW	MED	LOW	LOW		LOW - HIGH
Supratidal Buried Oil contact (eggs/young)	MED	LOW	LOW	LOW - MED		LOW - HIGH
	Birds					
	Inherent Oil Toxicity	**Oil Spatial Distribution**	**Exposure Likelihood**	**Summed Effects Assessment**		**Further Cleanup Impact**
Supratidal Buried Oil contact (adult)	MED	LOW	POSS	POSS		HIGH
Submerged Oil Mat aquatic contact	MED	LOW	POSS	POSS		HIGH
SSRB ingestion (adult, surface foraging)	MED	MED	LOW	LOW		HIGH
SSRB ingestion (adult, subsurface probing)	MED	MED	MED	MED		HIGH
SSRB contact (young)	MED	LOW	POSS	POSS		HIGH
Supratidal Buried Oil contact (eggs/young)	MED	LOW	POSS	POSS		HIGH
	Mammals (Beach Mouse)					
	Inherent Oil Toxicity	**Oil Spatial Distribution**	**Exposure Likelihood**	**Summed Effects Assessment**		**Further Cleanup Impact**
Supratidal Buried Oil contact (adult)	MED	LOW	LOW	POSS		HIGH
Submerged Oil Mat aquatic contact	MED	LOW	LOW	POSS		LOW
SSRB ingestion (adult)	MED	MED	LOW	POSS		MED
SSRB contact (young)	MED	MED	LOW	POSS		MED
Supratidal Buried Oil contact (eggs/young)	MED	LOW	LOW	POSS		HIGH

Figure 1: OSAT-2 Net Environmental Benefits Analysis (NEBA) matrix to help decide if residual oil left on sand beaches is more harmful than taking further actions to remove the oil. Scores range from possible (POSS, least impact) to high (HIGH, most severe impact). For example, removal of Supratidal buried oil by excavation was evaluated to result in a HIGH negative impact to nesting sea turtles from the cleanup activities. LOW-MED entry for sea turtle eggs reflects variable risk from different weathering states of oil; LOW-HIGH entries for sea turtle cleanup impacts reflect seasonal presence of nesting animals and nests on sand beaches.

TABLE OF CONTENTS

OPERATIONAL SCIENCE ADVISORY TEAM

SUMMARY REPORT FOR FATE AND EFFECTS OF REMNANT OIL REMAINING IN THE BEACH ENVRIONMENT

1. INTRODUCTION

The purpose of this report is to provide the Federal On-Scene Coordinator (FOSC) with a risk-based Net Environmental Benefits Analysis (NEBA) associated with removing remnant oil from the near shore, surf zone, and shoreline sandy beach areas following the Macondo 252 well oil spill. This report was produced relying primarily on data collected along the shoreline prior to the OSAT-2 effort. These data, however, were supplemented with laboratory and modeling information and certain supplemental data acquired during the course of the study. While no single source of information used by OSAT is conclusive, the multiple lines of evidence obtained informed the conclusions.

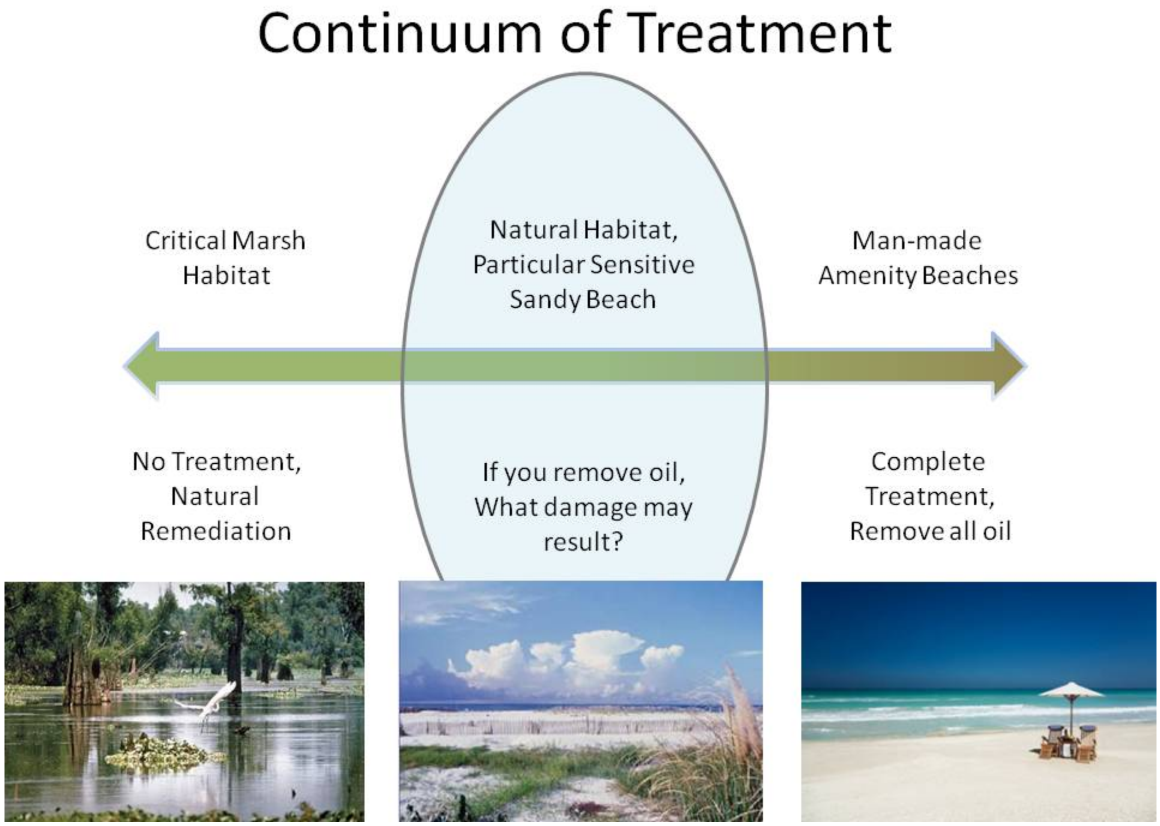
Much of the oil residue on and near the shoreline has been cleaned during the Response phase of the oil spill. As the Gulf shoreline is a dynamic environment, oil residue that is uncovered or moved onto beaches (for example, tar residue balls) will continue to be removed as part of the Monitoring and Maintenance phase of the recovery. Three types of located oil residue were identified as particularly challenging, or potentially damaging to the environment if removed. These three types are the following:

- Supratidal Buried Oil (SBO): This oil residue is typically buried below the six-inch surface cleaning depth near sensitive habitats. Removal of this oil would damage these sensitive habitats and impact protected resources.

- Small Surface Residual Balls (SSRBs): SSRBs are oil residue left behind after beaches are cleaned via mechanical and/or manual means. Removing SSRBs would involve sieving sand so finely that it may remove material (such as shell and wrack) that organisms use for habitat, thus altering the natural condition of the beach.

- Surf Zone Submerged Oil Mats (SOM): Submerged oil mats exist in the inshore surf zone in troughs between sand bars. It is particularly difficult to locate and conduct oil recovery operations in this area because the inshore surf zone has a large amount of wave energy, making precise underwater operations with shallow draft vessels challenging. As a result, the spatial extent of SOMs is uncertain. These mats are subject to currents and wave energy; the presence of tar balls that wash ashore can be used as a helpful indicator in identifying the locations of SOMs.

Previous oil spills have demonstrated that removing oil residue from shoreline environments can cause more harm to the ecosystem than leaving the residue in place. A “Continuum of Treatment”, as illustrated in the conceptual model below, summarizes the major issues:



In deciding whether to remove oil residue or leave it in place, the relevant question becomes "Under which action will the ecosystem recover more quickly?" Experience has shown (e.g. during the Amoco Cadiz oil spill) that removing oil residue from critical marsh habitats is damaging to the ecosystem, and the treatment may delay recovery of the wetland for many years. In this one extreme of the continuum of treatment, no active intervention would be recommended. This study is focused on sandy beaches does not address marsh cleanup options. Further information this subject can be found in the National Response Team document "Oil Spill Response Strategies for Coastal Marshes during the Deepwater Horizon MC252 Spill" found online at: <http://www.nrt.org/Production/NRT/NRTWeb.nsf/AllAttachmentsByTitle/SA-1061NRT_Marsh_Cleanup_Options_DWH.06032010.pdf/$File/NRT_marsh_cleanup_overview_6-15.pdf>.

The other extreme of the continuum would be a man-made or constantly groomed amenity beach, where aesthetic concerns drive the degree of clean-up. In this case, washing sand to remove as much oil residue as practical is an acceptable option, as there are limited natural habitats that will be disturbed. The scope of the OSAT-2 report focuses in the middle of the Continuum of Treatment. The area of study consists of sandy beaches that are natural habitats to sensitive resources.

Protecting wildlife and their habitats is a primary mission of the National Parks Service (NPS) and the U.S. Fish and Wildlife Service (USFWS). NPS and USFWS lands along the Gulf coast were specifically selected to protect critical habitats for sensitive species, and these agencies have taken a cautious approach to oil residue removal operations. Although this report focuses on these types of beach areas, the information contained herein will be useful to inform oil residue response decisions on all sandy beaches.

To evaluate the decision to leave the oil residue in place, answers were sought for three questions:

1. Are there human health concerns in leaving the three types of oil residue in place?

2. If no further action is taken aside from monitoring and maintenance, what are the potential effects of the three types of oil residue to the environment?

3. Does the Net Environmental Benefit Analysis (NEBA) justify a decision to remove the three types of oil residue or to leave it in place?

The information, discussion, analysis, and recommendations contained in this report are based on published literature, data, and other relevant information available at the time of the public release of this report. Additional studies and monitoring efforts, (including but not limited to determination of injury to natural resources), pertaining to the Deepwater Horizon MC252 Spill and related response actions are ongoing. The OSAT-2 report is only intended to be a guidance document for operational purposes. This report is not intended to be a definitive risk assessment, nor is intended to replace any other ongoing efforts (i.e., damage assessments).

2. OIL REMAINING ON SANDY BEACHES

This section describes the current (as of January 12, 2011) spatial oil distribution of the MC252 oil that remains on sandy shorelines after the Deepwater Horizon oil spill. Four representative case studies are presented that illustrate the remaining distribution of oil in three shoreline zones. Refer to Annex B for a detailed temporal and spatial description of oil on Gulf Coast sandy beaches and the cleanup progress and requirements. After the Deepwater Horizon blowout occurred on April 20, 2010, MC252 oil was released approximately 5,000 feet below the sea surface. The oil that rose to the sea surface and spent approximately one month at sea experienced substantial weathering (physical and chemical alteration and break down) at sea before it became stranded on beaches. Refer to other sections for weathering and depletion details.

Oil was deposited along the shoreline in three zones: the subtidal, intertidal, and supratidal (see Figure 2.1). Oil that remains in the subtidal zone is in the form of submerged oil mats (SOM) and oil that remains in the supratidal zone (supratidal buried oil, SBO) is oil that was buried during storm events. Small surface residual balls (SSRBs) are most often a product of beach cleaning (sieving oil from sand) with a diameter of the smallest screen used. SSRBs may be found in all three zones, but are generally restricted to the intertidal. Refer to Figures 2.2, 2.3, and 2.4 for examples of these oil types.

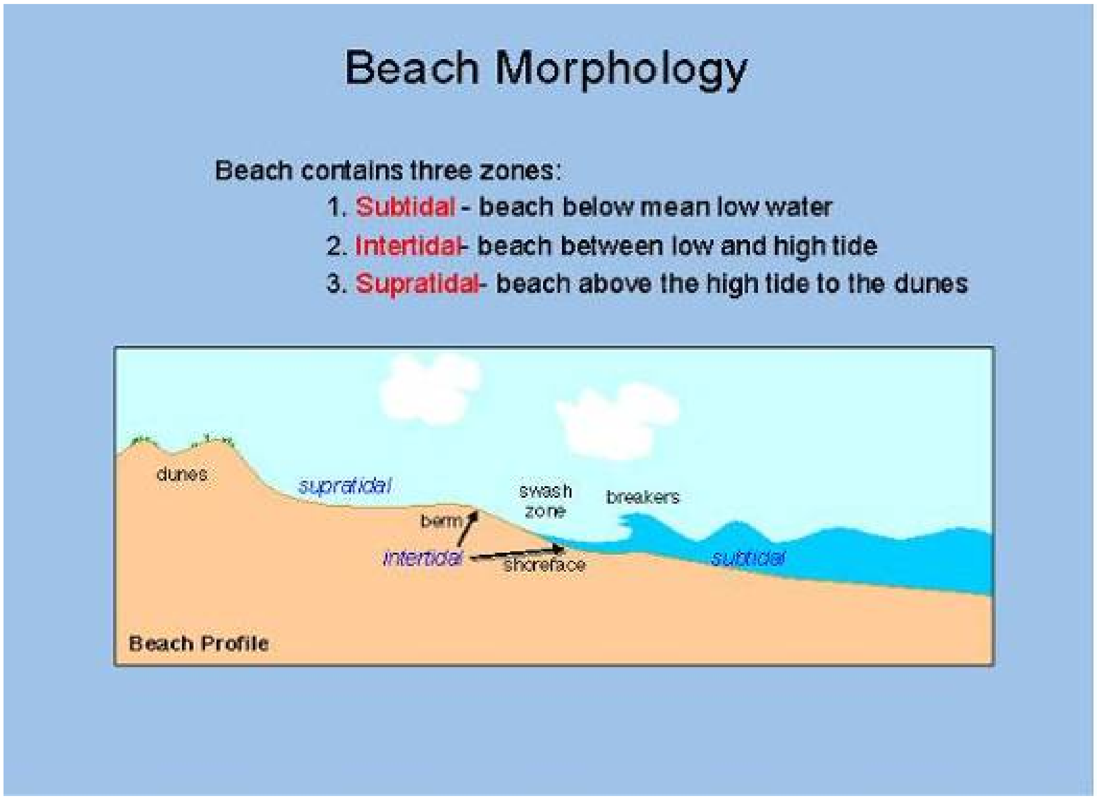


Figure 2.1. Shoreline zones. From J. Michel, pers. comm.

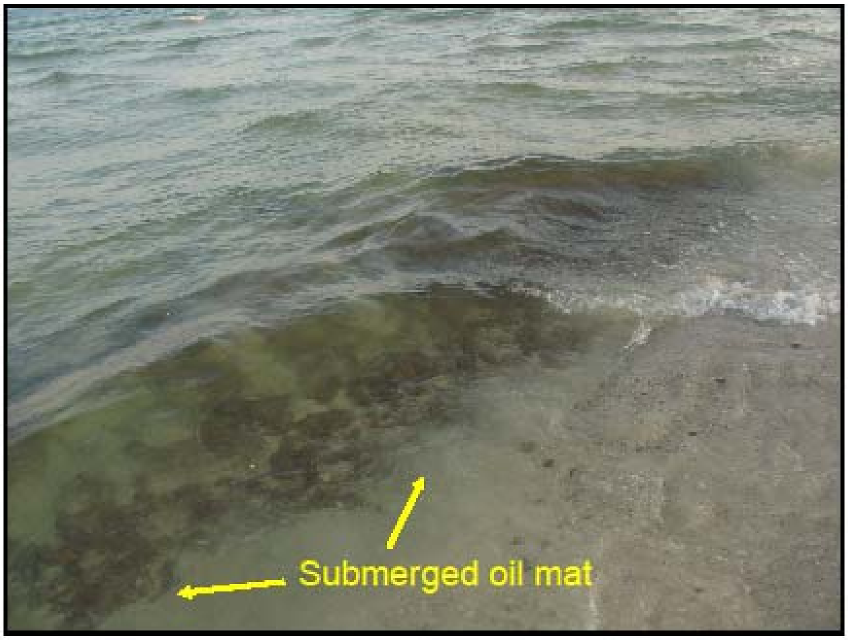


Figure 2.2. Submerged oil mats (SOM) and surface residue balls.

Figure 2.3. Small surface residual balls (SSRBs) remaining after cleaning and sieving.

Figure 2.4. Supratial buried oil (SBO) that is buried and exposed with changes in beach profile.

The texture and consistency of the residual oil-sand matrices will vary with temperature but data are not available to evaluate these changes and the risk to humans and wildlife resources. Uncertainties in the assessments related to changes in consistency are discussed for the appropriate receptors (e.g. turtles).

As part of the OSAT-2 effort, four oiled sandy beaches were chosen as case studies for in-depth analysis of the spatial distribution of oil. One sandy beach was chosen in each state (Louisiana, Mississippi, Alabama, and Florida; see Figure 2.5), based on increasing distances from the site of the spill, the degree of oiling that the respective beaches received relative to surrounding beaches, the presence of SBO, the presence of sensitive habitats, and availability of data. A sample of each oil type (SOM, SSRB, and SBO) was collected at each of the case study sites and chemically analyzed for this effort.

Shoreline Cleanup and Assessment Technique (SCAT) teams conducted surveys along the beaches to determine the location and severity of oiling on Louisiana, Mississippi, Alabama, and Florida beaches. SCAT reports, that were digitally converted for Geographic Information Systems (GIS) usage and uploaded to the National Oceanic and Atmospheric Administration's (NOAA) Environmental Response Management Application (ERMA) website, were utilized for this analysis. The NOAA ERMA tool is accessible to the public through the GeoPlatform website and may be found at: (http://www.geoplatform.gov/gulfresponse/).

One important factor in the spatial distribution analysis was the impact of remnant oil on sensitive habitat. The GeoPlatform website, which houses a compilation of state and federal species and habitat information, was utilized to determine the locations of sensitive habitat along the Louisiana, Mississippi, Alabama, and Florida beaches and in the surrounding shallow water. Information from the database indicated that the sandy shoreline from Louisiana to Florida, including the case study sites, supported habitat for federally endangered and threatened mammals, birds, and reptiles that utilize these beaches. Specific resources of concern are addressed in subsequent sections.

Figure 2.5 shows the counts of oiled and non-oiled locations along coastal sandy beaches from Louisiana to Florida. The four case study locations (shown in yellow boxes) are compared to surrounding beaches (shown in black boxes). The oiling that occurred at Grand Isle, LA was similar to the oiling that occurred on surrounding barrier beaches and the beaches in the Mississippi River Delta. Petit Bois Island, MS; Bon Secour, AL; and Fort Pickens, FL generally received more oiling than the average of the surrounding beaches, and can serve as examples of worse-case scenarios with respect to surrounding beaches.

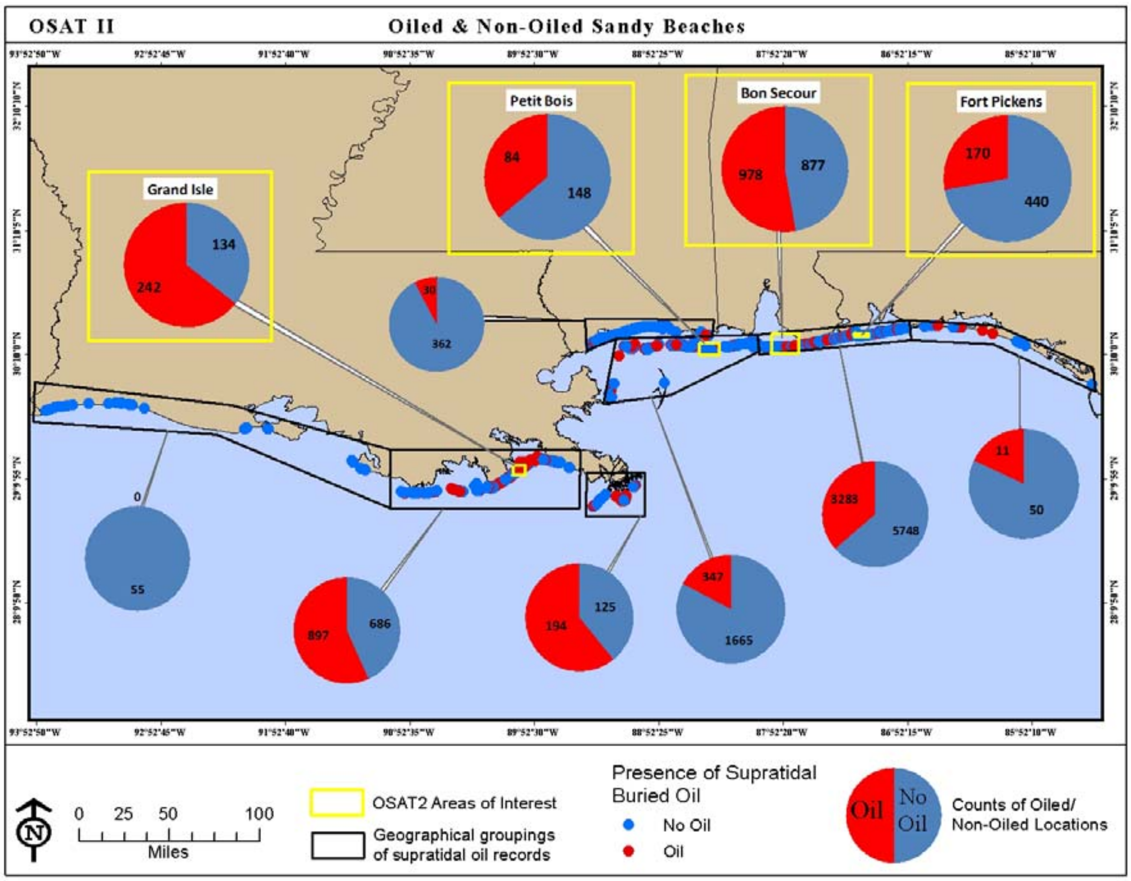


Figure 2.5. Shows the number of oiled and non-oiled pits and trenches sampled by SCAT along coastal sandy beaches.

At each case study site, one sample of each type of oil was analyzed for oil and sand content. The results of the content analysis enabled a general description of oil from west to east and along a beach profile. Refer to Table 2.1 for the sand and oil content of samples collected for this analysis.

Location	Oil Type					
	Submerged Oil Mats		SSRBs		Supratidal Buried Oil	
	% Sand	% Oil	% Sand	% Oil	% Sand	% Oil
Grand Isle	83.2	16.8	87.2	12.8	92.3	7.7
Petit Bois Island	90.6	9.4	91.4	8.6	91.1	8.9
Bon Secour	89.3	10.7	92.6	7.4	93.5	6.5
Fort Pickens	90.0	10.0	95.8	4.2	96.8	3.2

Table 2.1. Mass percent of sand and oil in samples for three oil types.

Oil in the subtidal zone (below the low tide line) was deposited as submerged oil mats (see Figure 2.2). The matrix of material (oil plus sand) stranded in mats below the low tide line had the greatest percentage of oil compared to sand of the three shoreline zones analyzed. The oil mats (see Table 2.1) were composed of 83.2 - 90.6 percent sand and 9.4 - 16.8 percent oil, with the highest percentage of oil stranded in mats off beaches closest to the source of the oil spill. Oil mats that have been identified were excavated and removed; however, due to the transient nature of the mats (they break up with storm activity) some pieces may still exist in the environment. One indicator of the presence of submerged oil mats is the transport of tar balls onto the beach, which can be used to identify submerged oil mats for subsequent removal.

Bulk oil deposits in the intertidal zone (zone between the low and high tide marks) on all amenity (public) and non-amenity (National Park Service - NPS or United States Fish and Wildlife Service - USFWS) beaches were or are in the process of being removed. The removal methodology varied on beaches according to the approved Shoreline Treatment Recommendation (STR) for that area. Amenity beaches were subject to excavation and removal of all identified oil to the depth of deposition using mechanical and sifting techniques. The sensitive habitats on NPS and USFWS beaches experienced primarily manual surface bulk oil removal, with additional, more invasive oil removal as approved on a case by case basis. Oil residue in the form of SSRBs remained on all beaches after the sand was passed through screens to remove bulk oil (see Figure 2.3). Refer to Table 2.2 for the smallest screen size used at the four case study sites. Based on most STR recommendations, SSRBs will cover less than 1 percent of the beach surface. SSRBs analyzed as part of this effort consisted of 87.2 - 95.8 percent sand and 4.2 - 12.8 percent oil with their outer surface encrusted in sand (see Table 2.1). The percentage of oil in the SSRBs decreased along the coastline from Louisiana to Florida.

Location	SSRB Size	
	Smallest Sieve Sizes Used	
	mm	inch
Grand Isle	19	3/4
Grand Isle State Park	3	1/8
Petit Bois Island	17	2/3
Bon Secour - USFWS	17	2/3
Bon Secour - Amenity	6	1/4
Fort Pickens - NPS	6	1/4
Fort Pickens - Amenity	6	1/4

Table 2.2. Smallest screen size used on case study beaches.

Oil in the supratidal zone (the zone above the high tide line) was deposited during storm events. As a result of dynamic beach changes, this oil was buried by sand up to depths of 105 cm (41 inches). Over time as the beach profile changed due to wind and wave action, the oil was either exposed (as sand was blown or washed from the surface during storms) or reburied (as sand piled above the oil) (see Figure 2.4). The SBO contained the least amount of oil in the three forms discussed. These oil deposits were predominantly sand and become encrusted with an outer layer of sand when exposed (see Table 2.1). A worst case scenario estimate of SBO at the four case study sites indicates that 2 to 8 percent of the buried oil still remains (see Annex B for details). Any oil that has been buried near vegetation was not removed to prevent damage to plant root systems. SSRBs may also be present in the supratidal zone as a result of sand sieving during beach cleanup activities.

Oil Distribution at Case Study Sites as of January 12, 2011

Grand Isle, Louisiana

Grand Isle was oiled early (May 2010) and repeatedly. This beach site experienced the heaviest oiling of the four case study sites and due to the early timing of oil stranding compared to the other beaches studied. Grand Isle received oil that was weathered at-sea for less time than the other beaches. The Grand Isle shoreline was aggressively cleaned to the STR Stage III cleanup standards (no visible oil or oiled debris above background level of oiling based on natural Gulf oil seeps and beach oiling, for both surface and subsurface oil; Figure 2.6). The areas shown in Figure 2.6 where a light blue line is drawn along the beach indicate that bulk surface oil, buried oil, and submerged oil mats that were present along the beaches have been removed and the beach has been cleaned to STR standards for no further treatment. The remainder of the island, where yellow lines are drawn, is still being cleaned as of January 12, 2011. The cleaning activities still in progress are focusing on the removal of submerged oil mats and supratidal buried oil.

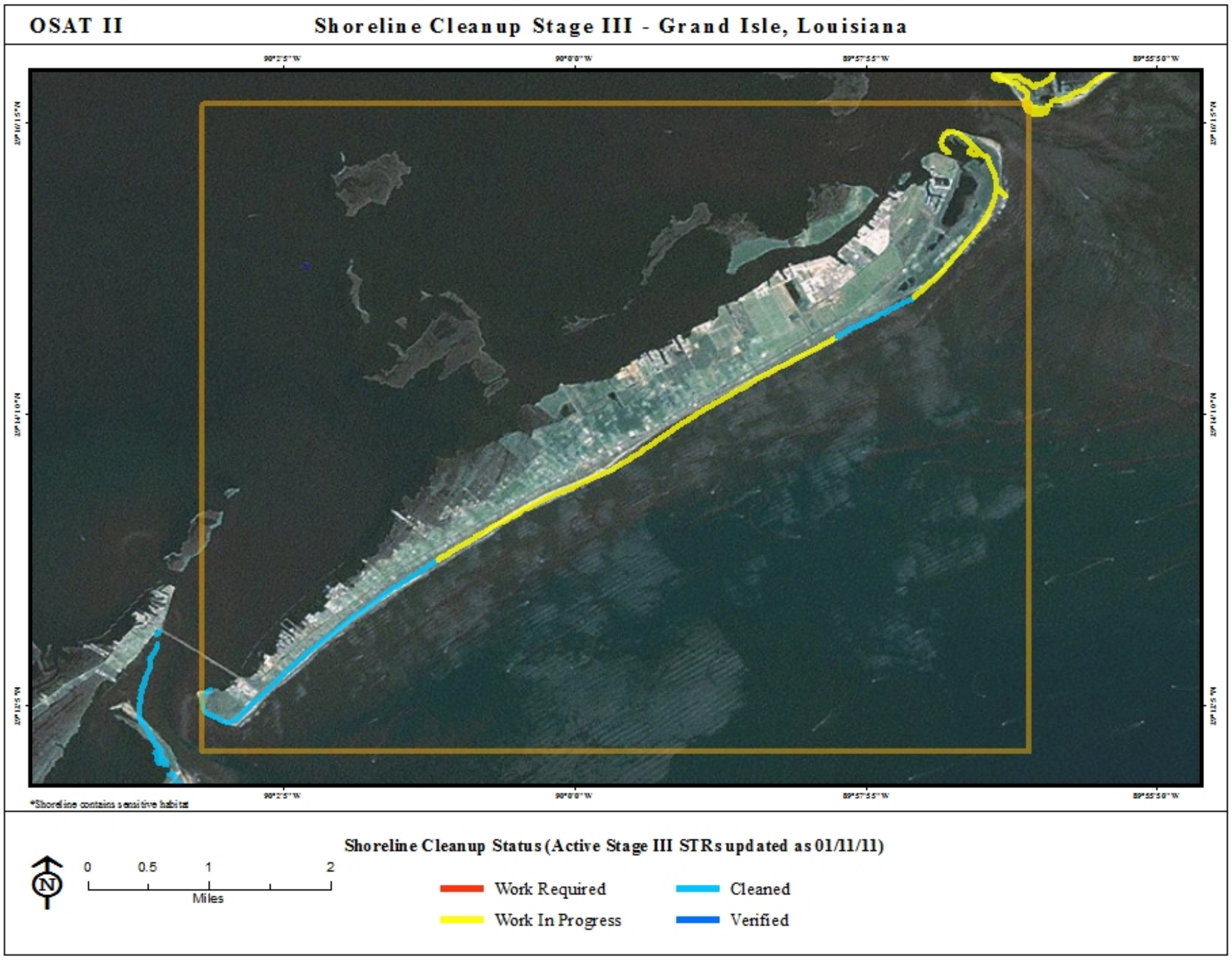


Figure 2.6. Current Stage III cleanup conditions of Grand Isle, Louisiana, January 12, 2011.

Petit Bois Island, Mississippi

The stranding patterns on Petit Bois Island resulted in heavy oiling along the majority of the Gulf-facing beaches. Light oiling was reported along the backside of the island and along small stretches of the Gulf side of the island, between the heavily oiled areas. Petit Bois Island has been cleaned after it was oiled. As of January 12, 2011, a majority of Petit Bois Island has been cleaned to Stage III cleanup standards (manual removal of bulk surface oil and shallow subsurface oiling to a maximum depth of 3 inches below the sand; Figure 2.7). Restrictions were placed on the cleanup of Petit Bois beaches because it is part of Gulf Islands National Seashore (GUIS) under NPS protection and considered to be sensitive habitat.

The areas shown in Figure 2.7 where a light or dark blue line is drawn along the beach indicate that bulk surface oil, buried oil, and submerged oil mats that were present along the beaches have been removed and the beach has been cleaned to STR standards for no further treatment. Any oil below three inches of sand still remains. The one stretch of beach on the eastern Gulf-facing beach that still has work in progress (yellow line) had heavy supratidal oil deposits.

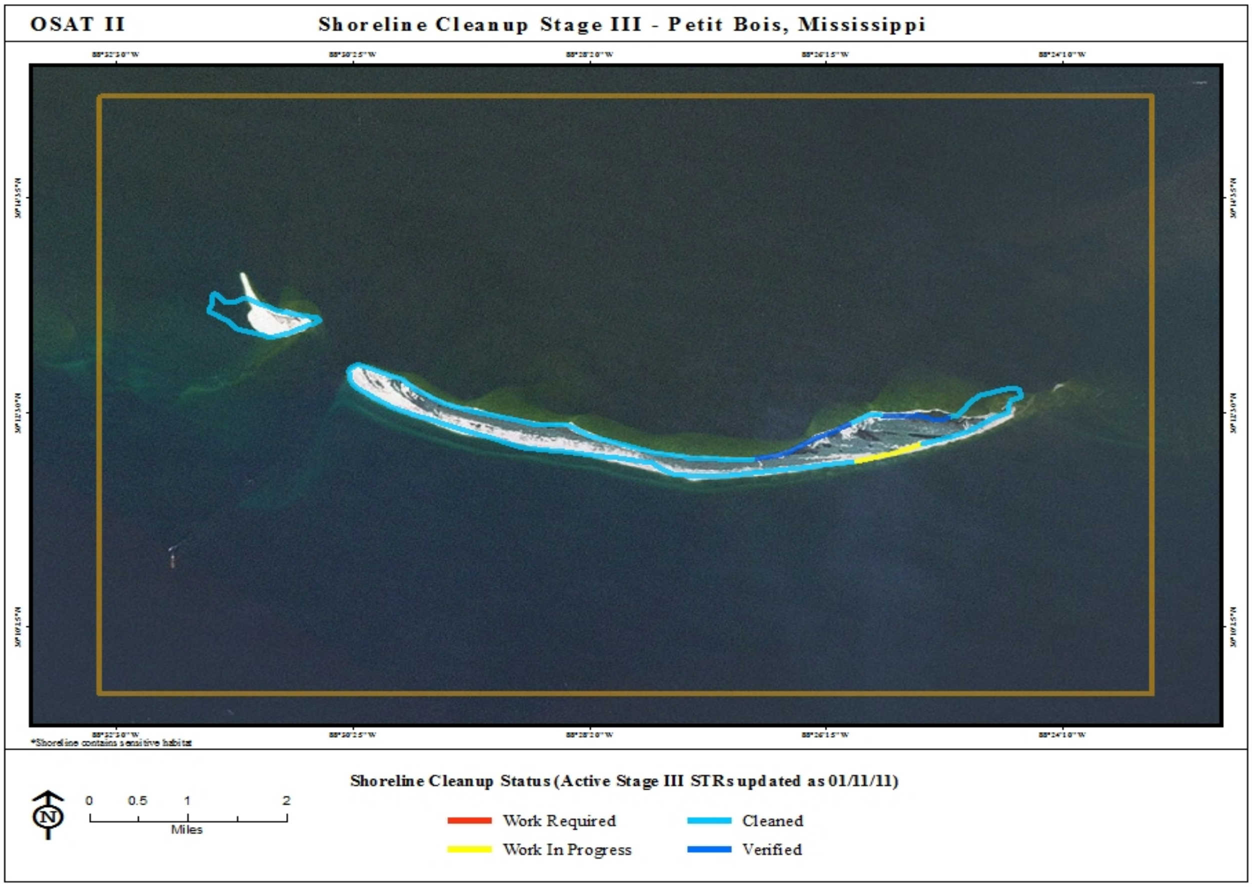


Figure 2.7. Current Stage III cleanup conditions of Petit Bois Island, Mississippi, January 12, 2011.

Bon Secour, Alabama

The majority of Gulf-facing beaches at Bon Secour experienced heavy oiling. Only one small section of the beach had light oiling. The bayside of Bon Secour was reported to only have trace (< 1 percent) oil deposits remaining on the beach or no oil observed at all. Bon Secour was cleaned after it was oiled. The majority of Bon Secour currently has either cleanup in progress or cleanup work that was still required according to Stage III cleanup standards (see Figure 2.8). Bon Secour has both amenity beaches and a USFWS National Wildlife Refuge. Specific Shoreline Treatment Recommendations (STRs) were adapted for the sensitive habitat of the wildlife refuge and differ from those for the amenity beaches.

In Figure 2.8, the stretches of beach where light blue lines are drawn indicate that bulk surface oil, buried oil, and submerged oil mats that were present along the beaches have been removed and these stretches of beach have been cleaned to STR standards for no further treatment (less that 1 percent surface distribution of oil remaining on the beach and no remaining oiled debris).

The areas that still required work (shown as red lines in Figure 2.8) or where work was still in progress (shown as yellow lines in Figure 2.8) were areas where there was heavy to moderate buried supratidal oil and submerged oil mats. The long stretch of beach where work is in progress is within the USFWS National Wildlife Refuge (where only manual removal of oil is permitted and large submerged oil mats were present). The remainder of the beaches where work is required is amenity beaches that are deep cleaned to remove all oil above background concentrations of natural beach oiling from Gulf oil seeps to the depth of penetration. Submerged oil mats also are present in these locations.

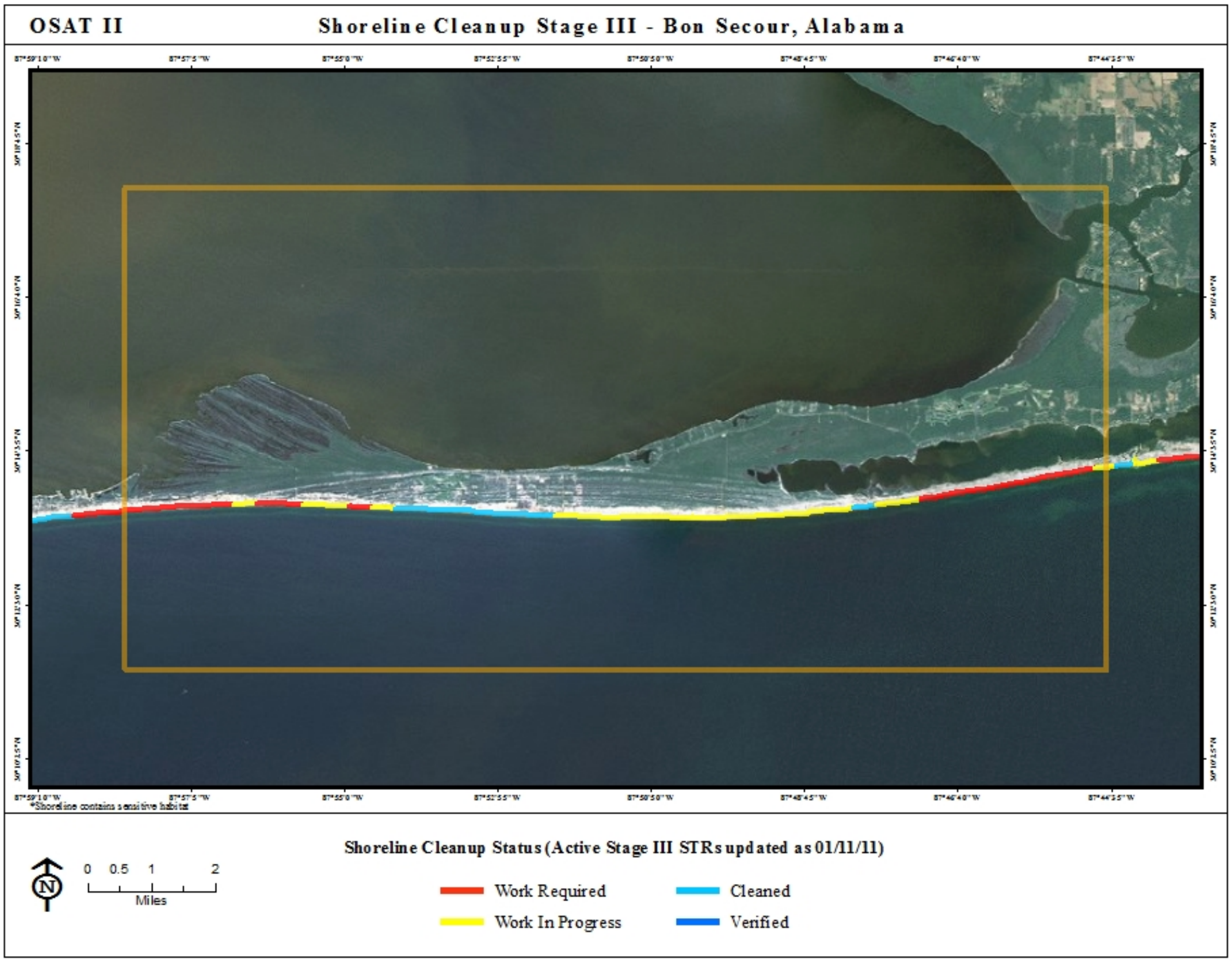


Figure 2.8. Current Stage III cleanup conditions at Bon Secour, Alabama, January 12, 2011.

Fort Pickens, Florida

The majority of Gulf-facing beaches at Fort Pickens experienced heavy oiling. Only one small section of the beach had light oiling. The backside of Fort Pickens primarily experienced light oiling, with a few locations where either heavy or no oil was observed. The majority of Fort

Pickens was verified as cleaned by SCAT teams or had cleanup in progress according to Stage III cleanup standards (see Figure 2.9). Part of Fort Pickens belongs to the Gulf Islands National Seashore (GUIS) operated by the NPS. There also are amenity beaches on this peninsula. The amenity beaches at Fort Pickens are those where work is still in progress (yellow lines shown in Figure 2.9). The amenity beaches have a shoreline treatment recommendation that calls for no visible surface oil above background levels, no oiled debris, and no visible subsurface oil above background levels, to a maximum depth of 18 inches below the sand surface. The removal of the subsurface oil is still in progress.

The non-amenity NPS beaches have been verified by SCAT teams as cleaned to the STR (dark blue lines shown in Figure 2.9), which does not allow subsurface oil removal and permits only bulk oil removal to a depth of 6 inches below the sand surface. Beaches are considered clean when there is less than 1 percent surface oil and no surface residual material greater than 2.5 cm (1 inch) in diameter on the sand. There may, however, be oil present below 6 inches of cleaned surface, but this oil is to remain in place according to the STR.

No submerged oil has been identified offshore from Fort Pickens, however, there were oil mats present to the east. Because oil mats are known to break up in the subtidal zone, it is possible that pieces of an oil mat may be transported to Fort Pickens and subsequently would require removal.

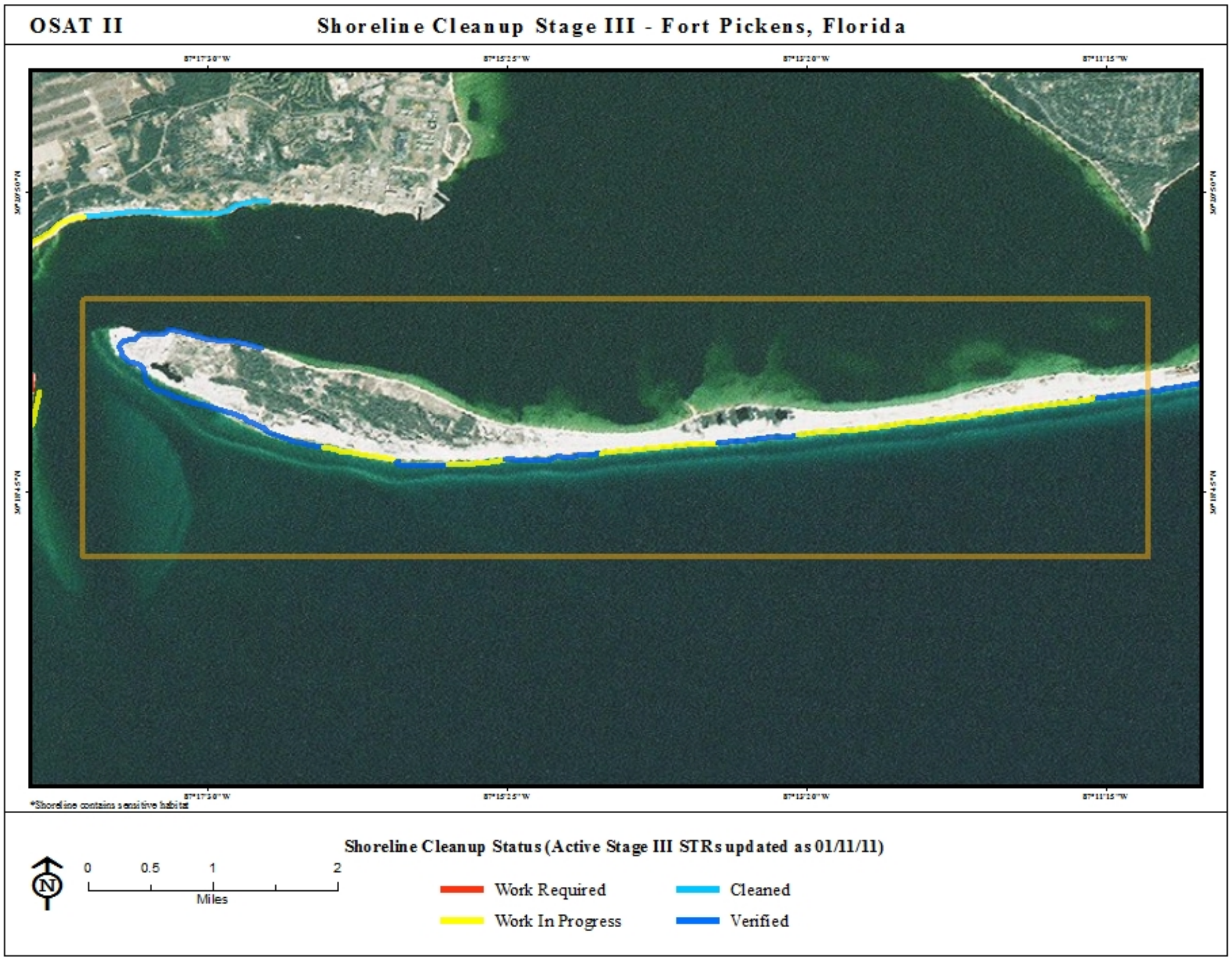


Figure 2.9. Current Stage III cleanup conditions at Fort Pickens, Florida, January 12, 2011.

Potential impacts of the remaining oil on the beaches (based on available data and literature searches) were used in a Net Environmental Benefit Analysis (NEBA) to assess if the remaining oil on the NPS and USFWS beaches should be cleaned up or left in place to naturally attenuate.

3. WEATHERING AND DEPLETION OF OIL

Crude oil is a unique mix of compounds, and impacts to exposed organisms are influenced by its physical and chemical properties. In offshore spills, numerous processes act on these compounds long before oil reaches shorelines. These processes include weathering (dissolution, evaporation, photo-oxidation, and emulsification) and biodegradation. In this oil spill, low molecular weight alkanes and volatile benzene, toluene, ethylbenzene, and xylenes (BTEX) and two-ring polycyclic aromatic hydrocarbons (PAH) compounds were mostly depleted from oil that reached shorelines. OSAT-2 used available datasets and one new round of sampling of residual oil to understand current chemical condition of shoreline oil. Samples of supratidal buried oil (SBO) collected from sand beaches between October 2010 and January 2011 are substantially depleted in total PAHs (TPAH >86% depletion). Although the higher molecular weight PAHs (4-6 rings) have also been depleted (68-98%) compared to the source oil, some samples still have measureable amounts of these more persistent compounds (Figure 3.1).

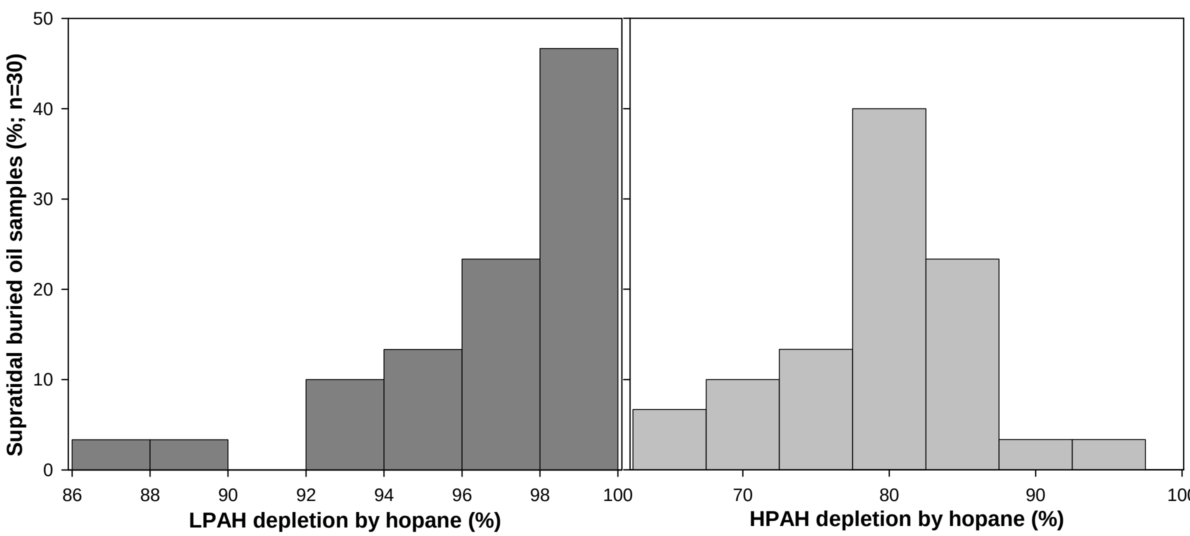


Figure 3.1. Depletion of low (2-3 ring) and high (4-6 ring) molecular weight PAHs (LPAH and HPAH, respectively) in supratidal buried oil samples (n = 30).

Weathering of shoreline oil varies by residual oil type and location. Grand Isle oil is the least weathered, while Petit Bois oil is the most weathered. Submerged oil mats (SOM) are less weathered than oils stranded on beaches. SOM from Bon Secour and Fort Pickens had the highest concentrations of individual PAHs and are less weathered than the other forms of oil within these areas. The SOM are the least weathered oil residues, and could persist in the environment in the absence of the high physical energy encountered in the wave-break zone of the beaches, where the SOM most often occur. The residual oil evaluated in this report contained high molecular weight hydrocarbons including the more toxic PAHs that are recalcitrant to weathering and microbial biodegradation. Research on other spills indicates that sequestered oil may persist longer than would be expected based on laboratory degradation studies. Limiting factors to biodegradation in the environment include: moisture, temperature, nutrients, and characteristics of microorganisms. Physical disturbances, such as storms, beach erosion and depositional processes can impact rates of depletion.

Models

Two numerical models, SEAM 3D and BIOMARUN, were used to predict potential depletion processes and rates. SEAM 3D accounts for oil biodegradation as it dissolves in the water table, while BIOMARUN models persistence of the source oil.

SEAM 3D simulates the dissolution of PAHs from SBO and the transport of the dissolved compounds by flowing groundwater in the subsurface environment of Grand Isle, Louisiana. Simulations using SEAM 3D predicted PAH concentrations approximately 1,000 fold less at 1.0 m from the source than in the source. This is likely due to the combined effects of low solubility of these PAHs, their tendency to adhere to the sand, and their biodegradability. Thus, if the oil remains in place, exposure to plants and animals through leaching into the groundwater is minimal.

The BIOMARUN model simulates the biodegradation of residual oil both below and above the water table, and as such is directly applicable to oil in tidally influenced beaches where the soil moisture varies with time. The simulations focused on the biodegradation of long chain alkanes and PAH. At Bon Secour and Fort Pickens, the soil moisture surrounding the oil was about 20 to 30% of the porosity, while it was more than 90% at Grand Isle. The simulation results for Bon Secour and Fort Pickens indicate alkanes and PAHs would degrade to approximately 15-20% of the current concentration within 2.5 to 5 years. Simulation results indicate that oil biodegradation is slower at Grand Isle. After 5 years the concentrations of alkanes and PAHs were predicted to be 80% and 95% of the initial concentrations, respectively. The range of uncertainty for the times to depletion is ± 50%. For example, at Fort Pickens, the decrease of the alkane concentration to 15% should be read as occurring at 2.5 years ± 1.25 year. Similarly, the decrease of the PAHs concentration to 20% should be viewed as occurring at 5.0 years ± 2.5 year.

MC252 oil has weathered and biodegraded significantly from its point of release. Residual oil addressed in the OSAT-2 analysis contains recalcitrant and potentially toxic components of oil. These exist in environments where there is greater potential for persistence. Model results indicate, however, that soluble components of degraded oil will not travel far from the source. SBO concentrations after 5 years are predicted to be 20% of the initial concentrations, except under conditions similar to those found at Grand Isle, where depletion time was predicted to be significantly longer. The PAH depletion results from subsurface oil samples collected on Eastern (FL, AL, MS) sandy beaches over a four month period (October 2010 – January 2011), which showed measurable degradation of the high molecular weight PAH, are generally consistent with the model results.

4. HUMAN HEALTH CONSIDERATIONS

In order to address human health concerns related to petroleum residues occurring on beaches, a screening human health risk assessment was performed utilizing data from 22 petroleum residue samples collected on the shorelines of Louisiana, Mississippi, Alabama, and Florida from October 2010 to January 2011. These samples represented the three types of oil of concern. These samples were analyzed for chemicals known to persist in weathered petroleum residues such as polycyclic aromatic hydrocarbons (PAHs).

While on the beach, humans may be exposed to SSRBs via skin (dermal) contact or ingestion. Guidance developed in September 2010 by the Florida Department of Health (FDOH), entitled "Framework for Data Organization, Review, Analysis, and Interpretation of Oil Impacted Gulf Beaches" was used to assess the potential human health risks from contact with these petroleum hydrocarbon residues. The FDOH Framework guidance addresses risks from exposure to petroleum hydrocarbons in sediment for two different exposure scenarios — a "Visitor" scenario and an "Unrestricted" scenario. The Visitor exposure scenario addresses the short-term exposure of a young child "visiting" a beach for 90 days over a 120-day period for one year. The Unrestricted scenario addresses long-term residential exposure conditions (i.e., from childhood through adult daily exposure for 30 years). In both scenarios, exposure to petroleum hydrocarbons was assumed to result from skin contact with sediment, ingestion of sediment, and inhalation of vapors and dusts.

The FDOH Framework guidance for sediment exposure and risk was adapted to address exposures to petroleum residues by incorporating two additional factors. First, concentrations of chemicals in the entire petroleum residue were adjusted to account for the actual petroleum content of samples versus non-petroleum content. The maximum measured petroleum content of the samples is 16.8 percent, but 20 percent was used for this analysis. The remaining portion of the petroleum residue is sand, sediment, or other non-petroleum constituents. Secondly, because only a small fraction of the beach is assumed to be affected by discrete pieces of petroleum residue samples, exposures were adjusted to account for the fraction of the beach surface covered by residues. In the case of the Visitor scenario, the fraction of the beach covered by petroleum residue was assumed to be 10 percent (0.10); for the long-term Unrestricted scenario, the value was set at 1 percent (0.01). These assumptions are considered health protective because beach cleanups are initiated when beach coverage by petroleum residues is at or above 1 percent (0.01). For this reason, it is unlikely that short-term beach goers would experience a beach with greater than 1 percent coverage for more than a few days, much less for months or years.

Potential human health risks were calculated for potential cancer and non-cancer health effects. In the case of the Visitor and Unrestricted exposure scenarios, the total risks from chemicals in each of the 22 samples were found to be less than the U.S. Environmental Protection Agency (USEPA) acceptable excess lifetime cancer risk range of 1 in 10,000 to 1 in 1,000,000. In fact, the calculated risks were below the most conservative level of 1 in 1,000,000. The cumulative non-cancer risks for chemical concentrations detected in each of the 22 samples were less than the USEPA-recommended criteria for non-carcinogens. These results indicate that human health risks from short-term and long-term exposures would not result in unacceptable health risks. Although some uncertainty remains regarding the degree of exposure and risk from contact with petroleum residues on beaches, it is likely that the procedures used in the screening risk assessment overestimate risk rather than underestimate any public health threat.

5. ECOLOGICAL FRAMEWORK

Localized deposits of the three forms of residual oil (supratidal buried oil - SBO, small surface residue balls-SSRBs, submerged oil mats - SOM) have been encountered on beach habitats along the shoreline impacted by the spill. Although residual oil stranded in the beach habitat is highly weathered, concerns exist regarding the potential effects the residual oil may have on beach biological resources. OSAT-2 focused on whether the three forms of oil pose unacceptable risks to beach biological resources. This assessment is not intended to estimate risks to all the possible receptor species under all possible exposure routes. Instead, a selected number of ecological receptors were selected based the following criteria: species sensitive to the adverse effects of oil residue, representatives of a larger group of species, or functional groups and reasonable exposure pathways.

OSAT-2 characterized the potential risk to the following receptors:

- Aquatic fauna: aquatic invertebrates and fish may be directly or indirectly exposed to submerged oil mats. These receptors are treated as a group, which encompassed mollusks, marine worms, and crustaceans, among others.
- Many bird species use sand beaches along the Gulf as foraging and nesting grounds. These habitats also are important wintering grounds for migratory species.
- Five species of marine turtles inhabit the waters of the Gulf, and are listed species of concern. Accessible flat beaches along the impacted shoreline likely represent important nesting grounds for these species, where eggs can be deposited below the sand surface and above the high tide line.
- Several subspecies of small terrestrial mammals inhabit coastal dunes of Florida and Alabama. Four of these mammals are listed species with critical habitats restricted to specific beach habitats along the Gulf.
- Additional ecological receptors were considered regarding potential impacts from the residual oil, including plants, ghost crabs, supratidal invertebrates, and marine mammals.

Assessments of ecological risk evaluated crude oil, and petroleum constituents such as PAHs and dibenzothiophenes (DBTs), the primary compounds of concern due to their toxicity and persistence in the environment. In addition, toxicity benchmarks are available or calculated for these compounds. The pathways by which resources may be exposed to the toxic components of the three forms of residual oil include direct and indirect contact. Direct exposure may occur through incidental ingestion of oil residues by receptors feeding on sand beaches, or through physical (dermal) contact, particularly with the less weathered and less viscous oil residues. Aquatic organisms can be indirectly exposed to toxic constituents via diffusion of dissolved oil fractions across gills and cell membranes, or directly exposed by feeding on suspended oil residues.

6. SEA TURTLES

The Gulf Coast provides nesting habitat for five of the world's seven sea turtle species. All five of these sea turtle species are listed as either threatened or endangered. Sea turtle species known to use the Gulf's shores for nesting are the green, loggerhead, hawksbill, leatherback, and Kemp's Ridley. Similar to other marine species, sea turtles are potentially vulnerable to the presence of oil as a result of physical contact as well as ingestion. Sea turtle adults do not feed as they approach, traverse, or leave the beach during nesting, nor do hatchlings feed on or near the beach (the area encompassing the three forms of oil residue considered in this report). Therefore, ingestion of oil residue is not an apparent exposure pathway for the sea turtles. As a result, the only exposure pathway considered for sea turtles as part of this study is dermal or physical contact with sandy beach oil deposits.

There is a range of weathering and biodegradation of oil residues found on and along the majority of the sand beaches addressed in this assessment. Similarly toxicity and other effects (e.g., physical fouling) vary with the weathering of oil. The majority of oil deposits on the Gulf beaches are highly weathered, therefore this assessment focuses on these types of deposits. Potential effects of less weathered residues of this type of oil are described where they differ from the predictions for more weathered deposits.

Risks to sea turtles from exposures to the weathered oil deposits remaining on the sand beaches are evaluated to be low. Greater risk is expected for the "less weathered" oil deposits because the potential for transfer of oil to turtle skin. Fresh oil can be injurious to turtle skin, but the risk of skin oiling from the weathered oil deposits is anticipated to be low, because of low transferability. This low risk of injury is predicted for adult turtles as well as the hatchlings. Uncertainty around this prediction is the potential for the oil deposits to soften in the summer months compared to what was observed when this analysis was performed. There may be a greater potential for adverse impacts to the adults and/or hatchlings if oil from the softened deposit more readily transfers to the turtles' skin. A better physical characterization of the residual oil will permit a better understanding of the potential for this to occur.

There is a potential for nesting turtles to be adversely impacted by hardened oil deposits in the supratidal areas due to an inability to dig through them. The risk is influenced by the hardness and thickness of the deposits and the amount of beach area affected. Based on SCAT data collected from Petit Bois and Bon Secour, it is calculated that 2 to 8 percent of these beaches are underlain by oil deposits. Better estimates on the extent and hardness of deposits and its influence on turtle nesting would help to refine assessment of potential impacts.

Turtle eggs are not expected to be adversely impacted by the weathered oil deposits, based upon studies done with weathered oil on hatchability. Fresh oil can have adverse effects on turtle eggs. Therefore, there is some concern over the less weathered oil if turtle eggs are laid in these deposits, although the literature indicates that even modest (several months) weathering of crude oil can substantially reduce toxicity to turtle eggs and embryos.

7. WATER BIRDS

Many important species of water birds nest, winter, stop over, or permanently inhabit the northern Gulf of Mexico. All forage in the spill-affected area and several nest there as well. A number of these water bird populations, especially those nesting on shores in temperate climates, are in decline as a result of human development and associated disturbances. Events such as the Deepwater Horizon oil spill further impact these already vulnerable populations. The effects on bird populations as a result of the spill, are twofold – harm associated with the toxic and physical properties of the released oil, and harm from the resultant cleanup efforts.

Exposure of water birds to the three types of oil considered in this assessment throughout the spill-impacted area is primarily through direct ingestion or via direct contact with eggs. As a result, toxicity analyses focused on these routes of exposure.

With respect to ingestion, the goal was to conservatively determine from the literature the lowest ingested doses associated with effects that could manifest at the population level or compromise individual fitness. Suitable information representing six water bird species (mallard ducks being the most common subject) was obtained from two published studies. Literature studies expressed doses as a volume of oil administered to a bird or a percentage of oil in the diet. A lowest observed effect level (LOEL) of 250 mg crude oil x kg body mass^{-1} day^{-1} was found to cause fewer eggs to be lain by mallards. A different study was used for a no-observed effect level (NOEL) of 43 mg crude oil x kg body mass^{-1} day^{-1}, associated with reduced avoidance behavior, was used for a threshold of less serious effects.

With respect to direct contact with eggs, a LOEL of 1 µL south Louisiana crude oil, applied directly to mallard eggs, was reported in several studies of the literature. In each case, significant embryo mortality occurred and no associated NOELs were found.

Regarding harm to bird populations as a result of cleanup operations, while less weathered oil occasionally becomes exposed, the physical hazards to birds are mainly from the actual cleanup activities. Cleanup activities on beaches may be expected to harm birds directly, remove materials important to shorebird foraging and roosting, and reduce foraging time up to 50 percent. While some impacts have been ameliorated by following best management practices, direct effects and reduced nutrition may be critical to migrating and reproducing birds, indicating medium to high risk from oil cleanup activities.

Among water birds most at risk are those nesting on beaches and shorebirds foraging on beaches because these populations are most likely to be exposed to the three forms of residual oil. Birds are more likely to be exposed to SSRBs than to buried or submerged oil, but interchange between the three forms may occur.

Risk assessment for oil toxicity is based on comparing data from toxicity studies to estimates of exposure. Two bird species were selected to estimate exposure from ingestion — the western sandpiper (WESA) because of its small size and the piping plover (PIPL) because it is a federally-listed species. For egg exposure, the snowy plover (SNPL) and the least tern (LETE) were selected because they are among the smallest beach-nesting birds, the SNPL forages on beaches, and LETE is federally listed.

Estimates of oil in the diet are based on incidental ingestion. The WESA probes sand in the swash zone for isopods and other invertebrates. Because WESA do not typically feed by sight, it is possible that SSRBs, whether on or just below the surface, could be ingested incidentally while probing the sand. Assumptions were made that SSRBs are equivalent to a prey item, and are ingested in direct proportion to the extent of their coverage. This approach is conservative because SSRBs may be seen and avoided, or taken and rejected. The proportions of SSRBs in the diet and the extent of oil weathering were assumed to vary in space and time. Ranges of SSRB coverage (0.1% to 100%) and extent of degradation (0% to 99%) were used to estimate oil ingestion rates for WESA and PIPL.

Current, post-treatment conditions for SSRBs were assessed by combining 80 percent oil degradation with both 0.1 percent and 1.0 percent SSRB coverage. The 1-percent SSRB coverage is a cleanup criterion; current observations of beaches after cleanup indicate SSRB coverage is closer to 0.1 percent. The combined conditions for PIPLs, which are mainly visual feeders, indicate low risk, while those for the WESA show a range from low to medium risk.

SNPLs may nest singly or in loose colonies on beaches and other dry, flat areas where vegetation is sparse or absent. LETEs nest in colonies in similar habitat to SNPL. In both cases, nests are close enough to water to co-occur with SSRBs, and SSRBs also may be moved by strong winds into nesting areas.

For egg exposure, the relative surface area was estimated for a SNPL's egg that would be covered by 1 µL of oil. Considering oil degradation and other factors, an estimated coverage of 193 SSRBs/m^2 would be needed to reach the toxicity threshold. The highest SSRB coverage observed on a treated beach (Dauphin Island) is 11 SSRBs/m^2. So, it is possible but unlikely that treated beaches will have enough SSRB coverage to harm bird eggs under current conditions. Future risks to eggs may result from buried oil becoming exposed, if the oil fills the sand pores in an area of about 1 cm^2 or greater.

In conclusion, uncertainty is associated with all aspects of a risk assessment and can include errors in design, measurement, analysis, omission and judgment, as well as the consequences of assumptions. Specific issues that may be important in this analysis include the ingestion estimate (likely overestimated), the egg exposure estimate (likely overestimated) and omission of evaluations for cumulative, indirect, and long-term risks (overall risk likely underestimated).

To summarize, risks from the three forms of residual oil to foraging birds range from low to medium. Risks to eggs of beach-nesting birds are possible, but unlikely. Risks from cleanup activities are medium to high.

8. TERRESTRIAL MAMMALS

The effects of individual PAHs have been documented for laboratory and domestic mammals, and results have shown that chronic exposures to PAHs can lead to a wide range of effects. However, laboratory exposure conditions do not necessarily reflect those experienced by wildlife resources. Experimental studies with deer mice designed to be representative of field PAH exposures via ingestion of contaminated food found reduced food consumption (2-30 percent) and suppression of immune response. Field studies, on the other hand, have not linked exposure and effects, even in populations inhabiting highly polluted areas. Since PAHs generally do not accumulate in the food web, direct ingestion of contaminated soil is a particularly important pathway of exposure for wildlife. Therefore, beach-dwelling mammals may be potentially exposed to SSRBs via incidental ingestion of residual oil in soil, and only if these mammals construct burrows, may they be directly exposed to supratidal buried oil.

Early during the oil spill response, the U.S. Fish and Wildlife Service (USFWS) raised concerns regarding the potential impact of oil to several endemic subspecies of beach mouse inhabiting coastal dunes and barrier islands of Alabama and Florida: the Perdido Key, Choctawhatchee, St. Andrew, and Alabama beach mouse. These four endangered species and their critical habitats are federally protected under the Endangered Species Act of 1973. These beach mice species have experienced dramatic habitat losses from coastal development, and are threatened by the introduction of predators (e.g., domestic cat), as well as competition with house mice. Since these four species of beach mouse are similar in size and in habitat utilization, this assessment focused on the Alabama beach mouse, which served as the representative member of this group. This selection was based on the following considerations: (1) this subspecies has the western-most distribution –closer to the oil source– (see Annex J for details); (2) it has the smallest known habitat area (4.9 km^2) compared to the other three subspecies (Perdido: 5.2 km^2, Choctawhatchee: 9.7 km^2, and St. Andrew: 10 km^2); and (3) its habitat had the largest percentage of observations with degree of oiling other than “No Oil Observed” (40 percent) compared to the habitat of other subspecies for which similar data is available (Perdido: 16 percent and Choctawhatchee: 8 percent). The endangered Alabama beach mouse occurs in a few, isolated populations along the Gulf Coast of Alabama (Figure 8.1), and is protected in Bon Secour National Wildlife Refuge, Alabama (USFWS).

Exposure of the Alabama beach mouse to PAHs can occur via dermal exposure, and via incidental ingestion of contaminated soil via foraging or grooming. Currently, there is no information to adequately quantify dermal exposure, and therefore, risks from this exposure pathway remain uncertain. However, buried oil information collected through the SCAT program combined with the known habitat of this species, points to a low risk of exposure. As part of the shoreline assessment effort, a total of 1,501 trenches were dug within the Alabama beach mouse habitat, with 97 percent of the trenches categorized as no oil observed/ light/ very light oiling, and 3 percent of the trenches categorized as moderate-heavy oiling (see Figure 8.1). Chemical analyses from supratidal buried oil have shown a substantial depletion of total PAHs (greater than 86 percent), indicating a low likelihood of effects. Furthermore, it is likely that the Alabama beach mouse would avoid burrowing in areas with high levels of residual oils.
The risk from incidental exposure of SSRBs was quantified by comparing estimated doses versus Toxicity Reference Values (TRVs) derived specifically for mammals. These TRVs were

developed by the USEPA from hundreds of studies with mammals exposed to PAHs with documented chronic effects (i.e., growth and reproduction; http://www.epa.gov/ecotox/ecossl/). TRVs for low (2-3 ring) and high (4-6 ring) molecular weight PAHs are 65.6 and 0.615 mg dry weight per kg body weight per day, respectively. Estimated PAH daily doses were calculated by integrating information on daily food ingestion, contribution of SSRBs to the overall daily diet, PAH concentration in a handful of tar ball samples matching the fingerprint of MC252 oil, the assumed foraging area of the Alabama beach mouse, and its body weight. A plausible environmental scenario was created by adjusting the incidental ingestion to 10 percent SSRBs, consistent with similar assessments within this report. Under this scenario, estimated daily doses for low and high molecular weight PAHs were below the TRV values, suggesting a low risk from incidental exposure to SSRBs by the Alabama beach mouse.

A major assumption in the model was that the primary pathway for contaminant uptake occurs through direct incidental ingestion of SSRBs present in soil, and therefore exposure via contaminated water or through incidental ingestion of residual oil via grooming was not considered. However, other assumptions made in this model were biased towards overprotection of the Alabama beach mouse. Some of these assumptions included the use of the smallest reported weight, which would translate into a higher estimated PAH daily dose, and the assumption that the entire foraging area occurs within the contaminated area. Furthermore, this model did not take into account the fact that the mouse may effectively avoid foraging in areas with high concentrations of SSRBs. Given all the assumptions in the model, this analysis indicated that chronic risk from ingestion of SSRBs is possible for this receptor species.

The USFWS also raised concerns regarding potential impacts of response actions to the Alabama beach mouse. The habitat of this receptor has been reduced by coastal development, and additional alteration or damages to its habitat from cleanup activities and increased human traffic on the beaches, may result in increased threat to this species.

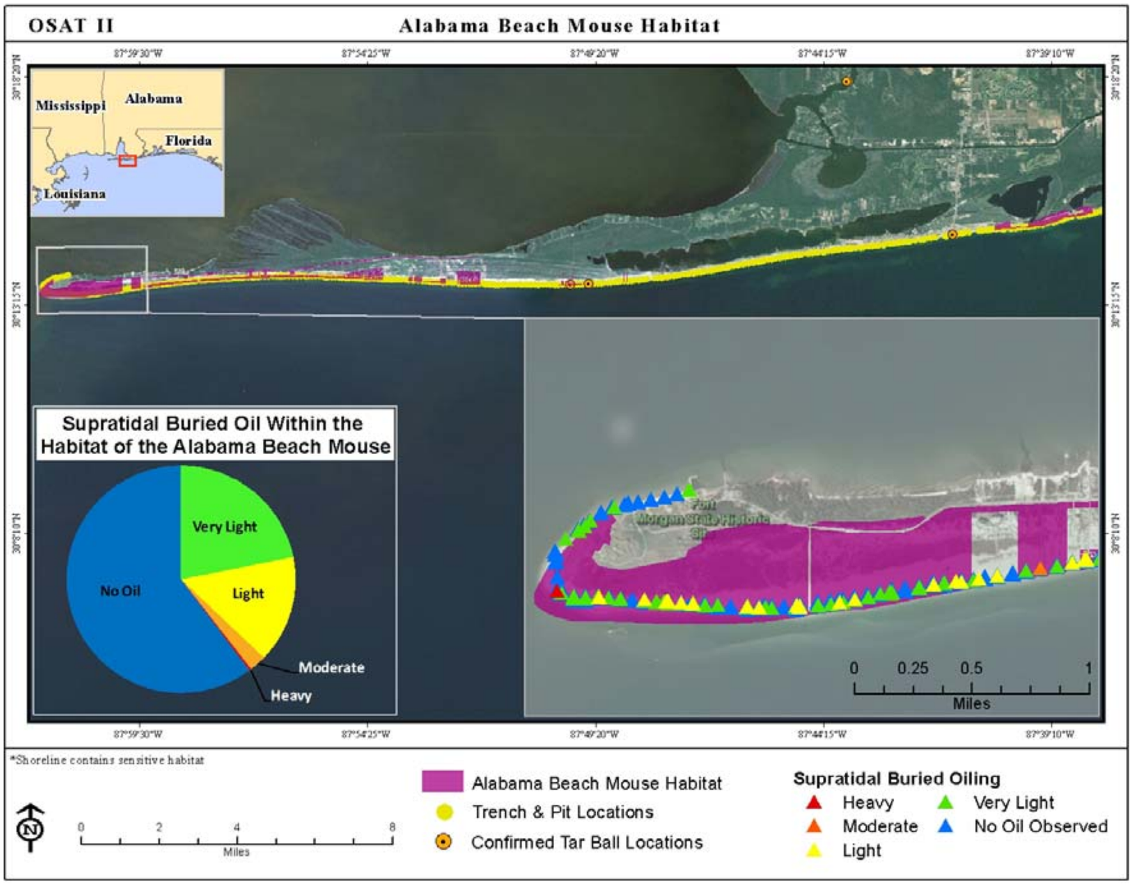


Figure 8.1. Overlay of the Alabama beach mouse with trench and tar ball oiling data.

9. AQUATIC INVERTEBRATES AND FISH

A major concern associated with the release of crude oil into the aquatic environment is the potential toxic effect to aquatic organisms (or receptors). Release of oil into the environment enables constituents of the oil to dissolve into receiving waters, thus creating potential toxicity to aquatic organisms that are exposed to these various components. When oil and water are equilibrated under laboratory conditions, the resulting aqueous solution is known as the water-accommodated fraction (WAF) of the oil. This WAF is often tested to estimate the potential for the oil to cause toxicity if it were released to receiving waters. Researchers have reported varying levels of WAF toxicity depending on the crude oil source, the WAF preparation method, the extent of weathering, the type of toxicity test, and the organism tested.

In order to bridge the gap between measured chemicals of concern in the three types of residual oil (Section 2) and potential toxicity of relevant environmental concentrations, WAFs were prepared using the three types of residual oil from the four case study areas. Direct comparison of WAF concentrations to US EPA Aquatic Life benchmarks is not standard scientific practice because of the uncertainties involved with equating laboratory-controlled WAF concentrations with concentrations found in the aquatic environment. The environmental relevance is a combination of the fact that concentrations approaching those measured in the WAF could be found only in close proximity to residual oil and that the residual oil material is non-uniformly distributed in the beach environment. Concentrations of oil constituents in the aquatic environment are predicted to drop off exponentially within millimeters from the micro-layer around the SSRBs or SOMs as a result of mixing.

Standard methodologies for preparation of the WAF are for liquid oil. These methods were modified in order to assess the three forms of oil of concern which exist as a solid. The resulting WAFs were centrifuged to eliminate particulate oil (e.g., micelles); however, in some cases the analytical results indicated that oil particles remained in the water phase. These samples were not considered for the WAF calculations, because they do not represent true dissolved fractions.

Two comparisons were used to assess the potential for residual oil to cause aquatic toxicity. The first was performed by using the concentrations of PAHs, dibenzothiophenes and dibenzofuran from the WAFs as inputs into the Sum Toxic Unit calculation (Annex K, Aquatic Invertebrates and Fish) and related to US EPA Aquatic Life benchmarks. In addition, total petroleum hydrocarbon (TPH) concentrations measured in the WAFs were compared to TPH toxicity values reported in the literature.

The potential for aquatic toxicity exists if Sum Toxic Unit values are greater than 1.0. The values for the WAFs ranged from 0.20 – 0.77 for the acute (short-term exposure) toxicity calculation and from 0.85 – 3.22 for the chronic (long-term exposure) toxicity calculation. These findings imply that acute toxicity from exposure to concentrations equal to those measured in the WAFs would not be expected, but chronic toxicity at these concentrations may be possible.

For the TPH comparison, the measured concentrations in the WAFs were compared to literature-reported WAF toxicity values. The toxicity values chosen were 4- to 6-day LC50s (lethal to 50 percent of the test organisms) for WAFs prepared with South Louisiana crude oil. The LC50 range for the selected studies was 7.10 mg/L to 15.2 mg/L. Toxicity values with a LC50 endpoint are not generally utilized as “benchmarks”, but these were the only WAF toxicity values identified for South Louisiana crude oil and they do provide some range for comparison. The TPH concentrations in the WAF ranged from 0.43 mg/L to 0.90 mg/L. This comparison implies that significant acute aquatic toxicity from the WAFs would not be expected based on the TPH measured.

WAF concentrations provide some indication of a possible worst case scenario for potential oil constituent concentrations in water that is in very close association with the SSRBs and SOM surfaces. The WAF data imply that elevated petroleum concentrations might be found in pores in the sand next to an SSRB, or within a few millimeters of the surface of a SOM. The dynamic nature of the surf zone and subtidal areas, however, and the associated water movement in these areas are expected to rapidly dilute petroleum concentrations to non-significant levels as the water moves away from the oil deposit’s surface. As a result, any toxicologically significant petroleum concentrations in these areas would be expected to be localized in the micro-layer adjacent to the SOM or SSRB surface.

The Sum Toxic Unit PAH concentrations exceeded chronic toxicity benchmarks, but did not exceed acute benchmarks, which implies that a receptor would need to be exposed to the WAF concentrations in the environment for multiple days to be adversely affected. This scenario is not likely in an environment as dynamic as that of a beach. Given these considerations, it is unlikely that the SSRBs in the intertidal zone or the SOMs in the subtidal areas will pose a significant risk to aquatic organism populations along the sandy beaches. The exception to this assumption is the potential physical and chemical impact of the SOMs. Elevated petroleum concentrations as well as low dissolved oxygen (DO) concentrations would cause additional impact to the area under SOMs. This impact would be localized to the “footprint” of the SOM, and the overall extent of the impact would be directly dependent on the extent of SOM coverage along the Gulf coast.

10. NET ENVIRONMENTAL BENEFITS ANALYSIS (NEBA)

Net environmental benefits analysis (NEBA) is a method used to compare the environmental costs and benefits associated with various management actions. In an oil spill context, NEBA is a way to evaluate the tradeoffs related to spill response and cleanup techniques. NEBA has its origins in an oil spill response, the 1989 *Exxon Valdez* oil spill, where it was used to consider a novel cleanup technology.

The sand beaches in the Gulf are highly valued and used by both humans and natural resources. Cleanup guidelines have been developed for these beaches, and application of a NEBA indicates that the guidelines, when met, strike the scientifically supported balance between "enough" cleanup and "too much." As a result, the NEBA for the OSAT-2 study addresses the following question: "Does the available technical information support the defined cleanup guidelines for sand beaches in the operational areas?" Three forms of sand beach oil are considered to be of interest to OSAT-2:

1. Supratidal oil buried (SBO) below a surface cleaning depth of 6 inches;
2. Small surface residue balls (SSRBs) found on mechanically-cleaned beaches; and,
3. Surf zone submerged oil mats (SOMs).

In this case, the NEBA was used to compare potential impacts of oil remaining in the environment once cleanup endpoints are attained, to the potential impacts of further treatment to remove more oil. To accomplish this comparison, toxicology and risk assessment specialists examined the environmental risk of the remaining oil for specific groups of resources known to use sand beaches in the Gulf, and compared this environmental risk to risks/impacts associated with additional cleanup activities to remove more oil.

Background levels of oiling are important when considering cleanup guidelines and this concept is especially relevant for the Gulf of Mexico, where petroleum seeps are well-known as natural sources that release oil into the water and onto the shorelines. In addition to so-called "natural" sources of oil present in the Gulf, ships and previous spills contribute oil into the environment. Background levels of oil vary from place to place and time to time, but overall background levels are not zero.

The NEBA process for OSAT-2 is summarized in a matrix shown here as Figure 10.1. The matrix of risk "grades" was based on analyses of data generated from the spill, review of the scientific literature, and the combined experience and knowledge of OSAT-2 specialists. Although the matrix entries are simple and descriptive (i.e., Possible, Low, Medium, High), they are supported by a great deal of review and analysis (see Annex M, NEBA).

Members of OSAT-2 researched the potential exposure effects of the particular forms of residual oil to resources of concern and used the results of that work to fill out the matrix of predicted risk from the oil. Exposure effects were compared to predicted impacts of activities to clean beaches beyond the established cleanup endpoints. These two sets of matrix results are the heart of the NEBA.

The results of the analysis indicate that the environmental effects of the residual oil remaining after cleanup are relatively minor, especially when considered in the context of pre-spill background of shoreline oiling and longer-term monitoring to ensure that cleanup guidelines are not exceeded. Continued cleanup to a higher degree, on the other hand, would be expected to result in an increasingly greater extent of negative impact to habitats and associated resources as more and more effort is directed toward removing diminishing amounts of oil. As winter transitions into spring and summer, critical seasons for both human and resource uses also become important factors in considering shoreline cleanup impacts and use conflicts.

NEBA MATRIX

ROUTE OF EXPOSURE	RESOURCE AT RISK

	Aquatic Invertebrates & Fish				
	Inherent Oil Toxicity	Oil Spatial Distribution	Exposure Likelihood	Summed Effects Assessment	Further Cleanup Impact
Supratidal Buried Oil contact (adult)	LOW	LOW	N/A	N/A	LOW
Submerged Oil Mat aquatic contact	MED	LOW	LOW	LOW	LOW
SSRB ingestion (adult)	MED	MED	N/A	N/A	LOW
SSRB contact (young)	MED	MED	LOW	LOW	LOW
Supratidal Buried Oil contact (eggs/young)	MED	LOW	N/A	N/A	LOW

	Sea Turtles				
	Inherent Oil Toxicity	Oil Spatial Distribution	Exposure Likelihood	Summed Effects Assessment	Further Cleanup Impact
Supratidal Buried Oil contact (adult)	MED	LOW	LOW	LOW	LOW - HIGH
Submerged Oil Mat aquatic contact	MED	LOW	LOW	LOW	LOW
SSRB ingestion (adult)	HIGH	MED	N/A	N/A	LOW - HIGH
SSRB contact (young)	LOW	MED	LOW	LOW	LOW - HIGH
Supratidal Buried Oil contact (eggs/young)	MED	LOW	LOW	LOW - MED	LOW - HIGH

	Birds				
	Inherent Oil Toxicity	Oil Spatial Distribution	Exposure Likelihood	Summed Effects Assessment	Further Cleanup Impact
Supratidal Buried Oil contact (adult)	MED	LOW	POSS	POSS	HIGH
Submerged Oil Mat aquatic contact	MED	LOW	POSS	POSS	HIGH
SSRB ingestion (adult, surface foraging)	MED	MED	LOW	LOW	HIGH
SSRB ingestion (adult, subsurface probing)	MED	MED	MED	MED	HIGH
SSRB contact (young)	MED	LOW	POSS	POSS	HIGH
Supratidal Buried Oil contact (eggs/young)	MED	LOW	POSS	POSS	HIGH

	Mammals (Beach Mouse)				
	Inherent Oil Toxicity	Oil Spatial Distribution	Exposure Likelihood	Summed Effects Assessment	Further Cleanup Impact
Supratidal Buried Oil contact (adult)	MED	LOW	LOW	POSS	HIGH
Submerged Oil Mat aquatic contact	MED	LOW	LOW	POSS	LOW
SSRB ingestion (adult)	MED	MED	LOW	POSS	MED
SSRB contact (young)	MED	MED	LOW	POSS	MED
Supratidal Buried Oil contact (eggs/young)	MED	LOW	LOW	POSS	HIGH

Figure 10.1. OSAT-2 Net Environmental Benefits Analysis (NEBA) matrix to help decide if residual oil left on sand beaches is more harmful than taking further actions to remove the oil. Scores range from possible (POSS, least impact) to high (HIGH, most severe impact). For example, removal of Supratidal buried oil by excavation was evaluated to result in a HIGH negative impact to nesting sea turtles from the cleanup activities. LOW-MED entry for sea turtle eggs reflects variable risk from different weathering states of oil; LOW-HIGH entries for sea turtle cleanup impacts reflect seasonal presence of nesting animals and nests on sand beaches.

11. OSAT Membership

Agency	Specialty	OSAT Member	Email
USCG	OSAT-2 Project Manager	LCDR Kenneth Boda	Kenneth.j.boda@uscg.mil
BOEMRE	Marine Ecology	Michelle Nannen	michelle.nannen@boemre.gov
NOAA	Environmental Toxicology	Adriana Bejarano	abejarano@researchplanning.com
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