UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF OCEAN ENERGY MANAGEMENT,
REGULATION AND ENFORCEMENT
GULF OF MEXICO OCS REGION
NEW ORLEANS, LOUISIANA

SITE-SPECIFIC ENVIRONMENTAL ASSESSMENT

OF

EXPLORATION PLAN
NO. S-7444

FOR

SHELL GULF OF MEXICO INC

May 10, 2011

RELATED ENVIRONMENTAL DOCUMENTS

Environmental Impact Statement for Gulf of Mexico OCS Oil and Gas Lease Sales: 2007-2012; Western Planning Area Sales 204, 207, 210, 215, and 218; Central Planning Area Sales 205, 206, 208, 213, 216, and 222 (OCS EIS/EA MMS 2007-018)

Supplemental Environmental Impact Statement for Gulf of Mexico OCS Oil and Gas Lease Sales: 2009-2012; Central Planning Area Sales 208, 213, 216, and 222; Western Planning Area Sales 210, 215, and 218 (OCS EIS/EA MMS 2008-041)

FINDING OF NO SIGNIFICANT IMPACT (FONSI)

In accordance with the National Environmental Policy Act (NEPA), Council on Environmental Quality (CEQ) regulations at 40 C.F.R. §§ 1501.3 and 1508.9, Department of the Interior (DOI) regulations implementing NEPA at 43 C.F.R. Part 46, and Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) policy, BOEMRE prepared a Site-Specific Environmental Assessment (SEA), No. S-7444, which analyzed the potential effects of Shell Gulf of Mexico Inc's (Shell) supplemental Exploration Plan (EP) for drilling operations on the Outer Continental Shelf (OCS) of the Gulf of Mexico (GOM). The SEA of the proposed action is complete and the BOEMRE has found no information to indicate that the proposed action will significantly affect the quality of the human environment within the meaning of Section 102(2)(c) of the NEPA. Therefore, the BOEMRE has determined that an Environmental Impact Statement (EIS) is not required and is issuing a Finding of No Significant Impact (FONSI).

The BOEMRE has determined that the mitigation measure listed below and analyzed in the *Gulf of Mexico OCS Oil and Gas Lease Sales: 2007-2012; Western Planning Area Sales 204, 207, 210, 215, and 218; Central Planning Area Sales 205, 206, 208, 213, 216, and 222; Final Environmental Impact Statement* (USDOI, MMS, 2007); the *Gulf of Mexico OCS Oil and Gas Lease Sales: 2009-2012; Central Planning Area Sales 208, 213, 216, and 222; Western Planning Area Sales 210, 215, and 218; Final Supplemental Environmental Impact Statement* (USDOI, MMS, 2008); and in this SEA is necessary to minimize certain possible adverse effects of this action upon the environment. The mitigation is as follows:

AVOIDANCE OF POTENTIAL ARCHAEOLOGICAL RESOURCES: Our review indicates that the operator's proposed activities are in the vicinity of the unidentified side-scan sonar targets listed under separate cover, features that may represent significant archaeological resources. In accordance with 30 C.F.R. § 250.194(b), you must either (1) conduct an underwater archaeological investigation (diver and/or ROV investigations) prior to commencing the proposed activities to determine whether these features represent archaeological resources, or (2) ensure that all seafloor disturbing actions resulting from the proposed activities avoid the subject features by a distance greater than that listed under separate cover. If the operator conducts an underwater archaeological investigation, contact either Dr. Jack Irion at (504) 736-1742 or Dr. Christopher Horrell at (504) 736-2796 at least two weeks prior to performing operations to obtain the investigation methodology. If the operator chooses to avoid the features, submit an as-built map at a scale of 1-in. = 1,000-ft. with DGPS accuracy, showing the location of all seafloor disturbances (e.g., the rig or platform, anchors, anchor chains, wire ropes, cables, etc.) relative to these features to the Regional Supervisor, Field Operations, Plans Section (MS 5231), at the same time the operator submits an End of Operations report (Form MMS-125) to the appropriate BOEM GOMR District Office and notification of platform installation date and final as-built location data as directed in 30 C.F.R. § 250.900(e).

Chief, Environmental Compliance Section
Leasing and Environment, GOM OCS Region

5/10/2011
Date

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SITE-SPECIFIC ENVIRONMENTAL ASSESSMENT (SEA) PREPARED FOR SHELL GULF OF MEXICO INC'S SUPPLEMENTAL EXPLORATION PLAN; S-7444

1. OVERVIEW

The purpose of this Site-Specific Environmental Assessment (SEA) is to determine whether the proposed drilling activities outlined in the supplemental Exploration Plan (EP), S-7444, initially submitted by Shell Gulf of Mexico Inc (Shell) on September 20, 2010, will significantly affect the quality of the human environment within the meaning of Section 102(2)(c) of the National Environmental Policy Act (NEPA) and whether an Environmental Impact Statement (EIS) must be prepared. Shell's EP proposes to explore for hydrocarbons by drilling and temporarily abandoning 10 exploration wells, Wells SS B, SS C, SS D, SS E, SS F, SS G, SS H, SS I, SS J, and C ST, in Mississippi Canyon Area, Blocks 348, 391, and 392 (with possible bottom-disturbances in Blocks 347, 348, 349, 391, 392, 393, 435, and 436) in the Central Planning Area (CPA)[1]. This SEA is tiered from two prior EIS': (1) *Gulf of Mexico OCS Oil and Gas Lease Sales: 2007-2012; Western Planning Area Sales 204, 207, 210, 215, and 218; Central Planning Area Sales 205, 206, 208, 213, 216, and 222; Final Environmental Impact Statement* (Multisale EIS) (USDOI, MMS, 2007); and (2) *Gulf of Mexico OCS Oil and Gas Lease Sales: 2009-2012; Central Planning Area Sales 208, 213, 216, and 222; Western Planning Area Sales 210, 215, and 218; Final Supplemental Environmental Impact Statement* (Supplemental EIS) (USDOI, MMS, 2008). The Multisale EIS and the Supplemental EIS evaluated a broad spectrum of potential impacts resulting from drilling activities across the Central and Western Planning Areas of the Gulf of Mexico (GOM) Outer Continental Shelf (OCS).

This "tiering" process is provided for in the NEPA implementing regulations (40 C.F.R. §§ 1502.20 and 1508.28) and is designed to reduce and simplify the size of subsequent environmental analyses of actions included within the broader program previously examined in NEPA compliance documents by eliminating discussions of impacts that would be repetitive to allow focus on those site-specific concerns and effects related to the specific action proposed. Document tiering in the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) is subject to additional guidance under Department of the Interior (DOI) regulations at 43 C.F.R. § 46.140 wherein the site-specific analysis must note which conditions and effects addressed in the programmatic document remain valid and which conditions and effects require additional review.

Although the analyses of drilling-related impacts prepared in the Multisale EIS and Supplemental EIS are comprehensive, new information has become available with respect to the following:

- **Emission Impacts on Air Quality** – the EP contains project-specific emissions data not known during the preparation of the programmatic analyses;
- **Discharge Impacts on Offshore Water Quality** – new environmental conditions now exist and the EP contains project-specific discharge data not known during the preparation of the programmatic analyses;
- **Mooring Impacts on Deepwater Benthic Communities** – the EP contains project-specific anchoring information not known during the preparation of the programmatic analyses;
- **Noise/Vessel-Strike Impacts on Marine Mammals –** new environmental conditions now exist since the preparation of the programmatic analyses;
- **Noise/Vessel-Strike Impacts on Sea Turtles –** new environmental conditions now exist since the preparation of the programmatic analyses;
- **Discharge Impacts/Disturbances to Fish and Fisheries –** new environmental conditions now exist since the preparation of the programmatic analyses; and

[1] Section 1.3 of this SEA provides specific details on the drilling activities proposed in Shell's EP.

- **Mooring/Drilling Impacts on Potential Archaeological Resources** – the EP contains project-specific drilling and anchoring information not known during the preparation of the programmatic analyses.

Therefore, Chapter 3 of this SEA focuses on how the new information, including a discussion of the known effects of the Macondo well blowout, spill, and remediation on the analyzed resources, relates to the routine, accidental, and cumulative environmental effects of this proposed action. Where applicable, relevant affected environment discussions and impact analyses from the Multisale EIS and Supplemental EIS are summarized and utilized for this site-specific analyses, and are incorporated by reference into this SEA. Relevant mitigation measures identified in Multisale EIS, and Supplemental EIS have been considered in the evaluation of the proposed action.

1.1. BACKGROUND

The BOEMRE is mandated to manage and oversee the exploration and development of OCS oil, gas, and mineral resources while ensuring safe operations and the protection of the human, marine, and coastal environments. The BOEMRE issues oil and gas leases and regulates exploration, development, production, and decommissioning. Prior to authorizing activities related to these phases, BOEMRE conducts the appropriate NEPA review. The BOEMRE's Field Operations (FO) Plan Program oversees the submittal of EPs and Development Operations Coordination Documents (DOCDs) pursuant to 30 C.F.R. Part 250, Subpart B.

Lessees and operators submit EPs and DOCDs to provide BOEMRE with information needed to adequately evaluate the overall potential impacts on OCS resources prior to seeking any individual permit approvals, such as an application for permit to drill (APD). Most of the information in EPs and DOCDs is presented in basic statements, figures, lists, and tables that simply provide the necessary details on the proposed exploration, development, production, and/or transportation operations. One exception is the Environmental Impact Analyses (EIA) required in EPs under 30 C.F.R. § 250.227 and in DOCDs under 30 C.F.R. § 250.261; wherein, the operator provides environmental information and makes impact conclusions regarding their activities.

On April 20, 2010, while working on an exploratory well approximately 50 mi (80 km) offshore Louisiana, the semisubmersible drilling rig *Deepwater Horizon* experienced an explosion and fire, resulting in an uncontrolled release of oil and natural gas from the Macondo reservoir. Oil was dispersed into the water column, but heavier oil fractions and tarballs washed onto shorelines in varying concentrations. Natural gas dissolved into the water column or vented into the atmosphere. On July 15, 2010, the leaking well was capped and a relief well encountered and plugged the Macondo wellbore on September 19, 2010. Prior to capping/plugging the well, approximately 53,000-62,000 bbl per day (2.23-2.60 million gallons) were released from the well, with an approximate total release of 4.9 million bbl of oil (206,000,000 gallons) over an 87-day period.

The Macondo Event has resulted in changes in environmental conditions over a large portion of the Northern Gulf of Mexico. Some of the information/impact determinations found in recent EIAs has relied upon out-of-date and inaccurate data. For this reason, BOEMRE reviewed, but did not rely upon, any environmental information and/or assumptions provided by the operator in the EIA when conducting this analysis.

The scope of the effects on the environment in the GOM from the activities proposed in Shell's supplemental EP were fully discussed and analyzed in the Multisale EIS and Supplemental EIS, and the specific locations, equipment, methodologies, and the duration of the proposed exploration activities will result in impacts similar to those discussed in the EISs. However, there is new information from the Macondo Event in scientific literature that is peer-reviewed as well as new mitigation methodologies such as oil spill remediation that could alter the baseline for the affected environment. This information was not previously available and could not be considered or analyzed during the preparation of the Multisale EIS or Supplemental EIS. Therefore, this SEA was prepared by BOEMRE to evaluate the applicant's proposed drilling activities in light of the new information.

1.2. PURPOSE OF AND NEED FOR THE PROPOSED ACTION

The purpose of the proposed action is to approve, approve with modification, or disapprove Shell's supplemental EP. Authorizing the proposed action as outlined in the EP, S-7444, allows Shell to pursue its rights under the lease and to conduct exploration drilling activities.

The need for the proposed action arises from Section 11 of the Outer Continental Shelf Lands Act (OCSLA). Section 11 (43 U.S.C. § 1340) requires oil and gas lessees seeking to conduct exploratory activities to first obtain approval from the Secretary who has delegated the authority to grant such approval to the BOEMRE. In response to the proposed action in Shell's plan, BOEMRE is required by OCSLA to approve, approve with modifications, or deny the plan within 30 days. (*See* 43 U.S.C. § 1340(c)(1)). The criteria that BOEMRE will apply in reaching a decision to approve, approve with modifications, or deny the plan within 30 days and the scope of its discretion are provided by Section 11 of OCSLA and detailed in the implementing regulations (30 C.F.R. Part 250, Subpart B).

1.3. DESCRIPTION OF THE PROPOSED ACTION

Shell's supplemental EP proposes to explore for hydrocarbons by drilling and temporarily abandoning ten exploration wells, Wells SS B, SS C, SS D, SS E, SS F, SS G, SS H, SS I, SS J, and C ST, in Mississippi Canyon Area, Blocks 348, 391, and 392 (with possible bottom-disturbances in Blocks 347, 348, 349, 391, 392, 393, 435, and 436) in the Central Planning Area (CPA) (Shell, 2010). The proposed drilling operations are located south of Mobile, Alabama, approximately 70 mi (113 km) from the nearest Louisiana shoreline and 19 mi (31 km) from the site of the Macondo Well in Mississippi Canyon Block 252. The water depth at the proposed well sites is approximately 7,150 ft (2,179 m).

Shell proposes using a semisubmersible mobile offshore drilling unit (MODU), *Transocean Deepwater Nautilus*, to drill and temporarily abandon the ten wells. The MODU will be moored to the seabed with suction pile anchors deployed between 13,000–15,500 ft (3,962–4,724 m) from the well locations. A remotely-operated vehicle (ROV) survey was completed and submitted on April 27, 2010 following the drilling of the OCS-G 26253 No. 1 well, Location A approved in Shell's Initial EP N-9387. The projected duration of rig mobilization/movement, drilling, and temporary abandonment of the ten exploration wells is 974 days over the next seven years (Shell, 2010). Shell does not expect any shore-based construction or expansion in association with this proposed action. Supply and crewboat facilities to support the proposed action are located in Port Fourchon, Louisiana, approximately 135 mi (217 km) northwest of the project location. Port Fourchon will be used as the debarkation point for equipment, supplies, and crews. Air operations and traffic (helicopter) will use an existing facility in Boothville, Louisiana, 90 mi (145 km) northwest of the proposed exploration activities. The types of support vessels and their potential travel frequency during exploratory drilling are shown in the table below.

Support Vessels and Frequency

Support Vessel	Maximum Trips in the Area at Any One Time	Trip Frequency or Duration
Offshore Support Vessels	3	2 per week
Crewboats	2	2 per week
Tug Boats	2	3 days
Anchor Handling Vessel	3	20 days
Helicopter	1	7 per week

1.4. IMPACT-PRODUCING FACTORS

An impact-producing factor (IPF) is any activity or process resulting from an approved operation that causes impacts to the environment, such as an emission, effluent, or physical disturbance. The IPFs from the routine exploration activities proposed by the operator in this plan include: (1) waste and discharges

from vessel operations and drilling activities, (2) air emissions from equipment and vessels; (3) noise from vessel and helicopter transportation and drilling activities, and (4) bottom disturbances from wells and anchoring (including the anchors and associated wire, chain, and/or wire rope). The routine IPFs are expected to occur during the operations conducted under the proposed action and are addressed in each of the site-specific analyses in Chapter 3 under "Routine Activities."

The analyses in Chapter 3 also consider IPFs that might result from an accidental event. The primary IPFs from potential accidents related to OCS drilling activities include: (1) vessel collisions with marine mammals and sea turtles, (2) oil spills and blowouts, and (3) vessel and helicopter collisions with coastal and/or marine birds. Unlike the IPFs associated with routine activities, the IPFs from accidental events are not expected due to the low probabilities of such events from occurring, existing/recently implemented safety/mitigation measures, and an increased level of operator awareness observed since the Macondo Event. The accidental IPFs are detailed and addressed in each of the site-specific analyses under "Accidental Events."

The Multisale EIS and the Supplemental EIS considered the routine and accidental IPFs described above; however, additional information related to the oil spill/blowout IPF has been collected since the Macondo Event that was not available during the preparation of the programmatic analyses. Appendix A, Accidental Oil-Spill Discussion, introduces the new data and describes the circumstances that might result if an accidental spill were to occur. Additionally, the analyses of the "Accidental Events" incorporate information from Appendix B, "Catastrophic Spill Event Analysis," to address the potential impacts to the environment in the unlikely event that a catastrophic spill similar to the Macondo Event was to occur.

Accidental Spill Concerns

Since spills are unplanned, unforeseeable events, BOEMRE is required to rely on past experiences to predict many factors regarding oil-spill risks. Based on experience and the operations proposed in Shell's plan, the potential sources of hydrocarbon spills from the proposed activity would include the following:

- A storage tank accident on the semi-submersible drilling rig;
- A transfer operation mishap between the supply vessel and the drilling rig;
- A leak resulting from damage to the fuel tanks on one of the supply or crew boats; and/or
- A blowout of one of the proposed wells.

Potential Spills from Vessels/Transfer Operations

As indicated above, offshore spills from Shell's proposed action are possible if an accident were to damage a storage tank onboard the drilling rig, the crewboat, or supply vessels. Historically, accidents of this nature have resulted from unintentional vessel collisions and transfer incidents during the offloading of diesel fuel to the drilling rig. Shell has contracted an anchored semisubmersible MODU, *Transocean Deepwater Nautilus*,, to drill and temporarily abandon ten proposed exploration wells. There are several tanks onboard the MODU that store fuel and lubricants necessary for the rig's operation. A worst-case discharge scenario from a rupture and spill from the largest main tank on the drilling rig would be 4,554 bbl of diesel fuel, with the total diesel, lube, and fuel oil capacity on the semisubmersible at 27,024 bbl. Additionally, the supply boat proposed to support the drilling operations has an estimated diesel tank capacity of 9,750 gallons, the diesel oil supply vessel has an estimated capacity of 9,750 gallons, and the associated crewboat has a capacity of 1,040 gallons.

Potential Spills from a Loss of Well Control/Blowout

Losses of well control (also known as blowouts) can occur during exploratory drilling, development drilling, completion, production, or workover operations. Blowouts occur when improperly balanced well pressures result in the sudden, uncontrolled releases of fluids from a wellbore or wellhead. Historically, since 1971, most OCS blowouts have resulted in the release of gas; blowouts resulting in the release of oil have been rare. As described in Chapter 1.1 above, the most recent blowout was related to the Macondo Event, which resulted in the release of both gas and oil. Though not proposed or expected, Shell has estimated that a worst-case discharge (WCD) scenario from a blowout of one of the wells under this

proposed action could be 405,000 BOPD of 37.5° American Petroleum Institute (API) crude. In accordance enhanced agency oversight, BOEMRE verified the operator's calculations used to determine the WCD volume.

In the unlikely event that a blowout was to occur, one of the primary processes that could stop the uncontrolled flow is a process called "bridging off." Bridging is a phenomenon that occurs when severe pressure differentials are imposed at the well/reservoir interface and the formation around the wellbore collapses and seals the well. Shell indicated within their plan that it is possible that the borehole for these wells could fail, collapse, or bridge over within the span of a few days if the formation is not supported by a casing or a cemented wellbore (Shell, 2010).

Outside of bridging, the main tool for recovery from a blowout event is a blowout preventer (BOP) attached to the well. Most BOP systems allow activation of selected components with the intent sever the drill pipe and seal off the well bore. As per the information provided in their plan, Shell proposes to employ the following BOP/rig components:

- two shearing rams in the BOP for added redundancy;
- remotely operated vehicle (ROV) hot stab capabilities on the BOP;
- a "deadman" system that automatically shuts-in the wellbore upon loss of both electric and hydraulic communication with the rig;
- an "auto-shear" system that automatically shuts-in the wellbore upon an unplanned disconnect from the riser; and
- a gas handler system on the MODU at the top of the riser consisting of two annular preventers that can be closed in to allow hydrocarbons in the riser to be contained or circulated thru the rig's well control system (Shell, 2010).

If the BOP fails, there are other options available to control the blowout that include capping/shut-in, capping/diverting, surface stinger, vertical intervention, offset kill, and relief wells. Of these methods, a relief well is often considered most important, and may be required immediately (even if it is not the first choice), since it is typically considered the ultimate solution for well control. The amount of time required to drill a relief well may depend upon the complexity of the intervention, the location of a suitable rig, the operations that may be required to release the rig, and any problems mobilizing personnel/equipment. For this project, Shell estimates that it will take approximately 14 days to contract or mobilize a rig, 3 days for rig transit, and 111 days for them to drill a relief well for a total of 128 days. Shell presently has four deepwater rigs on contract in the GOM and could also request rig availability from other GOM operators. Additional details related to the proposed action can be found in Shell's proposed exploration plan (Shell, 2010) and general information on other intervention methodologies and recovery tools can be found in Appendix A.

Estimated Spill Occurrence Rates

Data from past OCS spills are used to estimate future potential OCS spills. The BOEMRE has estimated spill rates for spills from the following sources: facilities/platforms, pipelines, and drilling activities. Spill rates for facilities and pipelines have been developed for several time periods, and an analysis of trends for spills is presented in *Update of Comparative Occurrence Rates for Offshore Oil Spills* (Anderson and LaBelle, 2000). Spill rates for the most recent period analyzed, 1985-1999, are presented here. Data for this period should reflect more modern spill-prevention requirements than was required prior to 1985. An internal review of recent historical data following the spill events that occurred as a result of hurricanes that occurred in the Gulf of Mexico from 2004 to 2009 indicated that there had been no change in the 1985-1999 spill rates identified in the aforementioned report. The BOEMRE is in the process of updating these spill rates, which will include the recent Macondo Event; however, significant changes to the spill rates for the entire OCS are not anticipated (Anderson, personal communication, 2010).

An estimate of spill risk from Shell's proposed activities was calculated using the drilling spill rate for the entire OCS and the estimated number of wells to be drilled. The resulting value, 0.00071 or 0.071 percent, is used to address the risk of a spill >1,000 bbl occurring during the proposed action. When examining only wells in deep water (in water depths ≥500 ft; 152 m), past data suggest the chance of a

major spill from a deepwater well under current regulations and practices is 1 in about 4,123. Prior to the Macondo Event, two of the largest spills resulting from blowouts on the Gulf of Mexico OCS occurred in 1970, releasing 30,000 and 53,000 bbl of oil, respectively. Since 1970, there has been a total of 13 losses of well-control events that have resulted in >50 bbl of oil being spilled. Most of these losses of well-control events were of short duration, more than one-half lasting less than a day (USDOI, BOEMRE, 2010). Additional details on estimating accidental spill occurrence rates can be found in Appendix A.

In addition to the extremely low probability noted above, there are several new factors that were not taken into consideration in the historical/statistical evaluation. The BOEMRE recently promulgated an interim Drilling Safety Rule that imposes requirements that will help enhance the safety of OCS drilling operations addresses improvement with both well bore integrity and well control equipment and procedures. Two new Notices to Lessees and Operators (NTLs) were developed to provide additional guidance on agency regulations related to spill response efforts and the development/implementation of subsea blowout containment resources. Issued in June 2010, NTL No. 2010-N06, "Information Requirements for Exploration Plans, Development and Production Plans, and Development Operations Coordination Documents on the OCS," outlined how operators must certify that they are prepared to deal with a potential blowout and describe measures they propose to enhance their ability to prevent or reduce the likelihood of a blowout and to conduct early and effective intervention, including measures for drilling a relief well. The BOEMRE also issued NTL No. 2010-N10, "Statement of Compliance with Applicable Regulations and Evaluation of Information Demonstrating Adequate Spill Response and Well Containment Resources," which informs operators that they must attest that they will conduct all authorized activities in compliance with all applicable regulations and that they have the demonstrated capacity to deploy containment resources that could adequately and promptly respond to a blowout/loss of well control.

Ultimately, when one considers the historical data, the low estimated spill risk (.07 percent), the recent response and containment improvements, BOEMRE's enhanced oversight, and industry's heightened safety awareness since the Macondo Event, it is reasonable to conclude that an accidental spill event is not very likely to occur.

Spill Response Requirements

Agency regulations require that all owners and operators of oil handling, storage, or transportation facilities located seaward of the coastline submit an Oil-Spill Response Plan (OSRP) before they can use a facility. The Environmental Protection and Response Plan within the OSRP outlines the availability of spill containment and cleanup equipment and trained personnel necessary to ensure that a full-response can be deployed during an oil-spill emergency. Shell provided a Regional OSRP in 2009, which was revised to address issues related to the Macondo Even in June, 2010. The review and approval of the revised OSRP is pending; however, in the interim, Shell submitted a certification letter on December 3, 2010, in compliance with 30 C.F.R. §254.2(b) that confirms they have the capability to respond, to the maximum extent practicable, to a worst case discharge or a substantial threat of such a discharge.

Catastrophic Spill Event Analysis

Appendix B, "Catastrophic Spill Event Analysis," is a region-wide evaluation that identifies the most likely and most significant impacts from a high-volume blowout and oil spill that continues for an extended period of time. The scenario and impacts discussed in Appendix B are similar to that of a spill similar to the Macondo Event and are not associated with IPFs anticipated to result from routine activities or even more reasonably-feasible, accidental events that could occur during the proposed action.

The analysis utilizes two general analyses approaches. The first approach consists of a bounding analysis for each individual resource category (e.g., marine mammals, sea turtles, etc.), selecting a different set of factors and scenarios for each resource affected by a worst-case analysis. The second approach selects a single set of key circumstances that, in combination, result in catastrophic consequences. By combining the two approaches, relying on a generalized scenario while identifying site-specific severity factors for individual resources, this analysis allows for the scientific investigation of a range of possible, although not necessarily probable, consequences of a catastrophic blowout and oil spill in the Gulf of Mexico.

To analyze a hypothetical catastrophic event in an area such as the Gulf of Mexico, several assumptions and generalizations were made. Additionally, the life cycle of a catastrophic blowout and spill is divided into four geographic areas and/or time periods, some of which may overlap:

- Phase 1: Initial event (Section 2)
- Phase 2: Offshore spill (Section 3)
- Phase 3: Onshore contact (Section 4)
- Phase 4: Post-spill, long-term recovery (Section 5)

All four phases of a catastrophic oil spill is addressed and for each phase, the scenario is described, factors that could produce environmental impacts are listed, and the most likely and most significant impacts are discussed. The conclusions made in the Catastrophic Spill Event Analysis are addressed in the SEA's impact analyses (Chapters 3.2 to 3.8).

2. ALTERNATIVES CONSIDERED

2.1. NO ACTION ALTERNATIVE

Alternative 1 –*Disapproval of the Proposed Action* – If selected, BOEMRE would not approve the EP and the operator would not be allowed to undertake the proposed activities. If the proposed activities are not undertaken, all environmental impacts, including additional routine, accidental, or cumulative impacts to the environmental and cultural resources described in the Multisale EIS, Supplemental EIS, and this SEA would not occur.

2.2. APPROVAL OF THE PROPOSED ACTION AS SUBMITTED

Alternative 2 – If selected, the operator would be permitted to undertake the proposed activities as requested in its plan. This alternative assumes that the operator will conduct their operations in accordance with their lease stipulations, the OCSLA and all applicable regulations (as per 30 C.F.R. §250.101(a)), and guidance provided in all appropriate NTLs (as per 30 C.F.R. §250.103). However, no additional, site-specific mitigation would be required by BOEMRE.

2.3. APPROVAL OF THE PROPOSED ACTION WITH EXISTING AND/OR ADDITIONAL MITIGATIONS

Alternative 3 – *Preferred Alternative* – If selected, BOEMRE would approve the operator's proposed activities, as requested and conditioned by stipulations, regulations, and guidance (similar to alternative 2); however, BOEMRE would require the operator to undertake additional mitigation as identified by BOEMRE (listed in Section 2.4 below and described in the effects analyses) in order to fully address the potential site- and project-specific impacts of the proposed action. Alternative 3 is the preferred alternative.

2.4. SUMMARY AND COMPARISON OF THE ALTERNATIVES

If selected, Alternative 1, the no action alternative (disapproval of the proposed action), would prevent the operator from exercising its rights under the lease and conducting their proposed exploratory drilling activities. Alternative 1 would not result in any impacts to the environmental resources analyzed in Chapter 3; however, it does not allow the lessee to develop the oil and gas resources of its lease for the benefit of the U.S. economy. Alternative 2 allows the lessee to achieve its objectives; however, BOEMRE has determined that additional mitigation (described below) is needed to limit or negate possible environmental impacts. Alternative 2 does not include the additional mitigation.

Alternative 3 is the preferred alternative because it allows the lessee to achieve its development objectives and also provides for additional mitigation requirements to limit or negate potential environmental impacts.

Mitigation Required under the Preferred Alternative

The need for, and utility of, the following mitigation measure is discussed in the relevant impact analysis section of this SEA. To ensure adequate environmental protection, the following mitigation is applied:

AVOIDANCE OF POTENTIAL ARCHAEOLOGICAL RESOURCES: Our review indicates that the operator's proposed activities are in the vicinity of the unidentified side-scan sonar targets listed under separate cover, features that may represent significant archaeological resources. In accordance with 30 C.F.R. § 250.194(b), you must either (1) conduct an underwater archaeological investigation (diver and/or ROV investigations) prior to commencing the proposed activities to determine whether these features represent archaeological resources, or (2) ensure that all seafloor disturbing actions resulting from the proposed activities avoid the subject features by a distance greater than that listed under separate cover. If the operator conducts an underwater archaeological investigation, contact either Dr. Jack Irion at (504) 736-1742 or Dr. Christopher Horrell at (504) 736-2796 at least two weeks prior to performing operations to obtain the investigation methodology. If the operator chooses to avoid the features, submit an as-built map at a scale of 1-in = 1,000-ft. with DGPS accuracy, showing the location of all seafloor disturbances (e.g., the rig or platform, anchors, anchor chains, wire ropes, cables, etc.) relative to these features to the Regional Supervisor, Field Operations, Plans Section (MS 5231), at the same time the operator submits an End of Operations report (Form MMS-125) to the appropriate BOEM GOMR District Office and notification of platform installation date and final as-built location data as directed in 30 C.F.R. § 250.900(e).

2.5. ALTERNATIVES CONSIDERED BUT NOT ANALYZED

Several other alternatives were considered and reviewed during the preparation of this SEA and coordination of the resource reviews. Ultimately, a viable alternative is required to be a logical option for carrying out the proposed action, ensure that the purpose of and need can be met, and be feasible under the regulatory directives of the OCSLA and all other applicable guidance. The table below lists the alternatives that were considered but dismissed and not analyzed further along with the rational for the decision:

Alternatives Considered but Not Analyzed

Dismissed Alternative	Alternative Detail	Reason Not Analyzed
Daytime Drilling Only	The alternative would restrict all drilling operations to the hours between legal sunrise and sunset to take advantage of the increased lighting in an effort to improve safety.	This alternative does not consider that adequate lighting is available on vessels and MODUs, existing safety protocol, and that the premature stopping of some drilling/well operations prior to critical junctures could lead to highly-problematic and unsafe situations.
Drilling from Dynamically-Positioned (DP) MODUs Only	The alternative would only allow the proposed drilling activities from DP MODUs (drillships or semisubmersibles) to reduce the possible impacts from anchoring activities.	This alternative does not consider the limited availability of DP MODUs in the GOM or the adequate mitigation and guidance shown to reduce/negate impacts from anchoring.
Incorporation of "Seasonal" Drilling Windows	The alternative would be based upon observed 'seasonal" migrations or behavioral patterns exhibited by marine protected species (MPS) and would restrict the proposed drilling operations for several weeks/months each year.	This alternative would have to rely upon incomplete seasonal data as most migratory MPS are not found in the Western GOM and it would not be able to account for year-round equipment and personnel contracting.

3. DESCRIPTION OF THE AFFECTED ENVIRONMENT AND ENVIRONMENTAL IMPACTS

3.1. INTRODUCTION

The discussion below will (1) briefly describe/summarize the pertinent affected resources; (2) discuss whether proposed exploration activities and their IPFs would have significant impacts to the human environment of the Gulf of Mexico; and (3) identify significant impacts, if any, that would require further NEPA analysis in an EIS. The description of the affected environment and impact analysis are presented together in this section for each resource. For the impact analysis, resource-specific significance criteria were developed for each category of the affected environment. The criteria reflect consideration of both the context and intensity of the impact at issue (see 40 C.F.R. § 1508.27). For the sake of this document, the criteria for impacts to environmental resources are classified into one of the three following levels:

- Significant Impact (including those that could be mitigated to non-significance);
- Adverse but Not Significant Impact; or
- Negligible Impact.

Preliminary screening for this assessment was based on a review of this relevant literature; previous SEAs; the Multisale EIS, and Supplemental EIS; and statistics/data pertinent to historic and projected activities. The BOEMRE initially considered the following resources for impact analysis:

- marine mammals (including Endangered Species Act (ESA) listed species and strategic stocks);
- sea turtles (all are ESA listed species);
- fishes (including listed species and ichthyoplankton);
- commercial and recreational fisheries;
- coastal and marine birds (including ESA listed species);
- benthic communities (including deepwater benthic communities, live bottoms, and topographic features);
- archaeological resources;
- military uses;
- recreational and commercial diving;
- socioeconomic conditions (including employment, marine transportation, and infrastructure)
- geology/sediments; and
- air and water quality.

The impact analyses focus on a broad group of oil and gas activities and resources with the potential for non-negligible impacts. Routine, accidental, and cumulative impacts from exploration activities similar to those proposed by Shell are analyzed in the Multisale EIS and Supplemental EIS. The Multisale EIS and the Supplemental EIS considered the proposed exploration activities as well as impacts to resources relevant to the proposal. The level of impacts associated with each interaction was analyzed and described in the Multisale EIS and Supplemental EIS and is incorporated by reference.

The Multisale EIS and the Supplemental EIS provide a comprehensive characterization of biological and socioeconomic resources that may be adversely affected by oil and gas exploration and development activities. For this SEA, BOEMRE evaluated the potential impacts resulting from the operator's proposed exploration activities that were not considered in the Multisale EIS and the Supplemental EIS. For the reasons set forth on page 1, this section concentrates on the potential impacts of the proposed action on the following affected resources:

- air quality
- offshore water quality,
- deepwater benthic biologically sensitive resources,
- marine mammals (including Threatened/Endangered and Nonendangered Species),
- sea turtles (all are ESA listed species)
- fisheries and essential fish habitat (EFH), and
- archaeological resources.

Other environmental and socioeconomic conditions, identified in the initial list of resources considered for impact analysis above, such as military uses, were considered and the potential impacts that could occur from activities, such as the proposed exploration activities, were fully addressed in the Multisale EIS and the Supplemental EIS and deemed negligible (40 C.F.R. § 1508.27) and are not discussed in this SEA. Space-use conflicts with any recreational or commercial fishing vessels, as well as recreational and/or commercial diving operations, are minimal, if any, because of the proposed activities, the water depth (> 7,150 ft), and the distance to shore (~ 70 miles). Coastal and marine birds were not further analyzed due to the distance from shore (~ 70 miles) and the temporary nature of the proposed activities. Topographic and pinnacle features were not further analyzed due to the distance from the proposed exploration activities to the nearest topographic and/or pinnacle features (> 45 miles). No socioeconomic effects were further analyzed due to the type, the temporary nature, and employment size, of the proposed activity. There is no expansion or modification of support bases proposed as a result of this activity. Additionally, support vessel operations are comparable to that described and analyzed in the Multisale EIS and the Supplemental EIS for similar activities. The potential impacts of a low-probability, Catastrophic Oil-Spill event, such as the Macondo Event (see below) to the environmental resources and socioeconomic conditions listed above are fully addressed in the Catastrophic Spill Event Analysis (Appendix B) and a respective resource summary of that analysis is provided in each impact review below.

Macondo Well Blowout, Spill, and Remediation

On April 20, 2010, while working on an exploratory well approximately 50 mi (80 km) offshore Louisiana, the semisubmersible drilling rig *Deepwater Horizon* experienced an explosion and fire, resulting in an uncontrolled release of oil and natural gas from the Macondo reservoir. Oil was dispersed into the water column, but heavier oil fractions and tarballs washed onto shorelines in varying concentrations. Natural gas dissolved into the water column or vented into the atmosphere. On July 15, 2010, the leaking well was capped and a relief well reached and plugged the Macondo wellbore on September 19, 2010. Prior to capping/plugging the well, approximately 53,000-62,000 bbl per day (2.23-2.60 million gallons) were released from the well, with an approximate total release of 4.9 million bbl (206,000,000 gallons) over an 87-day period. The following information was made available by the Deepwater Horizon Unified Command (DHUC) (2010a):

- More than 6,050 response vessels and approximately 47,849 personnel responded to protect the shoreline and wildlife and to cleanup vital coastlines;
- At the surface, approximately 34.7 million gallons (827,251 bbl) of oily water were recovered and an estimated 11.14 million gallons (265,450 bbl) of oil burned;
- Approximately 1.84 million gallons (43,809 bbl) of dispersant were applied (1.07 million gallons [25,476 bbl] on the surface and 771,000 gallons [18,357 bbl] subsea);
- More than 3.33 million feet (1,003 km) of containment boom and 9.7 million feet (2,469 km) of sorbent boom were deployed;
- Approximately 641 mi (1,032 km) of Gulf Coast shoreline was oiled, including approximately 368 mi (592 km) in Louisiana, 112 mi (180 km) in Mississippi, 73 mi (117 km) in Alabama, and 88 mi (142 km) in Florida.

According to the National Marine Fisheries Service (NMFS), approximately 80,228 square miles (mi^2) (207,790 square kilometers [km^2]) of Federal waters were closed to commercial and recreational fishing, approximately 33 percent of the Gulf of Mexico Federal waters (USDOC, NMFS, 2010a).

Macondo Impacts Incorporated into SEA Analyses

The BOEMRE, in conjunction with the well operator and other Federal and State agencies, continues to monitor and evaluate both the short-term and long-term impacts of the accidental spill. There is ongoing research to assess the impacts to resources from the Macondo well blowout, spill, and remediation efforts. For many resources, the data are still being collected and analyzed through the National Resource Damage Assessment (NRDA) process. The BOEMRE continues to seek data and research results from the NRDA process and the scientific community. Results of this research are forthcoming, and BOEMRE subject matter experts (SMEs) are continuing to update their analyses as this information becomes available.

Chapter 3 of this document describes the environmental and archaeological resources and the potential routine, accidental, and cumulative impacts of the proposed action on the resources that could be affected by the proposed exploration activities. These descriptions present environmental resources as they are now, thus providing new baseline information that is informed by the Macondo Event for analyses of potential impacts from the exploration activities.

3.2. AIR QUALITY

3.2.1. Affected Environment

The complete description of the air quality in the Gulf of Mexico region is set forth in Chapter 3.1.1 of the Multisale EIS and Chapter 4.1.1 of the Supplemental EIS. The following information is a summary of the description incorporated from the Multisale EIS and Supplemental EIS. Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 is located west of 87.5° W. longitude and hence, falls under BOEMRE jurisdiction for enforcement of the Clean Air Act (CAA). The air over the OCS water is not classified, but it is presumed to be better than the National Ambient Air Quality Standards (NAAQS) for all criteria pollutants (USDOI, MMS, 1997). Shell's proposed exploration activities in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 are located approximately 70 mi (113 km) from the nearest coastline, south of Theodore, Alabama, an area that is in attainment of the NAAQS for carbon monoxide, nitrogen oxides, sulphur oxides, ozone, and particulate matter and that, for Prevention of Significant Deterioration (PSD) purposes, is classified as a Class II Area.

Influences to onshore air quality are dependent upon meteorological conditions and air pollution emitted from operational activities. The pertinent meteorological conditions regarding air quality are the wind speed and direction, the atmospheric stability, and the mixing height (which govern the dispersion and transport of emissions). The typical, large-scale wind flow for the Mississippi Canyon area is driven by the clockwise circulation around the Bermuda High, resulting in a prevailing southeasterly to southerly wind flow, which is conducive to transporting air pollution emissions toward shore. However, superimposed upon this large-scale circulation are smaller scale wind-flow patterns, such as the land/sea breeze phenomenon. In addition, there are other large-scale weather features that occur periodically, namely tropical cyclones, and mid-latitude frontal systems. Because of the routine occurrence of these various conditions, the winds blow from all directions in the area of concern (Florida A&M University, 1988).

3.2.2. Impact Analysis

A detailed impact analysis of the routine and accidental impacts of the proposed exploration activities on air quality can be found in Chapter 4.2.2.1.1 of the Multisale EIS. The following information is a summary of the impact analysis.

3.2.2.1 Alternative 1

Alternative 1, the no action alternative (disapproval of the proposed action), would result in the operator's not being permitted to drill the proposed exploration wells. Therefore, the impact producing

factors to air quality would not occur. For example, there would be no VOC emissions that would result in potential localized degradation of air quality.

3.2.2.2 Alternative 2

If selected, Alternative 2, approval of the proposed action as proposed, would allow the operator to undertake the proposed activities, as requested and conditioned in the plan. As described in the analyses below, impacts to air quality from the proposed action are expected to be short-term, localized, and not lead to significant impacts.

Routine Activities

Air quality would be affected in the immediate vicinity of the exploratory operations, service vessels, and aircraft. The impact from emissions for the proposed activities described in this supplemental EP will not exceed BOEMRE's exemption levels per 30 C.F.R. § 250.303(d), which would exempt the operator from additional air quality modeling. The drilling activities are not expected to significantly affect onshore air quality, due to the temporary nature of the activities, the distance from shore, and the distance from Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 to any PSD Class I air quality area, such as the Breton National Wildlife Refuge (approximately 50 miles [80 km]).

Shell has requested that the area in which the proposed operations are to be conducted be classified by BOEMRE in accordance with 30 C.F.R. § 250.490 (c), as "H_2S known." Shell has indicated that the proposed wells might encounter H_2S between 10 to 40 parts per million (ppm). As a result, Shell will comply with the appropriate requirements of 30 C.F.R. §250.490.

Accidental Events

Hydrogen sulfide is a toxic gas; at the expected concentration of 10 to 40 ppm, short term exposure is not considered lethal. Therefore, an accidental release of gas from this project would not have a substantial impact on the air quality in the immediate area within the offshore environment. In the event of an accidental release of H_2S, it is assumed that impacts on marine mammals and turtles would be similar to impacts to humans (for the applicable H_2S concentration levels), impacts to birds would be less than mammals (because birds are generally more tolerant of H_2S), and impacts to fish would be negligible since fish avoid water that is contaminated with H_2S. Measures taken to prevent an accident and measures to mitigate impacts in the event of an accident are to be included in Shell's H_2S Contingency Plan required by 30 C.F.R. § 250.290(f) which Shell will submit to BOEMRE prior to commencing any drilling activities.

Should a spill of oil occur, the volatile organic compounds (VOCs), which would escape to the atmosphere from a surface slick, are precursors to photochemically produced ozone. A spike in VOCs could contribute to a corresponding spike in ozone, especially if the release were to occur on a hot sunny day in a NO_2-rich environment. The corresponding onshore area is in attainment for ozone. Due to the distance from shore, the proposed exploration activities are not expected to have any impacts to onshore air quality, including nonattainment areas. If a fire occurs, prior to containment, particulate and combustible emissions will be released in addition to the VOCs. Emissions of pollutants into the atmosphere from routine activities associated with the proposed exploration activities are projected to have minimal impacts to onshore air quality because of the prevailing atmospheric conditions, emission heights, emission rates, and the distance of these emissions from onshore.

Despite the recent Macondo Event, historical trends in the GOM (see Chapter 1.4) indicate that catastrophic spill events are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action. In the event of a catastrophic spill similar to the Macondo Event, the Catastrophic Spill Analysis in Appendix B discusses the most likely and most significant impacts to air quality as it relates to the four phases of a major spill/blowout:

1) **Initial Event** (Section 2.2.1.1.; Page B-7);
2) **Offshore Spill** (Section 3.2.1.1; Page B-18);
3) **Onshore Contact** (Section 4.2.1.1; Page B-32); and
4) **Post-Spill, Long-Term Recovery** (Section 5.2.1.1.; Page B-42).

As the analysis in Appendix B concludes, the potential impacts from a catastrophic spill could include air quality impacts that would require extensive recovery times.

Conclusion

Hydrogen sulfide is a toxic gas; at the expected concentration of 10 to 40 ppm, short term exposure is not considered lethal. Therefore, an accidental release of gas from this project would not have a substantial impact on the air quality in the immediate area within the offshore environment. The air quality in the immediate vicinity of the proposed activities would be affected by the short-term projected emissions, but the 70-mi distance between Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 and the shoreline results in substantial dilution factors for point-source emissions from the proposed action so that onshore air quality impacts would be well below levels considered to be significant. Therefore, because of the short duration of the proposed activities and the distance from shore, no substantial long-term impacts on air quality would be expected from the proposed exploration activities. The potential impacts from a catastrophic spill as described and analyzed in Appendix B could include air quality impacts that would require extensive recovery times.

Cumulative Impacts

Cumulative impacts on air quality that result from oil and gas leasing, exploration, development, and production activity were discussed in Chapter 4.5.1 of the Multisale EIS. Cumulative impacts on air quality within the offshore area would come primarily from non-OCS oil/gas activities in the Gulf as well as sources on land such as generated outside the OCS and include emissions from industrial plants, power generation, and urban transportation. The location of the Cardamom Project is far removed from coastal populations or industrial activity. The proposed drilling activities are located over 70 miles from shore, and would not affect the overall quality of air over the Louisiana coast because of the temporary nature of the proposed activity and the distance to shore. Most of the Gulf's coastal areas, except for Southeast Texas, are currently designated as "attainment" for all the NAAQS regulated pollutants (USEPA, 2003).

No substantive cumulative impacts on air quality are expected as a result of the proposed exploration activities when added to the impacts of past, present, or reasonably foreseeable oil and gas development in the area, as well as other activities in the area.

3.2.2.3 Alternative 3

If selected, Alternative 3, approval of the proposed action with additional mitigation, would allow the operator to undertake the proposed activities, as requested and conditioned in the plan; however, the operator would be required to undertake additional mitigation as identified by BOEMRE, none of that mitigation is designed to reduce the impacts to air quality. As described in the analyses above for alternatives 1 and 2, impacts to air quality from the proposed action are expected to be short-term, localized and not lead to significant impacts. The mitigation measures outlined in Chapter 2 and discussed in the other resource sections is not expected to increase or decrease the potential for effects to air quality from the proposed action. Alternative 3 does not differ from Alternative 2 because the additional mitigation measures do not address this resource (i.e., all assumptions, estimates, and conclusions are identical), see the analysis provided in Section 3.2.2.2 for this alternative for this resource.

3.3. OFFSHORE WATER QUALITY

3.3.1. Affected Environment

The description of water quality in offshore waters of the Gulf of Mexico is set forth in Chapter 3.1.2.2 of the Multisale EIS and Chapter 4.1.2.2 of the Supplemental EIS. The following information is a summary of the description incorporated from the Multisale EIS and the Supplemental EIS.

The water offshore of the Gulf's coasts can be divided into two regions: the continental shelf and slope (<1,000 ft; 305 m) and deep water (>1,000 ft; 305 m). Waters on the continental shelf and slope are heavily influenced by the Mississippi and Atchafalaya Rivers, the primary sources of freshwater, sediment, nutrients, and pollutants from a huge drainage basin encompassing 55 percent of the continental

U.S. (Murray, 1998). Lower salinities are characteristic nearshore where freshwater from the rivers mix with Gulf waters. The presence or extent of a nepheloid layer at the sea bottom affects water quality on the shelf and slope. Deep waters east of the Mississippi River are affected by the Loop Current and associated warm-core (anti-cyclonic) eddies that consist of clear, low-nutrient water (Muller-Karger et al., 2001). However, cold-core cyclonic eddies (counter-clockwise rotating) also form at the edge of the Loop Current and are associated with upwelling and nutrient-rich, high-productivity waters.

Compared with the Eastern and Western Gulf, the Central Gulf generally has higher levels of total organic` carbon and hydrocarbons in sediment, particularly those from terrestrial sources (Gallaway and Kennicutt, 1988). Hydrocarbons in sediments have been determined to influence biological communities of the Gulf slope, even when present in trace amounts (Gallaway and Kennicutt, 1988).

Natural hydrocarbon seepage is considered to be the predominant source of petroleum in Gulf waters (NRC, 2003). The National Research Council (NRC) estimated an annual input of oil from seeps to be approximately 980,000 bbl/yr for the entire Gulf (NRC, 2003). In addition to hydrocarbon seeps, other fluids leak from the underlying sediments into the bottom water along the slope. These fluids have been identified to have three origins: (1) seawater trapped during the settling of sediments; (2) brine from dissolution of underlying salt diapirs; and (3) deep-seated formation waters (Fu and Aharon, 1998; Aharon et al., 2001).

Produced water (formation water) is the largest waste stream by volume from the oil and gas industry that enters Gulf waters. Produced water is commonly treated to separate free oil and is either injected back into the reservoir or discharged overboard according to NPDES permit limits (Shell, 2010). The NRC has estimated the quantity of oil in produced water entering the Gulf per year to be 473,000 bbl (NRC, 2003).

Deepwater sediments, with the exception of barium concentrations in the vicinity of previous drilling, do not appear to contain elevated levels of metal contaminants (USDOI, MMS, 1997 and 2000). Reported total hydrocarbons, including biogenic (e.g., from biological sources) hydrocarbons, in sediments collected from the Gulf slope range from 5 to 86 nanograms/gram (Kennicutt et al., 1987).

Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 is entirely in deep water, for which limited information is available on water quality. Despite more limited information on the water quality of deep water, it is clear that the condition of the offshore waters of the Gulf of Mexico is being altered as the Macondo Event evolves. The oil that entered the GOM from the Macondo well is a South Louisiana sweet crude oil (i.e., it is low in sulfur) and is fairly high in alkanes (organic compounds containing only carbon and hydrogen and single bonds; sometimes called paraffin or aliphatic compounds) (NOAA, 2010a). Because alkanes are simple hydrocarbons, these oils are likely to undergo biodegradation more easily (NOAA, 2010a). Weathering of crude can occur within the first 24-48 hours with up to a 40% weight loss within seven days (Restek, 2010). Also, this oil is less toxic than other crude oils in general because this oil is lower in polyaromatic hydrocarbons (PAHs) than many crude oils.

The Macondo Event released natural gas, primarily in the form of methane, into the water column in addition to oil. Although limited research is available for biogeochemistry of hydrocarbon gases in the marine environment, it is thought that methane may stay in the marine environment for long periods of time as the compound is highly soluble in sea water at the high pressures and cold temperatures found in deep water environments (NRC, 2003; Patin, 1999). However, methane diffusing through the water column would likely be oxidized in the aerobic zone and would rarely reach the air-water interface (Mechalas, 1974).

One tool that was used in response to the Macondo spill is dispersants, which can have both positive and negative effects. The purpose of chemical dispersants is to facilitate the movement of oil into the water column in order to encourage weathering and biological breakdown of the oil (i.e., biodegradation) (NRC, 2005; AMSA, 2010). If the oil moves into the water column and is not on the surface of the water, it is less likely to reach sensitive shore areas (EPA, 2010c). In addition to dispersion being enhanced by artificial processes, oil may also be dispersed from natural processes. For instance, microbial metabolism of crude oil results in the dispersion of oil (Bartha and Atlas, 1983). The positive effect is that the oil, once dispersed, is more available to be degraded. The negative effect is that the oil, once dispersed, is more available to microorganisms, which temporarily increases the toxicity (Bartha and Atlas, 1983). Toxicity of dispersed oil in the environment will depend on many factors, including the effectiveness of the dispersion, temperature, salinity, the degree of weathering, type of dispersant and degree of light penetration in the water column (NRC, 2005). The toxicity of dispersed oil is primarily due to the toxic components of the oil itself (AMSA, 2010).

The dispersants Corexit® 9500 and 9527 were used in the Macondo Event (EPA, 2010c). The components of these dispersants are identical with the exception of the base solvent; Corexit® 9527 has an organic solvent as a base (McDonald et al., 1984; EPA, 2010c). Dispersants used in the 1960s were quite toxic, but more recently developed dispersants such as Corexit® are considerably less toxic (Doe and Wells, 1978) (Leahy and Colwell, 1990). Lindstrom and Braddock (2002) found that environmental use of Corexit® 9500 could result in either increases or decreases in the toxicity of residual oil through selective microbial mineralization of hydrocarbons. In fact, reviews of studies have found that the general effectiveness of dispersants in enhancing biodegradation of crude oil and individual hydrocarbons is highly variable and depends on several factors including the chemical formulation of the dispersant, its concentration, and the dispersant/oil application ratio (Boehm, 1983). However, there was evidence that the dispersants worked in the case of the Macondo Event (NOAA, 2010a; EPA, 2010c). Corexit® 9527 has been shown to greatly increase volatile liquid hydrocarbons incorporation into water as well as to accelerate the process in experiments compared to if no dispersant was used (McDonald et al. 1984). In fact, dispersant use during the Macondo Event has been noted to reduce the volatile organic compounds which can be a workplace issue for response workers on ships near the site (White House Press Briefing, 2010). Since the amount of dispersants used in the Macondo Event is unprecedented and since this is the first time dispersants have been applied in deep waters, continual monitoring and evaluation of their use is imperative (White House Press Briefing, 2010).

As a result of the use of subsea dispersants, clouds or plumes of dispersed oil may occur near the blowout site in offshore waters. Reports thus far have found such plumes and have shown that the concentrations of these clouds drop to undetectable levels within a few miles (NOAA, 2010a). Dissolved oxygen levels are a concern with any release of a carbon source, such as oil and natural gas, and became a particular concern during the Macondo Event since dispersants were used in deep waters for the first time. Thus, the EPA required monitoring protocols in order to use subsea dispersants (NOAA, 2010b). In areas where plumes of dispersed oil were previously found, dissolved oxygen levels decreased by about 20% from long-term average values in the GOM, however, scientists reported that these levels have stabilized and are not low enough to be considered hypoxic (NOAA, 2010c). The drop in oxygen, which has not continued over time, has been attributed to microbial degradation of the oil. Initially released studies indicate that bacteria are degrading hydrocarbons from both gas and oil, but the degradation rates reported in the studies varied considerably (Camilli et al., 2010; Hazen et al., 2010; Valentine et al., 2010). Over time, as the oil continues to be degraded and diffuses, hypoxia becomes less of a concern. In fact, the 2010 hypoxic zone could not be linked to the Macondo Event in either a positive or a negative manner (LUMCON, 2010).

3.3.2. Impact Analysis

A detailed impact analysis of the routine, accidental, and cumulative impacts of the proposed development activities on offshore water quality can be found in Chapters 4.2.1.1.2.2, 4.4.2.2, and 4.5.2.2 of the Multisale EIS and Chapter 4.1.2.2.2 of the Supplemental EIS. The impact-producing factors associated with the proposed exploration activities in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 that could affect marine water quality include: (1) discharges during the drilling of wells; and (2) accidental spills of crude oil, diesel fuel, chemicals, or other materials from vessels in marine waters. As explained below, due to the type and the temporary nature of the proposed activities, no substantive impacts would be expected from the routine exploration activities proposed by Shell.

3.3.2.1 Alternative 1

If selected, Alternative 1, the no action alternative (disapproval of the proposed action), would result in the operator not being permitted to drill the proposed exploration wells. Therefore, the impact producing factors to offshore water quality would not occur. There would be no discharges during the drilling of wells and no accidental spills of crude oil, diesel fuel, chemicals, or other materials from vessels in marine waters. In addition, there would be no turbidity issues related to anchoring/well activities that would result in potential localized degradation of water quality.

3.3.2.2 Alternative 2

If selected, Alternative 2, approval of the proposed action as submitted by the operator, would allow the applicant to drill the proposed exploration wells. As described in the analyses below, impacts to water quality from the proposed action, as submitted by the operator, are expected be short-term, localized and not lead to significant impacts.

Routine Operations

The water depth at the proposed well sites is approximately 7,150 ft (829 m). These deep marine waters and environments would be most directly affected by the proposed mooring activities. Localized sediment disturbance and increased turbidity near the sea bottom would occur from installation of the suction piles associated with each well location. These disturbances would not adversely affect offshore water quality because the area of potential disturbance is relatively small and the effects would be temporary. Elevated turbidity would be a short-term, localized, and reversible condition once the disturbance ceases.

The USEPA regulates discharges associated with offshore oil and gas exploration, development, and production activities on the outer continental shelf (OCS) under the Clean Water Act's (CWA) National Pollutant Discharge Elimination System (NPDES) program. Regulated wastes include drilling fluids, drill cuttings, deck drainage, produced water, produced sand, well treatment fluids, well completion fluids, well workover fluids, sanitary wastes, domestic wastes, and miscellaneous wastes (USEPA, 2009). The USEPA's NPDES general permit for the Western Gulf of Mexico, Region 6, (GMG290000, which authorizes discharges to surface water during drilling and production) was reissued and went into effect on October 1, 2007 (USEPA, 2007). Overboard discharges and wastes intended from the project are shown in the wastes and discharge tables (Shell, 2010). The types and discharge rates would be in accordance with NPDES General Permit (GMG 290000; USEPA, 2007) and wastes destined for onshore disposal or recycling pose no potential significant impacts to affected resources unless spilled. A total of three wells would be drilled under the plan; all using synthetic-based drilling fluid (SBF) that would be recovered and recycled. Sanitary and domestic waste would be produced on the MODU as well as the support vessels; however, these discharges would be treated to meet USEPA discharge requirements. Water would be impacted by the introduction of suspended solids and biochemical oxygen demand (BOD) matter.

Accidental Events

The BOEMRE has determined, based on historical trends in the GOM (see Chapter 1.4 and Appendix A) that blowouts are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action. In 2007, then MMS (Izon, Danenberger, and Mayes, 2007) looked at the occurrences of blowouts during a 15 year period. From 1992 to 2006, 39 blowouts occurred at a rate of one blowout for every 387 wells drilled. Spills that occur from the proposed drilling activity would be few (if any) and small in size (<1,000 bbls) (see Chapter 1.4, Appendix A, and Anderson and LaBelle, 2000). Spilled oil originating from the project is not expected to be ≥1,000 bbl and is expected to be substantially recovered and/or weathered while still at sea.

A surface slick from a blowout begins to weather as soon as it forms, depending on a number of factors, particularly the characteristics of the released oil and oceanographic conditions. Some of the subsurface oil may disperse within the water column. A variety of physical, chemical, and biological processes act to disperse and degrade the slick once oil enters the ocean. These include spreading, evaporation of the more volatile constituents, dissolution into the water column, emulsification of small droplets, agglomeration sinking, microbial modification, photochemical modification, and biological ingestion and excretion. Some oil from the slick would be mixed into the water and dispersed by wind and waves. The quality of marine waters on the surface or in a rising subsurface plume from a blowout would be temporarily affected by the solubility of hydrocarbon components and by small, dispersed oil droplets that do not rise to the surface due to current activity or that are mixed downward by surface turbulence. Dispersion by currents and microbial degradation remove the oil from the water column and eventually dilute the constituents to background levels.

In the event of a catastrophic spill similar to the Macondo Event, the Catastrophic Spill Analysis in Appendix B discusses the most likely and most significant impacts to offshore water quality as it relates to three of the four phases of a major spill/blowout:

1) **Initial Event** (Section 2.2.1.2.; Page B-8);
2) **Offshore Spill** (Section 3.2.1.2; Page B-19);
3) **Onshore Contact** (offshore water quality not included in this discussion); and
4) **Post-Spill, Long-Term Recovery** (Section 5.2.1.2.; Page B-42).

The potential impacts from a catastrophic spill could result in both temporary and long term offshore water quality degradation that would require extensive recovery times. However, despite the recent Macondo Event, historical trends in the GOM (see Chapter 1.4 and Appendix A) indicate that catastrophic spill events are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action.

Conclusion

No significant long-term impacts on offshore water quality would be expected from the proposed action because of the type of and temporary nature of the proposed activity. Near-bottom water quality would be affected by increased turbidity and disturbed substrates during the period of installation anchors and mooring lines/chains. Any effects from the elevated turbidity would be short term, localized, and reversible. Small numbers of bottom-dwelling invertebrates may be killed or adversely impacted.

Impacts on offshore water quality from the operational discharges that would be expected to result from the proposed action are negligible because of; 1) existing EPA regulations cited above, 2) water depth, 3) distance of the project from the coast, 4) weathering, and 5) dilution factors. Spilled oil originating from the project is not expected to be ≥1,000 bbl and is expected to be substantially recovered/weathered while still at sea (see Chapter 1.4 and Appendix A). Operator-initiated activities to contain and clean up an oil spill would begin as soon as possible after an event. Small quantities of unrecovered oil would weather and largely biodegrade within two weeks.

Cumulative Impacts

Cumulative impacts on offshore water quality that result from oil and gas leasing, exploration, development, and production activity were discussed in Chapter 4.5.2.2 of the Multisale EIS and Chapter 4.1.2.2 of the Supplemental EIS.

Exploration, development, and production activity contribute to cumulative water quality degradation in offshore waters. Spills of oil, diesel fuel, and other materials may occur from vessels transporting crude oil and petroleum products; from vessels involved in commercial fishing, freight or passenger transport; and from OCS operations. Well blowouts can disturb the bottom, increase turbidity, and put oil into the sea. Should a blowout occur, involving an oil spill ≥1,000 bbl, localized, short-term changes in water quality would be expected and cumulative impacts would be negligible. Activities that would contribute to cumulative impacts, for example bottom area disturbances resulting from other, like dredging, are not expected due to water depths in the area of the proposed action. Bottom disturbances from anchoring of the proposed MODU would produce short-lived effects on water quality related to each anchor site.

Therefore, no significant cumulative impacts on offshore water quality would be expected as a result of the proposed exploration activities when added to the impacts of past, present, or reasonably foreseeable oil and gas development; as well as other activities in the area.

3.3.2.3 Alternative 3

If selected, Alternative 3, approval of the proposed action with additional mitigation, would allow the operator to undertake the proposed activities, as requested and conditioned in the plan; however, the operator would be required to undertake additional mitigation as identified by BOEMRE. As described in the analyses above, impacts to offshore water quality from the proposed action are expected to be short-term, localized and not lead to significant impacts. The mitigation measures outlined in Chapter 2 and

discussed in the other resource sections is not expected to increase or decrease the potential for effects to offshore water quality from the proposed action. Alternative 3 does not differ from Alternative 2 because the additional mitigation measures do not address this resource (i.e., all assumptions, estimates, and conclusions are identical), see the analysis provided in Section 3.2.2.2 for this alternative for this resource.

3.4. DEEPWATER BENTHIC COMMUNITIES

3.4.1. Chemosynthetic Deepwater Benthic Communities

A remarkable assemblage of invertebrates are found in association with hydrocarbon seeps, including chemosynthetic organisms that use a carbon source independent of photosynthesis and the sun-dependent photosynthetic food chain that supports most all other life on the planet. Chemosynthetic communities begin with bacterial mats that consume methanes and sulfides; their respiration results in the precipitation of carbonate, forming a hard substrate. Other chemosynthetic organisms can then become established on the carbonate substrate. These other chemosynthetic organisms form additional structure upon the seafloor, increasing the complexity of the habitat and supporting a variety of nonchemosynthetic invertebrates and fishes.

3.4.1.1. Affected Environment

The description of the chemosynthetic deepwater benthic communities in the Gulf of Mexico region can be found in Chapter 3.2.2.2.1 of the Multisale EIS and Chapter 4.1.5 of the Supplemental EIS. The following information is a summary of the description in the Multisale EIS and the Supplemental EIS and it is incorporated by reference into this SEA.

The continental slope in the Gulf of Mexico extends from the edge of the continental shelf at a depth of about 656 ft (200 m) to a water depth of approximately 9,840 ft (3,000 m) (USDOI, MMS, 2007b). The vast majority of the Gulf of Mexico has a soft, muddy bottom in which burrowing infauna are the most abundant invertebrates. Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 falls into this category, and the proposed wells are at a water depth of approximately 7,150 ft (2,179 m).

Chemosynthetic communities are defined as persistent, largely sessile assemblages of marine organisms dependent upon symbiotic chemosynthetic bacteria as their primary food source (MacDonald, 1992). Bacteria live within specialized cells in these invertebrate organisms and are supplied with oxygen and chemosynthetic compounds by the host via specialized blood chemistry (Fisher, 1990). The host, in turn, lives off the organic products subsequently released by the chemosynthetic bacteria and may even feed on the bacteria themselves. Additional information on the biology, life history, and distribution of chemosynthetic deepwater benthic communities can be found in Chapter 3.2.2.2 of the Multisale EIS and Chapter 4.1.4 of the Supplemental EIS.

Hydrocarbon seep communities in the GOM have been reported to occur at water depths between 951 and 9,430 ft (290 and 2,875 m) (USDOI, MMS, 2007b). The total number of chemosynthetic communities in the Gulf is now known to exceed 60. A recent MMS study, *Investigations of Chemosynthetic Communities on the Lower Continental Slope of the Gulf of Mexico*, performed exploration surveys specifically targeting water depths below 3,280 ft (1,000 m) (Brooks et al., 2009). This study confirmed the presence of 12 additional chemosynthetic communities not previously know in these water depths. What was initially thought to be relatively rare occurrences of chemosynthetic communities is now known to be far more common and regularly associated with primary geophysical signatures of the seabed, including faulting with conduits for hydrocarbons to the surface from deeper depths and precipitation of carbonate deposits on the seafloor. Acoustic amplitude anomalies on the seabed are major features related to almost all known chemosynthetic communities in the CPA and WPA, and these kinds of features are now relatively well mapped throughout the entire northern Gulf of Mexico. The total number of features on the northern Gulf slope that have probable associated communities now number close to 8,000.

A review for the potential occurrence of chemosynthetic communities associated with the proposed project in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 was performed for

this SEA. No known high-density, chemosynthetic invertebrate communities exist in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436.

The Macondo Event released an estimated 53,000-62,000 bbl of oil per day for almost 3 months. Much of the oil was treated with dispersant at the sea surface and at the source in a water depth of 1,500 m (5,000 ft). The dispersed oil mixed with the water; its movement was dictated by water currents and the physical processes of degradation. It is assumed that most of the dispersed oil eventually went to the ground on some portion of the seafloor; the longer it remained suspended, the more it dispersed. Depending on how long it remained in the water column, it may have been thoroughly degraded by biological action before contact or it may have contacted the seafloor more quickly. Oil may reach the seafloor through consumption by plankton, with excretion distributed over the seafloor. Water currents could have carried a plume to contact the seafloor directly but a likely scenario would be for the oil to adhere to other particles and precipitate to the seafloor, much like rainfall. This would result in a wide distribution of small amounts of oil.

Oil from the Macondo Event would be subject to biodegradation from bacterial action that would continue on the seafloor, resulting in scattered microhabitats with an enriched carbon environment. Chemosynthetic communities are adapted to gas seeps, which in some cases release oil also. For example, in a USDOI, MMS (2002) study it is stated that "three of our [chemosynthetic community] sites are clearly anomalous in terms of [high] oil concentration." These sites that may have received low quantities of well-dispersed oil undergoing biodegradation are likely to have experienced little negative effect. Exposure may be similar to normal conditions for these communities or toxic oil may have caused some fluctuation in health, resulting in slower growth or delayed spawning. Since these organisms grow slowly, the effects of a small amount of oil exposure could eliminate a year or more of normal growth. Chemosynthetic communities exposed to more concentrated oil may experience detrimental toxic effects of oil including death of affected organisms, tissue damage, lack of growth, interruption of reproductive cycles, and loss of gamete viability (USDOI, BOEMRE, 2010; Peters et al., 1981; Reimer, 1975; Loya and Rinkevich, 1979; Rinkevich and Loya, 1977; Cohen et al., 1977; Guzman and Holst, 1993). Other invertebrates associated with chemosynthetic communities, particularly the crustaceans, would likely be more susceptible to damage from oil exposure because they are not obligatory residents of gas seep habitats that may include oil seepage (Dean and Jewett, 2001; Gómez Gesteria and Dauvin, 2000). Recolonization of severely damaged or destroyed communities could take years to decades because chemosynthetic communities have low reproductive effort and are long-lived (ecologically k-selected) (MEC, 1995; Rinkevich and Loya, 1977; CSA and GERG, 2001; MRRI, 1984; Montagna and Holmberg, 2000). Data on the short and long term impacts of toxic oil on chemosynthetic communities or their recovery from disturbance are lacking.

3.4.1.2. Impact Analysis

A detailed impact analysis of the routine, accidental, and cumulative impacts of the proposed development activities on chemosynthetic communities can be found in Chapters 4.2.1.1.4.2.1, 4.2.2.1.4.2.1, 4.4.4.2.1, and 4.5.4.1 of the Multisale EIS and Chapter 4.1.4.1 of the Supplemental EIS and it is hereby incorporated by reference into this SEA. The following information is a summary of the impact analysis in the Multisale EIS and Supplemental EIS.

The impact-producing factors associated with the exploration activities in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 that could affect deepwater benthic communities include physical impacts from: (1) anchoring, including related chains and cables; (2) drilling discharges, including primarily cuttings with associated drilling muds; and (3) possible seafloor blowouts during well drilling.

3.4.1.2.1 Alternative 1

If selected, Alternative 1, the no action alternative (disapproval of the proposed action), would result in the operator not being permitted to drill the proposed exploration wells. Therefore, the impact-producing factors to chemosynthetic deepwater benthic communities would not occur. For example, there would be no anchoring concerns or well placement activities that could result in physical damage to the chemosynthetic communities or their substrates, no drilling discharges that could result in burial of the organisms, or no damage from contact with oil from blowouts/spills.

3.4.1.2.2 Alternative 2

If selected, Alternative 2, approval of the proposed action as submitted by the operator, would allow the operator to drill the proposed exploration wells according to the operator's plan. Examples of potential impacts to chemosynthetic deepwater benthic communities include, but are not limited to, damage from anchoring activities. Because the operator is required to follow all existing lease stipulations as well as the applicable regulations as clarified by NTLs (the operator reaffirmed compliance in its plan as cited above), conditions outlined in the following analyses related to NTL No. 2009-G40 will result in negating or lessening the probability of a significant impact to deepwater benthic communities.

Routine Operations

The NTL No. 2009-G40, "Deepwater Benthic Communities," provides guidance related to BOEMRE's regulations implementing a policy of avoidance of dense chemosynthetic communities (such as Bush Hill-type communities) or areas that have a high potential for supporting these community types, as interpreted from geophysical records. Lessees intending to explore or develop in water depths >984 ft (300 m) are required to provide information about geophysical surveys of the area of proposed activities and to evaluate the data for indications of conditions that may support chemosynthetic communities.

There are no known high-density chemosynthetic communities in the area of potential impact for the proposed activities. Anchors and mooring lines from the MODU can cause disturbances with lethal effects such as (1) crushing by anchors or mooring lines; (2) burial or disruption the organisms from scraping, plowing, or redistribution of bottom sediment by mooring lines that pivot on their anchors; and (3) increased turbidity from sediment that is resuspended as a result of anchor emplacement or mooring line motion that fouls or interferes with filter-feeding organs.

Routine surface discharges of drilling cuttings have been documented to reach the seafloor in water depths greater than 1,310 ft (400 m); however, significant accumulation thickness will be limited to a relatively close distance from the surface discharge point. A study looked at both exploration and production facility drilling discharges in water depths of 3,280 ft (1,000 m) and reported detectable accumulations at distances as far as 0.6 mi (1 km) (CSA, 2006). Realistically, splays of discharges only move in limited directions depending on prevailing currents; a good estimate would be 1/3 of the circumference of a circle with a radius of 3,280 ft (1,000 m) or 260 acres (105 hectares). Routine surface discharges of drilling cuttings would not result in a significant impact on the benthic communities because the duration, as described in Chapter 1, and areal extent of the proposed activities, i.e., exploratory drilling, would be limited and recolonization of benthic communities would be facilitated from nearby surrounding areas because numerous widespread pelagic larvae can settle on sediment where mortality to chemosynthetic organisms may reduce crowding and open up space for colonization.

Accidental Events

A blowout at the seafloor occurs when excess pressure in the well exceeds the capacity (both the operator's and the drilling apparatus' capacity) to contain the well. A blowout could create a crater on the sea bottom and resuspend and disperse large quantities of bottom sediments within a 985 ft (300 m) radius of the blowout site, burying both infaunal (living in the sediment) and epifaunal (living on sediment) organisms and interfering with sessile invertebrates that rely on filter-feeding organs. Rapid burial by accumulations of sediment >1 ft (>30 cm) in thickness is likely to be lethal for all benthic organisms based on analysis of escape trace fossils from the geologic record (Frey, 1975; Basan et al., 1978; Eckdale et al., 1984). Burial by thinner accumulations of sediment (or cuttings) may be lethal to some sessile (attached or immotile) invertebrates and survivable by motile organisms. Similar to impacts from drill cuttings, impacts from a blowout would be limited because the duration, as discussed in Chapter 1, and areal extent [within a radius of 985 ft (300 m)] would be limited and recolonization of communities would be facilitated from nearby surrounding areas because numerous widespread pelagic larvae can settle on sediment where mortality to chemosynthetic organisms may reduce crowding and will open up space for colonization. Shell's exploratory drilling wells will not be placed near sensitive high-density chemosynthetic communities because BOEMRE is prohibited under its regulations, from approving the placement of any wells near these communities. Consequently, sensitive high-density chemosynthetic communities would not be affected by sediments.

Oil released by a seafloor blowout could have potential negative effects on chemosynthetic communities. However, there are two reasons why substantive impacts are very unlikely: (1) the surface areas of possible communities is very small compared with the surrounding soft bottoms so they present relatively small, widely dispersed targets for contact by an oil spill; and (2) the likelihood of any size blowout is very small. Impacts from a potential blowout similar to the Deepwater Horizon incident is examined in the Catastrophic Spill Analysis located in Appendix B. Oil treated with dispersant on the sea surface or at depth could contact chemosynthetic communities beyond the immediate area of the drilling activity. There are no potential high-density chemosynthetic communities within or near the area of proposed activities. Currently there is limited information on toxicity of oil to chemosynthetic organisms. Data on the general toxicity of oil to organisms suggests that if oil contacted chemosynthetic communities, potential toxic effects would range from no discernable effect (for well-dispersed oil undergoing biodegradation) to lack of growth, to interruption of reproductive cycles, to loss of gamete viability, to tissue damage, and to death of affected organisms, depending on the amount and duration of contamination. Chemosynthetic organisms are adapted to exposure to gas seeps that may include oil discharge. For example, a USDOI, MMS (2002) study stated that "three of our [chemosynthetic community] sites are clearly anomalous in terms of [high] oil concentration." Such organisms may be more tolerant to exposure to oil than other invertebrates associated with chemosynthetic communities, particularly the crustaceans, and would likely be less susceptible to damage from oil exposure. Recolonization of severely damaged or destroyed communities could take years to decades because the organisms are long-lived with relatively low reproductive rates (i.e., they are ecologically k-selected).

Despite the recent Macondo Event, historical trends in the GOM (see Chapter 1.4) indicate that catastrophic spill events are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action. In the event of a catastrophic spill similar to the Macondo Event, the Catastrophic Spill Analysis in Appendix B discusses the most likely and most significant impacts to deepwater benthic habitats as it relates to three of the four phases of a major spill/blowout:

1) **Initial Event** (Section 2.2.2.5.; Page B-10);
2) **Offshore Spill** (Section 3.2.2.7; Page B-25);
3) **Onshore Contact** (deepwater benthic communities not included in this discussion); and
4) **Post-Spill, Long-Term Recovery** (Section 5.2.2.8; Page B-45).

The potential impacts from a catastrophic spill to chemosynthetic communities would be similar to aforementioned routine and accidental issues, and any substantive impact to chemosynthetic communities is very unlikely, due to the low probability of oil contacting the widely scattered, small targets represented by the communities.

Conclusion

Although high-density chemosynthetic community components could potentially occur in the vicinity of the proposed drilling activities in Mississippi Canyon Area Blocks 347, 348, 349, 391, 392, 393, 435, and 436 the proposed exploration activities are not expected to impact either known or probable areas of high-density chemosynthetic communities. The operator proposes compliance with the regulations as clarified by NTL No. 2009-G40; therefore, the operations are not expected to significantly impact any chemosynthetic communities during routine activities. To ensure compliance, the operator will submit additional information after the activities are completed noting location of the sites and anchoring equipment. Significant impacts to chemosynthetic communities are not expected from accidental blowouts due to their low probability and the low probability of oil contacting such communities (representing very small, widely dispersed targets). Additionally, the distance from the well sites to the potential communities are such that impacts from discharges are expected to be negligible.

The potential impacts from a catastrophic spill to chemosynthetic communities would be similar to aforementioned routine and accidental issues, and any substantive impact to chemosynthetic communities is very unlikely, due to the low probability of oil contacting the widely scattered, small targets represented by the communities.

Cumulative Impacts

Cumulative impacts on chemosynthetic deepwater benthic communities that result from oil and gas leasing, exploration, development, production, and non-OCS related activity were discussed in Chapter 4.5.4.2 of the Multisale EIS and Chapter 4.1.5.4 of the Supplemental EIS. This SEA directly tiers from the Multisale EIS and the Supplemental EIS. Impacts of any disturbance from routine activities would be local and short-term and unlikely to occur more than once to any area. Severe impacts resulting from a major blowout event could severely damage localized areas supporting chemosynthetic communities. However, the chance of such a blowout is very low and would only damage a chemosynthetic community that happens to be directly in the path of a subsea plume at the seafloor. Effects to the overall ecosystem of chemosynthetic communities in the GOM would be minimal. For the same reasons described above, even the most severe impacts, from a blowout, are not expected to significantly impact a chemosynthetic community.

Therefore, no significant cumulative impacts to chemosynthetic deepwater benthic communities would be expected as a result of the proposed exploration activities when added to the impacts of past, present, or reasonably foreseeable oil and gas development in the area as well as other activities in the area.

3.4.1.2.3. Alternative 3.

If selected, Alternative 3, approval of the proposed action with additional mitigation, would allow the operator to undertake the proposed activities, as requested and conditioned in the plan; however, the operator would be required to undertake additional mitigation as identified by BOEMRE. Because the operator is required to follow all existing lease stipulations as well as the applicable regulations as clarified by NTLs (the operator reaffirmed compliance in its plan), conditions outlined in the following analyses related to NTL No. 2009-G40 (Deepwater Benthic Communities) will result in negating or lessening the probability of a significant impact to deepwater benthic communities. The mitigation measure outlined in Chapter 2 is not expected to increase or decrease the potential for effects to deepwater benthic communities from the proposed action. Alternative 3 does not differ from Alternative 2 because the additional mitigation measures do not address this resource (i.e., all assumptions, estimates, and conclusions are identical), see the analysis provided in Section 3.4.1.2 for this alternative for this resource.

3.4.2. Nonchemosynthetic Deepwater Benthic Communities

Hard-bottom habitats in deep water include invertebrate communities dominated by the thicket-forming hard coral, *Lophelia pertusa*, with other corals such as the bamboo coral (*Keratoisis flexibilis*) and hidden white coral (*Madrepora oculata*). Numerous other invertebrates are also associated with these benthic habitats (Sulak et al., 2008a; Cordes et al., 2008; Fisher et al., 2007; Schroeder et al., 2005). The hard substrate underlying deep coral habitats in the deep Gulf of Mexico is formed by the processes of chemosynthetic organisms consuming hydrocarbons. Bacteria consume methanes and sulfides; their respiration results in the precipitation of carbonate, forming a hard substrate. The deep coral communities can form on the hard substrate after the hydrocarbon seep subsides or on the periphery away from the immediate effects of the seep. The coral community forms additional structure upon the seafloor, increasing the complexity of the habitat and supporting a variety of invertebrates and fishes.

3.4.2.1. Affected Environment

The description of the nonchemosynthetic deepwater benthic communities in the Gulf of Mexico region can be found in Chapter 3.2.2.2.2 of the Multisale EIS and Chapter 4.1.5 of the Supplemental EIS. The following information is a summary of the description in the Multisale EIS and the Supplemental EIS, and it is incorporated by reference into this SEA.

The continental slope in the Gulf of Mexico extends from the edge of the continental shelf at a depth of about 656 ft (200 m) to a water depth of approximately 9,840 ft (3,000 m) (USDOI, MMS, 2007b). The vast majority of the Gulf of Mexico has a soft, muddy bottom in which burrowing infauna are the most abundant invertebrates. Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and

436 falls into this category, and the proposed wells are at a water depth of approximately 7,150 ft (2,179 m).

Deepwater coral habitats and other potential hard-bottom communities are often associated with chemosynthetic communities. Chemosynthetic bacteria at hydrocarbon and sulfide seep sites produce chemical reactions that result in the precipitation of hard carbonate substrate. While these hard substrates support complex chemosynthetic communities they also harbor deep coral communities. Corals are able to thrive on the periphery of chemosynthetic habitat and even replace them after the hydrocarbon seep subsides. These unique communities are distinctive and similar in nature to protected pinnacles and topographic features on the continental shelf.

Any hard substrate communities located in deep water would be particularly sensitive to impacts from OCS activities, such as bottom disturbances and increased turbidity. Such impacts to these sensitive habitats could permanently prevent recolonization with similar organisms requiring hard substrate. Using complete 3-dimensional seismic seabed amplitude anomaly coverage of the area, there are no known hard-bottom areas in the area of the proposed bottom disturbing activities, Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436.

The Macondo Event resulted in the release of an estimated 53,000-62,000 bbl of oil per day for almost 3 months. Much of the oil was treated with dispersant at the sea surface and at the source in a water depth of 5,000 ft (1,500 m). The dispersed oil mixed with the water; its movement was dictated by water currents and the physical processes of degradation. It is assumed that most of the dispersed oil eventually went to the ground on some portion of the seafloor; the longer the oil remained suspended, the more it dispersed and degraded. Depending on how long the oil remained in the water column, it may have been thoroughly degraded by biological action before contact with the seafloor or the dispersed oil may have quickly dropped to the seafloor. Oil may have also reached the seafloor indirectly through consumption by plankton, with excretion distributed over the seafloor. It is possible that water currents could have carried a plume directly to the seafloor directly but a more likely scenario would have been for the oil to adhere to other particles and precipitate to the seafloor, much like rainfall. This scenario would have resulted in a wide distribution of small amounts of oil. Oil distributed in this way would be subject to the process of biodegradation from bacterial action that would continue on the seafloor, resulting in scattered microhabitats with an enriched carbon environment.

There have been no experiments and thus, no information regarding the response of deepwater corals to oil exposure. Experiments with shallow water tropical corals indicate that corals have a high tolerance to oil exposure (Shigenaka, 2001). Though deepwater corals live in a different environment, their general physiology is similar to shallow water tropical corals and, therefore, similar response to oiling can be expected. The mucus layers on coral resist penetration of oil and slough off the contaminant. Longer exposure times and areas of tissue where oil adheres to the coral in shallow waters are more likely to result in tissue damage and death of polyps. Corals with branching growth forms appear to be more susceptible to damage from oil exposure (Shigenaka, 2001). The most common deepwater coral, *Lophelia pertusa*, is a branching species. Tests with shallow tropical gorgonians indicate relatively low toxic effects to the coral, suggesting deepwater gorgonians may have a similar response. Deepwater coral response to exposure to oil would vary, depending on the level of exposure. Exposure to widely dispersed oil adhering to organic detritus and partially degraded by bacteria may be expected to result in little effect; such oil was undetectable on the seafloor following the Ixtoc spill (ERCO, 1982). Direct contact with plumes of relatively fresh dispersed oil in the vicinity of the incident could cause death of affected coral polyps because concentrated oil has the ability to penetrate their exoskeletons and impair photosynthesis carried out in symbiotic algae that the polyps rely upon for oxygen and food (Cook and Knap, 1983). Median levels of exposure to dispersed oil in a partly degraded condition may result in effects similar to those of shallow tropical corals, with often no discernable effects other than temporary contraction and some sloughing. The health of corals may be degraded by the necessary expenditure of energy as the corals respond to oiling. Communities exposed to more concentrated oil may experience detrimental effects including death of affected organisms, tissue damage, lack of growth, interruption of reproductive cycles, and loss of gametes (Peters et al., 1981; Reimer, 1975; Loya and Rinkevich, 1979; Rinkevich and Loya, 1977; Cohen et al., 1977; Guzman and Holst, 1993). Many invertebrates associated with deepwater coral communities, particularly the crustaceans, would likely be more susceptible to damage from oil exposure (Dean and Jewett, 2001; Gómez Gesteria and Dauvin, 2000). Recolonization of severely damaged or destroyed communities could take years to decades.

3.4.2.2. Impact Analysis

A detailed impact analysis of the routine, accidental, and cumulative impacts of the proposed development activities on nonchemosynthetic benthic communities can be found in Chapters 4.2.1.1.4.2.2, 4.2.2.1.4.2.2, 4.4.4.2.2, and 4.5.4.2 of the Multisale EIS and Chapter 4.1.5 of the Supplemental EIS. The following information is a summary of the impact analysis in the Multisale EIS and Supplemental EIS, and it is hereby incorporated by reference into this SEA. The potential impacts to nonchemosynthetic deepwater benthic communities expected to inhabit Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 are discussed in this section.

Similar to the previously discussed chemosynthetic communities, the IPFs associated with the exploration activities in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 that could affect nonchemosynthetic deepwater benthic communities include physical impacts from: (1) anchoring, including related chains and cables; (2) drilling discharges, including primarily cuttings with associated drilling muds; and (3) possible seafloor blowouts during well drilling.

3.4.2.2.1 Alternative 1

If selected, Alternative 1, the no action alternative (disapproval of the proposed action), would result in the operator not being permitted to drill the proposed exploration wells. Therefore, the impact producing factors to nonchemosynthetic deepwater benthic communities would not occur. For example, there would be no anchoring concerns or well placement activities that could result in physical damage to the nonchemosynthetic communities or their substrates, no drilling discharges that could result in burial of the organisms, or no damage from contact with oil from blowouts/spills.

3.4.2.2.2 Alternative 2

If selected, Alternative 2, approval of the proposed action as submitted by the operator, would allow the operator to drill the proposed exploration wells according to the operator's plan as submitted. Examples of potential impacts to nonchemosynthetic deepwater benthic communities include, but are not limited to, damage from anchoring activities. Because the operator is required to follow all existing lease stipulations and regulations as clarified by NTLs (the operator reaffirms such compliance in its plan cited above), conditions outlined in the following analyses related to NTL No. 2009-G40 should negate or lessen the chance of a significant impact to deepwater benthic communities. If selected, Alternative 2 would not leave nonchemosynthetic deepwater benthic communities open to potential significant impacts.

Routine Operations

Anchors and mooring lines from the MODU can cause disturbances to nonchemosynthetic communities with lethal affects such as (1) crushing by anchors or mooring lines; (2) burial or disruption the organisms from scraping, plowing, or redistribution of bottom sediment by mooring lines that pivot on their anchors; and (3) increased turbidity from sediment that is resuspended as a result of anchor emplacement or mooring line motion that fouls or interferes with filter-feeding organs.

Although a recent study looked at both exploration and production facility drilling discharges in water depths of 3,280 ft (1,000 m) and reported detectable accumulations at distances as far as 0.6 mi (1 km), significant accumulation of sediments from drilling discharges (cutings and muds) will be limited to a close distance from the well (CSA, 2006) because splays of discharges only move in limited directions depending on prevailing currents; a good estimate would be 1/3 of the circumference of a circle with a radius of 3,280 ft (1,000 m) or 260 acres (105 hectares). This would not result in a significant impact on the nonchemosynthetic benthic communities because the duration, as described in Chapter 1, and areal extent of the proposed activities would be limited and recolonization of benthic communities is facilitated from nearby surrounding areas. There are no potential nonchemosynthetic communities within or near the area of proposed activities. Impacts to hard-bottom communities are expected to be avoided by the compliance with BOEMRE regulations and guidance described in NTL 2009-G40.

Accidental Events

A blowout at the seafloor occurs when excess pressure in the well exceeds the capacity (both the operator's and the drilling apparatus' capacity) to contain the well. A blowout could create a crater on the sea bottom and resuspend and disperse large quantities of bottom sediments within a 985 ft (300 m) radius of the blowout site, burying both infaunal (living in the sediment) and epifaunal (living on sediment) organisms and interfering with sessile invertebrates that rely on filter-feeding organs. Rapid burial by accumulations of sediment >1 ft (>30 cm) in thickness is likely to be lethal for all benthic organisms based on analysis of escape trace fossils from the geologic record (Frey, 1975; Basan et al., 1978; Eckdale et al., 1984). Burial by thinner accumulations of sediment (or cuttings) may be lethal to some sessile (attached or immotile) invertebrates and survivable by motile organisms. Similar to impacts from drill cuttings, impacts from a blowout would be limited because the duration and areal extent would be limited and recolonization of communities would be facilitated from nearby surrounding areas. Shell's exploratory drilling wells will not be placed near nonchemosynthetic communities because BOEMRE is prohibited, under its regulations, from approving the placement of any wells near these communities. Consequently, nonchemosynthetic communities would not be affected by sediments. Oil released by seafloor blowouts could have potential negative effects on deepwater hard-bottom communities. Oil treated with dispersant on the sea surface or at depth could contact sensitive benthic communities beyond the immediate area of the activity. Potential blowouts similar to the Deepwater Horizon incident are described in the Catastrophic Spill Analysis located in Appendix B.

There have been no experiments and thus, no information regarding the response of deepwater corals to oil exposure. Experiments with shallow water tropical corals indicate that corals have a high tolerance to oil exposure (Shigenaka, 2001). Though deepwater corals live in a different environment, their general physiology is similar to shallow water tropical corals and, therefore, similar response to oiling can be expected. The mucus layers on coral resist penetration of oil and slough off the contaminant. Longer exposure times and areas of tissue where oil adheres to the coral in shallow waters are more likely to result in tissue damage and death of polyps. Corals with branching growth forms appear to be more susceptible to damage from oil exposure (Shigenaka, 2001). The most common deepwater coral, Lophelia pertusa, is a branching species. Tests with shallow tropical gorgonians indicate relatively low toxic effects to the coral, suggesting deepwater gorgonians may have a similar response. Deepwater coral response to exposure to oil would vary, depending on the level of exposure. Exposure to widely dispersed oil adhering to organic detritus and partially degraded by bacteria may be expected to result in little effect; such oil was undetectable on the seafloor following the Ixtoc spill (ERCO, 1982). Direct contact with plumes of relatively fresh dispersed oil in the vicinity of the incident could cause death of affected coral polyps, because concentrated oil has the ability to penetrate their exoskeletons and impair photosynthesis carried out in symbiotic algae that the polyps rely upon for oxygen and food (Cook and Knap, 1983). Median levels of exposure to dispersed oil in a partly degraded condition may result in effects similar to those of shallow tropical corals, with often no discernable effects other than temporary contraction and some sloughing. The health of corals may be degraded by the necessary expenditure of energy as the corals respond to oiling. Communities exposed to more concentrated oil may experience detrimental effects including death of affected organisms, tissue damage, lack of growth, interruption of reproductive cycles, and loss of gametes (Peters et al., 1981; Reimer, 1975; Loya and Rinkevich, 1979; Rinkevich and Loya, 1977; Cohen et al., 1977; Guzman and Holst, 1993). Many invertebrates associated with deepwater coral communities, particularly the crustaceans, would likely be more susceptible to damage from oil exposure (Dean and Jewett, 2001; Gómez Gesteria and Dauvin, 2000). Recolonization of severely damaged or destroyed communities could take years to decades (MEC, 1995; Rinkevich and Loya, 1977; CSA and GERG, 2001; MRRI, 1984; Montagna and Holmberg, 2000).

Other invertebrates associated with deepwater coral communities, particularly the crustaceans, would likely be more susceptible to damage from oil exposure. Recolonization of severely damaged or destroyed communities could take years to decades.

In the event of a catastrophic spill similar to the Macondo Event, the Catastrophic Spill Analysis in Appendix B discusses the most likely and most significant impacts to deepwater benthic habitats as it relates to three of the four phases of a major spill/blowout:

1) **Initial Event** (Section 2.2.2.5.; Page B-10);
2) **Offshore Spill** (Section 3.2.2.7; Page B-25);

3) **Onshore Contact** (deepwater benthic communities not included in this discussion); and

4) **Post-Spill, Long-Term Recovery** (Section 5.2.2.8; Page B-45).

In the event of a catastrophic spill similar to the Macondo Event, any substantive impact to deepwater benthic communities is very unlikely because the potential impacts from a catastrophic spill would be similar to aforementioned routine and accidental issues. However, despite the recent Macondo Event, historical trends in the GOM (see Chapter 1.4) indicate that catastrophic spill events are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action.

Conclusion

The proposed exploration activities are expected to have negligible impacts on the ecological function, biological productivity, or distribution of hard-bottom non-chemosynthetic communities. Bottom disturbances from the discharge of drilling cuttings and associated drilling muds would not be of a sufficient size or duration to adversely affect these benthic community types to any significant or permanent degree. Minor and temporary impacts, such as interference with filter-feeding structures, could occur over areas inside an envelope estimated to be no more than about 260 acres (105 hectares). Routine discharges at the sea surface are not expected to adversely impact these community types because of the water depth in Mississippi Canyon Area Blocks 347, 348, 349, 391, 392, 393, 435, and 436. Bottom disturbance from a blowout during the drilling of wells is not likely, based on the historical record of blowout events in the Gulf. The recruitment of new organisms would take place from nearby areas, and organisms from undisturbed areas are free to migrate into disrupted areas after the disturbance ceases. Impacts to hard-bottom communities are expected to be avoided as a consequence of the compliance with existing BOEMRE regulations and adherence by the operator to NTL 2009-G40 for such communities; however there is no means to verify this without monitoring the situation over time. The same geophysical conditions associated with the potential presence of chemosynthetic communities also result in hard carbonate substrate. Hard bottoms are rare in the deep Gulf and there are no known hard-bottom areas near this block.

Cumulative Impacts

Cumulative impacts on nonchemosynthetic deepwater benthic communities that result from oil and gas leasing, exploration, development, and production activity were discussed in Chapter 4.5.4.2 of the Multisale EIS and Chapter 4.1.5.4 of the Supplemental EIS. This SEA directly tiers from the Multisale EIS and the Supplemental EIS. The proposed action may result in slight increases in turbidity in the vicinity of possible nearby hard-bottom communities; such effects would be temporary and negligible. No direct physical impacts are expected. The remote possibility of a catastrophic blowout would add to cumulative impacts if it did occur, but it is very unlikely and would produce localized effects wherever concentrated oil directly contacts sensitive communities. Therefore, no significant cumulative impacts to nonchemosynthetic deepwater benthic communities would be expected as a result of the proposed exploration activities when added to the impacts of past, present, or reasonably foreseeable oil and gas development in the area as well as other activities in the area.

3.4.2.2.3 Alternative 3

If selected, Alternative 3, approval of the proposed action with additional mitigation, would allow the operator to undertake the proposed activities, as requested and conditioned in the plan; however, the operator would be required to undertake additional mitigation as identified by BOEMRE. Because the operator is required to follow all existing lease stipulations and regulations as clarified by NTLs (the operator reaffirms such compliance in its plan), conditions outlined in the previous analyses related to NTL No. 2009-G40 (Deepwater Benthic Communities) should negate or lessen the chance of a significant impact to deepwater benthic communities. The mitigation measure outlined in Chapter 2 is not expected to increase or decrease the potential for effects to deepwater benthic communities from the proposed action. Alternative 3 does not differ from Alternative 2 because the additional mitigation measure does not address this resource (i.e., all assumptions, estimates, and conclusions are identical). See the analysis provided in Section 3.4.2.2 for this alternative for this resource.

3.5. MARINE MAMMALS

3.5.1. Affected Environment

Twenty-nine species of marine mammals occur in the GOM (Davis et al., 2000). The GOM's marine mammals are represented by members of the taxonomic order Cetacea, which is divided into the suborders Mysticeti (i.e., baleen whales) and Odontoceti (i.e., toothed whales), as well as the order Sirenia, which includes the manatee and dugong. Within the GOM, there are 28 species of cetaceans (7 mysticete and 21 odontocete species) and 1 sirenian species (the manatee).

Threatened or Endangered Marine Mammal Species

Five baleen cetaceans (the North Atlantic right, blue, fin, sei, and humpback whales), one toothed cetacean (the sperm whale), and one sirenian (the West Indian manatee) occur in the GOM and are listed as endangered under the Endangered Species Act (ESA). The sperm whale is common in oceanic waters of the northern GOM and appears to be a resident species, while the baleen whales are considered rare or extralimital in the GOM (Würsig et al., 2000). The National Marine Fisheries Service's (NMFS) annual Stock Assessment Report (SAR) for the GOM indicates that the northern right, blue, fin, sei, and humpback whales are rare in the GOM (Waring et al., 2009). The life history, population dynamics, status, distribution, behavior, and habitat use of baleen and toothed whales can be found in Chapter 3.2.3.1 of the Multisale EIS (USDOI, MMS, 2007), Chapter 4.1.6.1 of the Supplemental EIS (USDOI, MMS, 2008), and in the NMFS 2009 SAR (Waring et al., 2009). The West Indian manatee (*Trichechus manatus*) typically inhabits only coastal marine, brackish, and freshwater areas. The distribution, feeding habits, habitat use, and population estimates of manatees can be found in Chapter 3.2.3.1.3 of the Multisale EIS.

Non-ESA-Listed Marine Mammal Species

The remaining 22 marine mammal species that occur in the GOM are not protected under the ESA. However, all marine mammals are protected by the Marine Mammal Protection Act (MMPA). There are two species of non-ESA-listed baleen whales that may occur in the GOM – the minke whale and the Bryde's whale. The minke whale is considered rare and is not included in the NMFS SAR for the GOM (Wursig et al., 2000; Waring et al., 2009). The Bryde's whale is considered uncommon but is the most frequently sighted baleen whale in the GOM (Wursig et al., 2000).

Non-ESA-listed toothed whales include all of the dolphin and small whale/"blackfish" species in the GOM and comprise 20 species. The *Kogia* species (pygmy and dwarf sperm whales) are small and cryptic whales that inhabit offshore waters. Very little is known of their life history. The beaked whales have been highly publicized in the last several years due to strandings and deaths attributed to military sonar. Beaked whales are not as small as *Kogia,* but they are just as cryptic and difficult to survey. As with *Kogia*, very little is known about beaked whales (Waring et al., 2009).

Additional information on non-ESA-listed marine mammal species of the GOM is provided in Chapter 3.2.3.2 of the Multisale EIS (USDOI, MMS, 2007), Chapter 4.1.6.1 of the Supplemental EIS (USDOI, MMS, 2008), and in the NMFS 2009 SAR (Waring et al., 2009) and is incorporated by reference into this SEA.

3.5.2. Impact Analysis

The impact-producing factors associated with the proposed drilling activities in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 that could affect marine mammals include: (1) vessel noise and collisions; (2) marine debris; (3) water-quality degradation from drilling rig effluents; (4) oil spills and spill-response activities; and (5) drilling noise. These impact-producing factors are the same for nonthreatened and nonendangered marine mammal species as well as those listed under the Endangered Species Act of 1973 (ESA).

3.5.2.1 Alternative 1

If selected, Alternative 1, the no action alternative (disapproval of the proposed action), would result in the operator's not being permitted to drill the proposed exploration wells. Therefore, the impact producing factors to marine mammals would not occur. These factors include vessel/drilling noise that would result in behavioral change, masking, or non-auditory effects to marine mammals, no long-term or permanent displacement of the animals from preferred habitats, and no destruction or adverse modification of any habitats. Because there would be no support vessel traffic related to the drilling operation, there would be no risk of collisions with marine mammals, and there would be no water degradation as a result of the exploration activities.

3.5.2.2 Alternative 2

If selected, Alternative 2, the approval of the proposed action as submitted by the operator, would allow the operator to drill the proposed exploration wells as specified in its plan. The operator has proposed adherence with the guidance provided under NTL No. 2007-G03, "Marine Trash and Debris Awareness and Elimination" and NTL No. 2007-G04, "Vessel Strike Avoidance and Injured/Dead Protected Species Reporting" (Shell, 2010). Compliance with the regulations as clarified in these NTLs should negate or lessen the chance of significant impacts to marine mammals under this alternative.

Routine Operations

Vessel Noise and Collisions

The proposed exploration drilling activities are expected to require a maximum of six roundtrip supply-vessel and three roundtrip crew-vessel trips per week. Deep-diving whales may be more vulnerable to vessel strikes given the longer surface period required to recover from extended deep dives. Given NMFS has determined vessel strikes to be a discountable concern for sperm whales (NMFS, 2007) , a deep-diving species, the faster diving marine mammal species with less surface recovery time would be expected to have even less risk of vessel strikes. Although manatees have been killed by vessel strikes (e.g., Schiro et al., 1998), they are rare in the deepwater GOM, and consequently, the proposed activity should pose little, if any, risk to them.

The dominant source of noise from vessels is from the propeller operation, and the intensity of this noise is largely related to ship size and speed. Vessel noise from the proposed action will produce low levels of noise, generally in the 150 to 170 dB re 1 μPa-m at frequencies below 1,000 Hz. Vessel noise is transitory and generally does not propagate at great distances from the vessel. As a result, the NMFS 2007 ESA Biological Opinion concluded that the effects to sperm whales from vessel noise are discountable (USDOC, NMFS, 2007).

The noise and the shadow from helicopter overflights, take-offs, and landings can cause a startle response and can interrupt whales and dolphins while resting, feeding, breeding, or migrating (Richardson et al., 1995). The Federal Aviation Administration's Advisory Circular 91-36D (September 17, 2004) encourages pilots to maintain higher than minimum altitudes over noise-sensitive areas. Guidelines and regulations put in place by NOAA Fisheries under the authority of the Marine Mammal Protection Act include provisions specifying that helicopter pilots maintain an altitude of 1,000 ft (305 m) within 300 ft (91 m) of marine mammals. The proposed action is expected to have three helicopter trips per week. These occurrences would be temporary and pass within seconds. Marine mammals are not expected to be adversely affected by routine helicopter traffic operating at prescribed altitudes.

Atmospheric noise inputs, however, are negligible relative to other sources of noise that are propagated in water (e.g., vessel traffic and platform and drill rig operations). Noise from service-vessel traffic may elicit a startle and/or avoidance reaction from whales and dolphins or mask their sound reception. There is the possibility of short-term disruption of movement patterns and behavior, but such disruptions are unlikely to affect survival or productivity. The behavioral disruptions potentially caused by noise and the presence of service-vessel traffic will have negligible affects on cetacean populations in the northern Gulf of Mexico.

Drilling activities would produce sounds transmitted into the water at intensities and frequencies that could be heard by cetaceans. Noise from drilling could be intermittent, sudden, and at times could be

high intensity as operations take place. Sound from a fixed, ongoing source like an operating drillship is continuous. However, the distinction between transient and continuous sounds is not absolute on a drillship as generators and pumps operate essentially continuously, but there are occasional transient bangs and clangs from various impacts during operations (Richardson et al. 1995). Drilling from semi-submersible vessels estimated frequencies are broadband from 80-4000 Hz with an estimated source level (SL) of 154 dB re 1μPa at 1 m. Tones of 60 Hz has SLs of 149 dB, 181 Hz was 137 dB, and 301 Hz was 136 dB (Greene 1986). The potential effects that water-transmitted noise have on marine mammals include disturbance (subtle changes in behavior, interruption of previous activities, or short- or long-term displacement), masking of sounds (calls from conspecifics, reverberations from own calls, and other natural sounds such as surf or predators), physiological stress, and hearing impairment. Individual marine mammals exposed to recurring disturbance could be negatively affected. Malme et al. (1986) observed the behavior of feeding gray whales in the Bering sea during four experimental playbacks of drilling sounds (50 to 315 Hz; 21- min overall duration and 10% duty cycle; source levels 156 to 162 dB re: 1 μPa-m). In two cases for received levels (RLs) 100 to 110 dB re: 1 μPa, there was no observed behavioral reaction. Avoidance behavior was observed in two cases where RLs were 110 to 120 dB re: 1 μPa. These source levels are all below NMFS' current 160 dB level B harassment threshold under the MMPA.

The source levels from drilling are relatively low (154 dB and below, as cited by Greene, 1986 in Richardson et al. 1995), below the level B (behavioral) harassment threshold of 160 dB (set by NMFS). According to Southall et al. (2007), for behavioral responses to nonpulses (such as drill noise), data indicate considerable variability in received levels associated with behavioral responses. Contextual variables (such as novelty of the sound to the marine mammal and operation features of the sound source) appear to have been at least as important as exposure level in predicting response type and magnitude. While there is some data from the Arctic on baleen whales, there is little data on the behavioral responses of marine mammals in the Gulf of Mexico from the sound of drilling. Southall et al (2007) summarized the existing research, stating that the probability of avoidance and other behavioral affects increases when received levels increase from 120 to 160 dB. Marine mammals may exhibit some avoidance behaviors, but their behavioral or physiological responses to noise associated with the proposed project, however, are unlikely to have population-level impacts to marine mammals in the northern Gulf of Mexico.

Marine Debris

Many types of plastic materials end up as solid waste during drilling and production operations. Some of this material is accidentally lost overboard where cetaceans could consume it or become entangled in it. The incidental ingestion of marine debris and entanglement could adversely affect marine mammals. The operator has proposed adherence with the guidance provided under NTL No. 2007-G03, "Marine Trash and Debris Awareness and Elimination," which appreciably reduces the likelihood of marine mammals encountering marine debris from the proposed activity (Shell, 2010).

Water Degradation

Most operational discharges are diluted and dispersed when released in offshore areas and are considered to have sublethal effects (NRC, 1983; API, 1989; Kennicutt, 1995; Kennicutt et al., 1996). Any potential impacts from drilling fluids would be indirect, either as a result of impacts to prey species or possibly through ingestion via the food chain (Neff et al., 1989). Marine mammals generally are thought to be inefficient assimilators of petroleum compounds within prey (Neff, 1990).

Accidental Events

Oil Spills and Response Activities

The oil from an oil spill can adversely affect cetaceans by causing soft tissue irritation, fouling of baleen plates, respiratory stress from inhalation of toxic fumes, food reduction or contamination, direct ingestion of oil and/or tar, and temporary displacement from preferred habitats. The long-term impacts to marine mammal populations are poorly understood but could include decreased survival and lowered reproductive success. The range of toxicity and degree of sensitivity to oil hydrocarbons and the effects

of cleanup activities on cetaceans are unknown. One assumption concerning the use of dispersants is that chemical dispersion of oil will considerably reduce the impacts to seabirds and aquatic mammals, primarily by reducing their exposure to petroleum hydrocarbons (French-McCay 2004; NRC, 2005). Chemical dispersant application during an oil spill may lower the amount of oil to which a bird or aquatic mammal is exposed while increasing the potential loss of the insulative properties of feathers or fur through the reduction of surface tension at the feather/fur-water interface (NRC, 2005).

Impacts from the dispersants are unknown but may have similar irritants to tissues and sensitive membranes as they are known to have had on seabirds and marine mammals (NRC, 2005). There have been no experimental studies and only a handful of observations suggesting that oil has harmed any manatees (St. Aubin and Lounsbury, 1990). Types of impacts to manatees and dugongs from contact with oil include (1) asphyxiation due to inhalation of hydrocarbons, (2) acute poisoning due to contact with fresh oil, (3) lowering of tolerance to other stress due to the incorporation of sublethal amounts of petroleum components into body tissues, (4) nutritional stress through damage to food sources, and (5) inflammation or infection and difficulty eating due to oil sticking to the sensory hairs around their mouths (Preen, 1989, in Sadiq and McCain, 1993, AMSA, 2003). For a population whose environment is already under great pressure, even a localized incident could be significant (St. Aubin and Lounsbury, 1990). Spilled oil might affect the quality or availability of aquatic vegetation, including seagrasses, upon which manatees feed.

In the event of catastrophic spill similar to the Macondo Event, the Catastrophic Spill Analysis in Appendix B discusses the most likely and most significant impacts to marine mammals as it relates to the four phases of a major spill/blowout:

1) **Initial Event** (Section 2.2.2.3.; Page B-9);
2) **Offshore Spill** (Section 3.2.2.3; Page B-21);
3) **Onshore Contact** (Section 4.2.2.3; Page B-35); and
4) **Post-Spill, Long-Term Recovery** (Section 5.2.2.3; Page B-43).

In the event of a catastrophic spill similar to the Macondo Event, any substantive impact to marine mammals is very unlikely because the potential impacts from a catastrophic spill would be similar to aforementioned routine and accidental issues. However, despite the recent Macondo Event, historical trends in the GOM (see Chapter 1.4) indicate that catastrophic spill events are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action.

Conclusion

The sections above discuss the potential range of effects to marine mammals from the proposed activity and any of these effects has the potential individually or cumulatively to result in impacts to marine mammal species commonly found in the GOM and proposed action area. However, BOEMRE finds that the potential for such effects from the proposed action are unlikely to rise to significant levels for the following reasons:

- Mysticetes, as low-frequency hearing specialists, are the species groups most likely to be susceptible to impacts from nonpulse sound (intermittent or continuous) given that their hearing ranges overlap most closely with the noise frequencies produced from drilling (Southall et al., 2007). However, all mysticete species that may occur in the GOM (i.e., North Atlantic right, blue, fin, sei, humpback, minke and Bryde's whales) are considered either "extralimital," "rare," or "uncommon" within the GOM (Wursig et al., 2000; Waring et al., 2009). Given the small geographic scope of the proposed action, the presence of these species within the action area is unlikely.
- The remaining marine mammal species in the GOM (e.g., sperm whales, dwarf or pygmy sperm whales, and dolphins) are considered mid-frequency hearing specialists with hearing ranges that slightly overlap with sound frequencies produced from drilling noise (Southall et al., 2007). It is expected that there will be some overlap in the frequencies of the drill source and the hearing thresholds of the marine mammals present in the GOM. Greene (1986) estimated the broadband frequencies of semi-submersible drill vessels to be from 80-4000 Hz with an estimated SL of 154

dB re 1μPa at 1 m. Tones of 60 Hz had source levels of 149 dB, 181 Hz was 137 dB, and 301 Hz was 136 dB. Wartzok and Ketten (1999) stated that bottlenose dolphins have hearing thresholds ranging from less than 5 kHz to over 100 kHz, Ridgway and Carder (2001) found, through auditory brainstem analysis, that pygmy sperm whales have thresholds from 90 to 150 kHz. Gordon et al. (1996) found that a stranded sperm whale had lower hearing limits at around 100 Hz while Ridgway and Carder (2001) found that a sperm whale calf had best hearing sensitivity between 5 and 20 kHz. Since there is some overlap in the sound levels produced and hearing thresholds of marine mammals, there is potential for the drilling noise produced to cause auditory and non-auditory effects, PTS, TTS, behavioral changes, or masking but it is expected to be limited.

- The NMFS sets the 180-dB root-mean-squared (rms) isopleth where on-set of auditory injury or mortality (level A harassment) to cetaceans may occur. Southall et al. (2007) suggests this level should rather be at 230 dB rms for a nonpulsed sound, such as drilling noise. Richardson et al (1995) cited Greene (1986) and stated drilling from semi-submersible vessels have estimated broadband frequencies from 80-4000 Hz with an estimated source level of 154 dB re 1microPa at 1 m. Tones of 60 Hz have source levels of 149 dB, while 181 Hz have source levels of 137 dB, and 301 Hz have source levels of 136 dB. These source levels all fall below the 180 dB level A harassment isopleths.
- The operator is required to adhere to the guidance provided under NTL No. 2007-G03, "Marine Trash and Debris Awareness and Elimination," which appreciably reduces the likelihood of marine mammals encountering marine debris from the proposed activity (Shell, 2010).

The geographic scope of the proposed action is small in relation to the ranges of marine mammals in the GOM. The proposed drilling activities are not expected to cause long-term or permanent displacement of the animals from preferred habitats, nor will they result in the destruction or adverse modification of any habitats. In conclusion, the scope, timing, and transitory nature of the proposed action and the mitigation and monitoring requirements in place, the noise related to the proposed drilling operation is not expected to result in PTS, TTS, behavioral change, masking, or non-auditory effects to marine mammals in the GOM that would rise to the level of significance.

Cumulative Impact Analysis

Chapter 4.5.5 of the Multisale EIS (USDOI, MMS, 2007), and Chapter 4.1.6.4 of the Supplemental EIS (USDOI, MMS, 2008) address the cumulative impacts on marine mammals as a result of oil and gas leasing, exploration, development and production activities, including the proposed drilling activities. Additionally, Chapter 4.4.5 of the Multisale EIS (USDOI, MMS, 2007) contains a discussion of additional impacts from accidental events (e.g., oil spills) that are particularly relevant in light of the Macondo Event. This information is summarized below and is incorporated by reference into this SEA.

The proposed action may cumulatively affect protected cetaceans when viewed in light of the Macondo Event and associated cleanup activities. Marine mammals could be impacted by oil and gas leasing, exploration, development and production activities including the degradation of water quality resulting from operational discharges, vessel traffic, noise generated by platforms, drillships, helicopters and vessels, seismic surveys, explosive structure removals, oil spills, oil-spill-response activities, loss of debris from service vessels and OCS structures, commercial fishing, capture and removal, and pathogens. The cumulative impact on marine mammals is expected to result in a number of chronic and sporadic sublethal effects (i.e., behavioral effects and nonfatal exposure to or intake of OCS-related contaminants or discarded debris) that may stress and/or weaken individuals of a local group or population and predispose them to infection from natural or anthropogenic sources (Harvey and Dahlheim, 1994).

Few deaths are expected from chance vessel collisions, ingestion of plastic material, commercial fishing, and pathogens. Disturbance (noise from vessel traffic and drilling operations, etc.) and/or exposure to sublethal levels of toxins and anthropogenic contaminants may stress animals, weaken their immune systems, and make them more vulnerable to parasites and diseases that normally would not be fatal (Harvey and Dahlheim, 1994). The net result of any disturbance will depend upon the size and percentage of the population likely to be affected, the ecological importance of the disturbed area, the environmental and biological parameters that influence an animal's sensitivity to disturbance and stress, or the accommodation time in response to prolonged disturbance (Geraci and St. Aubin, 1980).

The effects of the proposed action, when viewed in light of the effects associated with other relevant activities, may impact marine mammals in the GOM. However, the operator is required to follow all existing lease stipulations and regulations as clarified by NTLs. The operator's reaffirmed compliance with NTL No. 2007-G04 (Vessel-Strike Avoidance) and NTL 2007-G03 (Marine Trash and Debris), as well as the limited scope, timing, and geographic location of the proposed action, effects from the proposed drilling activities on marine mammals will be negligible. Therefore, no significant cumulative impacts to marine mammals would be expected as a result of the proposed exploration activities when added to the impacts of past, present, or reasonably foreseeable oil and gas development in the area as well as other activities in the area.

3.5.2.3. Alternative 3

If selected, Alternative 3, approval of the proposed action with additional mitigation. The operator would undertake the proposed activities, as requested and conditioned in the plan; however, the operator would be required to undertake additional mitigation as identified by BOEMRE. The operator is required to follow all existing lease stipulations and regulations as clarified in NTLs. Compliance with the regulations and as outlined in NTL No. 2007-G04 should negate or lessen the chance of a significant impact to marine mammals.. The mitigation measure outlined in Chapter 2 is not expected to increase or decrease the potential for effects to marine mammals from the proposed action. Alternative 3 does not differ from Alternative 2 because the additional mitigation measure does not address this resource (i.e., all assumptions, estimates, and conclusions are identical), see the analysis provided in Section 3.5.2.2 for this alternative for this resource.

3.6. SEA TURTLES

3.6.1. Affected Environment

Of the extant species of sea turtles, five are known to inhabit the waters of the GOM (Pritchard, 1997): the leatherback, green, hawksbill, Kemp's ridley, and loggerhead. These five species are all highly migratory, and individual animals will migrate into nearshore waters as well as other areas of the North Atlantic Ocean, GOM, and Caribbean Sea. All five species of sea turtles found in the Gulf of Mexico have been federally listed as endangered or threatened since the 1970's. There is currently no critical habitat designated in the GOM.

In 2007, FWS and NMFS published 5-year status reviews for all federally listed sea turtles in the GOM (USDOC, NMFS and USDOI, FWS, 2007a-e). A 5-year review is an ESA-mandated process that is conducted to ensure that the listing classification of a species as either threatened or endangered is still accurate. Both agencies share jurisdiction for federally listed sea turtles and jointly conducted the reviews. After reviewing the best scientific and commercially available information and data, agencies determined that the current listing classification for the five sea turtle species remain unchanged.

Additional information on sea turtle species of the GOM is provided in Chapter 3.2.4 of the Multisale EIS (USDOI, MMS, 2007), and Chapter 4.1.7.1 of the Supplemental EIS (USDOI, MMS, 2008) and is incorporated by reference into this SEA.

3.6.2. Impact Analysis

The diversity of a sea turtle's life history leaves it susceptible to many natural and human impacts, including impacts while it is on land, in the benthic environment, and in the pelagic environment. The impact-producing factors associated with the proposed drilling activities in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 that could affect sea turtles include: (1) vessel noise and collisions; (2) marine debris; (3) water-quality degradation from drilling rig effluents; (4) oil spills and spill-response activities; and (5) drilling noise.

3.6.2.1 Alternative 1

If selected, Alternative 1, the no action alternative (disapproval of the proposed action), would result in the operator not being permitted to drill the proposed exploration wells. Therefore, the impact producing factors to sea turtles would not occur. For example, there would be no vessel noise or drilling

noise that would result in behavioral change, masking, or non-auditory effects to sea turtles, no long-term or permanent displacement of the animals from preferred habitats, and no destruction or adverse modification of any habitats. Since there would be no vessel traffic related to the drilling operation, there would be no risk of collisions with sea turtles.

3.6.2.2 Alternative 2

If selected, Alternative 2, approval of the proposed action as submitted by the operator, would allow the operator to drill the proposed exploration wells. The operator has proposed adherence with the guidance provided under NTL No. 2007-G03, "Marine Trash and Debris Awareness and Elimination" and NTL No. 2007-G04, "Vessel Strike Avoidance and Injured/Dead Protected Species Reporting" (Shell, 2010). Compliance with the regulations as clarified in these NTLs should negate or lessen the chance of significant impacts to sea turtles under this alternative.

Routine Operations

Vessel Noise and Collisions

The first IPF associated with the proposed action that could affect ESA-listed sea turtles is impacts from vessel noise and vessel collisions. The dominant source of noise from vessels is propeller operation, and the intensity of this noise is largely related to ship size and speed. Vessel noise from the proposed action would produce low levels of noise, generally in the 150 to 170 dB re 1 μPa-m at frequencies below 1,000 Hz. Vessel noise is transitory and generally does not propagate at great distances from the vessel. Also, available information indicates that sea turtles do not greatly utilize environmental sound. As a result, the NMFS 2007 Biological Opinion concluded that effects to sea turtles from vessel noise are discountable (USDOC, NMFS, 2007).

Drilling activities would produce sounds transmitted into the water that could be intermittent, sudden, and at times could be high intensity as operations take place. However, sea turtles are not expected to be impacted by this disturbance because NMFS in their 2007 Biological Opinion determined that "drilling is not expected to produce amplitudes sufficient to cause hearing or behavioral effects to sea turtles or sperm whales; therefore, these effects are insignificant."

Sea turtles spend at least 3-6 percent of their time at the surface for respiration and perhaps as much as 26 percent of time at the surface for basking, feeding, orientation, and mating (Lutcavage et al., 1997). Data show that collisions with all types of commercial and recreational vessels are a cause of sea turtle mortality in the GOM (Lutcavage et al., 1997). Stranding data for the U.S. Gulf and Atlantic Coasts, Puerto Rico, and the U.S. Virgin Islands show that between 1986 and 1993 about 9 percent of living and dead stranded sea turtles had boat strike injuries (Lutcavage et al., 1997). Vessel-related injuries were noted in 13 percent of stranded turtles examined from the GOM and the Atlantic during 1993 (Teas, 1994), but this figure includes those that may have been struck by boats post-mortem. Large numbers of loggerheads and 5-50 Kemp's ridley turtles are estimated to be killed by vessel traffic per year in the U.S. (NRC, 1990; Lutcavage et al., 1997).

There have been no documented sea turtle collisions with drilling and service vessels in the GOM; however, collisions with small or submerged sea turtles may go undetected. Based on sea turtle density estimates in the GOM, the encounter rates between sea turtles and vessels would be expected to be greater in water depths less than 200 m (USDOC, NMFS, 2007). To further minimize the potential for vessel strikes, BOEMRE issued NTL 2007-G04, which clarifies 30 C.F.R. § 250.282 and provides NMFS guidelines for monitoring procedures related to vessel strike avoidance measures for sea turtles and other protected species. With implementation of these measures and the avoidance of potential strikes from OCS vessels, the NMFS 2007 Biological Opinion concluded that the risk of collisions between oil/gas-related vessels (including those for G&G, drilling, production, decommissioning, and transport) and sea turtles is appreciably reduced, but strikes may still occur. The BOEMRE monitors for any takes that have occurred as a result of vessel strikes and also requires that any operator immediately report the striking of any animal (see 30 C.F.R. § 250.282 and NTL 2007-G04).

To date, there have been no reported strikes of sea turtles by drilling vessels. Given the scope, timing, and transitory nature of the proposed action and with this established mitigation, effects to sea turtles from drilling vessel collisions is expected to be negligible.

Marine Debris

Many types of plastic materials end up as solid waste during drilling and production operations. Some of this material is accidentally lost overboard where sea turtles could consume it or become entangled in it. The incidental ingestion of marine debris and entanglement could adversely affect sea turtles. As proposed in their plan, the operator proposes compliance with the guidelines provided in NTL 2007-G03 "Marine Trash and Debris Awareness and Elimination", which appreciably reduces the likelihood of sea turtles encountering marine debris from the proposed activity.

Water Degradation

Most operational discharges are diluted and dispersed when released in offshore areas and are considered to have sublethal effects (NRC, 1983; API, 1989; Kennicutt, 1995; Kennicutt et al., 1996). Any potential impacts from drilling fluids would be indirect, either as a result of impacts to prey species or possibly through ingestion via the food chain (Neff et al., 1989). Impacts from water degradation are expected to be negligible due to the localized nature of the proposed activity and the wide-ranging habits of sea turtle species in the GOM.

Accidental Events

Oil Spills and Response Activities

The oil from an oil spill can adversely affect sea turtles by causing soft tissue irritation, respiratory stress from inhalation of toxic fumes, food reduction or contamination, direct ingestion of oil and/or tar, and temporary displacement from preferred habitats. The long-term impacts to sea turtle populations are poorly understood but could include decreased survival and lowered reproductive success. The range of toxicity and degree of sensitivity to oil hydrocarbons and the effects of cleanup activities on sea turtles are unknown. Impacts from the dispersants are unknown, but may have similar irritants to tissues and sensitive membranes as they are known to have had on seabirds and marine mammals (NRC, 2005).

In the event of a catastrophic spill similar to the Macondo Event, the Catastrophic Spill Analysis in Appendix B discusses the most likely and most significant impacts to sea turtles as it relates to the four phases of a major spill/blowout:

1) **Initial Event** (Section 2.2.2.4.; Page B-9);
2) **Offshore Spill** (Section 3.2.2.4; Page B-22);
3) **Onshore Contact** (Section 4.2.2.4; Page B-35); and
4) **Post-Spill, Long-Term Recovery** (Section 5.2.2.4; Page B-43).

In the event of a catastrophic spill similar to the Macondo Event, any substantive impact to sea turtles is very unlikely because the potential impacts from a catastrophic spill would be similar to aforementioned routine and accidental issues. However, despite the recent Macondo Event, historical trends in the GOM (see Chapter 1.4) indicate that catastrophic spill events are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action.

Conclusion

The sections above discusses the potential range of effects to sea turtles from the proposed action, including: (1) vessel noise and collisions; (2) marine debris; (3) water-quality degradation from drilling rig effluents; and (4) oil spills and spill-response activities. The potential effects of the proposed activity on sea turtles will not rise to the level of significance for the following reasons:

- The best available scientific information indicates that sea turtles do not greatly use sound in the environment for survival; therefore, disruptions in environmental sound would have little effect.

- The scope, timing, and transitory nature of the proposed action will produce limited amounts of drilling noise in the environment. As described, effects of vessel noise on sea turtles are considered "discountable" (USDOC, NMFS, 2007).
- Implementation of the regulations as clarified in NTL 2007-G03 "Marine Trash and Debris Awareness and Elimination", appreciably reduces the likelihood of sea turtles encountering marine debris from the proposed activity.

The risk of collisions between sea turtles and vessels associated with the proposed action exists but would not rise to the level of significance given:

- Under 30 C.F.R. § 250.282 clarified by NTL 2007-G04, BOEMRE provides guidelines for the monitoring programs designed to minimize the risk of vessel strikes to sea turtles and other protected species and the reporting of any observations of injured or dead protected species.
- The NMFS 2007 Biological Opinion determined that monitoring measures should appreciably reduce the potential for vessel strikes. The NMFS issued an Incidental Take Statement on sea turtle species; the Statement contains reasonable and prudent measures (RPM's) with implementing terms and conditions to help minimize take. As the operator has indicated that the vessel strike avoidance guidance (NTL 2007-G04) will be followed, there should be an appreciably reduced the numbers of sea turtles that may be incidentally taken from routine offshore vessel operations; however, the available information on the relationship between these species and OCS oil and gas activities indicates that sea turtles may be killed or injured by vessel strikes. Therefore, pursuant to Section 7(b)(4) of the ESA, NMFS anticipates incidental take and granted a limited number of Incidental Take Authorizations to BOEMRE for sea turtle mortalities by vessel strikes. The BOEMRE continues to monitor for any strikes to ensure this authority is not exceeded and to date, none have been reported.
- The scope, timing, and transitory nature of the proposed action will result in limited opportunity for vessel strikes to sea turtles.

Cumulative Impact Analysis

Chapter 4.5.6 of the Multisale EIS (USDOI, MMS, 2007), and Chapter 4.1.7.4 of the Supplemental EIS (USDOI, MMS, 2008) address the cumulative impacts of oil and gas leasing, exploration, development and production activities on sea turtles. Additionally, Chapter 4.4.6 of the Multisale EIS (USDOI, MMS, 2007) contains a discussion of additional impacts to sea turtles related to accidental events (e.g., oil spills) that are relevant in light of the recent Macondo Event. This information is summarized below and is incorporated by reference into this SEA.

Activities considered under the cumulative scenario, including the proposed action, may affect sea turtles. Sea turtles may be impacted by oil and gas leasing, exploration, development and production activities including the degradation of water quality resulting from operational discharges, vessel traffic, noise generated by platforms, drillships, helicopters and vessels, seismic surveys, explosive structure removals, oil spills, oil-spill-response activities, loss of debris from service vessels and OCS structures, commercial fishing, capture and removal, and pathogens. The cumulative impact of these ongoing OCS activities on sea turtles is expected to result in a number of chronic and sporadic sublethal effects (i.e., behavioral effects and nonfatal exposure to or intake of OCS-related contaminants or discarded debris) because…that may stress and/or weaken individuals of a local group or population and that may predispose them to infection from natural or anthropogenic sources.

Few deaths are expected from chance collisions with OCS service vessels, ingestion of plastic material, commercial fishing, and pathogens. Disturbance (noise from vessel traffic and drilling operations, etc.) and/or exposure to sublethal levels of toxins and anthropogenic contaminants may stress animals, weaken their immune systems, and make them more vulnerable to parasites and diseases that normally would not be fatal during their life cycle. The net result of any disturbance depends upon the size and percentage of the population likely to be affected, the ecological importance of the disturbed

area, the environmental and biological parameters that influence an animal's sensitivity to disturbance and stress, or the accommodation time in response to prolonged disturbance (Geraci and St. Aubin, 1980). As discussed above, lease stipulations and regulations are in place to reduce vessel strike mortalities.

Incremental injury effects from the proposed action on sea turtles are expected to be negligible for drilling and vessel noise and minor for vessel collisions, but will not rise to the level of significance because of the limited scope, duration, and geographic area of the proposed drilling and vessel activities and the relevant regulatory requirements.

The effects of the proposed action, when viewed in light of the effects associated with other relevant activities, may affect sea turtles occurring in the GOM. With the enforcement of regulatory requirements for drilling and vessel operations and the scope of the proposed action, incremental effects from the proposed drilling activities on sea turtles will be negligible (drilling and vessel noise) to minor (vessel strikes). The best available scientific information indicates that sea turtles do not greatly use sound in the environment for survival; therefore, disruptions in environmental sound would have little effect. Consequently, no significant cumulative impacts would be expected from the proposed exploratory drilling activities or as the result of past, present, or reasonably foreseeable oil and gas leasing, exploration, development and production in the GOM.

3.6.2.3 Alternative 3

If selected, Alternative 3, approval of the proposed action with additional mitigation, would allow the operator to undertake the proposed activities, as requested and conditioned in the plan; however, the operator would be required to undertake additional mitigation as identified by BOEMRE. As with Alternative 2, the operator is required to follow all existing lease stipulations and regulations that would result in negating or lessening the chance of significant impacts to sea turtles. The mitigation measure outlined in Chapter 2 is not expected to increase or decrease the potential for effects to sea turtles from the proposed action. Alternative 3 does not differ from Alternative 2 because the additional mitigation measure does not address this resource (i.e., all assumptions, estimates, and conclusions are identical). See the analysis provided in Section 3.6.2.2 for this alternative for this resource.

3.7. FISH RESOURCES AND ESSENTIAL FISH HABITAT

3.7.1. Affected Environment

Healthy fish resources and fishery stocks depend on essential fish habitat (EFH) waters and substrate necessary to fish for spawning, breeding, feeding, and growth to maturity. Due to the wide variation of habitat requirements for all life history stages for managed species, NOAA initially identified EFH throughout the Gulf of Mexico to include all coastal and marine waters and substrates from the shoreline to the seaward limit of the Exclusive Economic Zone (200 mi [322 km] from shore).

Fish resources are described on a Gulfwide basis in Chapter 3.2.8 of the Multisale EIS. The Gulf of Mexico supports a wide variety of finfish, and most of the commercial finfish resources are linked either directly or indirectly to the estuaries that ring the Gulf of Mexico. The life history of estuarine-dependent species involves spawning on the continental shelf; the transportation of eggs, larvae, or juveniles back to the estuary nursery grounds; and the migration of the adults back to the sea for spawning. Movement of the adult estuarine-dependent species is essentially onshore-offshore with no extensive east-west migration. Darnell et al. (1983) observed that the density distribution of fish resources in the Gulf was highest nearshore off the central Gulf Coast. For all seasons, the greatest abundance occurred between Galveston Bay and the mouth of the Mississippi River. Recent monthly ichthyoplankton collections over the years 2004-2006 offshore of Alabama have confirmed that peak seasons for ichythoplankton concentrations on the shelf are spring and summer (Hernandez et al., 2010).

The Deepwater Horizon spill on April 20, 2010, introduced large quantities of oil into the water column between the spill site and the marshes of the central Gulf Coast. Oil from this incident has made contact with shorelines from Galveston, Texas, to Apalachicola, Florida, with the primary areas of oiling occurring from Grande Isle, Louisiana, west of the mouth of the Mississippi River to Santa Rosa Island, Florida (U.S. Department of the Interior, 2010). The oil has penetrated estuaries at least along the Louisiana and Mississippi coasts and has been driven farther inshore by the passage of Hurricane Alex, which made landfall near the Texas/Mexico border.

All of these estuaries are extremely important nursery areas (EFH) for fish and aquatic life. Impacts related to oiling of these areas, depending on the severity, can include destruction of nutrient-rich marshes, which can lead to the erosion of coastlines (when the grass dies, the coastline is moved back and eroded. Anything, whether it is salt water or oil that kills grass, erodes coastline). Marshes and coastlines in the central Gulf Coast have already been significantly damaged in recent years, first in 2005 by Hurricanes Katrina and Rita as described in Chapter 4.5.10 of the Multisale EIS and then in September 2008 when Hurricanes Gustav and Ike made landfall on the Gulf Coast. The Louisiana Dept. of Wildlife and Fisheries (2008a and b) released preliminary nonquantitative reports of the effects of Hurricane Gustav on Louisiana fisheries. In the reports, they noted the extensive marsh erosion and vegetative debris present in the canals of southeastern Louisiana as well as localized fish kills, the loss of marsh through erosion and displacement, and the encroachment of saltwater into freshwater areas, which is a contributor to loss of EFH.

Early life stages of animals are usually more sensitive to environmental stress than adults (Moore and Dwyer, 1974). Weathered crude oil has been shown in laboratory experiments to cause malformation, genetic damage, and even mortality at low levels in fish embryos of Pacific herring (Carls et al., 1999). There is a high probability of mortality in the larval stages of fishes of the Gulf that have come into contact with the spilled oil.

Corexit® 9500, the dispersant used during the Macondo Event, is believed to be the least toxic of all of its counterparts to small fish. Its toxicity, mixed with oil, to specific species is currently being studied by NOAA and USEPA, who have proposed a monitoring program that will assess the toxicity of 20:1 oil/dispersant to Atlantic silversides. Corexit® 9500 works, as do all dispersants, by breaking the oil into smaller droplets. The addition of Corexit® 9500 at the seafloor of the spill site and at the surface resulted in the dispersion of plumes of oil particles in the water column. Thus far, these underwater plumes of oil have had relatively low concentrations of oil above background, but they do pose the potential for low dissolved oxygen pockets to form as a result of microbial action utilizing available oxygen to break down the oil. The first Joint Analysis Group sampling cruise in May 2010 discovered that total petroleum hydrocarbon concentrations were at or below 2 parts per million and that there were no indications of large-scale hypoxiaareas devoid of oxygen that do not support marine life. (Joint Analyis Group, 2010). The full extent of the ichthyplankton mortality due to all factors related to the oil and dispersantsis unknown and may not be known unless a significant portion of a year class is absent from next year's fishery.

Methane gas (CH4) is commonly found in the Gulf of Mexico in concentrations ranging from 6 x10 - 5 ml/l to 125 x 10-5 ml/l (Frank et al, 1970). Recent reports resulting from the Deepwater Horizon spill have indicated elevated methane levels as a result of this spill, although no specific methane levels have as yet been reported. At their baseline levels, methane levels are controlled by methanotrophs (methane degrading bacteria) (Patin, 1999). Very little is really known about the effects of methane on fish. Patin, (1999), reported that elevated concentrations of methane resulting from gas blowouts from drilling platforms in the Sea of Asov, resulted in significant species specific pathological changes including damages to cell membranes, organs and tissues, modifications of protein synthesis and other anomalies typical for acute poisoning of fish. These impacts, however, were observed at levels of 1-10 ml/l.

Adult fish tend to avoid contact with oil in the water column. Specific effects of oil on fish can include direct lethal toxicity, sublethal disruption of physiological processes (internal lesions), effects of direct coating by oil (suffocation by coating gills), incorporations of hydrocarbons, causing tainting or accumulation in the food chain and changes in biological habitat (Moore and Dwyer, 1974). In the case of biological habitat, changes include the potential for contact with waters low in dissolved oxygen, as described above. Direct lethality of the dispersant used and the dispersant mixed with oil is unknown for individual fish species.

Thus far, only anecdotal (observational) evidence is available concerning fish kills. Offshore, a few small fish kills very near the spill site have been reported. On the shelf and off the coast of Louisiana, a few small fish kills have been reported that included common inshore species such as menhaden and saltwater catfish (Bourgeois, personal communication, 2010). Similar kills with similar species composition have been reported in off the coasts of Mississippi (Devers, Pers. Comm) and Alabama (Denson, Pers. Comm.).

Recently, whale sharks were sited swimming in heavy oil 4 mi (6.4 km) from the spill site. These large, migratory sharks have been traced by satellite tags to come to the Gulf in the summer from as far away as Belize and Honduras. They are surface feeders, filtering plankton and tiny fish through their

mouths. Oil poses a threat to them not only by direct ingestion but also by coating their gills (Raines, 2010).

Of particular importance is the bluefin tuna that spawn in the northwestern and northeastern Gulf in January through June, with peak spawning in April and May (Teo et al., 2007a and b). The bluefin tuna forage from the surface down as far as 3,000 ft (914 m) (Horst and Lane, 2007). Eggs, which are produced in large numbers and fertilized externally at depth, quickly become buoyant and float to the surface (Teo et al., 2007a and b). The bluefin tuna is a prized commercial and sport fish that could potentially occur in the area of the proposed action. The western Atlantic stock of bluefin tuna has suffered a significant decline in spawning stock biomass since 1950, and a 20-year rebuilding plan has failed to revive the population or the North American fishery. The failure of the Gulf of Mexico spawning population to rebuild, as well as the scope of illegal and under-reported catches - particularly in the Mediterranean Sea - are of such major concern that the species was recently considered by the Convention of International Trade in Endangered Species (CITES) for endangered species listing in March 2010. Because of their decline in stock, the timing of their spawn in the Gulf, their buoyant eggs, and the timing of the Deepwater Horizon spill, there is concern about further decline in the Gulf stock of blue fin tuna. The effects at this time are, however, unknown.

How assemblages of fish have changed or will change as a result of the Deepwater Horizon incident is unknown at this time. Adult fish tend to avoid contact with oil in the water column. Specific effects of oil on fish can include direct lethal toxicity, sublethal disruption of physiological processes (internal lesions), effects of direct coating by oil (suffocation by coating gills), incorporations of hydrocarbons in organisms causing tainting or accumulation in the food chain and changes in biologic habitat (Moore and Dwyer, 1974).

The benthic fish populations of the Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 are expected to be very low in density. Rowe and Kennicutt (2001) found that species richness and abundance decreased with depth in the Gulf of Mexico. In the 2,000- to 3,000-m depth zone, only 71 species representing 33 families were collected, although nearly one-third of the species were epipelagic or mesopelagic and were probably captured in the water column.

Descriptions of other ecological groups of fishes that would occur in the area, including oceanic pelagics and mesopelagics, can be found in Chapter 3.2.8.1 of the Multisale EIS.

3.7.2. Impact Analysis

The impact-producing factors associated with exploration activities proposed in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 that could affect EFH and fish resources include: (1) coastal and marine environmental degradation; (2) presence of a semisubmersible drill rig; (3) temporary discharge of drilling cuttings and associated drilling fluids; and (4) blowouts and oil spills. Chapters 4.2.1.1.8, 4.2.2.1.10, and 4.4.10 of the Multisale EIS (USDOI, MMS, 2007b) contain a discussion of impacts to fish resources and EFH from OCS activity and are hereby incorporated by reference into this SEA.

3.7.2.1 Alternative 1

If selected, Alternative 1, no action alternative (disapproval of the proposed action), would result in the operator not being permitted to drill the proposed exploration wells. Therefore, the impact producing factors to fish and EFH would not occur. For example, there would be no drilling noise that would result in behavioral change, masking, or non-auditory effects to the fish resources, no long-term or permanent displacement of fish resources from preferred habitats, and no destruction or adverse modification of any habitats.

3.7.2.2 Alternative 2

If selected, Alternative 2, approval of the proposed action as submitted by the operator, would allow the operator to drill the proposed exploration wells. As described in the analyses below, impacts to fish and EFH from the proposed action are expected to be short-term, localized and not lead to significant impacts.

Routine Activities

Routine activities, such as the discharge of drilling fluids and cuttings offshore would contribute to localized temporary marine environmental degradation. Drilling operations are restricted in time, and pelagic species in the area could easily avoid discharge plumes. Routine discharges from the semisubmersible drilling rig would be highly diluted in the open marine environment. The presence of the semisubmersible drilling rig will also act as a fish-attracting device for the short period of time the semisubmersible drilling rig is on each site, and consequently, routine discharges on fish resources will be very limited in duration.

Accidental Events

Accidental blowouts and spills with associated hydrocarbons also have the potential to affect fish resources and EFH, but there is no evidence to date that fish or EFH in the Gulf have been adversely affected on a regional population level by spills or chronic contamination. The effects of the Deepwater Horizon Spill on ichthyoplankton, juvenile and adult fish in the Gulf of Mexico and the extent of those effects are, at this time, unknown and will be unknown for some time.

A discussion of the impacts of oil on adult fish, fish eggs, and larvae can be found in Chapter 4.2.2.1.10 of the Multisale EIS. Given that the potential for a blowout or a spill is small, there is a limited possibility for large amounts of oil released from a blowout or spill reaching shore.

In the event of a catastrophic spill similar to the Macondo Event, the Catastrophic Spill Analysis in Appendix B discusses the most likely and most significant impacts to fish as it relates to the four phases of a major spill/blowout:

1) **Initial Event** (Section 2.2.2.2.; Page B-9);
2) **Offshore Spill** (Section 3.2.2.2; Page B-20);
3) **Onshore Contact** (Section 4.2.2.2; Page B-34); and
4) **Post-Spill, Long-Term Recovery** (Section 5.2.2.2; Page B-43).

In the event of a catastrophic spill similar to the Macondo Event, any substantive impact to fish is very unlikely because the potential impacts from a catastrophic spill would be similar to aforementioned routine and accidental issues. However, despite the recent Macondo Event, historical trends in the GOM (see Chapter 1.4) indicate that catastrophic spill events are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action.

Conclusion

The proposed action is expected to have little impact on any fish or EFH endemic to the northern Gulf of Mexico. Specific effects from any one oil spill would depend on several factors, including timing, location, volume and type of oil, environmental conditions, and countermeasures used. If a blowout occurred, ichythyoplankton, fish eggs, or larvae would suffer mortality in areas where their numbers are concentrated and where oil concentrations are high. However, impacts are still expected to be minimal to nonexistent based on the low probability of a spill occurring (see Chapter 1.4)

Cumulative Impacts

Cumulative impacts on fish and EFH that result from oil and gas leasing, exploration, development, and production activity are discussed in Chapter 4.5.10 of the Multisale EIS. Cumulative activities that could impact fish and EFH include State oil and gas activity, coastal development, crude oil imports by tanker, commercial and recreational fishing, hypoxia (i.e., red or brown tides), removal of OCS structures, and offshore discharges of drilling muds and produced waters. It is expected that environmental degradation from the the proposed action and non-OCS activities would affect fish populations and EFH; however, the incremental contribution of the proposed action to these cumulative impacts would be small and almost undetectable. Therefore, no significant cumulative impacts on EFH and fish resources would be expected as a result of the proposed exploration activities when added to the impacts of past, present, or reasonably foreseeable oil and gas development in the area as well as other activities in the area.

3.7.2.3 Alternative 3

If selected, Alternative 3, approval of the proposed action with additional mitigation, would allow the operator to undertake the proposed activities, as requested and conditioned in the plan; however, the operator would be required to undertake additional mitigation as identified by BOEMRE. As described in the analyses above, impacts to fish and EFH from the proposed action are expected to be short-term, localized and not lead to significant impacts. The mitigation measure outlined in Chapter 2 is not expected to increase or decrease the potential for effects to fish and EFH from the proposed action. Alternative 3 does not differ from Alternative 2 because the additional mitigation measure does not address this resource (i.e., all assumptions, estimates, and conclusions are identical), see the analysis provided in Section 3.7.2.2 for this alternative for this resource.

3.8 ARCHAEOLOGICAL RESOURCES

3.8.1 Affected Environment

Archaeological resources are defined in 30 C.F.R. § 250.105 as "any material remains of human life or activity that are at least 50 years of age and that are of archaeological interest." Archaeological resources on the OCS can be divided into two types: prehistoric and historic. Detailed descriptions of these resource types are provided in Chapter 3.3.4 of the Multisale EIS and Chapter 4.1.15.1 of the Supplemental EIS. The following information is a summary of these descriptions, which are hereby incorporated by reference into this SEA.

Prehistoric

Geographic features that have a high probability for associated prehistoric sites in the northwestern and north central Gulf (from Texas to Alabama) include barrier islands and back barrier embayments, river channels and associated floodplains and terraces, and salt dome features. Also, a high probability for prehistoric resources may exist landward of a line that roughly follows the 60-m bathymetric contour, which represents the Pleistocene shoreline during the last glaciation some 12,000 years ago when the coastal area of Texas and Louisiana is generally considered to have been populated. Water depth at the proposed drill site precludes the potential for prehistoric sites or artifacts.

Historic

Historic archaeological resources on the federal OCS include shipwrecks and a single light house (Ship Shoal Light). Historic research has identified over 4,000 potential shipwreck locations in the Gulf, with nearly 1,500 of these potential shipwreck locations on the OCS (Garrison et al., 1989). The historic record, however, is by no means complete, and the predictions of potential sites may be inaccurate. As demonstrated by several studies (e.g., Pearson et. al. 2003; Lugo-Fernandez et al., 2007; Krivor et al., 2011; and Rawls and Bowker-Lee, in press) many more shipwrecks are likely to exist on the seafloor than have been accounted for in available historic literature, indicating a high-resolution remote sensing survey may be the most reliable method for identifying and avoiding historic archaeological resources.

Historic shipwrecks have, with the exception of three significant vessels found by treasure salvers, been primarily discovered through oil industry sonar surveys in water depths up to 7,400 ft. In fact, in the last 5 years, over a dozen shipwrecks have been located in deep water and nine of these ships have been confirmed visually as historic vessels. Many of these wrecks were not previously suspected to exist in these areas, based on the historic record.

The Macondo Event released an estimated 53,000-62,000 bbl of oil per day for almost 3 months. Much of the oil was treated with dispersant at the sea surface and at the source in a water depth of 1,500 m (5,000 ft). In Chapter 4.1.15.3 of the Supplemental EIS, it was concluded that "impacts [from an oil spill] to historic resources would be limited to visual impacts and, possibly, physical impacts associated with spill cleanup operations." This analysis did not anticipate the use of dispersants at the wellhead that could result in currently unknown effects from dispersed oil droplets settling to the seafloor and that could possibly contaminate exposed artifacts and wood or steel hulls such as those observed on many deepwater sites (Atauz et al., 2006; Church et al., 2007; Church and Warren 2008; Ford et al., 2008). BOEMRE recognizes the need to better understand the effects of deep water oil spills and dispersants on submerged

archaeological resources and is pursuing options for developing studies to assist in collection and interpretation of this data; however, even if a study was initiated immediately, the resulting information would not be available in time to inform the analysis for this proposed action.

The best available information does not provide a complete understanding of the effects, if any, of the spilled oil from the Macondo Well and potential response/cleanup activities on archaeological resources that may be located in deep water. Though information on the actual impacts to submerged archaeological resources is non-existent at this time, oil settling to the seafloor due to dispersant use at the wellhead could come into contact with archaeological resources. At present, there is no evidence of this having occurred. A recent experimental study has suggested that while the degradation of wood in terrestrial environments is initially retarded by contamination with crude oil; at later stages, the biodeterioration of wood was accelerated (Ejechi, 2003). While there are different environmental constraints that affect the degradation of wood in terrestrial and waterlogged environments, soft-rot fungal activity, one of the primary wood degrading organisms in submerged environments, was shown to be increased in the presence of crude oil.

3.8.2. Impact Analysis

The impact-producing factor (IPF) associated with the proposed action that could affect submerged archaeological resources is seafloor disturbances. Chapters 4.2.1.1.12 and 4.2.2.1.14 of the Multisale EIS (USDOI, MMS, 2007) and Chapter 4.1.15.2 of the Supplemental EIS (USDOI, MMS, 2008) contain discussions of the likely impacts (routine, accidental, and cumulative) that OCS activities could have on archaeological resources. These discussions are summarized below and hereby incorporated by reference into this SEA.

The routine IPF associated with Shell's proposed exploration activities in Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 that could affect archaeological resources is limited to direct contact or disturbance during well emplacement by the well or equipment used for the drilling operations (including anchors, anchor chains, and lines). If a historic resource exists in the area of proposed action, direct physical contact with a shipwreck site could destroy fragile remains, such as the hull and wooden or ceramic artifacts, and could disturb the site context (Atauz et al., 2006; Church and Warren, 2008). The IPFs that could be associated with accidental events include seafloor disturbances from jettisoned/lost debris and, as discussed above, deterioration from potential oil spills. Similar to routine impacts, discarded/lost material that falls to the seabed has the potential to damage and/or disturb any archaeological resources. Oil spills and their remediation efforts could also accelerate deterioration of archaeological resources. A detailed discussion of all potential impacts is found below.

3.8.2.1 Alternative 1

If selected, Alternative 1, the *no action alternative* (disapproval of the proposed action), would result in the operator not being permitted to drill the proposed exploration wells. Therefore, the IPFs mentioned above (i.e., bottom disturbance associated with well emplacement, use of equipment associated with drilling operations, and anchoring) would not take place, and any impact that these actions could cause would not occur. Likewise, under the no action alternative, there would be no possibility of a spill. As a result, whatever archaeological resources may be present in the area of potential effect (APE) would not be affected in any way if the no-action alternative were selected.

3.8.2.2 Alternative 2

Alternative 2, approval of the proposed action as submitted by the operator, would allow the operator to drill the proposed exploration wells. Examples of potential impacts to archaeological resources without implementation of the mitigation noted in Chapter 2.4 and the following analysis include, but are not limited to, damage to potential resources from well emplacement and lost/discarded material. (More details on the potential for impacts absent these mitigation measures are described further in the sections below.) Without mitigation, this Alternative would not limit or negate potential impacts to archaeological resources beyond what is proposed in the EP itself or under applicable law.

Routine Activities

Historic modeling assumes that shipwrecks would be found closest to shore along the Federal/State boundary or within 10 miles of their reported loss location. However high-resolution data acquired by oil and gas industry remote sensing surveys now indicates that this model may be too limited. For example, several vessel casualties from World War II with historically reported coordinates were later discovered well over ten miles outside the 9-block square area assumed to be their location by the model (Irion, 2002). An early nineteenth century steamship lost off the Texas coast was found by treasure salvers over 120 miles from the area of its presumed loss in the MMS model (Irion, personal communication, 2011). These situations, coupled with the fact that no confirmed historic shipwreck sites had been found in any of the designated historic high probability area in 20 years, led to a new study released in 2003 (Pearson et al., 2003) to reassess the high-probability model. Some of the recommendations of this study were implemented in July of 2005 with the revision of NTL No. 2005-G07, *Archaeological Resource Surveys and Reports*, which added 1,802 lease blocks, mostly in deepwater locations in Mississippi Canyon (MC), Green Canyon (GC), and Viosca Knoll (VK) areas, to the "high-probability" block list requiring archaeological surveys. The table below notes the results of the requisite surveys implemented since 2003.

Table 3.8.1.
Archaeological Surveys and Resources Identified since 2003

Year	Blocks Surveyed	Confirmed Shipwreck Sites	Potential Shipwreck Sites Mitigated by Avoidance (identified through requisite industry surveys)
2003	233	1	514 magnetic anomalies and 43 sonar targets
2004	139	3	342 magnetic anomalies and 57 sonar targets
2005	902	16	768 magnetic anomalies and 116 sonar targets
2006	237	37	799 magnetic anomalies and 254 sonar targets
2007	319	18	652 magnetic anomalies and 189 sonar targets
2008	166	17	705 magnetic anomalies and 212 sonar targets
2009	117	9	479 magnetic anomalies and 103 sonar targets
2010[2]	74	8	275 magnetic anomalies and 101 sonar targets

Prior to NTL No. 2005-G07, there were only 48, 9-mi^2 lease blocks in the MC area that required archaeology surveys/assessments; in which, 9 potential shipwrecks were previously located. Since implementation of the NTL and addition of 794 blocks in the MC area, an additional 25 confirmed shipwrecks have been discovered to date as a result of the surveys conducted on only 306 of those new MC blocks. During that same time period, BOEMRE also conducted 2,250 archaeological reviews of proposed oil and gas operations in the MC area and identified 537 previously-unreported sonar targets that may or may not represent historic sites. The addition of the new blocks, industry's resultant survey data, and the subsequent increase in the number of shipwrecks discovered further suggests that the potential distribution of significant historic resources is wider than originally thought.

To date, two historically-significant shipwrecks (see Table 3.8.2.) were found to have suffered damage from drilling activities because of a lack of knowledge of their presence.

2 BOEMRE GOMR received a substantially lower number of surveys following the Macondo Event.

Table 3.8.2. Archaeological Sites Identified since 2001 that Have Suffered Damage			
Shipwreck ID Number	Protraction	Survey Available Prior to Permitting (to assist in mitigation)	Damage
15321	VK	No	Anchor chain from a MODU bisected shipwreck causing major damage to site. The site and the damage from the MODU anchoring array were identified during a pipeline survey.
521	GC	No	Site was impacted during anchoring of a MODU. Anchor and chain was hung up on the site during anchor recovery. The site and damage were identified during a pipeline survey and though the damage appears to be major, a complete impact assessment has yet to be conducted.

Recent research on historic shipping routes from the 16th through the 19th centuries concluded that the area of the proposed action is located along the colonial French and Spanish trade routes between Veracruz, New Orleans, and Havana, increasing the likelihood that historic shipwrecks could be located in this area of the GOM (Lugo-Fernandez et al., 2007; Krivor et al., 2011; see Figure 3-1). The study, entitled *Archival Investigations for Potential Colonial-Era Shipwrecks in Ultra-Deep Water within the Gulf of Mexico,* projected a 100-mile wide swath encompassing the variation in the depiction of the historic trade routes on contemporary maps. The routes generally struck a course north northeastward from Veracruz until reaching the Loop Current between 25º and 27.5º north latitude, then traveled westward to west Florida, then turned southeast, crossed the Florida Straits, and reached Havana. A wide variability within the general route may be expected as a result of several factors that affected navigation during this period including: the limited capabilities of the navigational technology available to sailors[3], shifting currents, and prevailing wind patterns and storms.

The paleographer and scientists analyzing the records admitted that due to the sheer volume of records[4] and limited study funding they were unable to examine all records for the period; however, the authors noted that the records that were examined were not detailed enough to identify accurately where a wreck occurred or was likely to have occurred. The authors reported that while vessel losses were noted throughout the historic record, the precise location of vessel loss was impossible to identify based on limiting factors such as the capabilities of sailors to accurately note where a wrecking event occurred using contemporary navigational techniques and tools. Additionally, the authors reported that the historic documents often noted that a vessel may have left a port such as Veracruz bound for New Orleans or Havana, crossing over the deepwater protractions of the GOM, but never arrived at its final destination. These records would simply note that the vessel was lost enroute to their final destination. The authors concluded that it would be impossible to accurately identify losses of historic shipwreck sites based on archival information alone and that high-resolution survey data in these areas was necessary to accurately prevent impacts to significant archaeological sites (Krivor et al., 2011).

The study area including the area of the proposed action continued to be traversed extensively by shipping throughout the 19th and 20th centuries as new ports developed along the Texas coast, such as Galveston (est. 1825) and Brazos Santiago (1848). With the advent of steam, oil screw, and gasoline or diesel-propelled vessels and improved navigational instruments, sailors' options to set a course irrespective of prevailing winds and currents greatly increased expanding even further the potential for a shipwreck to have occurred in the project area.

3 Longitude, for example, could not be calculated with any degree of certainty until the perfection of the chronometer in the last quarter of the 18th century.

4 The Archivo General de Indias in Seville contains some 80-86 million pages of documents in 46,000 *Legajos*, or "Bundles."

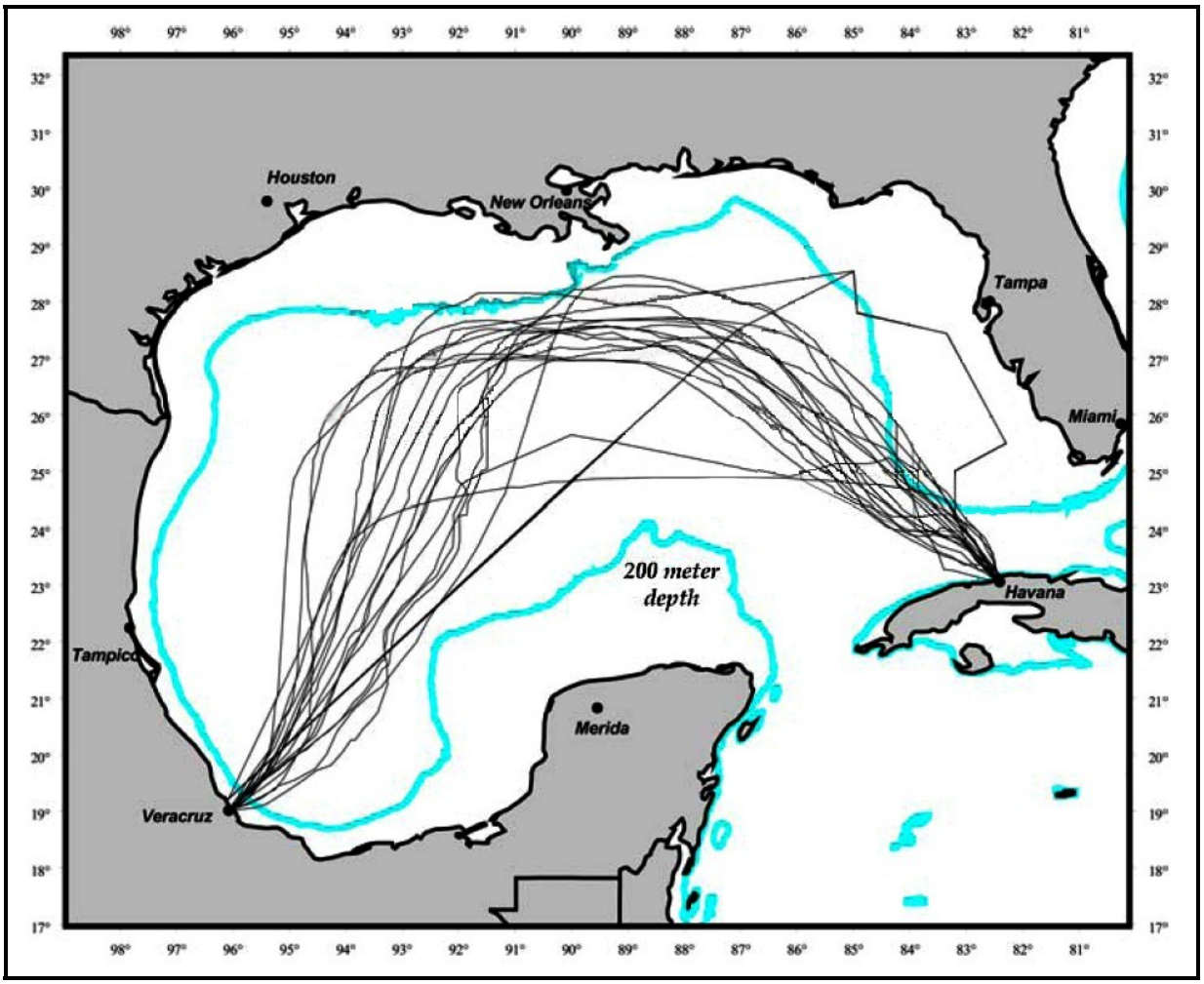

Figure 3-1. Sailing routes across the Northern GOM as depicted on 16th through mid-19th century maps (*from* Lugo-Fernandez et al., 2007).

Based on these recent studies and findings, there is a likelihood that an archaeological resource may exist in the area of the proposed action and that Shell's proposed activities have the potential to cause impacts in the event that a resource is present. BOEMRE's regulation at 30 C.F.R. § 250.194 requires that an archaeological survey be conducted prior to development of leases within the high-probability zones for historic and prehistoric archaeological resources. Currently, Mississippi Canyon Area, Blocks 347, 348, 349, 391, 392, 393, 435, and 436 are designated as high-probability blocks. Shell has conducted surveys covering the areas of potential bottom impacts. From these high-resolution surveys, sidescan sonar targets have been identified near/within the area of Shell's proposed activity. These targets may potentially represent significant archaeological resources.

Impacts to a historic site could result from direct physical contact causing irreversible damage. The undisturbed provenience of archaeological data (i.e., the 3-dimensional location of archaeological artifacts) allows archaeologists to accumulate a record of where every item is found, and to develop a snapshot as to how artifacts relate to other items or the site as a whole. The analysis of artifacts and their provenience is one critical element used to make a determination of eligibility to the National Register of Historic Places and is essential in understanding past human behavior and ways of life. Impacts from drilling operations could alter the provenience and destroy fragile remains, such as the hull, wood, glass, ceramic artifacts and possibly even human remains, or information related to the operation or purpose of the vessel. The destruction and loss of this data eliminates the ability of the archaeologist to fully and accurately detail activity areas found at the site, variation and technological advances lost to history, the

age, function, and cultural affiliation of the vessel, and its overall contribution to understanding and documenting the maritime heritage and culture of the region.

Accidental Events

Although unlikely, accidental blowouts and spills from the proposed action could lead to oil contact with submerged archaeological resources. While there is no information on the actual impacts of the Macondo Event on submerged archaeological resources, should an accidental blowout and spill occur during the operator's proposed action, oil may settle on the seafloor due to dispersant use at the wellhead and could come into contact with archaeological resources. Although there is uncertainty and limited data on the effects of an oil spill at depth on submerged archaeological resources, a recent experimental study has suggested that while the degradation of wood in terrestrial environments is initially retarded by contamination with crude oil; at later stages, the biodeterioration of wood was accelerated (Ejechi, 2003). While there are different environmental constraints that affect the degradation of wood in terrestrial and waterlogged environments, soft-rot fungal activity, one of the primary wood degrading organisms in submerged environments, was shown to be increased in the presence of crude oil. No impacts are expected from marine remediation efforts because bottom-disturbing activities are not anticipated.

Another IPF that could result from an accidental event is from the loss of debris from the MODU during drilling operations. Debris such as structural components (i.e., grating, wire, tubing, etc.), boxes, pallets, and other loose items can become dislodged during heavy seas or storm events and fall to the seabed. Similarly, thousands of joints of drill pipe are used during drilling operations; requiring regular transport out to the MODU via workboats. There is the potential to lose pieces of drill pipe during transfer operations or when "tripping pipe" in and out of the wellbore. Similar to the impacts noted under Routine Activities, if lost drill pipe or debris were to fall onto an unknown archaeological resource near the well site, damage could destroy fragile remains, such as the hull and wooden or ceramic artifacts, and could disturb the site's context and associated artifact assemblage. Additionally, lost material could result in the masking of actual archaeological resources or the introduction of false targets that could be mistaken in the remote sensing record as historic resources.

In the event of a catastrophic spill similar to the Macondo Event, the Catastrophic Spill Analysis in Appendix B discusses the most likely and most significant impacts to archaeological resources as it relates to the four phases of a major spill/blowout:

1) **Initial Event** (Section 2.2.3.1.; Page B-14);
2) **Offshore Spill** (Section 3.2.3.1; Page B-31);
3) **Onshore Contact** (Section 4.2.3.1; Page B-43); and
4) **Post-Spill, Long-Term Recovery** (Section 5.2.3.1; Page B-52).

In the event of a catastrophic spill similar to the Macondo Event, any substantive impact to archaeological resources is very unlikely because the potential impacts from a catastrophic spill would be similar to aforementioned routine and accidental issues. However, despite the recent Macondo Event, historical trends in the GOM (see Chapter 1.4) indicate that catastrophic spill events are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action.

Conclusion

Based on the previous information, study conclusions, and the number of confirmed wrecks recently found in similar water depths, there is reason to believe that archaeological resources could be present in the area of the proposed action. Shell has conducted high-resolution surveys covering the area of potential effects (APE) and the surveys noted the presence of several sidescan sonar targets. These targets may represent significant archaeological resources. Routine impacts may include damage and/or disturbance to the potential resources from drilling the well, associated equipment, and anchoring. Impacts from accidental events related to the proposed action such as accidental oil spills and their remediation efforts are not expected because of the water depth at the well sites and the historically low probability of a loss of well control/blowout. However, debris resulting from accidental events could lead to impacts similar to those expected from routine impacts such as contact with the well and/or well equipment. Since it is likely that a submerged archaeological resource could exist in the area of the

proposed action and sonar targets have been identified, without necessary avoidance mitigation, selecting Alternative 2 could result in significant impacts to archaeological resources.

Cumulative Analysis

Cumulative impacts on unknown archaeological resources that may be present in the area of the proposed action could result from other GOM activities. Since water depth at the proposed well sites is approximately 7,150 ft (2,179 m) and the area of the proposed action is over 70 mi (113 km) from shore, those activities would be limited to commercial fishing, marine transportation, and adjacent oil and gas exploration, development, and production operations.

During adjacent oil and gas operations, commercial fishing, and maritime transportation activities, there is associated the loss or discard of debris that could result in the masking of archaeological resources or the introduction of false targets that could be mistaken in the remote sensing record as historic resources. Future exploration, development, and production operations and/or any related infrastructure support could lead to bottom disturbances in the area of the proposed action; however, no additional activities have been proposed or are under review at this time. Similarly, geologic and geophysical (G&G) surveys could result in the seabed deployment of receivers and/or their anchors that have the potential to damage unknown archaeological resources that may exist in the area of the proposed action as they descend through the water column; however, they are not expected to cause significant impacts.

Unknown archaeological resources could be impacted by contact with oil from a blowout or spill from adjacent oil and gas operations. The cumulative impacts from accidental oil spills and remediation efforts for adjacent oil and gas operations are not expected because of the water depth at the well sites and the historically low probability of a loss of well control/blowout.

Considering the potential cumulative impacts from all other GOM activities, the operator's proposed drilling activities would constitute the primary effect on any unknown archaeological resource that may exist in the area of the proposed action.

3.8.2.3 Alternative 3

Alternative 3, approval of the proposed action with additional mitigation, would allow the operator to undertake the proposed activities, as requested; however, the operator will be required to follow avoidance criteria as identified by BOEMRE. The additional conditions outlined in Section 2.4 and discussed below would ensure that potential archaeological resources identified in the area of the proposed action are avoided by bottom-disturbing activities and are subsequently protected. For the reasons set forth below, inclusion of these measures under Alternative 3 allows the activity to proceed while limiting/negating potential impacts to archaeological resources.

Routine Activities

The analysis of the possible impacts from routine activities for Alternative 3 remains the same as that discussed for Alternative 2, above. As previously noted, Shell's proposed activities have the potential to cause impacts to potential archaeological resources identified through their survey work. Impacts to a historic site could result from direct physical contact causing irreversible damage. The undisturbed provenience of archaeological data (i.e., the 3-dimensional location of archaeological artifacts) allows archaeologists to accumulate a record of where every item is found, and to develop a snapshot as to how artifacts relate to other items or the site as a whole. The analysis of artifacts and their provenience is one critical element used to make a determination of eligibility to the National Register of Historic Places and is essential in understanding past human behavior and ways of life. Impacts from drilling and anchoring operations could alter the provenience and destroy fragile remains, such as the hull, wood, glass, ceramic artifacts and possibly even human remains, or information related to the operation or purpose of the vessel. The destruction and loss of this data eliminates the ability of the archaeologist to fully and accurately detail activity areas found at the site, variation and technological advances lost to history, the age, function, and cultural affiliation of the vessel, and its overall contribution to understanding and documenting the maritime heritage and culture of the region.

By requiring the applicant to avoid the sonar targets under Alternative 3, these potential impacts would be avoided to the maximum extent practicable. In addition to avoidance, the mitigation allows the

operator to work with BOEMRE to undertake additional investigation to determine if the targets are archaeological resources. The implementation of the mitigation reduces the potential for impacts from routine events of the proposed action.

Accidental Events

The analysis of the possible impacts from accidental events for Alternative 3 remains the same as that discussed for Alternative 2, above. Although unlikely, accidental blowouts and spills from the proposed action could lead to oil contact with submerged archaeological resources. Although there is uncertainty and limited data on the effects of an oil spill at depth on submerged archaeological resources, a recent experimental study has suggested that while the degradation of wood in terrestrial environments is initially retarded by contamination with crude oil; at later stages, the biodeterioration of wood was accelerated (Ejechi, 2003). While there are different environmental constraints that affect the degradation of wood in terrestrial and waterlogged environments, soft-rot fungal activity, one of the primary wood degrading organisms in submerged environments, was shown to be increased in the presence of crude oil.

Similar to the impacts from seabed disturbances noted under Routine Activities, if lost drill pipe or debris were to fall onto an unknown archaeological resource near the well site, damage could destroy fragile remains, such as the hull and wooden or ceramic artifacts, and could disturb the site's context and associated artifact assemblage. Additionally, lost material could result in the masking of actual archaeological resources or the introduction of false targets that could be mistaken in the remote sensing record as historic resources.

In the event of a catastrophic spill similar to the Macondo Event, any substantive impact to archaeological resources is very unlikely because the potential impacts from a catastrophic spill would be similar to aforementioned routine and accidental issues. However, despite the recent Macondo Event, historical trends in the GOM (see Chapter 1.4) indicate that catastrophic spill events are not likely to occur as a result of drilling and temporary abandonment associated with the proposed action.

The potential for accidental events associated with the proposed action would be limited or negated under this Alternative 3 by distancing the bottom disturbing activities, including well drilling operations and anchoring activities, away from the potential archaeological resources. In addition to avoidance, the mitigation allows the operator to work with BOEMRE to undertake additional investigation to determine if the targets are archaeological resources. In the unlikely event of a catastrophic spill, however, with oil entrained in the water column and/or the use of dispersants, oil may travel far enough to have the potential to impact archaeological resources present.

Conclusion

Based on the previous information, study conclusions, and the number of confirmed wrecks recently found in similar water depths, there is reason to believe that archaeological resources could be present in the area of the proposed action. Shell has conducted high-resolution surveys covering the area of potential effects (APE) and the surveys noted the presence of several sidescan sonar targets. These targets may represent significant archaeological resources. Routine impacts may include damage and/or disturbance to the potential resources from drilling the well, associated equipment, and anchoring. Impacts from accidental events related to the proposed action such as accidental oil spills and their remediation efforts are not expected because of the water depth at the well sites and the historically low probability of a loss of well control/blowout. However, debris resulting from accidental events could lead to impacts similar to those expected from routine impacts such as contact with the well and/or well equipment.

The avoidance mitigation outlined in Section 2.4 will reduce the likelihood of an impact to the potential archaeological resources near/within the area of the proposed activities. Therefore, under Alternative 3, the proposed action is not expected to result in significant impacts to currently unknown archaeological resources.

Cumulative Analysis

The cumulative analysis for Alternative 3 remains the same as that discussed for Alternative 2, above. However, the imposition of the avoidance requirements identified in Chapter 2.4 will further ensure that the potential impacts of the proposed action on potential archaeological resources that may exist within

the area of the proposed action will be low or non-existent, because activities will be sited away from the potential archaeological resources. Therefore, no significant cumulative impacts on archaeological resources would be expected as a result of the proposed exploration activities when added to the impacts of past, present, or reasonably foreseeable oil and gas development in the area as well as other activities in the area.

4. CONSULTATION AND COORDINATION

Consultations with FWS and NMFS under Section 7 of the Endangered Species Act of 1973 on the effects of the Five-Year Outer Continental Shelf Oil and Gas Leasing Program (2007-2012) in the Central and Western Planning Areas of the Gulf of Mexico were completed in 2007. The BOEMRE requested annual concurrence from both NMFS and FWS under these existing consultations. For 2010, NMFS communicated their concurrence, by an email message, to BOEMRE on December 3, 2009, and FWS communicated their concurrence, by an email message to BOEMRE on December 8, 2009.

In response to the Macondo Event, BOEMRE will request reinitiation of the existing consultations from both FWS and NMFS. The existing consultations remain in effect until the reinitiated consultation is completed and new Biological Opinions are available. In the interim, BOEMRE will continue to comply with all Reasonable and Prudent Measures and the Terms and Conditions under these existing consultations, along with implementing the current BOEMRE-imposed mitigation, monitoring, and reporting requirements. Based on the most recent and best available information at the time, BOEMRE will also continue to closely evaluate and assess risks to listed species and designated critical habitat in upcoming environmental compliance documentation under NEPA and other statutes.

5. PUBLIC COMMENT

On March 31, 2011, Shell's plan was deemed complete and placed on Regulations.gov for a 10-day public review period. Upon the close of the comment period on April 10, 2011, comments were received from 8 individuals representing either themselves and/or industry/non-governmental organizations. The plan was placed back on Regulations.gov on April 13, 2011, for an additional comment period after receipt of the final plan amendment. Upon close of the amendment's 5-day public review period on April 18, 2011, no additional comments were received. A review was conducted of all comments received; however, no new or additional information was provided that required modification of the NEPA review or resulted in changes to the analyses prepared in this SEA.

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8. APPENDICES

Appendix A—Accidental Oil-Spill Discussion

Appendix B—Catastrophic Spill Event Analysis

Appendix A
Accidental Oil-Spill Discussion

ACCIDENTAL OIL SPILL DISCUSSION

Introduction

The past several decades of spill data for all water depths on the Gulf of Mexico Federal Outer Continental Shelf (OCS) show that accidental oil spills (≥1,000 barrels [bbl]) associated with oil and gas exploration and development are low-probability events in OCS waters of the Gulf of Mexico. However, as the 2010 Macondo Event in Mississippi Canyon Area, Block 252 (MC 252) has shown, there is a potential, however slight, for such spills to occur and the impacts have the potential to be catastrophic. The discussion in this appendix describes a low probability catastrophic spill specific to the proposed activity whereas Appendix B provides a more generic overview of potential impacts on the environment from a catastrophic event such as the Macondo spill.

Potential Sources of a Spill

Potential sources of hydrocarbon spills from an OCS drilling activity would include the following:

- a storage tank(s) accident on the semi-submersible drilling rig;
- a transfer operation mishap between the supply vessel and the drilling rig;
- a leak resulting from damage to the fuel tanks on one of the supply or crew boats; and/or
- a blowout of one of the proposed wells.

Facility Storage and Transfer Operations

As indicated above, offshore spills from an OCS activity are possible if an accident were to damage a storage tank on board the drilling rig, crewboat, or supply vessels. Transfer incidents during the offloading of diesel fuel to the drilling rig are also possible. The associated tank volumes will vary depending on the rig used and vessel support required for the proposed action. The specifics are outlined in the respective plan and in Chapter 1.4 of the SEA.

Blowout

The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) requires that all losses of well control (blowouts) be reported. In 2006, BOEMRE revised the regulations for incident reporting. Consequently, the number of losses of well control or blowouts reported for 2006 may be affected by this change and may make difficult a comparison with data from previous years. The current definition for loss of well control used by BOEMRE:

- uncontrolled flow of formation or other fluids (The flow may be to an exposed formation [an underground blowout] or at the surface [a surface blowout]);
- flow through a diverter; and/or
- uncontrolled flow resulting from a failure of surface equipment or procedures.

Blowouts can occur during any phase of development: exploratory drilling, development drilling, completion, production, or workover operations. Blowouts occur when improperly balanced well pressures result in sudden, uncontrolled releases of fluids from a wellhead or wellbore (PCCI, 1999; Neal Adams Firefighters, Inc. 1991). Historically, since 1971, most OCS blowouts have resulted in the release of gas; blowouts resulting in the release of oil have been rare. The most recent blowout occurred on April 20, 2010, at the Macondo well in Mississippi Canyon Block 252 (i.e., Macondo Event). Although this is a rare event, the blowout resulted in the loss of large quantities of gas (to date this volume is undetermined) and oil (estimated 4.9 million bbl of oil) (DHUC, 2010).

As indicated by the Macondo Event, the loss of well control in deep water has proven to be somewhat different than the loss of well control in shallow waters. Although many of the same wild well control techniques used in shallow-water were used to attempt to control the MC 252 well, these well control efforts were hindered primarily due to the water depth, which required reliance solely upon the use of

remotely-operated vehicles (ROVs) for all well intervention efforts. This is a concern in deep water because the inability to quickly regain control of a well may result in increases in the size of a spill, as occurred during the Macondo Event. The Macondo Event required that the operator cap and attempt well control efforts at the seabed in very deep water depths (approximately 5,000 ft; 1,524 m) and, although not simultaneously, the operator was also required to handle fire-fighting efforts at the surface when the incident first occurred (USDOI, BOEMRE, 2010).

The main scenario for recovery from a blowout event is via intervention with the Blowout Preventer (BOP) attached to the well. There are built in redundancies in the BOP system to allow activation of selected components with the intent to seal off the well bore. However, if the BOP fails, as indicated in the 1991 Final Report of the Joint Industry Program for Floating Vessel Blowout Control and by the MC 252 blowout incident, there are several available options to control a well blowout. Common kill techniques include bridging, capping/shut-in, capping/diverting, surface stinger, vertical intervention, offset kill, and relief wells (Neal Adams Firefighters, Inc. 1991). Capping options and other source control and containment options are described in more detail under the BOEMRE Spill Response Program Source Control and Containment section of this Appendix (see Table A-6). Although much has been learned about well control in deep water as a result of the Macondo Event, in the event that a deepwater subsea blowout occurs in the future, it is likely that an operator will be required to immediately begin to drill one or more relief wells to gain control of the well. This may be required whether or not this is the first choice for well control because the relief well is typically considered the ultimate final solution for well control.

It is estimated that drilling an intervention well in deep water can take anywhere from 30 to 120 days (Regg, personal communication, 1998; Stauffer, personal communication, 1998; McCarroll, personal communication, 1998; BP, 2010). The actual amount of time required to drill the relief well will depend upon the complexity of the intervention, the location of a suitable rig, the type of operation that must be terminated in order to release the rig (e.g., may need to run casing before releasing the rig), and any problems mobilizing personnel and equipment to the location. The BOEMRE field engineers feel that, if a blowout were to occur, it is more likely for a blowout in deep water to occur at the seafloor rather than at the surface because there is less containment capability subsea (Regg, personal communication, 1998, Stauffer, personal communication, 1998, McCarroll, personal communication, 1998). Accordingly, the MC 252 blowout was a subsea blowout. However, it is possible that a surface blowout could occur.

The major differences between a blowout during the drilling phase versus the completion or workover phases is the drilling well tendency to "bridge off." Bridging is a phenomenon that occurs when severe pressure differentials are imposed at the well/reservoir interface and the formation around the wellbore collapses and seals the well. Deepwater reservoirs are susceptible to collapse under "high draw down" conditions. However, a completed well may not have the same tendency to passively bridge off as would a drilling well involving an uncased hole. Bridging would have a beneficial effect for spill control by slowing or stopping the flow of oil from the well (PCCI, 1999). There is a difference of opinion among blowout specialists regarding the likelihood of deepwater wells bridging naturally in a short period of time. Completed wells, or those in production, present more severe consequences in the event of a blowout due to the hole being fully cased down to the producing formation, which lowers the probability of bridging (PCCI, 1999). Therefore, the potential for a well to bridge is greatly influenced by the phase of a well.

Estimating Future Potential Spills

OCS Spills in the Past

This summary of past OCS spills presents data for the period 1985-1999. The 1985-1999 time period was chosen to reflect more modern engineering and regulatory requirements than were required prior to this and because OCS spill rates are available for this period. The BOEMRE is presently in the process of updating these spill rates through 2010, which will include the recent Macondo Event in 2010; however, this update report was not available at this time (Anderson, personal communication, 2010). Information on spills that have occurred since 1999 is published on the BOEMRE website (USDOI, BOEMRE, 2010). Utilizing more recent information through mid-2010, there have been 4,123 deepwater wells spud by mid-2010 on the OCS, not counting bypasses, in water depths of at least 500 ft (152 m). There have been 20 blowouts from these deepwater wells; 3 resulted in a spill, but only 1 (the Macondo Event) resulted in a

spill >1,000 bbl. The other two spills were estimated to be 11 and 200 bbl of crude/condensate spilled (Morin, written communication, 2010).

For the period 1985-1999, there were no spills ≥1,000 bbl from OCS platforms, eight spills ≥1,000 bbl from OCS pipelines, and no spills ≥1,000 bbl from OCS blowouts (Tables A-1 through A-3).

Table A-1

Historical Record of OCS Spills ≥1,000 Barrels from OCS Facilities, 1985-1999

Spill Date	Area and Block (water depth and distance from shore)	Volume Spilled (barrels)	Cause of Spill

No OCS facility spills ≥1,000 bbl during the period 1985-1999.

Table A-2

Historical Record of OCS Spills ≥1,000 Barrels from OCS Pipelines, 1985-1999

Spill Date	Area and Block (water depth and distance from shore)	Volume Spilled (barrels)	Cause of Spill
February 7, 1988	South Pass 60 (75 ft, 3.4 mi)	15,576	Service vessel's anchor damaged pipeline
January 24, 1990	Ship Shoal 281 (197 ft, 60 mi)	14,423*	Anchor drag, flange and valve broke off
May 6, 1990	Eugene Island 314 (230 ft, 78 mi)	4,569	Trawl drag pulled off valve
August 31, 1992	South Pelto 8 (30 ft, 6 mi)	2,000	Hurricane Andrew, loose drilling rig's anchor drag damaged pipeline
November 22, 1994	Ship Shoal 281 (197 ft, 60 mi)	4,533*	Trawl drag
January 26, 1998	East Cameron 334 (264 ft, 105 mi)	1,211*	Service vessel's anchor drag damaged pipeline during rescue operation
September 29, 1988	South Pass 38 (110 ft, 6 mi)	8,212	Hurricane Georges, mudslide parted pipeline
July 23, 1999	Ship Shoal 241 (133 ft, 50 mi)	3,189	Jack-up barge sat on pipeline

*condensate

Table A-3

Historical Record of OCS Spills ≥1,000 Barrels from OCS Blowouts, 1985-1999

Spill Date	Area and Block (water depth and distance from shore)	Volume Spilled (barrels)	Cause of Spill

No OCS blowout spills ≥1,000 bbl during the period 1985-1999.

Estimating Spill Rates Using Past OCS Spills

Data from past OCS spills are used to estimate future potential OCS spills. The BOEMRE has estimated spill rates for spills from the following sources: facilities, pipelines, and drilling. Spill rates for facilities and pipelines have been developed for several time periods, and an analysis of trends for spills is presented in *Update of Comparative Occurrence Rates for Offshore Oil Spills* (Anderson and LaBelle, 2000). Spill rates for the most recent period analyzed, 1985-1999, are presented here. Data for this period should reflect more modern spill-prevention requirements than was required prior to 1985. An internal review of recent historical data following the spill events that occurred as a result of hurricanes that occurred in the Gulf of Mexico from 2004 to 2009 indicated that there had been no change in the 1985-1999 spill rates identified in the aforementioned report. The BOEMRE is in the process of updating these spill rates, which will include the recent Macondo Event; however, significant changes to the spill rates for the entire OCS are not anticipated (Anderson, personal communication, 2010).

Spill rates for facilities and pipelines are based on the number of spills per volume of oil handled. Spill rates for blowouts are based on the number of blowouts with a release of oil per number of wells drilled. Spill rates for the period 1985-1999 are shown in Table A-4. It should be noted that there were no platform or blowout spills ≥1,000 bbl for the period 1985-1999. The use of "zero" spills would result in a zero spill rate. To allow for conservative future predictions of spill occurrence, a spill number of one was "assigned" to provide a non-zero spill rate for blowouts. Therefore, this spill rate already included the occurrence of the Macondo Event. The spill period was expanded to 1980 to include a spill for facilities. While there were no facility or blowout spills during the 1985-1999 period for which data are available, spills could occur in the future. In fact, a pipeline spill ≥1,000 bbl was reported subsequent to this period, so it is reasonable to include a spill to provide a non-zero spill rate. Spill rates are combined with site-specific data on production or pipeline volumes or number of wells being drilled to result in a site-specific risk for a spill to occur as a result of the proposed action.

Table A-4

Spill Rates Used to Estimate the Future Potential for Spills

Spill Source	Volume of Oil Handled in Billions of Barrels	Number of Wells Drilled	Number of Spills ≥1,000 Barrels	Risk of Spill from Facilities or Pipelines per Billion Barrels	Risk of Spill from Drilling Blowout per Well
Facilities	7.41[a]	Not Applicable	1[a]	>0 to <0.13[c]	Not Applicable
Pipelines	5.81	Not Applicable	8	1.38	Not Applicable
Drilling	Not Applicable	14,067	1[b]	Not Applicable	>0 to <0.00007[c]

[a] There were actually zero spills ≥1,000 bbl from facilities during the period 1985-1999. The data shown represent 1980-1999. The spill period for facility spills was expanded to 1980 to include a spill for facilities to result in a non-zero risk.

[b] There have been no spills ≥1,000 bbl from blowouts during the period 1985-1999. One spill was "assigned" to provide a non-zero spill rate.

[c] There were no facility or blowout spills ≥1,000 bbl for the period 1985-1999; however, a non-zero spill rate was calculated by expanding the facility period to 1980 and by "assigning" a blowout spill. Therefore, the spill rates for these categories are presented as >0 but below the rates calculated by expanding the data period and assigning a spill.

Hydrocarbon Spill Transport

Subsurface Spills

Submerged oils provide unique challenges in oil tracking and fate and transport modeling. Research funded by BOEMRE to determine oil-spill behavior from subsurface well blowouts in deep water was conducted in June 2000 in the Norwegian Sea. This field experiment is referred to as DeepSpill. The conclusions of the DeepSpill field experiment, two other follow-up laboratory studies, and three model

comparisons were summarized in a 2005 report entitled *Review of DeepSpill Modeling Activity Supported by the DeepSpill JIP and Offshore Operators Committee* (Adams and Socolofsky, 2005). The aforementioned six activities resulted in several conclusions about the fate of oil spilled subsurface within deep water. This 2005 report indicated that jets of oil and gas (if present) will break up into droplets and bubbles. The buoyancy of the oil droplets and gas bubbles will form a buoyant plume, with the gas providing the dominant source of buoyancy (if present). Near the point of release, this plume will behave like a single phase plume. Although slight leakage of entrained seawater and fine oil droplets can be expected in the lee of the plume, basic plume features in this near source can be easily described with conventional integral plume models. Above a certain height, ambient stratification and ambient currents will separate the dispersed phases from the entrained water. Above a current speed of 2.5 cm/sec, the current is the major factor, and separation can be expected at elevations of 180 m (591 ft) or less. It was determined that plume dynamics were relatively unimportant when determining the fate of oil released at depths of 800-1,000 m (2,625-3,281 ft) because the plume stage is short when compared with the water depth (Adams and Socolofsky, 2005).

The DeepSpill work indicated that, above the point of separation, gas bubbles and large oil droplets rise toward the surface while small oil droplets continue with the entrained seawater as a buoyant jet. Some of the modeling work indicated that the oil would rise to surface closer to the release point. However, since the field experiment resulted in only a small fraction of the diesel oil being recovered at the surface, it was determined that much of the oil could have been contained in the form of much finer droplets that were much more widely dispersed. Although earlier studies such as the 1997 S.L. Ross study indicated that the gas would be expected to convert very quickly to hydrates during a deepwater release, the Macondo Event did not result in released gas converting to hydrates, which reinforces the 2005 report's modeling work conclusions (S.L. Ross Environmental Research Ltd., 1997; Adams and Socolofsky, 2005).

The National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (USEPA), and the White House Office of Science and Technology Policy released peer-reviewed, analytical summary reports about subsurface oil monitoring in the Gulf of Mexico during the Macondo Event response. Their second report contains preliminary data collected at 227 sampling stations extending from 1 to 52 km (0.6 to 32.3 mi) from the MC 252 wellhead. This data indicated that the movement of subsurface oil is consistent with ocean currents and that concentrations continue to be more diffuse as one moves away from the source of the leak. These results confirmed the findings of their previous report. The fluorometric sampling confirmed that the subsurface oil moved consistent with the observed ocean currents. During the MC 252 response, many techniques were tested to better understand the extent of this unprecedented oil spill, and it was discovered that fluorometric sampling was useful to help identify the location and concentration of subsurface oil. Fluorometers use light waves to detect anomalies in the water column. Fluorometry measurements show repeated signals between approximately 3,300 and 4,300 ft (1,000-1,400 m) deep that were consistent with diffused oil in the water. For the areas sampled, the fluorescence data indicated movement primarily west-southwest until June 2, 2010. In mid-June, fluorescence indicated movement toward the northeast within the Gulf. As previously indicated, these movements were generally consistent with observed ocean currents in the area at that time (USDOC, NOAA, 2010a).

Therefore, in the event of a subsurface release of oil, it is anticipated that some (less than 13%) of the oil would remain subsurface, as described above, while the rest would surface (Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team., 2010). Based upon the DeepSpill research and experience gained during the MC 252 spill incident, it would be expected that any oil contained within the water column would be transported at that same depth by ocean currents. Refer to the section of this appendix entitled "Assumptions about the Characteristics and Fates of Spilled Hydrocarbons" for a discussion of the projected fate of this subsea oil.

Assumptions about the Characteristics and Fates of Spilled Hydrocarbons

Characteristics of Hydrocarbons

It is assumed that a typical diesel fuel oil is used for most drilling activities. Additionally, the oil that is generally produced in the GOM is a medium weight oil. Refer to Table 2 of Appendix B for further discussion regarding oil classification. For the purposes of this scenario, it will be assumed that the oil will have similar chemical characteristics as the oil spilled during the Macondo Event.

Subsurface Spills

If a subsurface spill occurs, it is anticipated that oil released would behave similarly to the oil released during the DeepSpill experiments and during the Macondo Event. Transport of oil in the water column and on the bottom will be dependent upon the properties of the oil, characteristics of the waterbody, and properties of suspended or bottom sediments (Coastal Response Research Center, 2007).

The DeepSpill experiment was conducted in the Norwegian Sea at the Helland Hansen site in June 2000 and included four controlled discharges of oil and gas from a water depth of 844 m (2,769 ft). This experiment was part of the DeepSpill project, organized as a Joint Industry Project (JIP), involving 23 oil companies and BOEMRE. Analysis of water samples taken during this experiment with a rosette sampler (guided by images from the echo sounder) revealed how the composition of the crude oil and diesel released as part of this experiment changed on its way to the sea surface due to dissolution of the water soluble components into the ambient water. The echo sounder images indicated that the methane gas did not reach the sea surface, with the signal from the rising cloud of gas bubbles vanishing from the images at about a water depth of 150 m (492 ft). The crude oil and the diesel oil did reach the sea surface in a relatively shorter period of time than expected. The crude oil release did form water-in-oil emulsion, which was also evident during the Macondo Event. This research also indicated that slicks from a submerged oil release were thinner than those resulting from surface spills, allowing them to weather more rapidly (Johansen et al., 2001). However, the oil released subsea that reached the water surface as a result of the Macondo Event did not seem to behave any differently than would a surface spill of the same oil.

The experiments indicated that oil is water-extracted after its subsea release on its way up to the sea surface. The rate of this extraction depends upon the solubility of the compounds in the water. For example, close to the surface, the naphthalenes are almost completely extracted from the oil. This is important because the water-soluble compounds are the most toxic ones when exposed to marine biota. The results from the experiments showed that the rising of the oil through the water column represents a kind of "stripping" process of some of the most toxic compounds in the oil. Therefore, a portion of the most toxic compounds are left in the water column. The largest concentration of hydrocarbons in the water column will be basically inside the "cloud" of rising oil droplets while the peak concentration may be deeper due to a larger exposure of oil droplets that has passed by. In a surface-generated slick, the most toxic compounds typically evaporate rather than dissolve into the sea (Johansen, et al., 2001).

Likewise, the theory that not all of the oil would surface as a result of a subsurface deepwater release was found to be an accurate assessment based upon observations during the Macondo Event. During the Macondo Event it was discovered that, due to the high speed of its release, some of the oil was naturally stripped off (naturally dispersed as oil droplets) as it rose to the surface in a water depth of approximately 5,000 ft (1,524 m). These oil droplets are neutrally buoyant and remain in the water column until they biodegrade. At this time, it is estimated that about 13 percent of the oil was lost into the water column as a result of this stripping (Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team., 2010). The NOAA, USEPA, and the White House Office of Science and Technology Policy's summary report about subsurface oil monitoring in the Gulf of Mexico after the MC 252 blowout indicated that average fluorescence in the depths of interest – 3,300 and 4,300 ft (1,005 and 1,311 m) – at sampled locations ranged from 4 to 7 parts per million oil. This estimated value is slightly higher than the laboratory-confirmed values previously reported, which at their highest, near the wellhead, were approximately 1-2 parts per million oil. The fluorometric signal to detect the presence of oil was strongest near the wellhead and decreased with distance, which was consistent with previous sampling. (USDOC, NOAA, 2010a).

For the Macondo Event, there is no published estimate of the amount of oil dispersed throughout the water column due to the use of subsurface dispersants at the wellhead; however, a total of 16 percent was estimated to have been dispersed by the application of chemical dispersants both on and below the surface (Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team., 2010). The chemically dispersed oil ended up deep in the water column and just below the surface because both surface and subsurface application was used. Dispersion, whether natural or chemical, increases the likelihood that the oil will be biodegraded, both in the water column and at the surface. However, until it is biodegraded, naturally or chemically dispersed oil, even in dilute amounts, can be toxic to vulnerable species (Lubchenco et al., 2010). Studies are presently ongoing to assess the short and long-term effects of dispersant usage during the Deepwater Horizon event.

Surface Spills

When oil is released in seawater, a combination of physicochemical and biological processes immediately begin to transform the oil into substances with characteristics that differ from the original material, while physical transport processes begin to dissipate it. Physicochemical processes include evaporation, emulsification, dissolution, and photo-oxidation, which are collectively referred to as weathering. Biological processes include microbial oxidation. Microbes consume the oil, and wave action, sun, currents, and continued evaporation and dissolution continue to break down the residual oil in the water and on shorelines. Transport processes include spreading, dispersion and entrainment, sinking and sedimentation, and stranding, which can lead to tar ball formation. These processes are described by the National Research Council (NRC, 2003).

For this scenario, it is assumed that oil would behave somewhat similarly to that spilled during the MC 252 spill. The MC 252 oil was relatively high in alkanes. Because alkanes are made up of single-bonded carbon chains that microorganisms can readily use as a food source, MC 252 oil was considered likely to biodegrade more readily than other crude oils. The MC 252 oil was also considered to be less toxic than some crude oils generally because it was relatively much lower in polyaromatic hydrocarbons (PAHs). The PAHs are highly toxic chemicals that tend to persist in the environment for long periods of time, especially if the spilled oil penetrated into the substrate on beaches or shorelines. The MC 252 oil was also low in sulphur. Like all crude oils, MC 252 oil contained volatile organic compounds (VOC's) such as benzene, toluene, and xylene. Some VOC's are acutely toxic but because they evaporate readily, they are generally a concern only when oil is fresh (USDOC, NOAA, 2010b).

It was estimated by the MC 252 National Incident Command's technical group that approximately 36 percent of the oil spilled as a result of the Macondo Event was lost once it reached the water surface due to dissolution, evaporation, and natural dispersion (Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team., 2010). The majority of this oil that was lost due to evaporation and dissolution (23%). Additional oil was lost due to these same processes as it weathered, although at a much smaller percentage. The evaporation rate was based upon scientific research and observations conducted during the Macondo Event (Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team., 2010).

Once surfaced, the MC 252 oil appeared as black or dark brown oil, sheens, and water-in-oil emulsion, or mousse. The MC 252 oil also formed tar balls. As MC 252 oil reached the surface and spread out across the water, its lighter components, including VOC's, soon evaporated, leaving heavier components behind. Fresh oil appears as a black or dark brown, thick, sticky liquid with petroleum odor. On open water, this oil will spread quickly. In the intertidal zone, this oil could pick up silt and sediment and sink. On the beach, this form of oil could release sheen when washed by tides or waves and could also penetrate beach substrate. Some of the remaining MC 252 oil became sheen, a very thin layer of floating oil (less than 0.0002 inches or 0.005 mm) that can be transparent, grey, silver, or rainbow-colored. Light sheens will degrade quickly while heavier sheens may concentrate on shorelines. The MC 252 oil also mixed with water to form a sticky, pudding-like water-in-oil emulsion, or mousse, typically brown, reddish, or orange in color. Typically, crude oil emulsifies on the sea surface as winds and waves mix it with water, but MC 252 oil also appeared to be incorporating water as it rose to the surface through 5,000 ft (1,524 m) of water. Water content reduces ignitability and biodegradability. Winds and waves tear oil and mousse patches into smaller pieces, eventually producing tar balls. The MC 252 tar balls typically were in the form of small, hard, black pellets. Tar balls can range in size from 5mm to 5 cm (0.20 to 2 inches). Tar balls can be very persistent in the marine environment and travel long distances. On the beach, tar balls may soften in hot sun. In intertidal waters, tar balls can pick up sediment or silt and sink. Occasionally, some burn residue can be mistaken for tar balls. Burn residue is brittle, hard, asphalt-like, and typically mixed with unburned fresh oil. Some of the MC 252 oil gathered offshore just below the water surface in thick mats or patches of emulsified oil (USDOC, NOAA, 2010a).

Dispersion increases the likelihood that the oil will be biodegraded, both in the water column and at the surface. Oil that is chemically dispersed at the surface will move into the top 20 ft (6 m) of the water column where it will mix with surrounding waters and begin to biodegrade. While there is more analysis to be done to quantify the rate of biodegradation in the Gulf after the MC 252 spill, early observations and preliminary research results showed that some of the oil biodegraded fairly quickly. Bacteria that break down the dispersed and weathered surface oil are abundant in the Gulf of Mexico in large part because of the warm water, the favorable nutrient and oxygen levels, and the fact that oil enters the Gulf of Mexico through natural seeps regularly (Lubchenco et al., 2010).

Using the information obtained as a result of the response to the Macondo Event, it is evident that, large amounts of oil could remain on the water surface and within the water column for some period of time during an ongoing spill event if it is not successfully contained by some other subsea source control measure. Approximately 17% of the oil was captured through the subsea containment effort during the Macando Event (Federal Interagency Solutions Group, Oil Budget Calculator Science and Engineering Team., 2010).

Spill Response

Potential impacts from an accidental release of oil from a high-volume blowout are a serious concern; however, the historical database indicates that it is rare for such a pollution event to occur. An operator is responsible for ensuring that the response to an oil spill would be in full accordance with the applicable Federal and State laws and regulations. The BOEMRE has requirements for preparedness to respond to a spill in the event of an accidental spill (30 C.F.R. Part 254 and 30 C.F.R. 250 Subpart C).

The ability to effectively respond to a spill that might occur in the deepwater areas of the OCS will vary depending upon a number of factors. Among these factors are the chemical and physical characteristics of an oil, the volume of oil spilled, the rate of spillage, the weather conditions at the time of the spill, the source of the spill, and the amount of time necessary for response equipment or chemical countermeasures to reach a spill site. The distance from shore for a deepwater drilling project would generally allow more time for cleanup efforts and natural weathering of the oil to take place before oil could reach shore.

Oil-Spill-Response Plan

As required by BOEMRE, operators are required to provide a regional oil-spill-response plan (ROSRP). During the review of a OSRP, the operators can submit a worst case discharge letter in compliance with 30 CFR 254.2(b). This regulatory provision allows an operator to operate their facility for up to two years while the BOEMRE reviews the OSRP if the operator certifies in writing that they have the capacity to respond to maximum extent possible to a worst case discharge of oil. An OSRP contains procedures for alerting, reporting, and cleaning up in the event of an oil spill. The OSRP is designed to help personnel respond quickly and effectively to environmental incidents and is a "guide" to assist in handling spill-response situations. The operator indicates within their OSRP that they have a current contract with an offshore oil-spill response organization.

The information included in the table below is included in an OSRP. In addition, appendices to this plan include (1) facility information, (2) training information, (3) drill information, (4) contractual agreements, (5) response equipment, (6) support services and supplies, (7) notification and reporting forms, (8) worst-case discharge scenarios, (9) oceanographic and meteorological information, and (10) bibliography. The proposed operations would be required to be conducted under the applicable provisions of OCS regulations and notices and in the interest of safety and pollution control.

Topics Covered by an OSRP

(1)	OSRP quick guide	(12)	strategic response planning
(2)	preface	(13)	resource protection methods
(3)	introduction	(14)	mobilization and deployment methods
(4)	organization	(15,16)	oil/debris removal/disposal procedures
(5)	spill response operations/communications	(17)	wildlife rehabilitation procedures
(6)	spill detection and source identification	(18)	dispersant use plan
(7,8)	internal and external notifications	(19)	in-situ burn plan
(9)	available technical expertise	(20)	chemical and biological response strategies
(10)	spill assessment	(21)	documentation
(11)	resource identification		

BOEMRE Spill-Response Program

The BOEMRE Oil-Spill Program oversees the review of oil-spill response plans, coordinates inspection of oil-spill response equipment, and conducts unannounced oil-spill drills. This program also

supports continuing research to foster improvements in spill prevention and response. Studies funded by BOEMRE address issues such as spill prevention and response, in-situ burning, and dispersant use. In addition, BOEMRE works with the U.S. Coast Guard (USCG) and other members of the multiagency National Response System to further improve spill-response capability in the Gulf of Mexico.

Subsurface Response

Most oil-spill response strategies and equipment are based upon the simple principle that oil floats. However, as evident during the Macondo Event, this is not always true. Sometimes oil suspends within the water column or sinks to the seafloor and sometimes it does all three: floats, suspends, and sinks. Oil suspended in the water column and moving with the currents is difficult to track using standard visual survey methods. Trajectory models traditionally used to predict floating oil movement and fate are not applicable to submerged oil - oil that is suspended in the water column and/or that sinks. There are no proven methods for the containment of submerged oil, and methods for recovery of submerged oil have limited effectiveness (Coastal Response Research Center, 2007).

Efforts to contain and/or recover suspended oil have focused on different types of nets, either the ad hoc use of fishing nets or specially designed trawl nets. There has been research conducted on the design of trawl nets for recovery of emulsified fuels. However, the overall effectiveness for large spills is expected to be very low. Suspended oil can occur as liquid droplets or semisolid masses in sizes ranging from millimeters to meters in diameter. At spills where oil has been suspended in the water column, responders have devised low technology methods for tracking the presence and spread of oil over space and time. For suspended oil, these methods include stationary systems such a snare sentinels, which can consist of any combination of the following: a single length of snare on a rope attached to a float and an anchor; one or more crab traps on the bottom that are stuffed with snare; and minnow or other type of traps that are stuffed with snare and deployed at various water depths. The configuration would depend upon the water depth where the oil is located within the water column. Currently, it is not possible to determine the particle size, number of particles, or percent oil cover in the water column based upon the visual observations of oil on these systems (Coastal Response Research Center, 2007).

Spills involving submerged oil trigger the need for real-time data on current profiles (surface to bottom), wave energy, suspended sediment concentrations, detailed bathymetry, seafloor sediment characteristics, and sediment transport patterns and rates. These data are needed to validate or calibrate models (both computer and conceptual), direct sampling efforts, and predict the behavior and fate of the submerged oil. This information might be obtained through the use of acoustic Doppler current profilers, dye tracer studies, rapid seafloor mapping systems, and underwater camera or video systems that could record episodic events (Coastal Response Research Center, 2007). During the Macondo Event, Fluorometers were used successfully to detect the presence of oil.

Surface Response

Prior to the DeepSpill sea trials, there was some doubt about whether oil released subsea in deep water would reach the sea surface. The surface slick formed after the DeepSpill crude oil releases contained patches of water-in–oil emulsion with film thickness more than adequate for containment with oil booms and also sufficient thickness for efficient treatment with chemical dispersant, similar to what actually happened during the Macondo Event. However, the DeepSpill sea trials indicated that the potential lifetime of the crude oil slick would be short, which resulted in the report suggesting that the slick could be left to disperse naturally without attempting any mechanical cleanup (Johansen et al., 2001). The fact that the experiment did not involve the quantity of crude that was lost per day and on an ongoing basis for approximately 87 days as occurred during the Macondo Event may account for the observed differences in slick behavior between the experiments and the Macondo Event. As occurred during the Norwegian Sea trials, there was no hydrate formation at the damaged riser during the uncontrolled flow during the MC 252 release.

The MC 252 spill incident indicated that, although released at a water depth of 5,000 ft (1,524 m), once the oil surfaced, a variety of response methods were effective on the oil that surfaced near the source. The options for oil combat in deep water are the same as those used for shallower waters (mechanical recovery, dispersion, in-situ burning). Response to the oil as it emulsified and moved farther from the source proved more difficult. The emulsified oil had to be chased down by the responders,

making it more difficult for the skimmers to stay in skimmable oil. The emulsified oil was also less likely to be effectively burned or dispersed.

A variety of standard cleanup protocols were used for removing MC 252 oil from beaches, shorelines, and offshore water (Table A-5).

Table A-5

Primary Cleanup Options Used during the MC 252 Response

	Fresh Oil	Sheens	Mousse	Tar Balls	Burn Residue
On-Water Response	Disperse, skim, burn	Light sheens very difficult to recover, heavier sheens picked up with sorbent boom or sorbent pads	Skim	Snare boom	Manual removal
On-Land Response	Sorbent pads, manual recovery, flushing with water, possible use of chemical shoreline cleaning agents	Light sheens very difficult to recover, heavier sheens picked up with sorbent boom or sorbent pads	Sorbent pads, manual recovery	Snare boom, manual removal, beach cleaning machinery	Manual removal

Source: USDOC, NOAA, 2010b.

Source Control and Containment

After the Deepwater Horizon event occurred, BOEMRE issued NTL No. 2010-N10 which became effective on November 8, 2010. This NTL applies only to operators conducting operations using subsea blowout preventers (BOPs) or surface BOPs on floating faculties. The NTL also informs lessees that BOEMRE will be evaluating whether each operator has submitted adequate information demonstrating that it has access to and can deploy surface and subsea containment resources that would be adequate to promptly respond to a blowout or other loss of well control. Although the NTL does not require that operators submit revised Oil Spill Response Plans that include this containment information at this time, operators were notified of BOEMRE's intention to evaluate the adequacy of each operator to comply in the operator's current OSRP. The type of information that BOEMRE will review for pursuant to this NTL includes, but is not limited to:

- Subsea containment and capture equipment, including containment domes and capping stacks.
- Subsea utility equipment, including hydraulic power, hydrate control, and dispersant injection equipment.
- Riser systems.
- Remotely operated vehicles.
- Capture vessels.
- Support vessels
- Storage facilities.

To address the new improved containment systems expectations to rapidly contain a spill as a result of a loss of well control from a subsea well addressed in NTL No. 2010 N10, several oil and gas industry majors initiated the development of a new, rapid response system. This system is designed to fully contain oil flow in the event of a potential future underwater blowout and to address a variety of

scenarios. The system would consist of specially designed equipment constructed, tested, and available for rapid response. It is envisioned that this system could be fully operational within days to weeks after a spill event occurs. The system is designed to operate in up to 10,000 feet water depth and will add containment capability of 100,000 BOPD (4.2 million gallons per day). The companies that originated this system are forming a non-profit organization, the Marine Well Containment Company (MWCC), to operate and maintain the system. MWCC will provide fully trained crews to operate the system, will ensure the equipment is operational and ready for rapid response and will conduct research on new containment technologies. This system will connect by risers to vessels that are designed to safely capture, store and offload the oil. This improves safety and environmental protection by fully securing the well via capping and shut-in or by containing the oil flow until the well is under control. It also enhances safe operations by reducing congestion (i.e., fewer vessels, risers/flowlines). Until this equipment is available, MWCC has built a subsea containment equipment system that is engineered to be used in water depths up to 8,000 feet and has the capacity to contain 60,000 barrels of oil per day. This initial response system includes a capping stack with the ability to shut in oil flow or to flow the oil via flexible pipes and risers to surface vessels.

Another option for source control and containment is through the use of the equipment stockpiled by Helix Energy Solutions Group, Inc (Helix). The Helix initiative involves more than 20 smaller energy companies, and supplements the MWCC response effort. Helix has stockpiled the equipment that it found useful in the MC 252 response and is offering it to oil and gas producers for immediate use. The Helix system centers on three ships: the *Helix Producer I*; the *Q4000*: and the *Express* deepwater construction vessel. These vessels played a role in the Macondo response and continue to work in the Gulf. Together, the Helix ships and related equipment can handle up to 55,000 barrels of oil a day, 70,000 barrels of liquid natural gas and 95 million cubic feet of natural gas at depths up to 8,000 feet. The primary difference between the MWCC system and the Helix system is that, nothing needs to be built for the Helix system, it has been field tested and is currently available. Another group, Wild Well Control, is also providing some subsea containment capability and debris removal to offshore operators.

The BOEMRE will not allow an operator to begin drilling operations until adequate subsea containment and collection equipment as well as subsea dispersant capability is determined by the agency to be available to the operator and sufficient for use in response to a potential incident form the proposed well(s). However, it would be impossible to predict with any degree of certainty the percentage of oil that could be contained subsea in the event of a spill or when or if complete containment would even be possible. There are some situations where this equipment might not be able to be used to control the well, for example, if the drilling structure were to fall directly on top of the well as debris during a loss of well control event. If a loss of well control event occurred in the future, it is possible that it could be contained in a best case scenario within weeks with the utilization of the rapid subsea containment packages thereby greatly limiting the amount of oil potentially lost to the environment.

Summary

In the event of a spill, particularly a blowout, there is no single method of containing and removing it that would be 100 percent effective. Removal and containment efforts to respond to an ongoing spill would likely require multiple technologies, including mechanical cleanup, burning of the slick, and chemical dispersants. Even with the deployment of all of these technologies, it is likely that, with the operating limitations of today's spill response technology, not all of the oil could be contained and removed offshore. It is likely that larger spills in deep waters under the right conditions would require the simultaneous use of all available cleanup methods (mechanical cleanup, dispersant application, and in-situ burning.

That being said, when one considers the historical/statistical data, the recent subsea containment improvements, BOEMRE's enhanced oversight, and industry's heightened safety awareness since the Macondo Event, it is reasonable to conclude that an accidental spill event is not very likely to occur.

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Appendix B
Catastrophic Spill Event Analysis

Catastrophic Spill Event Analysis: High-Volume, Extended-Duration Oil Spill Resulting from Loss of Well Control on the Gulf of Mexico Outer Continental Shelf

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1. INTRODUCTION

In 1986, the Council on Environmental Quality (CEQ) regulations were amended to rescind the requirement to prepare a "worst-case analysis" for an Environmental Impact Statement (EIS). *See* 40 C.F.R. § 1502.22(b)(4). The regulation, as amended, states that catastrophic, low-probability impacts must be analyzed if the analysis is "supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason."

The August 16, 2010, CEQ report, prepared following the Deepwater Horizon blowout and spill in the Gulf of Mexico (CEQ, 2010), recommended that the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), formerly the Minerals Management Service (MMS), should "ensure that NEPA documents provide decisionmakers with a robust analysis of reasonably foreseeable impacts, including an analysis of reasonably foreseeable impacts associated with low probability catastrophic spills for oil and gas activities on the Outer Continental Shelf" (CEQ, 2010). This Analysis provides that robust analysis of the impacts of low-probability catastrophic spills for all applicable decisionmakers including, but not limited to, the Secretary of the Department of the Interior (USDOI) for the National 5-Year Program, the Assistant Secretary of Land Management for an oil and gas lease sale, or the Regional Supervisor of the Office of Field Operations for an exploration or development plan. Chapter 1.4 of the SEA discusses the potential volumes and estimated risk related to an accidental spill from the proposed action and Appendix A provides a general discussion on the potential for an accidental oil spill, the fate of the oil in the marine environment, and the primary response methodologies. While the discussion in Appendix A describes a low probability catastrophic spill, this Analysis includes a more generic overview of past catastrophic events.

1.1 WHAT IS A CATASTROPHIC EVENT?

As applicable to NEPA, Eccleston (2008) defines a catastrophic event as "large-scale damage involving destruction of species, ecosystems, infrastructure, or property with long-term effects, and/or major loss of human life." For oil and gas activities on the Outer Continental Shelf (OCS), a catastrophic event is a high-volume, long-duration oil spill regardless of the cause, whether natural disaster (i.e., hurricane) or manmade (i.e., human error and terrorism). This high-volume, long-duration oil spill, or catastrophic spill, has been further defined by the National Oil and Hazardous Substances Pollution Contingency Plan as a "spill of national significance" or "a spill which due to its severity, size, location, actual or potential impact on the public health and welfare or the environment, or the necessary response effort, is so complex that it requires extraordinary coordination of federal, state, local, and responsible party resources to contain and cleanup the discharge" (40 C.F.R. Part 300, Appendix E).

Each oil-spill event is unique; its outcome depends on several factors, including time of year and location of release relative to winds, currents, land, and sensitive resources, specifics of the well (i.e., flow rates, hydrocarbon characteristics, and infrastructure damage), and response (i.e., speed and effectiveness). For this reason, the severity of an oil spill cannot be predicted based on volume alone, although a minimum volume of oil must be spilled to reach catastrophic impacts.

Though large spills may result from a pipeline rupture, this likely will not result in a catastrophic spill because the ability to detect leaks and shut off pipelines limits the spill to the contents of the pipeline. The largest, non-blowout-related spill on the Gulf of Mexico OCS occurred in 1967, a result of internal pipeline corrosion caused by anchor damage. In 13 days, 160,638 barrels of oil leaked (USDOI, BOEMRE, 2010a); however, no significant environmental impacts were recorded as a result of this spill.

Loss of well control creates the volume and duration that produces a catastrophic oil spill. Although loss of well control is defined as the uncontrolled flow of a reservoir fluid that may result in the release of gas, condensate, oil, drilling fluids, sand, or water, it is a broad term that includes very minor well control incidents as well as the most severe well control incidents. Historically, loss of well control incidents occurred during development drilling operations, but loss of well control incidents can occur during exploratory drilling, production, well completions, or workover operations. These loss of well control incidents may occur between zones in the wellbore or at the seafloor.

Blowouts are a more severe loss of well subset with that create a greater risk of an oil spill and human injury. Two blowouts that resulted in catastrophic spills have occurred in U.S. and Mexican waters of the Gulf of Mexico. In 1979, the Ixtoc blowout in shallow water (164 feet [ft] 50 miles (mi) offshore in the

Bay of Campeche, Mexico), spilled 3.5 million barrels of oil spilled in 10 months (USDOC, NOAA, Office of Response and Restoration, 2010a; USDOC, NOAA, Hazardous Materials Response and Assessment Division, 1992; ERCO, 1982). In 2010, the Deepwater Horizon blowout, in deepwater (4,992 ft) 48 miles offshore in Mississippi Canyon Block 252, spilled an estimated 4.9 million barrels of oil until it was capped almost 3 months later.

Prior to the Deepwater Horizon incident, the two largest spills in U.S. waters of the Gulf of Mexico OCS resulting from a loss of well control occurred in 1970 and released 30,000 and 53,000 barrels of oil (USDOI, BOEMRE, 2010a). These incidents resulted in four human fatalities. Although only 8-14 miles from shore, there was minor shoreline contact (USDOC, NOAA, Office of Response and Restoration, 2010b and 2010c). In 1987, a blowout of the Mexican exploratory oil well, YUM II, resulted in a spill of 58,640 barrels and 75 miles of impacted shoreline (USDOC, NOAA, Hazardous Materials Response and Assessment Division, 1992). None of these spills met the definition of a catastrophic event or spill. For this reason, only the Ixtoc and Deepwater Horizon blowouts and spills are analyzed below.

1.2. METHODOLOGY

Two general approaches are utilized to analyze a catastrophic event under NEPA. The first approach is a bounding analysis for each individual resource category (e.g., marine mammals, sea turtles, etc.). This requires selecting a different set of factors and scenarios for each resource affected by a worst-case analysis. The second approach selects a single set of key circumstances that, in combination, result in catastrophic consequences. This creates a site-specific analysis with limited usefulness in future NEPA documents and consultations. Accordingly, this analysis combines the two approaches, relying on a generalized scenario while identifying site-specific severity factors for individual resources. This combined approach allows for the scientific investigation of a range of possible, although not necessarily probable, consequences of a catastrophic blowout and oil spill in the Gulf of Mexico.

1.2.1. Geographic Scope

Because the Gulf of Mexico is a semi-enclosed basin with an extensive history of oil and gas activities and with unique environmental conditions and hydrocarbon reservoir properties, this analysis is applicable to the Gulf of Mexico OCS only. It is not intended for other OCS regions.

When possible, this analysis distinguishes between shallow water (<1,000 feet) and deep water (≥1,000 feet).

1.2.2. Impact-Producing Factors and Scenario

A hypothetical, yet feasible, scenario was developed to provide a framework for identifying the impacts of an extended oil spill from an uncontrolled blowout in both shallow and deep water. Unless noted, this scenario is based on the larger magnitude, blowout-related oil spills that have occurred in the Gulf of Mexico, discussed in Section 1.1. As noted above, because each spill event is unique, its outcome depends on many factors. Therefore, this scenario cannot predict the outcome of present or future spills.

1.2.3. Environmental and Socioeconomic Impacts

This analysis evaluates the impacts to the Gulf of Mexico's coastal, marine, environmental, and socioeconomic resources from a catastrophic blowout, oil spill and its associated cleanup activities.

Although the most recent EIS's prepared by MMS for oil and gas lease sales in the Gulf of Mexico analyze the potential impacts from smaller oil spills that are more reasonably foreseeable (USDOI, MMS, 2007 and 2008), the analysis below focuses on the most likely and most significant impacts created by a high-volume, extended-duration spill. Because catastrophic consequences may not occur for all resources, factors affecting the severity of impacts are identified by individual resource.

1.3. How to Use This Analysis

The purpose of this technical analysis is to assist BOEMRE in meeting CEQ requirements (40 C.F.R. § 1502.22) for analysis of catastrophic, low-probability impacts if the analysis is "supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason." Therefore, this analysis identifies the most likely and most significant impacts from a high-volume blowout and oil spill that continues for an extended period of time. The scenario and impacts discussed in this analysis should not be confused with the scenario and impacts anticipated to result from routine activities or more reasonably foreseeable accidental events of a proposed action.

This technical analysis is designed to be incorporated by reference in future NEPA documents and consultations. Therefore, factors that affect the severity of impacts of a high-volume, extended-duration spill are highlighted throughout the analyisis for use in subsequent site-specific analyses.

To analyze a hypothetical catastrophic event in an area such as the Gulf of Mexico, several assumptions and generalizations were made. However, future project-specific analyses should also consider specific details such as potential flow rates for the specific proposed activity, the properties of the targeted reservoir, and distance to shore of the proposed activities.

The life cycle of a catastrophic blowout and spill is divided into four geographic areas and/or time periods, some of which may overlap:

- Phase 1: Initial event (Section 2)
- Phase 2: Offshore spill (Section 3)
- Phase 3: Onshore contact (Section 4)
- Phase 4: Post-spill, long-term recovery (Section 5)

Each phase of a catastrophic oil spill is addressed in this analysis. For each phase, the scenario is described, factors that could produce environmental impacts are listed, and the most likely and most significant impacts are discussed.

2. INITIAL EVENT (PHASE 1)

While most of the environmental and socioeconomic impacts of a catastrophic blowout would occur during the ensuing high-volume, extended-duration spill (see Sections 3, 4, and 5), it is important to acknowledge the deadly events that could occur in the initial phase of a catastrophic blowout. The following scenario was developed to provide a framework for identifying the most likely and most significant impacts during the initial phase.

2.1. Impact-Producing Factors and Scenario

Phase 1 of the scenario is the initial incident of a catastrophic blowout. Impacts, response, and intervention depend on the spatial location of the blowout and leak. While there are several points where a blowout could occur, four major distinctions that are important to the analysis of impacts are described in Table 1 below.

For this analysis, an explosion and subsequent fire are assumed to occur. If a blowout associated with the drilling of a single exploratory well occurs, this could result in a fire that would burn for 1 or 2 days. If a blowout occurs on a production platform, other wells could feed the fire, allowing it to burn for over a month (USDOC, NOAA, Office of Response and Restoration, 2010c). The drilling rig or platform may sink. If the blowout occurs in shallow water, the sinking rig or platform may land in the immediate vicinity; if the blowout occurs in deep water, the rig or platform could land a great distance away, beyond avoidance zones. For example, the Deepwater Horizon drilling rig sank, landing 1,500 feet away on the seafloor. Regardless of water depth, the immediate response would be from search and rescue vessels and aircraft, such as United States Coast Guard (USCG) cutters, helicopters, and rescue planes, and firefighting vessels.

Table 1 Blowout Scenarios and Key Differences in Impacts, Response, and/or Intervention	
Location of Blowout and Leak	**Key Differences in Impacts, Response, and/or Intervention**
Blowout occurs at the sea surface (i.e., at the rig)	Offers the least chance for oil recovery due to the restricted access to the release point; therefore, greater impacts to coastal ecosystems. In addition to relief wells, there is potential for other intervention measures such as capping and possible manual activation of Blow-Out-Preventer (BOP) rams.
Blowout occurs along the riser anywhere from the seafloor to the sea surface. However, a severed riser would likely collapse, resulting in a leak at the seafloor.	In deep water, the use of subsea dispersants may reduce impacts to coastal ecosystems; however, their use may increase exposure of marine resources to oil. There is a possibility for limited recovery of oil at the source. In addition to relief wells, there is potential for other intervention measures, such as capping and possible manual activation of BOP rams.
At the seafloor, through leak paths on the BOP/wellhead	In deep water, the use of subsea dispersants may reduce impacts to coastal ecosystems; however, their use may increase exposure of deepwater marine resources to dispersed oil. With an intact subsea BOP, intervention may involve the use of drilling mud to kill the well. If the BOP and well stack are heavily compromised, the only intervention method may be relief wells. Greatest possibility for recovery of oil at the source, until the well is capped or killed.
Below the seafloor, outside the wellbore (i.e., broached)	Disturbance of a large amount of sediments resulting in the burial of benthic resources in the immediate vicinity of the blowout. The use of subsea dispersants would likely be more difficult (PCCI, 1999). Stopping this kind of blowout would probably involve relief wells. Any recovery of oil at the seabed would be very difficult.

2.2. Most Likely and Most Significant Impacts

Impacts during Phase 1 would be limited to environmental resources in the immediate vicinity of the blowout. The most recent EIS's prepared by MMS for oil and gas lease sales in the Gulf of Mexico detail the potential impacts from reasonably foreseeable blowouts (USDOI, MMS, 2007 and 2008). In addition to the impacts described in those documents, the most likely and most significant impacts resulting from a catastrophic blowout outside the wellbore are described below.

2.2.1. Physical Resources

2.2.1.1. Air Quality

A catastrophic blowout close to the water surface would initially emit large amounts of methane and other gases into the atmosphere. If high concentrations of sulfur are present in the produced gas, hydrogen sulfide (H_2S) could present a hazard to personnel. The natural gas H_2S concentrations in the Gulf of Mexico OCS are generally low; however, there are areas such as the Norphlet formation in the northeastern Gulf of Mexico, for example, that contain levels of H_2S up to 9 percent. Ignition of the blowout gas and subsequent fire would result in emissions of nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon monoxide (CO), volatile organic compounds (VOC's), particulate matter (PM_{10}), and fine particulate matter ($PM_{2.5}$). The fire could also produce polycyclic aromatic hydrocarbons (PAH's), which are known to be hazardous to human health. The pollutant concentrations would decrease with downwind distance. A large plume of black smoke would be visible at the source and may extend a considerable distance downwind. However, with increasing distance from the fire, the gaseous pollutants would undergo chemical reactions, resulting in the formation of fine particulate matter ($PM_{2.5}$) that includes nitrates, sulfates, and organic matter. The $PM_{2.5}$ concentrations in the plume would have the potential to temporarily degrade visibility in any affected Prevention of Significant Deterioration (PSD) Class I areas (i.e., National Wilderness Areas and National Parks) and other areas where visibility is of significant value.

2.2.1.2. Offshore Water Quality

During the initial phase of a catastrophic blowout, water quality impacts include disturbance of sediments and release and suspension of oil and natural gas (methane) into the water column. These potential impacts are discussed below. As this section deals with the immediate effects of a blowout that would be located at least 3 nautical mi from shore, it is assumed that there would be no impacts on coastal water quality during this initial stage.

Disturbance of Sediments

A catastrophic blowout below the seafloor, outside the wellbore (Table 1) has the potential to resuspend sediments and disperse potentially large quantities of bottom sediments. Some sediment could travel several kilometers, depending on particle size and subsea current patterns. In the deep Gulf of Mexico, surficial sediments are mostly composed of silt and clay, and, if resuspended, could stay in the water column for several hours to even days. Bottom currents in the deep Gulf of Mexico have been measured to reach 30 centimeters/second (cm/sec) with mean flows of 1.5-2.5 cm/sec (Hamilton, 1990). At these mean flow rates, resuspended sediment could be transported 1.3-2.1 kilometers/day. Sediment resuspension can lead to a temporary change in the oxidation-reduction chemistry in the water column, including a localized and temporal release of any formally sorbed metals, as well as nutrient recycling (Caetano et al., 2003; Fanning et al., 1982). Sediments also have the potential to become contaminated with oil components.

A subsea release also has the potential to destabilize the sediments and create slumping or larger scale sediment movements along depth gradients. These types of events would have the potential to move and/or damage any infrastructure in the affected area.

Release and Suspension of Oil into the Water Column

As the Deepwater Horizon incident showed, a subsea release of hydrocarbons at a high flow rate has the potential to disperse and suspend oil droplets (chemically dispersed or otherwise) within the water column and to induce large patches of sheen and oil on the surface. These dispersed hydrocarbons may adsorb onto marine detritus (marine snow) or may be mixed with drilling mud and deposited near the source. Mitigation efforts such as burning may introduce hydrocarbon byproducts into the marine environment, which would be distributed by surface currents. The acute and chronic sublethal effects of these dilute suspended “plumes” are not well understood and require future research efforts.

Large amounts of oil put into offshore water may alter the chemistry of the sea with unforeseeable results. The VOCs, including benzene, can have acutely toxic effects. The components of crude oil that are water soluble are more available than some of the heavier components to exert a toxic effect on marine life. The PAHs are present in crude oil and include carcinogenic compounds and compounds that pose various risks to marine organisms and possibly to the higher trophic level species, including humans that feed on these organisms. The PAHs are also persistent in the environment. Impacts from the subsequent extended oil spill on offshore water quality are discussed further in Section 3.2.1.2.

Release of Natural Gas (Methane) into the Water Column

A catastrophic blowout could release natural gas into the water column; the amount of gas released is dependent upon the water depth, the natural gas content of the formation being drilled, and its pressure. Methane is the primary component of natural gas (NaturalGas.org, 2010). Methane may stay in the marine environment for long periods of time (Patin, 1999; p. 237), as methane is highly soluble in seawater at the high pressures and cold temperatures found in deepwater environments (NRC, 2003; p. 108). However, methane diffusing through the water column would likely be oxidized in the aerobic zone and would rarely reach the air-water interface (Mechalas, 1974; p. 23). In addition to methane, natural gas contains smaller percentages of other gases such as ethane and propane. It may also contain VOCs (including benzene, toluene, ethylbenzene, and xylene) and H_2S, which have individual toxic characteristics. Methane and other natural gas constituents are carbon sources, and their introduction into the marine environment could result in reducing the dissolved oxygen levels due to microbial degradation of the methane potentially creating hypoxic or “dead” zones. Depletion of dissolved oxygen in the Gulf of Mexico due to the release of natural gas from the Macondo well (Deepwater Horizon incident) is

currently being examined as a result of the Deepwater Horizon incident (Schenkman, 2010). Unfortunately, little is known about methane toxicity in the marine environment, but there is concern as to how methane in the water column might affect fish (see Section 3.2.2.2).

2.2.2. Biological Resources

Impacts during the initial event would be limited to environmental resources in the immediate vicinity of the blowout as described below.

2.2.2.1. Marine and Migratory Birds

Many migratory birds use offshore platforms or rigs as rest sites during migration (Russell, 2005). In addition, seabirds are attracted to offshore platforms and rigs (Tasker et al., 1986; Weise et al., 2001). The numbers of birds present at a platform or rig are greater when platforms or rigs are closer to shore during drilling operations (Baird, 1990). Birds resting on the drilling rig or platform during a catastrophic blowout are likely to be killed by an explosion. While it is assumed that most birds in trans-Gulf migration would likely avoid the fire and smoke plume during the day, it is conceivable that the light from the fire could interfere with nocturnal migration, especially during poor visibility conditions. It has been documented that seabirds are attracted to natural gas flares at rigs and platforms (Russell, 2005; Wiese et al., 2001); therefore, additional bird fatalities could result from the fire following the blowout. Though different species migrate throughout the year, the largest number of species migrates from March through November. A blowout during this time would cause a greater number of bird fatalities. While the number and species of birds killed depends on the blowout location and time of year, these initial fatalities would likely not result in population-level impacts for species present at the time of the blowout and resulting fire (Russell, 2005: Table 6.12).

2.2.2.2. Fish, Fisheries, and Essential Fish Habitat

Depending on the type of blowout and the proximity of marine life to it (Table 1), an eruption of gases and fluids may generate not only a toxic effect but also pressure waves and noise significant enough to injure or kill local biota. Within a few thousand meters of the blowout, resuspended sediments may clog fish gills and interfere with respiration. Settlement of resuspended sediments may, in turn, smother invertebrates or interfere with their respiration. Offshore benthic habitats that support fisheries could also be impacted, as discussed below.

2.2.2.3. Marine Mammals

Depending on the type of blowout, the pressure waves and noise generated by the eruption of gases and fluids would likely be significant enough to harass, injure, or kill marine mammals, depending on the proximity of the animal to the blowout. A high concentration of response vessels could result in harassment or displacement of individuals and could place marine mammals at a greater risk of vessel collisions, which would likely cause fatal injuries.

In addition to the above, the presence of hydrocarbons and other materials generated from a spill through which marine mammals swim may result in direct harm by clogging blowholes, etc.

2.2.2.4. Sea Turtles

Five species of sea turtles are found in the waters of the Gulf of Mexico: green, leatherback, hawksbill, Kemp's ridley, and loggerhead. All species are protected under the Endangered Species Act (ESA), and all are listed as endangered except the loggerhead turtle, which is listed as threatened. Depending on the type of blowout (Table 1), an eruption of gases and fluids may generate significant pressure waves and noise that may harass, injure, or kill sea turtles, depending on their proximity to the accident. A high concentration of response vessels could place sea turtles at a greater risk of fatal injuries from vessel collisions.

Further, mitigation by burning puts turtles at risk because they tend to be gathered up in the corralling process necessary to concentrate the oil in preparation for the burning. Trained observers should be required during any mitigation efforts that include burning.

2.2.2.5. Offshore Benthic Habitats

Gulf of Mexico benthic resources are divided into shelf habitats and deepwater habitats. Shelf habitats of the Gulf of Mexico include soft-bottom habitats (sandy and muddy substrate) and hard-bottom habitats (rock or salt outcroppings that provide habitat for encrusting organisms). Deepwater benthic communities of the Gulf of Mexico include soft-bottom, coral, and chemosynthetic habitats. The impacts to these benthic communities depends on the location and the type of catastrophic blowout that occurs.

Introduction

Sediment disturbance as a result of the blowout above the seafloor would not occur. A catastrophic blowout that occurs above the seabed (at the rig, along the riser between the seafloor and sea surface, or through leak paths on the BOP/wellhead) would result in released oil rising to the sea surface. However, if the leak is deep in the water column and the oil is ejected under pressure, oil droplets may become entrained deep in the water column. The upward movement of the oil may be reduced if methane in the oil is dissolved at the high underwater pressures, reducing the oil's buoyancy (Adcroft et al., 2010). The large oil droplets will rise to the sea surface, but the smaller droplets, formed by vigorous turbulence in the plume or the injection of dispersants, may remain neutrally buoyant in the water column, creating a subsurface plume (Adcroft et al., 2010). Oil droplets less than 100 micrometers in diameter may remain in the water column for several months (JAG, 2010) where they will not be in contact with benthic habitats; similarly, large oil drops on the sea surface will not be in contact with benthos. However, oil in the water column or at the sea surface may sometimes sink, contact benthos, and have impacts, as discussed below.

As discussed below, a catastrophic blowout outside the well casing and below the seafloor or at the seafloor water interface could resuspend large quantities of bottom sediments and create a large crater, destroying many organisms within a few hundred meters of the wellhead. Some of the sediment could travel up to a few thousand meters before redeposition, negatively impacting a localized area of benthic communities.

The use of subsea dispersants would increase the exposure of offshore benthic habitats to dispersed oil droplets in the water column, as well as the chemicals used in the dispersants. The use of subsea dispersants is not likely to occur for seafloor blowouts outside the well casing.

Soft-Bottom Shelf Habitats

The vast majority of the Gulf of Mexico seabed is comprised of soft sediments. Microbes to metazoans (e.g., polychaete worms and crabs) inhabit the soft-bottom benthos, many forming the base of the food chain for several species. When soft-bottom infaunal communities are physically impacted by a blowout (either lost to the crater formation or smothered by sediment), recolonization by populations from neighboring soft-bottom substrate is expected within a relatively short period of time. Many of the organisms on soft bottoms live within the sediment and have the ability to migrate upward in response to burial by sedimentation. A blowout that occurs outside the well casing can rapidly deposit 30 cm (12 inches) or more of sediment within a few hundred meters and may smother much of the soft-bottom community in a localized area. In situations where soft-bottom infaunal communities are negatively impacted, recolonization by populations from neighboring soft-bottom substrate would be expected over a relatively short period of time for all size ranges of organisms, in a matter of days for bacteria, and probably less than 1 year for most macrofauna and megafauna species. Recolonization could take longer for areas affected by direct contact of concentrated oil. Initial repopulation from nearby stocks of pioneering species, such as tube-dwelling polychaetes or oligochaetes, may begin with the next recruitment event (Rhodes and Germano, 1982). Full recovery would follow as later stages of successional communities overtake the pioneering species (Rhodes and Germano, 1982). The time it takes to reach a climax community may vary depending on the species and degree of impact. Full benthic community recovery may take years to decades if the benthic habitat is heavily oiled (Gesteira and Dauvin, 2000; Sanders et al., 1980; Conan, 1982). A slow recovery rate will result in a community with reduced biological diversity and possibly a lesser food value for predatory species.

Hard-Bottom Shelf Habitats

The Gulf of Mexico shelf has several hard-bottom features upon which encrusting and epibenthic organisms attach. Though there are varying degrees of relief on the hard bottom, the impacts from a catastrophic blowout are similar for the banks of varying relief because similar organisms occur on these features. Thus, they are discussed as a single grouping under "hard-bottom communities," with references to specific communities where impacts may differ.

Topographic features are isolated areas of moderate to high relief that provide habitat for hard-bottom communities of high biomass and moderate diversity. These features provide shelter and food for large numbers of commercially and recreationally important fish. There are 37 named topographic features in the Gulf of Mexico with specific BOEMRE protections, including the Flower Garden Banks National Marine Sanctuary. The BOEMRE has created "No Activity Zones" around topographic features in order to protect these habitats from disruption due to oil and gas activities. A "No Activity Zone" is a protective perimeter drawn around each feature that is associated with a specific isobath (depth contour) surrounding the feature in which structures, drilling rigs, pipelines, and anchoring are not allowed. These "No Activity Zones" are areas where activity is prohibited based on BOEMRE policy. Notice to Lessees and Operators (NTL) 2009-G39 recommends that drilling should not occur within 152 meters ([m]; 500 ft) of a "No Activity Zone" of a topographic feature.

The northeastern portion of the central Gulf of Mexico is a region of low to moderate relief known as the "Pinnacle Trend" at the outer edge of the Mississippi-Alabama shelf between the Mississippi River and De Soto Canyon. These outcrops provide hard substrate for sessile invertebrate attachment that attracts fish. The NTL 2009-G39 recommends that no bottom-disturbing activities occur within 30 m (100 ft) of any hard bottoms/pinnacles with a relief of 8 ft or greater.

Potentially sensitive biological features are features that have moderate to high relief (8 feet or higher), provide hard surface for sessile invertebrates, attract fish, but are not located within Pinnacle-designated blocks or the "No Activity Zone" of topographic features. No bottom-disturbing activities that may cause impact to these features are permitted.

Impacts that occur to hard-bottom shelf habitats as a result of a blowout would depend on the type of blowout, distance from the blowout, relief of the biological feature, and surrounding physical characteristics of the environment (e.g., turbidity). The NTL 2009-G39 recommends the use of buffers to prevent blowouts in the immediate vicinity of a hard-bottom habitat or its associated biota. Much of the oil released from a blowout would rise to the sea surface, therefore minimizing the impact to benthic communities by direct oil exposure. However, small droplets of oil that are entrained in the water column for extended periods of time may migrate into "No Activity Zones." Although these small oil droplets will not sink themselves, they may attach to suspended particles in the water column and then be deposited on the seafloor (McAuliffe et al., 1975). These long-term impacts, such as reduced recruitment success, reduced growth, and reduced coral cover, as a result of impaired recruitment, are discussed in Section 3.2.2.6. Also, if the blowout were to occur beneath the seabed, suspension and subsequent deposition of disturbed sediment may smother localized areas of benthic communities, possibly including organisms within No Activity Zones or other hard-bottom substrate.

Benthic communities on a hard-bottom feature exposed to large amounts of resuspended and deposited sediments following a catastrophic, subsurface blowout could be subject to sediment suffocation, exposure to resuspended toxic contaminants, and reduced light availability. Impacts to corals as a result of sedimentation would vary based on coral species, the height to which the coral grows, degree of sedimentation, length of exposure, burial depth, and the coral's ability to clear the sediment. Impacts may range from sublethal effects such as reduced growth, alteration in form, and reduced recruitment and productivity to slower growth to death (Rogers, 1990).

The initial blowout impact would be greatest to communities located in clear waters that experience heavy sedimentation. Reef-building corals are sensitive to turbidity and may be killed by heavy sedimentation (Rogers, 1990; Rice and Hunter, 1992). However, it is unlikely that reef-building corals would experience heavy sedimentation as a result of a blowout because drilling activity would not be allowed near sensitive organisms in the "No Activity Zones," based on the NTL 2009-G39. The most sensitive organisms are also typically elevated above soft sediments, making them less likely to be buried. It is possible, however, for potentially sensitive biological features outside of "No Activity Zones" or Pinnacle-designated blocks to experience some turbidity or sedimentation impacts. Corals may also experience discoloration or bleaching as a result of sediment exposure, although recovery from such exposure may occur within 1 month (Wesseling et al., 1999).

Initial impacts would be much less extreme in a turbid environment (Rogers, 1990). For example, the Pinnacle Trend community exists in a relatively turbid environment, starting just 65 kilometers ([k]; 40 mi) east of the mouth of the Mississippi River and trending to the northeast. Sediment from a blowout, if it occurred nearby, may have a reduced impact on these communities compared with an open-water reef community, as these organisms are more tolerant of suspended sediment (Gittings et al., 1992). Many of the organisms that predominate in this community also grow tall enough to withstand the sedimentation that results from their turbid environment or they have flexible structures that enable the passive removal of sediments (Gittings et al., 1992).

A portion or the entire rig may sink to the seafloor as a result of a blowout. The benthic communities (hard- or soft-bottom communities) on the seafloor upon which the rig settles would be destroyed or smothered. A settling rig may suspend sediments, which may smother nearby benthic communities as the sediment is redeposited on the seafloor. The habitats beneath the rig may be permanently lost; however, the rig itself may become an artificial reef upon which epibenthic organisms may settle. The surrounding benthic communities that were smothered by sediment would repopulate from nearby stocks through spawning recruitment and immigration.

Deepwater Habitats

The effects of a catastrophic blowout event on Gulf of Mexico benthic resources in deep water (>1,000 ft; 300 m) are similar to those on the shelf communities. The main factors are the type of blowout and the proximity to the habitat. Known deepwater communities include soft bottoms and two types of hard-bottom communities: chemosynthetic communities and deep coral communities. Many of the organisms on soft bottoms live within the sediment and have the ability to migrate upward in response to burial by sedimentation. A blowout that occurs outside the well casing can rapidly deposit 30 cm (12 inches) or more of sediment within a few hundred meters and may smother much of the soft-bottom community in a localized area. In situations where soft-bottom infaunal communities are negatively impacted, recolonization by populations from neighboring soft-bottom substrate would be expected over a relatively short period of time for all size ranges of organisms, in a matter of days for bacteria, and probably less than 1 year for most macrofauna and megafauna species. Recolonization could take longer for areas affected by direct contact of concentrated oil.

BOEMRE restrictions applicable to work near deepwater hard-bottom areas (as described in NTL 2009-G40) would prevent direct negative effects from a seafloor blowout. The established policy prohibits location of wells within 2,000 ft (610 m) of a suspected hard-bottom habitat. Geophysical analyses have achieved a high degree of reliability in detecting the potential presence of hard-bottom communities in the Gulf of Mexico. In rare instances, the subtle geophysical signatures of hydrocarbon seepage, conducive to the development of a chemosynthetic deepwater community development at the seabed that are a probable indicator of a community are not discovered during routine environmental analysis. Therefore, it is possible that a well could be drilled close enough for a hard-bottom community to be damaged in the event of a catastrophic blowout.

Blowouts at points above the seafloor (in the riser or on the drill platform) would have little immediate effect on deepwater seafloor communities unless the structure sinks and physically impacts the seafloor. If a structure sank directly on a hard-bottom community, at least 2,000 ft (610 m) from the well, organisms could be crushed and smothered.

2.2.3. Socioeconomic Resources

2.2.3.1. Offshore Archaeological Resources

BOEMRE protects all known, discovered, and potentially historic and prehistoric archaeological resources on the OCS by requiring appropriate avoidance criteria as well as directives to investigate these resources.

Onshore archaeological resources, prehistoric and historic sites, would not be immediately impacted during the initial phase of a catastrophic blowout because the distance of a blowout site from shore is at least 3 nautical miles. However, offshore catastrophic blowouts, when compared with spills of lesser magnitude, may initially impact multiple archaeological resources. Resources adjacent to a catastrophic blowout could be damaged by the high volume of escaping gas, buried by large amounts of dispersed

sediments, crushed by the sinking of the rig or platform, destroyed during emergency relief well drilling, or contaminated by the hydrocarbons.

Based on historical information, over 2,100 potential shipwreck locations have been identified in the Gulf of Mexico OCS (USDOI, MMS, 2007). This number is a conservative estimate and is heavily weighted toward post-19th century, near-shore shipwrecks, where historic records documenting the loss of the vessels were generated more consistently. Of the 2,100 recorded wrecks, only 233 records were determined to have associated spatial data possessing sufficient accuracy for BOEMRE's needs.

The inadequacy of data related to these historic ship losses creates uncertainty in determining how many shipwrecks might be located near existing or planned oil and gas wells. If undiscovered shipwrecks are adjacent to a catastrophic blowout, the potential for impacting these nonrenewable resources is high. However, the potential of a well being drilled close enough to damage or bury a known prehistoric or historic resource, such as a shipwreck, is low when archaeological surveys are required prior to any exploration or development activities. In the past, BOEMRE has required surveys only on leases within blocks deemed to have a high potential for containing historic and/or prehistoric resources (NTL 2005-G07 and NTL 2008-G20). A new archaeological resources policy requires surveys in all OCS blocks throughout the GOM. Avoidance mitigations resulting from the surveys will further protect historic and prehistoric archaeological resources from the potential impacts of a catastrophic blowout.

2.2.3.2. Commercial Fishing

The initial explosion and fire could endanger commercial fishermen in the immediate vicinity of the blowout. Although commercial fishing vessels in the area would likely aid in initial search-and-rescue operations, the subsequent fire could burn for over a month, during which time commercial vessels would be expected to avoid the area so as to not interfere with response activities. This could impact the livelihood and income of these commercial fishermen.

2.2.3.3. Recreational Resources and Fishing

A substantial amount of recreational activity is associated in the immediate area around shallow water oil and gas structures because these structures function as artificial reefs, promote coral growth, and attract fish. About 20 percent of the recreational fishing activity and 90 percent of the recreational diving activity in the Gulf of Mexico occurs within 300 feet of oil and gas structures (Hiett and Milon, 2002). Therefore, an explosion and fire within 100 miles of shore could endanger recreational fishermen and divers in the immediate vicinity of the blowout, especially if the blowout is located between water depths of 100 and 200 feet. Recreational vessels in the area would likely aid in initial search-and-rescue operations but would also be in danger during the explosion and subsequent fire. The subsequent fire could burn for more than a month, during which recreational vessels would be expected to avoid the area and not interfere with response activities. This will impact the income of recreational fishing and diving businesses. Also, if the fire and smoke is visible from recreational beaches, their recreational use may be impacted.

2.2.3.4. Human Resources, Land Use, and Environmental Justice

Fatalities and serious injuries would likely occur during the initial explosion and/or fire. Due to the large number of people (>100) working on a deepwater drilling rig or platform, dozens of fatalities and serious injuries could occur.

With the explosion (>3 nautical miles) from the shore and the likelihood that the resulting fire will burn for a short duration, the initial fire and/or explosion is not expected to impact land use, demographics, or economics, although some recreational beach use may be impacted (Section 2.2.2.3). Thus, the initial fire and explosion should not disproportionately affect low-income persons or minorities, and therefore, will not raise environmental justice concerns.

3. OFFSHORE SPILL (PHASE 2)

3.1. IMPACT-PRODUCING FACTORS AND SCENARIO

Phase 2 of the analysis focuses on the spill and response in Federal and State offshore waters.

3.1.1. Duration of Spill

The duration of the offshore spill from a blowout depends on time needed for intervention and time the remaining oil persists offshore. If a blowout occurs and the damaged surface facilities preclude well reentry operations, a relief well may be needed to regain control. The f time required to drill the relief well depends on the complexity of the intervention, the location of a suitable rig, the type of operation that must be terminated to release the rig (e.g., casing may need to be run before releasing the rig), and problems mobilizing personnel and equipment to the location. A blown-out well may also be successfully capped prior to completion of relief wells, as occurred in the Deepwater Horizon incident. Assuming the duration of previous spills including the Deepwater Horizon and the type of oil and water temperatures found in the Gulf of Mexico, the majority of visibly spilled oil on the surface of the water would not persist more than 30 days after the oil flow stopped (Inter-agency, 2010a).

3.1.1.1. Shallow Water

If a blowout occurs in shallow water the entire intervention effort including drilling relief wells could take 1 to 3 months. This includes 1-3 weeks to transport the drilling rig to the well site. Spilled surface oil is not expected to persist more than 1 month after the flow is stopped. Therefore, the estimated spill duration resulting from a shallow water blowout in is 2-4 months.

3.1.1.2. Deepwater

If a blowout occurs in deepwater, the entire intervention effort including drilling relief wells could take 3 to 4 months. (USDOI, MMS, 2000; Regg, 2000). This includes 2-4 weeks to transport the drilling rig to the well site. Spilled surface oil is not expected to persist more than 1 month after the flow is stopped. Therefore, the estimated spill duration from a deep water blowout is 4-5 months.

3.1.2. Area of Spill

When oil reaches the sea surface, it spreads. The speed and extent of spreading depends on the type and volume that is spilled. However, a catastrophic spill would likely spread hundreds of square miles. Also, the oil slick may break into several smaller slicks, depending on local wind patterns that drive the surface currents in the spill area.

3.1.3. Volume of Spill

For this analysis, a higher flow rate is assumed for a blowout in deep water for the following reasons: After 50 years of Gulf of Mexico development most, if not all, of the largest shallow water prospects have been developed. As a result, reservoir pressures in shallow water are generally reduced. Although under certain conditions oil may be present with the natural gas, deeper shelf wells target natural gas. Also, because deepwater development is costly, only larger prospects with higher flow rates are currently targeted for exploration.

3.1.3.1. Shallow Water

For this analysis, an uncontrolled flow rate of 30,000 barrels per day is assumed for a catastrophic blowout in shallow water. This assumption is based upon the results of well tests in shallow water (see Section 3.1.3 above) and the maximum flow rate from the 1979 Ixtoc blowout, which occurred in shallow water. Using this flow rate, the total volume of oil spilled from a catastrophic blowout in shallow water is estimated at 900,000 to 3 million barrels for a spill lasting 1-3 months. In addition to the flow rate, it is assumed that any remaining diesel fuel from a sunken drilling rig would also leak.

3.1.3.2. Deep Water

For the purposes of this analysis, an uncontrolled flow rate of 30,000-60,000 barrels per day is assumed for a catastrophic blowout in deep water. This flow rate is based on the assumption in Section 3.1.3 above, well test results, and the maximum expected flow rate of the 2010 Deepwater Horizon blowout, which occurred in deep water. Therefore, total volume of oil spilled is estimated to be 2.7-7.2 million barrels over 3-4 months. In addition, deepwater drilling rigs hold a large amount of diesel fuel (10,000-20,000 barrels). Therefore, it is assumed that any remaining diesel fuel from a sunken drilling rig would also leak and add to the spill.

3.1.4. Oil in the Environment: Properties and Persistence

The fate of oil in the environment depends on many factors, such as the source and composition of the oil, as well as its persistence (NRC, 2003). Persistence can be defined and measured in different ways (Davis et al., 2004), but the National Research Council (NRC) generally defines persistence as how long oil remains in the environment (NRC, 2003; p. 89). Once oil enters the environment, it begins to change through physical, chemical, and biological weathering processes (NRC, 2003). These processes may interact and affect the properties and persistence of the oil through

- evaporation (volatilization),
- emulsification (the formation of a mousse),
- dissolution,
- oxidation, and
- transport processes (NRC, 2003; Scholz et al., 1999).

Horizontal transport takes place via spreading, advection, dispersion, and entrainment while vertical transport takes place via dispersion, entrainment, Langmuir circulation, sinking, overwashing, partitioning, and sedimentation (NRC, 2003). The persistence of an oil slick is influenced by the effectiveness of oil-spill response efforts and affects the resources needed for oil recovery (Davis et al., 2004). The persistence of an oil slick may also affect the severity of environmental impacts as a result of the spilled oil.

Crude oils are not a single chemical, but instead are complex mixtures with varied compositions. Thus, the behavior of the oil and the risk the oil poses to natural resources depends on the composition of the specific oil encountered (Michel, 1992). Generally, oils can be divided into three groups of compounds: (1) light-weight, (2) medium-weight, and (3) heavy-weight components. On average, these groups are characterized as outlined below in Table 2.

Table 2 Properties and Persistence by Oil Component Group			
Properties and Persistence	Light-weight	Medium-weight	Heavy-weight
Hydrocarbon compounds	Up to 10 carbon atoms	10-22 carbon atoms	>20 carbon atoms
API º	>31.1º	31.1º-22.3 º	<22.3 º
Evaporation rate	Rapid (within 1 day) and complete	Up to several days; not complete at ambient temperatures	Negligible
Solubility in water	High	Low (at most a few mg/L)	Negligible
Acute toxicity	High due to monoaromatic hydrocarbons (BTEX)	Moderate due to diaromatic hydrocarbons (naphthalenes – 2 ring PAH's)	Low except due to smothering (i.e., heavier oils may sink)
Chronic toxicity	None, does not persist due to evaporation	PAH components (e.g., naphthalenes – 2 ring PAH's)	PAH components (e.g., phenanthrene, anthracene – 3 ring PAH's)
Bioaccumulation potential	None, does not persist due to evaporation	Moderate	Low, may bioaccumulate through sediment sorption
Compositional majority	Alkanes and cycloalkanes	Alkanes that are readily degraded (specify, as done for others)	Waxes, asphaltenes, and polar compounds (not significantly bioavailable or toxic)
Persistence	Low due to evaporation	Alkanes readily degrade, but the diaromatic hydrocarbons are more persistent	High; very low degradation rates and can persist in sediments as tarballs or asphalt pavements

Sources: Michel, 1992; Canadian Center for Energy Information, 2010.

Of the oil reservoirs sampled in the Gulf of Mexico OCS, the majority fall within the light-weight category, while less than one quarter are considered medium-weight and a small portion are considered heavy-weight. Oil with an API gravity of 10.0 or less would sink and has not been encountered in the Gulf of Mexico OCS and, therefore, it is not analyzed in this paper (USDOI, BOEMRE, 2010c).

Heavy-weight oil may persist in the environment longer than the other two types of oil, but the medium-weight components within oil present the greatest risks to organisms because, with the exception of the alkanes, these medium-weight components are persistent, bioavailable, and toxic (Michel, 1992).

Previous studies (e.g., Johansen et al., 2001) supported the assumption that most, if not all, released oil would reach the surface of the water column. However, data and observations from the Deepwater Horizon incident challenge that assumption. While analyses are in their preliminary stages, it appears that measurable amounts of hydrocarbons (dispersed or otherwise) are being detected in the water column as subsurface "plumes" and on the seafloor in the vicinity of the release. While not all of these hydrocarbons have been definitively traced back to releases from the Macondo well (Deepwater Horizon incident), these early measurements and results warrant a reassessment of previous assumptions of the ultimate fate of hydrocarbons from unintended subsurface releases.

3.1.5. Release of Natural Gas

The quality and quantity of components in natural gas vary widely by the field, reservoir, or location from which the natural gas is produced. Although there is not a "typical" makeup of natural gas, it is primarily composed of methane (NaturalGas.org, 2010).

3.1.6. Offshore Cleanup Activities

As demonstrated by the Ixtoc and Deepwater Horizon spill responses, a large-scale response effort is certain to follow a catastrophic blowout. The number of vessels and responders would increase exponentially as the spill continued.

3.1.6.1. Shallow Water

Within the first week of an oil spill originating in shallow water, 25 vessels are estimated to respond, which would steadily increase to over 3,000 by the end of the spill. This includes about 25 skimmers in the vicinity of the well at a time. In addition, recovered oil may be barged to shore from recovery vessels.

Within the first week, over 500 responders are estimated to be deployed to a spill originating in shallow water, which would steadily increase up to 25,000 before the well is capped or killed within 2-4 months.

Response to an oil spill in shallow water is expected to involve over 10,000 feet of boom within the first week and would steadily increase up to 5 million feet (1,000 miles) for use offshore and nearshore, the amount dependent upon the location of the potentially impacted shoreline, environmental considerations, and agreed upon protection strategies involving the local potentially impacted communities.

Up to 25 planes and 50 helicopters are estimated to respond per day by the end of a shallow-water spill.

Along the Gulf Coast, dispersants are have been preapproved for use greater than 3 nautical miles from shore and in water depths greater than 33 feet, with the exception of Florida where the water depth must be 65 feet (USCG, 2010). However, the USEPA is presently examining these preapprovals and restrictions are anticipated regarding the future use of dispersants for ongoing spills as a result. Changes to the dispersant use preapprovals would be expected to limit this use in the future. Under pre-existing preapprovals it is estimated that up to a total of 35,000 barrels of dispersant would be used.5 Aerial dispersants would likely be applied from airplanes as a mist, which settles on the oil on the water's surface. In addition to dispersants, controlled burns may also occur.

3.1.6.2. Deep Water

Within the first week of oil spill originating in deep water, 50 vessels are estimated to respond, which would steadily increase to over 7,000 by the end of the spill. This includes about 25 skimmers in the vicinity of the well at a time. In addition, recovered oil may be shuttle tankered to shore from recovery vessels.

For an oil spill in deep water, over 1,000 responders are estimated to be deployed within the first week, which would steadily increase up to 50,000 before capping or killing the well within 4-5 months.

Over 20,000 feet of boom is estimated to be deployed within the first week of a deepwater spill, which would steadily increase up to 11 million feet (2,100 miles) offshore and nearshore, the amount dependent upon the location of the potentially impacted shoreline, environmental considerations, and agreed upon protection strategies involving the local potentially impacted communities.

Up to 50 planes and 100 helicopters are estimated to respond per day by the end of a deepwater spill.

With the exception of special Federal management areas or designated exclusion areas, dispersants have been preapproved in the vicinity of a deepwater blowout (USCG, 2010).). However, the USEPA is presently examining these preapprovals and restrictions are anticipated regarding the future use of dispersants as a result. Under pre-existing preapprovals it is estimated that up to 50,000 barrels of dispersant would could be applied (2/3 on the water surface and 1/3 subsurface, if possible). Changes to the dispersant use preapprovals would be expected to limit this use. No preapproval presently exists for the use of subsea dispersants and approval must be obtained before each use of this technology. The use of subsea dispersants depends on the location of the blowout, as discussed in Table 1. Aerial dispersants are applied from airplanes as a mist, which settles on the oil on the water's surface. In addition to dispersants, it is estimated that 5-10 controlled burns would be conducted per day in suitable weather. About 500 burns in all would remove 5-10 percent of the oil.

3.1.6.3. Vessel Decontamination Stations

To avoid contaminating inland waterways, multiple vessel decontamination stations may be established offshore in Federal and State waters. Vessels responding to the spill and commercial and

5 At the IXTOC-I Well Blowout in 1979, between 1 million and 2.5 million gallons of mostly Corexit dispersant products were applied over a 5-month period on the oil discharge. However, this scenario assumes a spill from a blowout in shallow water would last up to 3 months.

recreational vessels passing through the spill would anchor, awaiting inspection. If decontamination is required, work boats would use fire hoses to clean oil from the sides of the vessels. This could result in some oiling of otherwise uncontaminated waters. While these anchorage areas would be surveyed for buried pipelines that could be ruptured by ship anchors, they may not be surveyed adequately for benthic communities or archaeological sites. Therefore, some damage to benthic communities or archaeological sites may occur due to vessel decontamination activities associated with an oil spill in deep water (Alabama State Port Authority, 2010; Office of the Governor, State of Florida, 2010; Nodar, 2010; Unified Incident Command, 2010a-c; USDOC, NOAA, 2010a; USEPA, 2010a).

3.1.7. Severe Weather

A hurricane could accelerate biodegradation, increase the area affected by the spill, and/or slow the response effort. The Atlantic hurricane season runs from June 1st through November 30th, peaking in September. In an average Atlantic season, there are eleven named storms, six hurricanes, and two Category 3 or higher storms (USDOC, NOAA, National Weather Service, 2010a). As a result of a hurricane, high winds and seas would mix and "weather" the oil from an oil spill. This can help accelerate the biodegradation process (USDOC, NOAA, National Weather Service, 2010b). The high winds may distribute oil over a wider area (USDOC, NOAA, National Weather Center, 2010b). In the event of a hurricane, vessels would evacuate the area, delaying response efforts, including the drilling of relief wells and any well capping or collection efforts.

3.2. Most Likely and Most Significant Impacts

The most recent EISs prepared by BOEMRE for oil and gas lease sales in the Gulf of Mexico identify in detail the potential impacts from reasonably foreseeable oil spills (USDOI, MMS, 2007 and 2008). In addition to the impacts described in those documents, the most likely and most significant impacts due to the magnitude of shoreline oil as a result of a catastrophic spill are described below.

3.2.1. Physical Resources

3.2.1.1. Air Quality

In the Gulf of Mexico, evaporation from the oil spill would result in concentrations of volatile organic compounds (VOCs) in the atmosphere, including chemicals that are classified as being hazardous. The VOC concentrations would occur anywhere where there is an oil slick, but would be highest at the source of the spill because the rate of evaporation depends on the volume of oil present at the surface. VOC concentrations would and decreases with distance as the layer of oil gets thinner. The lighter fractions of VOC's would be most abundant in the immediate vicinity of the spill site. The heavier compounds would be emitted over a longer period of time and over a larger area. Some of the compounds emitted could be hazardous to workers in close vicinity of the spill site. The hazard to workers can be reduced by monitoring and using protective gear, including respirators. During the Deepwater Horizon incident, air samples collected by individual offshore workers by British Petroleum (BP), Occupational Safety and Health Administration (OSHA), and U.S. Coast Guard showed levels of benzene, toluene, ethylbenzene, and xylene that were mostly under detection levels. All samples had concentrations below the OSHA Occupational Permissible Exposure Limits (PELs) and the more stringent ACGIH (American Conference of Governmental Industrial Hygienists) Threshold Limit Values (TLVs) (U.S. Department of Labor, OSHA, 2010a).

The VOC emissions that result from the evaporation of oil contribute to the formation of particulate matter ($PM_{2.5}$) in the atmosphere. In addition, VOCs could cause an increase in ozone levels, especially if the release were to occur on a hot, sunny day with sufficient concentrations of NO_x present in the lower atmosphere. However, due to the distance from shore, the oil slick would not normally have any effects on onshore ozone concentrations.

It is assumed that response efforts would include hundreds of in-situ or controlled burns, which would remove an estimated 5-10 percent of the volume of oil spilled. This could be as much as 720,000 barrels of oil for a spill of 60,000 barrels per day for 120 days. In-situ burning would result in ambient concentrations of CO, NO_x, SO_2, PM_{10}, and $PM_{2.5}$ very near the site of the burn and would generate a plume of black smoke. The levels of $PM_{2.5}$ could be a hazard to personnel working in the area, but this

could be effectively mitigated through monitoring and relocating vessels to avoid areas of highest concentrations. In an experiment of an in-situ burn off Newfoundland, it was found that CO, SO_2, and NO_2 were measured only at background levels and were frequently below detection levels (Fingas et al., 1995). Limited amounts of formaldehyde and acetaldehyde were measured, but concentrations were close to background levels. Measured values of dioxins and dibenzofurans were at background levels. Measurements of PAH in the crude oil, the residues, and the air indicated that the PAH in the crude oil are largely destroyed during combustion (Fingas et al, 1995).

While containment operations may be successful in capturing some of the escaping oil and gas, recovery vessels may not be capable of storing the crude oil or may not have sufficient storage capacity. In this case, excess oil would be burned; captured gas cannot be stored or piped to shore so it would be flared. For example, in the Deepwater Horizon incident, gas was flared at the rate of 100-200 million cubic feet per day and oil burned at the rate of 10,000-15,000 barrels per day. The estimated NO_x emissions are about 13 tons per day. The SO_2 emissions would be dependent on the sulfur content of the crude oil. For crude oil with a sulfur content of 0.5 percent, the estimated SO_2 emissions are about 16 tons per day. Particulate matter in the plume would also affect visibility. Flaring or burning activities upwind of a PSD Class I area, e.g., the Breton National Wilderness Area, could be adversely affected due to SO_2 concentrations and reduced visibility.

3.2.1.2. Offshore Water Quality

The water offshore of the Gulf's coasts can be divided into two regions: the continental shelf and slope (<1,000 ft; 305 m) and deep water (>1,000 ft; 305 m). Waters on the continental shelf and slope are heavily influenced by the Mississippi and Atchafalaya Rivers, the primary sources of freshwater, sediment, nutrients, and pollutants from a huge drainage basin encompassing 55 percent of the continental U.S. (Murray, 1998). Lower salinities are characteristic nearshore where freshwater from the rivers mix with Gulf waters. The presence or extent of a nepheloid layer, a body of suspended sediment at the sea bottom (Kennett, 1982; p. 524), affects water quality on the shelf and slope. Deep waters east of the Mississippi River are affected by the Loop Current and associated warm-core (anti-cyclonic) eddies, which flush the area with clear, low-nutrient water (Muller-Karger et al., 2001). However, cold-core cyclonic eddies (counter-clockwise rotating) also form at the edge of the Loop Current and are associated with upwelling and nutrient-rich, high-productivity waters, although the extent of this flushing can vary seasonally.

While response efforts would decrease the fraction of oil remaining in Gulf waters, significant amounts of oil would remain (Inter-agency, 2010a). Natural processes will physically, chemically, and biologically aid the degradation of oil (NRC, 2003). The physical processes involved include evaporation, emulsification, and dissolution, while the primary chemical and biological degradation processes include photooxidation and biodegradation (i.e., microbial oxidation). Water quality would not only be impacted by the oil, gas, and their respective components but also to some degree from cleanup and mitigation efforts, such as from increased vessel traffic and the addition of dispersants and methanol to the marine environment.

In the case of a catastrophic subsea blowout in deep water, it is assumed that large quantities of subsea dispersants would be used. As a result, clouds or plumes of dispersed oil may occur near the blowout site. Reports thus far from the Deepwater Horizon incident have found such plumes and have shown that the concentrations of these clouds decrease to undetectable levels within a few miles of the source (USDOC, NOAA, 2010b). Additional reporting in the coming months will enhance the understanding of the effects of subsurface plumes. Dissolved oxygen levels are a concern with any release of a carbon source, and these levels became a particular concern during the Deepwater Horizon incident, since dispersants were used in deep waters for the first time. Thus, the U.S. Environmental Protection Agency (USEPA) required monitoring protocols in order to use subsea dispersants (USDOC, NOAA, 2010c). In areas where plumes of dispersed oil were previously found, dissolved oxygen levels decreased by about 20 percent from long-term average values in the Gulf of Mexico; however, scientists reported that these levels have stabilized and are not low enough to be considered hypoxic (USDOC, NOAA, 2010d). The temporary decrease in oxygen content has been attributed to microbial degradation of the oil. Over time, as the oil continues to be degraded and diffuses, hypoxia becomes less of a concern. As reported for the Deepwater Horizon incident, dissolved oxygen levels would likely remain above levels of immediate concern, but there would still be a need to monitor dissolved oxygen levels over time.

Toxicity of dispersed oil in the environment would depend on many factors, including the effectiveness of the dispersion, temperature, salinity, degree of weathering, type of dispersant, and degree of light penetration in the water column (NRC, 2005). The toxicity of dispersed oil is primarily due to the toxic components of the oil itself (Australian Maritime Safety Authority, 2010).

3.2.2. Biological Resources

The most recent EISs prepared by BOEMRE for oil and gas lease sales in the Gulf of Mexico detail potential localized impacts to specific species from reasonably foreseeable oil spills. However, a catastrophic event, such as a high-volume, extended-duration spill resulting from a blowout, has the potential to cause population-level impacts. Multiple Federal and State-listed, threatened and endangered species could be impacted from an extended offshore spill (USDOI, FWS, 2010a and 2010b).

3.2.2.1. Marine and Migratory Birds

During Phase 2 of a catastrophic spill, the primary concern for marine and migratory birds would be their vulnerability to oiling or ingesting oil, which is related to their behavior. Wading birds (e.g., herons, egrets, etc.) and species that feed by plunge-diving into the water to catch small fish (e.g., pelicans, gannets, terns, gulls, and pelagic birds) and those that use water as a primary means of locomotion, foraging, or resting and preening (e.g., diving ducks, cormorants, pelicans, etc.) are highly vulnerable to becoming oiled and also to ingesting oil, as are black skimmers. These birds tend to feed and concentrate in convergence zones, places in the ocean where strong opposing currents meet. In addition to concentrating prey, these zones also aggregate oil (Unified Incident Command, 2010d). Oiling interferes with the birds' ability to fly (thus to obtain food) and compromises the insulative characteristics of down and contour feathers making it difficult to maintain body heat. Attempts by the birds to remove the oil by preening causes oiled birds to ingest oil and may result in mortality.

3.2.2.2. Fish, Fisheries, and Essential Fish Habitat

Early life stages of animals are usually more sensitive to oil than adults (Boesch and Rabalais, 1987; NRC, 2005). Weathered crude oil has been shown in laboratory experiments to cause malformation, genetic damage, and even mortality at low levels in fish embryos of Pacific herring (Carls et al., 1999). There is a high probability of mortality for the eggs and larvae of Gulf fishes that come in contact with spilled oil.

Adult fish may be less at risk than earlier life stages in part because they are less likely to concentrate at the surface and may avoid contact with floating oil. There were, however, sightings of whale sharks (which are defined as "threatened" by the International Union for Conservation of Nature) swimming among slicks from the Deepwater Horizon spill. They were not visibly oiled, but there was concern that they could be affected because they are surface feeders (Howell, 2010). Effects of oil on organisms can include direct lethal toxicity, sublethal disruption of physiological processes (internal lesions), effects of direct coating by oil (suffocation by coating gills), incorporation of hydrocarbons in organisms causing tainting or accumulation in the food chain, and changes in biological habitat (decreased dissolved oxygen) (Moore and Dwyer, 1974).

Because oil found in the Gulf of Mexico would generally float on the surface, fish species whose eggs and larvae are found at or near the water surface are most at risk from an offshore spill. Species whose spawning periods coincide with the timing of the highest oil concentrations would be at greatest risk. If there is a subsea catastrophic blowout, it is assumed dispersants would be used. Then there could be effects on multiple life history stages and trophic levels. There is limited knowledge of the toxicity of dispersants mixed with oil to specific species or life stages of ichthyoplankton, and the likely extent of mortality due to the combination of factors is difficult to determine. The combined toxic effects of the oil and any dispersants that may be used may not be apparent unless a significant portion of a year-class is absent from next year's fishery (e.g., shrimps, crabs, snapper, and tuna).

Recent studies by USEPA using representative species provide some indication of the relative toxicity of Louisiana sweet crude oil, dispersants, and oil/dispersant mixes. Bioassays were conducted using two Gulf species—a mysid shrimp (*Amercamysis bahia*) and a small estuarine fish, the inland silverside (*Menidia beryllinina*)—to evaluate the acute toxic effects of oil, eight dispersants, and oil/dispersant mixtures. In addition, USEPA used standard *in vitro* techniques using the same dispersants to (1) evaluate

acute toxicity on three cell lines over a range of concentrations and (2) evaluate effects of these dispersants on androgen and estrogen function using human cell lines (to see if they are likely to disrupt hormonal systems). All dispersants showed cytotoxicity in at least one cell type at concentrations between 10 and 110 parts per million (ppm). Results of the *in vitro* toxicity tests were similar to the whole animal tests, showing generally low dispersant toxicity. Lethal concentration (LC50) values (the concentration at which half of the test subjects die) were lower than the cell-based assays. For all eight dispersants, for both species, the dispersants alone were less toxic than the dispersant/oil mixture. Louisiana sweet crude oil alone was determined to be more toxic to both the silverside fish and the mysid shrimp than the dispersants alone. The results of the testing for disruption of androgen and estrogen function indicate that the dispersants do not show biologically significant endrocrine activity via androgen or estrogen pathways (USEPA, Office of Research and Development, 2010a and 2010b).

The North Atlantic bluefin tuna is an example of a fish/fishery in the Gulf of Mexico that could be at risk to lose a year-class. It has a relatively narrow peak spawning period in April and May and floating eggs. A catastrophic blowout during the spring season could cause a negative effect to this population. The Gulf of Mexico is one of only two documented spawning grounds for the Atlantic bluefin tuna; the other is in the Mediterranean Sea. Spawning is clustered in a specific type of habitat along the continental slope. Bluefin tuna are among the most valuable fish in global markets. The International Commission for the Conservation of Atlantic Tunas (ScienceDaily, 2010) currently manages the Atlantic bluefin tuna as two distinct populations, with western Atlantic spawners of the Gulf of Mexico forming a population genetically distinct from the eastern spawners of the Mediterranean Sea. The western Atlantic stock has suffered, and a significant and a long-term rebuilding plan has failed to revive the population or the fishery. The failure of the Gulf of Mexico spawning population to rebuild and the scope of illegal and under-reported catches are of such concern that the species was considered for Appendix 1 listing (most endangered status) by the Convention of International Trade in Endangered Species (CITES) in March 2010.

A catastrophic deepwater spill could release natural gases with methane as the primary component (NaturalGas.org, 2010) into the water column, but little is known about the effects of elevated methane levels on fish. Patin (1999) studied the elevated concentrations of methane resulting from a gas blowout from drilling platforms in the Sea of Asov on fish. The pathological changes reported were species specific and included damages to cell membranes, organs, and tissues; modifications of protein synthesis; and other anomalies typical for acute poisoning of fish. These impacts, however, were observed at levels of 4-6 milligrams/liter of methane near the accidental well. The full effect of elevated methane levels on Gulf of Mexico fishes is currently unknown.

3.2.2.3. Marine Mammals

An oil spill and related spill-response activities can impact marine mammals that come into contact with oil and remediation efforts. The marine mammals' exposure to hydrocarbons persisting in the sea may result in sublethal impacts (e.g., decreased health, reproductive fitness, longevity, and increased vulnerability to disease), some soft tissue irritation, respiratory stress from inhalation of toxic fumes, food reduction or contamination, direct ingestion of oil and/or tar, and temporary displacement from preferred habitats or migration routes. More detail on the potential range of effects to marine mammals from contact with spilled oil can be found in Geraci and St. Aubin (1990). The best available information does not provide a complete understanding of the effects of the spilled oil and active response/cleanup activities on marine mammals. For example, it is expected that the large amount of chemical dispersants being used on the oil may act as an irritant on the marine mammals' tissues and sensitive membranes.

The increased human presence after an oil spill (e.g., vessels) would likely add to changes in behavior and/or distribution, thereby potentially stressing marine mammals further and perhaps making them more vulnerable to various physiologic and toxic effects. In addition, the large number of response vessels could place marine mammals at a greater risk of vessel collisions, which could cause fatal injuries.

The Potential Biological Removal (PBR) level is defined by the Marine Mammal Protection Act (MMPA) as the maximum number of animals, not including natural mortalities that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population. However, in the Gulf of Mexico, many marine mammal species have either entirely unknown PBRs or population size estimates that are more than 8 years old and therefore considered unknown. The biological significance of any injury or mortality would depend, in part, on the size and reproductive rates of the affected stocks, as well as the number, age, and size of the marine mammals affected.

According to the Consolidated Fish and Wildlife Collection Reports from the Deepwater Horizon incident, 103 marine mammals have been collected (9 alive and 94 deceased as of September 22, 2010). Thus, a high-volume oil spill lasting 120 days, could directly impact as many individuals or more. The majority would likely be coastal or estuarine bottlenose dolphins, as was the case with the Deepwater Horizon incident. This number represents only those marine mammals collected (either dead or alive) and does not address all potential impacts to the population. Based on these data, it is reasonable to assume that a catastrophic oil spill lasting up to 120 days could have population-level effects on many species of marine mammals (e.g., sperm whales, Bryde's whales, etc.).

3.2.2.4. Sea Turtles

Sea turtles are more likely to be affected by a catastrophic spill in shallow water than in deep water because not all sea turtles occupy a deepwater habitat. For example, Kemp's ridley sea turtles are unlikely to be in water depths of 160 feet or greater. Hawksbill sea turtles are commonly associated with coral reefs, ledges, caves, rocky outcrops, and high energy shoals. Green sea turtles are commonly found in coastal benthic feeding grounds, although they may also be found in the convergence zones of the open ocean. Convergence zones are areas that also may collect oil. Leatherback sea turtles are commonly pelagic and are the sea turtle species most likely to be affected by a deepwater oil spill. As the spilled oil moves toward land, additional species of sea turtles are more likely to be affected.

Based on the Consolidated Fish and Wildlife Collection Reports from the Deepwater Horizon incident, a few to over two dozen sea turtles could be impacted daily through oiling and/or collection. A high-volume oil spill lasting 120 days could impact greater than 1,000 sea turtles, and the majority could be Kemp's ridley turtles, which are listed as endangered under the ESA (USDOC, NOAA, NMFS, 2010a; Unified Incident Command, 2010e). In addition, the large number of response vessels could place sea turtles at a greater risk of vessel collisions, which could cause fatal injuries.

3.2.2.5. Offshore Habitats

Sargassum mats, which are mats made from a free-floating seaweed, that provide habitat for juvenile sea turtles and developing invertebrates, spawning sites for hundreds of fish species, and feeding sources for manatees. "In offshore waters, both free-floating patches of sargassum seaweed and spilled oil tend to accumulate in convergence zones, places in the ocean where strong opposing currents meet. Sea turtles, especially juveniles, use these areas for food and cover. Burn operations sometime occur there because of the aggregated oil" (Unified Incident Command, 2010d). Benthic resources are discussed below.

3.2.2.6. Continental Shelf Benthic Resources

A spill from a shallow-water blowout could impact benthic communities on the continental shelf due to the blowout's proximity to these habitats. A spill from a deepwater blowout could also impact shelf communities if oil that was chemically dispersed at the seafloor is transported to these areas.

Soft-Bottom Benthic Communities

Soft-bottom infaunal communities that come into direct contact with oil or dispersed oil may experience sublethal and/or lethal effects. Localized areas of lethal effects would be recolonized by populations from neighboring soft-bottom substrate once the oil in the sediment has been sufficiently reduced to a level able to support marine life (Sanders et al., 1980). This initial recolonization process may be fairly rapid, but full recovery may take up to 10 years depending on the species present, substrate in the area, toxicity of oil spilled, concentration and dispersion of oil spilled, and other localized environmental factors that may affect recruitment (Kingston et al., 1995; Gesteira and Dauvin, 2000; Sanders et al., 1980; Conan, 1982). Opportunistic species would take advantage of the barren sediment, repopulating impacted areas first. These species may occur within the first recruitment cycle of the surrounding populations or from species immigration from surrounding stocks and may maintain a stronghold in the area until community succession begins (Rhodes and Germano, 1982; Sanders et al., 1980).

Long-term or low-level exposure may occur to benthic infauna as a result of oil adhering to sediment. Mesocosm experiments using long-term, low-level concentrations of No. 2 fuel oil indicate acute toxicity

to meiofauna due to direct oil contact and sublethal effects from sedimented oil and byproducts of the decomposition of the sedimented oil (Frithsen et al., 1985). Long-term exposure to low levels of fuel oil was shown to affect recruitment success; meiofaunal population recovery took between 2 and 7 months (Frithsen et al., 1985). Oil entrained within sediments at the seafloor could create a layer toxic to infaunal species. This layer will persist through burial unless it is sufficiently degraded over time. Continued deposition of pelagic material could bury the layer, but it will remain intact over some timeframe as a potentially toxic or lethal horizon.

Continued localized disturbance of soft-bottom communities may occur during oil-spill response efforts. Anchors used to set booms to contain oil or vessel anchors in decontamination zones may affect infaunal communities in the response activity zone. Infaunal communities may be altered in the anchor scar and deposition of suspended sediment may result from the setting and resetting of anchors. The disturbed benthic community should begin to repopulate from the surrounding communities during their next recruitment event and through immigration of organisms from surrounding stocks. Any decontamination activities, such as cleaning vessel hulls of oil, may also contaminate the sediments of the decontamination zone, as some oil may settle to the seabed, impacting the underlying benthic community.

If a blowout occurs at the seafloor, drilling muds (primarily barite) may be pumped into a well in order to "kill" it. If a kill is not successful, the mud (possibly tens of thousands of barrels) may be forced out of the well and deposited on the seafloor near the well site. Any organisms beneath heavy layers of the extruded drilling mud would be buried. Base fluids of drilling muds are designed to be low in toxicity and biodegradable in offshore marine sediments (Neff et al., 2000). However, as bacteria and fungi break down the drilling fluids, the sediments may be come anoxic (Neff et al., 2000). Benthic macrofaunal recovery would occur when drilling mud concentrations are reduced to levels that enable the sediment to become re-oxygenated (Neff et al., 2000). Complete community recovery from drilling mud exposure may take 3-5 years, although microbial degradation of drilling fluids, followed by an influx of tolerant opportunistic species is anticipated to begin almost immediately (Neff et al., 2000). In addition, the extruded mud may bury hydrocarbons from the well, making them a hazard to the infaunal species and difficult to remove.

Hard-Bottom Benthic Communities

Sensitive reef communities flourish wherever hard bottoms occur in the Gulf of Mexico. Several categories are protected by BOEMRE. The eastern Gulf of Mexico contains scattered, low-relief live-bottoms including areas of flat limestone shelf rock. Potentially sensitive biological features are 8 feet or more above the seafloor. The Pinnacle Trend area includes low- and high-relief features and is 60-120 m (200-400 ft) below the sea surface, and topographic features are high relief and generally 15 m (49 ft) or more below the sea surface. Their depth below the sea surface protects all of these habitats from a surface oil spill.

Although hard-bottom benthic communities are initially buffered from surface oil slicks by their depth below the sea surface, surface oil may be brought to depth through physical processes. Rough seas may mix the oil into subsurface water layers, where it may impact sessile biota. The total time during which seas are rough would help affect the amount of oil from a surface slick that would be mixed into the water column. Measurable amounts of oil have been documented down to a 10-m (33-ft) depth, although modeling exercises have indicated such oil may reach a depth of 20 m (66 ft). At this depth, however, the oil is found at concentrations several orders of magnitude lower than the amount shown to have an effect on corals (Lange, 1985; McAuliffe et al., 1975 and 1981; Knap et al., 1985).

The presence of a subsurface oil plume may affect hard-bottom communities. A portion of the oil released is expected to rise rapidly to the sea surface. However, upward movement of the oil may be reduced if methane in the oil is dissolved under high pressures, and oil droplets may become entrained deep in the water column (Adcroft et al., 2010). Subsurface plumes generated by high-pressure dissolution of oil may come in contact with hard-bottom features. A sustained spill would continuously create surface slicks and possibly subsurface spill plumes. Some of the oil in the water column will become diluted or evaporated over time, reducing any localized transport to the seafloor (Vandermeulen, 1982). In addition, microbial degradation of the oil occurs in the water column so that the oil would be less toxic when it contacts the seafloor (Hazen et al., 2010). However, a sustained spill may result it elevated exposure concentrations to hard-bottom features if the plume reaches them. The longer the spill takes to stop, the longer the exposure time and concentration may be.

Low-level exposures of corals to oil from a subsea plume may result in chronic or temporary impacts. For example, feeding activity or reproductive ability may be reduced when coral is exposed to low levels of oil; however, impacts may be temporary or unable to be measured over time. Experiments indicated that normal feeding activity of *Porites porites* and *Madracis asperula* were reduced when exposed to 50 ppm oil (Lewis, 1971). Reefs of *Siderastrea sidereal* that were oiled in a spill produced smaller gonads than unoiled reefs, resulting in reproductive stress (Guzmán and Holst, 1993).

Elevated concentrations of oil may be necessary to measure reduced photosynthesis or growth in corals. Photosynthesis of the zooxanthellae in *Diplora strigosa* exposed to approximately 18-20 ppm crude oil for 8 hours was not measurably affected, although other experiments indicate that photosynthesis may be impaired at higher concentrations (Cook and Knap, 1983). Measurable growth of *Diploria strigosa* exposed to oil concentrations up to 50 ppm for 6-24 hours did not show any reduced growth after 1 year (Dodge et al., 1984).

Corals exposed to subsea oil plumes may incorporate petroleum hydrocarbons into their tissue. Records indicate that *Siderastrea siderea*, *Diploria strigosa*, and *Montastrea annularis* accumulate oil from the water column and incorporate petroleum hydrocarbons into their tissues (Burns and Knap, 1989; Knap et al., 1982; Kennedy et al., 1992). Most of the petroleum hydrocarbons are incorporated into the coral tissues, not their mucus (Knap et al., 1982). However, hydrocarbon uptake may also modify lipid ratios of coral (Burns and Knap, 1989). If lipid ratios are modified, mucus synthesis may be impacted, adversely affecting the coral's ability to protect itself from oil through mucus production (Burns and Knap, 1989).

If dispersants are used on the seafloor or at the surface, oil may mix into the water column well below the surface, can travel with currents through the water, and may contact settle on hard bottoms. If near the source, the dispersed oil could be concentrated enough to harm the community. If the oil remains suspended for a longer period of time, it would be more dispersed and present at lower concentrations. Reports on dispersant usage on surface plumes indicates that a majority of the dispersed oil remains in the top 10 m of the water column, with 60 percent of the oil in the top 2 m (McAuliffe et al., 1981). Dispersant usage also reduces the oil's ability to stick to particles in the water column, minimizing sedimented oil traveling to the seafloor (McAuliffe et al., 1981).

Dispersed oil reaching the benthic hard-bottom communities in the Gulf of Mexico would be expected to be at very low concentrations (less than 1 part per million) (McAuliffe et al., 1981). Such concentrations would not be life threatening to larval or adult stages at depth based on experiments conducted with coral. Any dispersed oil in the water column that comes in contact with corals may evoke short-term negative responses by the organisms (Wyers et al., 1986; Cook and Knap, 1983; Dodge et al., 1984).

Reductions in feeding and photosynthesis are some impacts that may occur to coral exposed to dispersed oil. Short-term, sublethal responses of *Diploria strigosa* were reported after exposure to dispersed oil at a concentration of 20 ppm for 24 hours. Although concentrations in this experiment were higher than what is anticipated for dispersed oil at depth, effects exhibited included mesenterial filament extrusion, extreme tissue contraction, tentacle retraction, and localized tissue rupture (Wyers et al., 1986). Normal behavior resumed within 2 hours to 4 days after exposure (Wyers et al., 1986). *Diploria strigosa* exposed to dispersed oil (20:1, oil:dispersant) showed an 85 percent reduction in zooxanthellae photosynthesis after 8 hours of exposure to the mixture (Cook and Knap, 1983). However, the response was short-term, as recovery occurred between 5 and 24 hours after exposure and return to clean seawater. Investigations 1 year after *Diploria strigosa* was exposed to concentrations of dispersed oil between 1 and 50 ppm for periods between 6 and 24 hours did not reveal any impacts to growth (Dodge et al., 1984).

Dispersed oil does appear to be more toxic to coral species than oil or dispersant alone. The greater toxicity may be a result of and increased number of oil droplets caused by the use of dispersant, resulting in greater contact area between oil, dispersant, and water (Elgershuizen and Kruijf, 1976). The dispersant causes a higher water-soluble amount of oil to contact the cell membranes of the coral (Elgershuizen and Kruijf, 1976). The mucus produced by coral, however, can protect the organism from oil. Both hard and soft corals have the ability to produce mucus, and mucus production has been shown to increase when corals are exposed to crude oil (Mitchell and Chet, 1975; Ducklow and Mitchell, 1979). Dispersed oil however, which has very small oil droplets, does not appear to adhere to coral mucus, and larger untreated oil droplets may become trapped by the mucus barrier (Knap, 1987; Wyers et al., 1986). However, entrapment of the larger oil droplets may increase the coral's long-term exposure to oil if the mucus is not shed in a timely manner (Knap, 1987; Bak and Elgershuizen, 1976).

Although dispersed oil may be more toxic than untreated oil to corals during exposure experiments, untreated oil may remain in the ecosystem for long periods of time, while dispersed oil does not (Baca et al., 2005; Ward et al., 2003). Twenty years after an experimental oil spill in Panama, oil and impacts from untreated oil were still observed at oil treatment sites, but no oil or impacts were observed at dispersed oil or reference sites (Baca et al., 2005). Long-term recovery of the coral at the dispersed oil site had already occurred as reported in a 10-year monitoring update, and the site was not significantly different from the reference site (Ward et al., 2003).

BOEMRE policy prevents wells from being placed immediately adjacent to sensitive communities. In the event of a seafloor blowout however, some oil could be carried to hard bottoms as a result of oil droplets sedimenting to suspended particles in the water column. Oiled sediment that settles to the seafloor may affect organisms attached to hard-bottom substrates. Impacts may include reduced recruitment success, reduced growth, and reduced coral cover as a result of impaired recruitment. Experiments have shown that the presence of oil on available substrate for larval coral settlement has inhibited larval metamorphosis and larval settlement in the area. There were also an increased number of deformed polyps after metamorphosis due to oil exposure (Kushmaro et al., 1997).

The majority of organisms exposed to sedimented oil however, are anticipated to experience low-level concentrations because as the oiled sediments settle to the seafloor they are widely dispersed. Coral may also be able to protect itself from low concentrations of sedimented oil that settles from the water column. Coral mucus may not only act as a barrier to protect coral from the oil in the water column but it has also been shown to aid in the removal of oiled sediment on coral surfaces (Bak and Elgershuizen, 1976). Coral may use a combination of increased mucus production and ciliary action to rid themselves of oiled sediment (Bak and Elgershuizen, 1976).

Oil-spill response activity may also impact sessile benthic features. Booms anchored to the seafloor are sometimes used to control the movement of oil at the water surface. Boom anchors can physically impact corals and other sessile benthic organisms, especially when booms are moved around by waves (Tokotch, 2010). Vessel anchorage and decontamination stations set up during response efforts may also break or kill hard-bottom features as a result of setting anchors. Injury to coral reefs as a result of anchor impact may result in long-lasting damage or failed recovery (Rogers and Garrison, 2001). Effort should be made to keep vessel anchorage areas as far from sensitive benthic features as possible to minimize impact.

Drilling muds comprised primarily of barite may be pumped into a well to stop a blowout. If a “kill” is not successful, the mud (possibly tens of thousands of barrels) may be forced out of the well and deposited on the seafloor near the well site. Any organisms beneath the extruded drilling mud would be buried. Based on NTL 2009-G39, a well should be far enough away from a hard-bottom community to prevent extruded drilling muds from smothering benthic communities. However, if drilling muds were to travel far enough or high enough in the water column to contact a hard-bottom community, the fluid would smother the existing community. Experiments indicate that corals perish faster when buried beneath drilling mud than when buried beneath carbonate sediments (Thompson, 1980). As discussed earlier, as the drilling fluids biodegrade, an anoxic zone surrounding the activity may occur. Recolonization would occur from the surrounding community once the area has enough oxygen to support new growth, which may take 3-5 years (Neff et al., 2000).

3.2.2.7. Deepwater Benthic Communities

It is not likely that deepwater benthic communities would be impacted by a spill from a shallow water blowout. However, a spill resulting from a catastrophic blowout in deep water has the potential to impact offshore benthic communities due to the blowout’s proximity to these habitats and the use of subsea dispersants.

Much of the oil is expected to be treated with dispersants at the sea surface and possibly subsea at the source in the event of a deep water blowout. The dispersed oil is mixed with the water, and its movement is then dictated by local currents and the physical, chemical, and biological degradation pathways. The oil would become more dispersed, less concentrated, and more biodegraded the longer it remains suspended in the water column. Depending on how long it remained suspended in the water column, it may be thoroughly degraded by biological action before contact with the seafloor and its sensitive resources occurs (Hazen et al., 2010; Valentine et al., 2010). Biodegradation rates in colder, deepwater environments are not well understood at this time. Oil may reach the seafloor in the following ways: as microbes begin to consume the oil particles; when the dispersed oil particles may flocculate (flocculation

is suspended particles collecting into larger suspended flakes),), thus increasing the density of the particles such that they are no longer in isostatic balance with the surrounding water and thus, sink to the seafloor; when larger plankton consume the bacteria-rich oil particles and their fecal pellets are excreted and distributed over the seafloor; when water currents carry a plume to contact the seafloor directly; or most likely, where the dispersed oil to adhere to other particles and sink to the seafloor. This last scenario would result in a wide distribution of small amounts of oil. This oil could be in the process of biodegradation from bacterial action that would continue on the seafloor, resulting in scattered microhabitats with an enriched carbon environment. Biodegradation processes, both on the bottom and in the water column, would be expected to cause at least some reduction of normal ambient dissolved oxygen levels; however, this has yet to be observed at a level that would be detrimental to animal respiration (Hazen et al., 2010).

Deepwater Soft-Bottom Benthic Communities

Soft bottoms are the overwhelming majority of the deep-sea environment. Large amounts of oil would only affect these deep environments if dispersants are used. As described above, the toxic effects of dispersed oil would continue to reduce as the concentration of oil is reduced via dispersion, localized mixing, and biodegradation. As with shelf habitats, the only soft bottom that is expected to suffer significant effects would be soft bottoms in the immediate vicinity of a seafloor blowout in which some oil is mixed into the sediment. In situations where soft-bottom infaunal communities are negatively impacted, recolonization by populations from neighboring soft-bottom substrate would be expected over a relatively short period of time for all size ranges of organisms - a matter of days for bacteria and probably less than 1 year for most macrofauna and megafauna species. This could take longer for areas affected by direct oil contact in higher concentrations.

Deepwater Coral Benthic Communities

There have been no experiments showing the response of deepwater corals to oil exposure. Experiments with shallow tropical corals indicate that corals have a high tolerance to oil exposure. The mucus layers on coral resist penetration of oil and slough off the contaminant. Longer exposure times and areas of tissue where oil adheres to the coral are more likely to result in tissue damage and death of polyps. Corals with branching growth forms appear to be more susceptible to damage from oil exposure (Shigenaka, 2001). The most common deepwater coral, *Lophelia pertusa*, is a branching species. Tests with shallow tropical gorgonians indicate relatively low toxic effects to the coral (Cohen et al., 1977), suggesting deepwater gorgonians may have a similar response. Response of deepwater coral to oil exposure from a catastrophic spill would vary, depending on the level of exposure. Exposure to widely dispersed oil adhering to organic detritus and partially degraded by bacteria may be expected to result in little effect. Direct contact with plumes of relatively fresh dispersed oil droplets in the vicinity of the incident could cause death of affected coral polyps through exposure and potential feeding on oil droplets by polyps. Median levels of exposure to dispersed oil in a partly degraded condition may result in effects similar to those of shallow tropical corals, with often no discernable effects other than temporary contraction and some sloughing. The health of corals may be degraded by the necessary expenditure of energy as the corals respond to oiling (Shigenaka, 2001). Communities exposed to more concentrated oil may experience detrimental effects, including death of affected organisms, tissue damage, lack of growth, interruption of reproductive cycles, and loss of gametes. Many invertebrates associated with deepwater coral communities, particularly the crustaceans, would likely be more susceptible to damage from oil exposure. The recolonization of severely damaged or destroyed communities could take years or decades. However, because of the scarcity nature of deepwater hard bottoms and the comparatively low surface area, it is unlikely that a sensitive habitat would be located near a seafloor blowout, or if near, that concentrated oil would contact the site.

Deepwater Chemosynthetic Benthic Communities

Chemosynthetic communities, which are adapted to gas seeps which sometimes release oil also. They may receive. . . , low quantities of well-dispersed oil undergoing biodegradation may and experience little negative effect. Exposure may be similar to normal conditions for these communities and may be within the normal variation of habitat conditions. However, oil contact could cause some

fluctuation in organism health, resulting in slower growth or delayed spawning. Since these organisms grow slowly, sublethal effects could eliminate a year or more of normal growth. Communities exposed to more concentrated oil may experience detrimental effects, including death of affected organisms, tissue damage, lack of growth, interruption of reproductive cycles, and loss of gametes. Other invertebrates associated with chemosynthetic communities, particularly the crustaceans, would likely be more susceptible to damage from oil exposure. Recolonization of severely damaged or destroyed communities could take years or decades.

3.2.3. Socioeconomic Resources

3.2.3.1. Offshore Archaeological Resources

Due the response methods (i.e., subsea dispersants) and magnitude of the response (i.e., thousands of vessels), a catastrophic blowout and spill have a greater potential to impact offshore archaeological resources than other accidental events.

Deep Water

In contrast to smaller spills or spills in shallow water, the use of large quantities of subsea dispersants could be used for a catastrophic subsea blowout in deep water. This could result in currently unknown effects from dispersed oil droplets settling to the seafloor. Though information on the actual impacts to submerged cultural resources is inconclusive at this time, oil settling to the seafloor could come in contact with archaeological resources. At present, there is no evidence of this having occurred. A recent experimental study has suggested that, while the degradation of wood in terrestrial environments is initially retarded by contamination with crude oil, at later stages, the biodeterioration of wood was accelerated (Ejechi, 2003). While there are different environmental constraints that affect the degradation of wood in terrestrial and waterlogged environments, soft-rot fungal activity, one of the primary wood degrading organisms in submerged environments, was shown to be increased in the presence of crude oil. There is a possibility that oil from a catastrophic blowout could come in contact with wooden shipwrecks and artifacts on the seafloor and accelerate their deterioration.

Ancillary damages from vessels associated with oil-spill response activities (e.g., anchoring) in deep water are unlikely due to the use of dynamically positioned vessels responding to a deepwater blowout. If response and support vessels were to anchor near a deepwater blowout site, the potential to damage undiscovered vessels in the area would be high due to the required number and the size of anchors and the length of mooring chains needed to safely secure vessels. Additionally, multiple offshore vessel decontamination stations would likely be established in shallow water outside of ports or entrances to inland waterways, as seen for the Deepwater Horizon incident. The anchoring of vessels could result in damage to both known and undiscovered archaeological sites; the potential to impact archaeological resources increases as the density of anchoring activities in these areas increases.

Shallow Water

The potential for damaging archaeological resources increases as the oil spill and related response activities progress landward. In shallower waters, most of the damage would be associated with oil cleanup and response activities. Thousands of vessels would respond to a shallow-water blowout and would likely anchor, potentially damaging both known and undiscovered archaeological sites. Additional anchoring would be associated with offshore vessel decontamination stations, as described above. As the spill moves into the intertidal zone, the chance of direct contact between the oil and archaeological resources increases. As discussed above, this could result in increased degradation of wooden shipwrecks and artifacts.

Additionally, in shallower waters, shipwrecks often act as a substrate to corals and other organisms, becoming an essential component of the marine ecosystem. These organisms often form a protective layer over the shipwreck, virtually encasing the artifacts and hull remains. If these fragile ecosystems were destroyed as a result of the oil spill and the protective layer removed, the shipwreck would then be exposed to increased degradation until it reaches a new level of stasis with its surroundings.

Regardless of water depth, because oil is a hydrocarbon, heavy oiling could contaminate organic materials associated with archaeological sites, resulting in erroneous dates from standard radiometric dating techniques (e.g., ^{14}C-dating). Interference with the accuracy of ^{14}C-dating would result in the loss of valuable data necessary to understand and interpret the sites.

3.2.3.2. Commercial Fishing

In 2008, the Gulf of Mexico provided over 33 percent of the commercial fishery landings in the continental U.S. (excluding Alaska), with nearly 1.3 billion pounds valued at nearly $660 million. (USDOC, NMFS, 2010).

Even though sensory and chemical testing may show no detectable oil or dispersant odors or flavors and the results could be well below the levels of concern, NOAA Fisheries would be expected to close large portions of the Gulf of Mexico during a high-volume spill as a precautionary measure to ensure public safety and to assure consumer confidence in Gulf seafood (USDOC, NOAA, NOAA Fisheries Service, 2010a). Up to 30-40 percent of Gulf of Mexico Exclusive Economic Zone (EEZ) could be closed to commercial fishing as the spill continues and expands (USDOC, NOAA, NOAA Fisheries Service, 2010b). This area could represent 50-75 percent of the Gulf seafood production (Flynn, 2010). The closure area may peak about 50 days into the spill and persist another 2-3 months until the well is killed or capped and the remaining oil is recovered or dissipates. During this period, portions or all of individual State waters would also be closed to commercial fishing.

The economic impacts of closures on commercial fishing are difficult to predict because they are dependent on the season and would vary by fishery. If fishers cannot make up losses throughout the remainder of the season, a substantial part of their annual income would be lost. In some cases, commercial fishers will move to areas still open to fishing, but at a greater cost due to longer transit times. Marketing issues are also possible; even if the catch is uncontaminated, the public may lack confidence in the product.

3.2.3.3. Recreational Fishing

Up to 30-40 percent of the Gulf of Mexico EEZ could be closed to recreational fishing as the spill continues and expands (USDOC, NOAA Fisheries, 2010b). The closure area could peak about 50 days into the spill and continue for another 2-3 months until the well is killed or capped and the remaining oil is recovered or dissipates. During this period, portions or all of individual State waters would also be closed to recreational fishing.

In 2008, over 24 million recreational fishing trips were taken, which generated about $12 billion in sales, over $6 billion in value-added impacts, and over 100,000 jobs (USDOC, NOAA, NMFS, 2010b). About 33 percent of the total Gulf catch came on trips that fished primarily in Federal and State waters (Pritchard, 2009). Recreational fishing is focused in the summer months. During this time, scheduled tournaments would be hard to reschedule. If the spill affected that time of year, normal direct income and indirect income to the communities that host these tournaments would be lost for that year. If a catastrophic spill occurs in the summer, a substantial number of recreational fishing trips would not occur and the economic benefits they generate would be lost for that year.

3.2.3.4. Tourism and Recreational Resources

While the spill is still offshore, there could be some ocean-dependent recreation that is affected (e.g., fishing, diving), as discussed above. In addition, there may be some effects due to either perceived damage to onshore recreational resources that has not yet materialized or to general hesitation on the part of travelers to visit the overall region due to the spill. For example, studies during the Deepwater Horizon oil spill show that perceptions can influence recreational activity, even if an oil spill has not yet damaged physical resources in an area (The Knowland Group, 2010; Market Dynamics Research Group, 2010). However, the majority of the impacts of a catastrophic spill would occur once the spill has contacted shore, as discussed in Section 4.2.3.4.

3.2.3.5. Employment and Demographics

In contrast to a less severe accidental event, suspension of some oil and gas activities would be likely following a catastrophic event. Depending on the duration and magnitude, this could impact hundreds of oil-service companies that supply the steel tubing, engineering services, drilling crews, and marine supply boats critical to offshore exploration. An interagency economic report estimated that the 6-month suspension, as a result of the Deepwater Horizon incident, may have directly and indirectly resulted in up to 8,000-12,000 fewer jobs along the Gulf Coast (Inter-agency, 2010b). Most of these jobs were not permanently lost as a result of the suspension and returned following the resumption of deepwater drilling in the Gulf of Mexico. These estimates are lower than earlier estimates of 15,000-60,000 rig and associated service jobs being at risk (Hargreaves, 2010; LMOGA, 2010; Zeller, 2010; Jindal, 2010).

Whatever the number, much of the employment loss would be concentrated in coastal oil-service parishes in Louisiana (St. Mary, Terrebonne, Lafourche, Iberia, and Plaquemines) and counties/parishes where drilling-related employment is most concentrated (Harris County, Texas, in which Houston is located, and Lafayette Parish, Louisiana) (Nolan and Good, 2010; U.S. Department of Labor, BLS, 2010). There would be additional economic impacts to commercial and recreational fishing, as discussed in Sections 3.2.3.2 and 3.2.3.3. This impact is also expected to be more heavily concentrated in smaller businesses than in the larger companies (Inter-agency, 2010b).

Demographic impacts are unlikely from temporary job losses.

3.2.3.6. Land Use and Coastal Infrastructure

Impacts to tourism and recreational resources are addressed in Section 3.2.3.4. Possible fisheries closures are addressed in Sections 3.2.3.2 and 3.2.3.3. While still offshore, a catastrophic oil spill would not impact other land use or coastal infrastructure.

3.2.3.7. Environmental Justice

The environmental justice policy, based on Executive Order 12898 of February 11, 1994, directs agencies to incorporate into NEPA documents an analysis of potentially disproportionate and detrimental environmental and health effects of their proposed actions on minorities and low-income populations and communities. While the spill is still offshore, the primary environmental justice concern would be large commercial fishing closures disproportionately impacting minority fishers. In the event of a catastrophic spill, Federal and State agencies would be expected to close substantial portions of the Gulf to commercial and recreational fishing (USDOC, NOAA, 2010g). While oystering occurs "onshore," oyster beds are also likely to be closed to harvests during Phase 2 of a catastrophic spill due to concerns about oil contamination and increased freshwater diversions to mitigate oil intrusion into the marshes (see Sections 3.2.3.2 and 3.2.3.3). These closures would directly impact commercial fishermen and oysterers, and indirectly impact such downstream activities as shrimp processing facilities and oyster shucking houses. The mostly African-American communities of Phoenix, Davant and Point a la Hache in Plaquemines Parish are home to families with some of the few black-owned oyster leases, which because of freshwater diversion projects for coastal restoration have already been threatened (Mock, 2010).

The Gulf Coast hosts multiple minority and low-income groups whose use of natural resources of the offshore and coastal environments make them vulnerable to fishing closures. While not intended as an inventory of the area's diversity, we have identified several Gulf Coast populations of particular concern. An estimated 20,000 Vietnamese fishermen and shrimpers live along the Gulf Coast; by 1990, over 1 in 20 Louisiana fishers and shrimpers had roots in Southeast Asia even though they comprised less than half a percent of the state's workforce (Bankston and Zhou, 1996). Vietnamese account for about one-third of all the fishermen in the central Gulf of Mexico (Ravitz, 2010). Islaños, African Americans, and Native American groups are also engaged in commercial fishing and oystering. Historically, Vietnamese and African Americans have worked in the fish processing and oyster shucking industries. Shucking houses particularly, have provided an avenue into the mainstream economy for minority groups.

Therefore, fishing closures during Phase 2 of a catastrophic spill impacting the central Gulf of Mexico would disproportionately affect such minority groups as the Vietnamese, Native Americans, African Americans, and Islaños (Hemmerling and Colten, 2003).

4. ONSHORE CONTACT (PHASE 3)

4.1. IMPACT-PRODUCING FACTORS AND SCENARIO

4.1.1. Duration

The duration of the shoreline oiling is measured from initial shoreline contact until the well is capped or killed and the remaining oil dissipates offshore. The time needed to cap or kill a well may vary, depending on the well's water depth. Depending on the spill's location in relation to winds and currents and the well's distance to shore, oil could reach the coast within 1 week to 1 month, based on evidence from previous spills in the Gulf of Mexico OCS. While it is assumed that the majority of spilled oil would dissipate offshore within 30 days of stopping the flow, some oil may remain in coastal areas until cleaned, as seen in Louisiana following the Deepwater Horizon blowout (The State of Louisiana, 2010B-d).

4.1.1.1. Shallow Water

Due to the distance from shore, oil spilled as a result of a blowout in shallow water could reach shore within 1-3 weeks and could continue until the well is killed or capped (1-3 months) and the oil dissipates offshore (1 month). Therefore, it is estimated that shoreline oiling would likely occur for 1-4 months following a catastrophic blowout.

4.1.1.2 Deep Water

As discussed in Section 3.1.1, intervention is more difficult and would take longer in deeper water. In general, most of the deep water in the Gulf of Mexico is located far from shore and therefore, it is assumed that oil would reach shore within 2-4 weeks. While most deep water is located far from shore, some areas of deep water are located relatively near shore so that oil could reach shore earlier.

The length of shoreline oiled would continue to increase until the well is killed or capped (3-4 months) and oil dissipates offshore (1 month). Therefore, shoreline oiling could occur for 3 to more than 4 months following a catastrophic blowout.

4.1.2. Volume of Oil

In the event of a catastrophic spill, not all of the oil spilled would contact shore. The amount of oil recovered and chemically or naturally dispersed would vary. For example, the following are recovery and cleanup rates from previous high-volume, extended spills:

- 10-40 percent of oil recovered or cleaned up (including burned, chemically dispersed, and skimmed);
- 25-40 percent of oil naturally dispersed, evaporated, or dissolved; and
- 20-65 percent of the oil remains available for biodegradation offshore or in shore contact

In the case of the Deepwater Horizon incident, "it is estimated that burning, skimming and direct recovery from the wellhead removed one quarter (25%) of the oil released from the wellhead. One quarter (25%) of the total oil naturally evaporated or dissolved, and just less than one quarter (24%) was dispersed (either naturally or as a result of operations) as microscopic droplets into Gulf waters. The residual amount — just over one quarter (26%) — is either on or just below the surface as light sheen and weathered tar balls, has washed ashore or been collected from the shore, or is buried in sand and sediments" (Inter-agency, 2010a).

For planning purposes, USCG estimates that 5-30 percent of oil will reach shore in the event of an offshore spill (33 C.F.R. Part 154, Appendix C, Table 2.). Using the USCG assumptions, a catastrophic spill could still result in a large amount of oil reaching shore.

4.1.3. Length of Shoreline Contacted

While larger spill volumes increase the chance of oil reaching the coast, other factors that influence the length and location of shoreline contacted include the duration of the spill and the well's location in relation to winds, currents, and the shoreline. As seen with the Deepwater Horizon spill, as the spill continued, the length of oiled shoreline at any one time increased exponentially as follows:

Duration of Spill	Length of Shoreline Oiled[1]
30 days	0-50 miles
60 days	50-100 miles
90 days	100-1,000 miles
120 days	>1,000 miles[2]

[1] Not cumulative.
[2] Length was extrapolated.

Dependent upon winds and currents throughout the spill event, already impacted areas could be re-oiled.

4.1.3.1. Shallow Water

While a catastrophic spill from a shallow-water blowout is expected to be lower in volume than a deepwater blowout, as explained in Section 3.1, the site would be closer to shore, allowing less time for oil to be weathered, dispersed, and recovered. This could result in a more concentrated and toxic oiling of the shoreline.

4.1.3.2. Deep Water

While a catastrophic spill from a deepwater blowout is expected to have a much greater volume than a shallow-water blowout (see Section 3.1), the site would be farther from shore, allowing more time for oil to be weathered, dispersed, and recovered. This could result in a broader, patchier oiling of the shoreline.

Translocation of the spilled oil via winds and currents is also a factor in the length of shoreline contacted. For example, oil could enter the Loop Current and then the Gulf Stream. However, the longer it takes oil to travel, the more it would degrade, disperse, lose toxicity, and break into streamers and tarballs (USDOC, NOAA, Office of Response and Restoration, 2010d).

4.1.4. Severe Weather

The Atlantic hurricane season runs from June 1st through November 30th, peaking in September. In an average Atlantic season, there are 11 named storms, 6 hurricanes, and 2 Category 3 or higher storms (USDOC, NOAA, National Weather Service, 2010a). In the event of a hurricane, vessels would evacuate the area, delaying response efforts, including the drilling of relief wells. The storm surge may push oil to the coastline and inland as far as the surge reaches, or the storm surge may remove the majority of oil from shore, as seen in some of the previous spills reviewed.

Movement of oil during a hurricane would depend greatly on the track of the hurricane in relation to the slick. A hurricane's winds rotate counter-clockwise. In general, a hurricane passing to the west of the slick could drive oil to the coast, while a hurricane passing to the east of the slick could drive the oil away

from the coast.

4.1.5. Onshore Cleanup Activities

As described in Section 3.1, a large-scale response effort would be expected for a catastrophic blowout. The number of vessels and responders would increase exponentially as the spill continued. In addition to the response described in the Section 3.1.6, the following response is also estimated to occur once the spill contacts the shore.

An exponential increase in the length of shoreline impacted would likely overwhelm response efforts.

4.1.5.1. Shallow Water

- There would be 5-10 staging areas established.
- Weathering permitting, about 200-300 skimmers could be deployed near shore to protect coastlines.

4.1.5.2 Deep Water

- There would be 10-20 staging areas established.
- Weather permitting, about 500-600 skimmers could be deployed near shore to protect coastlines. As seen in Louisiana following the Deepwater Horizon, a few hundred coastal skimmers could still be in operation a few months after the well is capped or killed (The State of Louisiana, 2010e).

4.2. MOST LIKELY AND MOST SIGNIFICANT IMPACTS

The most recent EISs prepared by BOEMRE for oil and gas lease sales in the Gulf of Mexico identify in detail the potential impacts from reasonably foreseeable oil spills (USDOI MMS, 2007 and 2008). The most likely and significant onshore impacts caused by a catastrophic spill are described below.

4.2.1. Physical Resources

4.2.1.1. Air Quality

As the spill nears shore, there would be low-level concentrations of odor-causing pollutants associated with evaporative emissions from the oil spill. These may cause temporary eye, nose, or throat irritation, nausea, or headaches, but the doses are not thought to be high enough to cause long-term harm (USEPA, 2010b). However, responders could be exposed to levels higher than OSHA permissible exposure levels (PEL) (U.S. Department of Labor, OSHA, 2010b). During the Deepwater Horizon oil spill, USEPA took air samples at various onshore locations along the length of the Gulf coastline. All except three measurements of benzene were below 3 parts per billion (ppb). The highest level was 91 ppb. During the Deepwater Horizon incident, air samples collected by BP, OSHA, and USCG near shore showed levels of benzene, toluene, ethylbenzene, and xylene that were mostly under detection levels. Among the 15,000 samples taken by BP, there was only one sample where benzene exceeded the OSHA Occupational PELs. All other sample concentrations were below the more stringent **American Conference of Governmental Industrial Hygienists (**ACGIH®**)** threshold limit values (TLVs) (U.S. Department of Labor, OSHA, 2010a). All measured concentrations of toluene, ethylbenzene, and xylene were well within the OSHA PELs and ACGIH TLVs.

4.2.1.2. Coastal Water Quality

Water quality governs the suitability of waters for plant, animal, and human use. Water quality is important in the bays, estuaries, and nearshore coastal waters of the Gulf because these waters provide feeding, breeding, and/or nursery habitat for many commercially significant invertebrates and fishes, as well as sea turtles, birds, and marine mammals. A catastrophic spill would significantly impact coastal water quality in the Gulf of Mexico. In the Gulf of Mexico, water quality prior to the Deepwater Horizon

incident was rated as fair while sediment quality was rated as poor (USEPA, 2008). In addition, the coastal habit index, a rating of wetlands habitat loss, was also rated as poor. Both the sediment quality and the coastal habitat index affect water quality.

Though response efforts would decrease the amount of oil remaining in Gulf waters and reduce the amount of oil contacting the coastline, significant amounts of oil would remain. Coastal water quality would be impacted not only by the oil, gas, and their respective components, but also to some degree from cleanup and mitigation efforts. Increased vessel traffic, hydromodification, addition of dispersants and methanol in an effort to contain, mitigate, or clean up the oil may also tax the environment.

The use of dispersants as a response tool involves a tradeoff. The purpose of chemical dispersants is to facilitate the movement of oil into the water column in order to encourage weathering and biological breakdown of the oil (i.e., biodegradation) (NRC, 2005; Australian Maritime Safety Authority, 2010). Thus, the tradeoff is generally considered to be between the shoreline and surface of the water versus the water column and benthic resources (NRC, 2005). If the oil moves into the water column and is not on the surface of the water, it is less likely to reach sensitive shore areas (USEPA, 2010c). Since sea birds are often on the surface of the water or in shore areas, dispersants are also considered to be very effective in reducing the exposure of sea birds to oil (Australian Maritime Safety Authority, accessed 2010, http://www.amsa.gov.au/Marine_Environment_Protection/National_plan/General_Information/Dispersants_Information/FAQ_Oil_Spills_Dispersants.asp). In addition to dispersion being enhanced by artificial processes, oil my also be dispersed from natural processes. For instance, microbial metabolism of crude oil results in the dispersion of oil (Bartha and Atlas, 1983). Dispersion has both positive and negative effects. The positive effect is that the oil, once dispersed, is more available to be degraded. The negative effect is that the oil, once dispersed, is more available to microorganisms which temporarily increases the toxicity (Bartha and Atlas, 1983). Toxicity of dispersed oil in the environment will depend on many factors, including the effectiveness of the dispersion, temperature, salinity, the degree of weathering, type of dispersant and degree of light penetration in the water column (NRC, 2005). The toxicity of dispersed oil is primarily due to the toxic components of the oil itself (Australian Maritime Safety Authority, accessed 2010, http://www.amsa.gov.au/Marine_Environment_Protection/National_plan/General_Information/Dispersants_Information/FAQ_Oil_Spills_Dispersants.asp).

Oxygen and nutrient concentrations in coastal waters vary seasonally. The zone of hypoxia (depleted oxygen) on the Louisiana-Texas shelf occurs seasonally and is affected by the timing of freshwater discharges from the Mississippi and Atchafalaya Rivers, which carry nutrients to the surface waters. The hypoxic conditions continue until local wind-driven circulation mixes the water again. The 2010 hypoxic zone could not be linked to the Deepwater Horizon incident in either a positive or a negative manner (LUMCON, 2010). Nutrients from the Mississippi River fueled enhanced phytoplankton and attributed to the formation of the hypoxic zone.

4.2.2. Biological Resources

Recent EISs prepared by BOEMRE for oil and gas lease sales in the Gulf of Mexico detail the potential localized impacts to individuals from reasonably foreseeable oil spills. However, a catastrophic event, such as a high-volume, extended-duration spill resulting from a blowout has the potential to cause population level impacts, as described below.

Dozens of Federal and State-listed threatened and endangered species could continue to be impacted during Phase 3 of a catastrophic oil spill as oil and response activities persist, including marine mammals, sea turtles, fish, and birds. Additional species could be impacted in extreme conditions (i.e., oil is pushed onto beaches or into rivers or marshes due to a hurricane) (USDOI, FWS, 2010a and 2010b).

4.2.2.1. Coastal and Marine Birds

Gulf coastal habitats are essential to the annual cycles of many species of breeding, wintering and migrating waterfowl, wading birds, shorebirds, and songbirds. For example, the northern Gulf Coast supports a disproportionately high number of beach-nesting bird species (USDOI, FWS, 2010c). Once oil contacts shore, a few dozen to over a hundred birds could be impacted daily by oiling and/or collection. By extrapolating the number of birds impacted as a result of the Deepwater Horizon incident, a spill lasting 120 days could result in direct mortality of over 7,000 birds (USDOI, FWS, 2010d). This number does not reflect total realized mortality but rather only the actual number of birds recovered to date. This

number represents a small fraction of total bird mortality due to carcasses sinking, being scavenged, drifting outside the search zone, or simply going undetected due to wind, current, weather, and habitat factors (Ford et al., 1987, Piatt et al., 1990, Fowler and Flint, 1997; Flint et al., 1999; Wiese and Robertson, 2004; Byrd et al., 2009). In an early review of oil-related mortality for seabirds, Dunnett et al. (1982) provided an estimate of 10 percent, and 60 percent of the dead birds may be recovered under typical field conditions. Piatt and Ford (1996:Table 1) summarized recovery rates from 17 carcass-drift experiments, indicating a range of 0-59 percent of carcasses being recovered. Using data from the *Exxon Valdez* oil spill, Piatt and Ford (1996) estimated recovery rates from joint probability and Monte Carlos simulations of only 8.0 percent and 6.9 percent, respectively.

Timing and location of the spill are the two primary factors for determining the severity of impacts on birds. The worst impacts to oiled birds or to those birds that have ingested oil with their prey would be if the oil spill occurs during the nesting season. An oil spill during nesting season could result in the loss of entire colonies of breeding birds on barrier islands surrounded by oil, along with the potential loss of all eggs and nestlings. Losses of shorebirds could occur through direct oiling of beaches on which nests are located, by oil covering the feeding sites near the nesting locations, or by the deaths of oiled parents, leaving eggs or hatchlings unprotected and unfed.

Endangered and Threatened Birds

Two species listed as endangered or threatened by the U.S. Fish and Wildlife Service that could be impacted by a catastrophic oil spill are the endangered least tern (*Sterna antillarum*) and the piping plover (*Charadrius melodus*). The Midwest Population of piping plovers, which nests along the Great Lakes, is listed as endangered while the Atlantic Coast and Northern Great Plains Populations are listed as threatened. The critical habitat for the plover is found within the wintering area which includes areas along the Gulf Coast from Texas to Florida (LeDee et al., 2008:Figure 1; Haig et al., 2005:Figure 1) where they feed on aquatic insects, invertebrates, and small crustaceans along the advancing and retreating water line of the beaches. Unknown numbers of piping plovers could therefore become oiled or have their feeding areas oiled if a spill occurred during the time of year, roughly October through March, when plovers are present (Haig et al., 2005: fig. 1, table 2).. Least terns breed in isolated, smaller colonies along the Gulf Coast (primarily in Texas and Louisiana) and apparently in greater numbers at more inland riverine sites (e.g., Rio Grande River, Texas; Lower Mississippi River, Tennessee) (Kirsch and Sidle, 1999; Szell and Woodrey, 2003), so oiling that occurs during the nesting season could not only affect least tern feeding areas (least terns are piscivorous) but also cause oiling and loss of eggs and young.

4.2.2.2. Fish, Fisheries, and Essential Fish Habitat

Estuarine-dependent fish species spawn on the continental shelf. transport eggs, larvae, or juveniles back to the estuary nursery grounds, and the adults migrate back to the sea for spawning (Deegan, 1989; Beck et al., 2001). All of these estuaries in the GOM are extremely important nursery areas and considered EFH for fish and aquatic life (Beck et al., 2001). Oiling of these areas, depending on the severity, can destroy nutrient-rich marshes and erode coastlines that have been significantly damaged by recent hurricanes.

The Gulf of Mexico supports a wide variety of finfish, and most of the commercial finfish resources are linked either directly or indirectly to the estuaries that ring the Gulf of Mexico. Darnell et al. (1983) observed that the density distribution of fish resources in the Gulf was highest nearshore off of the central Gulf Coast. For all seasons, the greatest abundance occurred between Galveston Bay and the mouth of the Mississippi River. Monthly ichthyoplankton collections over the years 2004-2006 offshore of Alabama have confirmed that peak seasons for ichthyoplankton concentrations on the shelf are spring and summer (Hernandez et al., 2010). Therefore, if a catastrophic blowout occurs in the spring and summer seasons, it could cause greater harm to fish populations, not just individual fish.

Oyster beds could be damaged by freshwater diversions that release tens of thousands of cubic feet of freshwater per second for months in an effort to keep oil out of the marshes. Adult oysters survive well physiologically in salinities from those of estuarine waters (about 7.5 parts per thousand sustained) to full strength seawater (Davis, 1958). While oysters may tolerate small changes in salinity for a few weeks, a rapid decrease in salinity over months would kill oysters. In the event of a catastrophic oil spill, the year's

oyster production would be lost because of exposure to freshwater and/or oil. Depending on the severity, oyster beds could take 2-5 years to recover (Burdeau, 2010).

4.2.2.3. Marine Mammals

Section 3.2.2 discusses the most likely and most significant impacts to the offshore marine mammal community. A high-volume oil spill lasting 120 days could directly impact almost 100 species of marine mammals. As the spill enters coastal waters, manatees and coastal and estuarine dolphins would be the most likely to be impacted.

Manatees primarily inhabit open coastal (shallow nearshore) areas and estuaries, and they are also found far up in freshwater tributaries. During warmer months, manatees are common along the Gulf Coast of Florida from the Everglades National Park northward to the Suwannee River in northwestern Florida, and they are less common farther westward. In winter, the Gulf of Mexico subpopulations move southward to warmer waters. The winter range is restricted to waters at the southern tip of Florida and to waters near localized warm-water sources, such as power plant outfalls and natural springs in west-central Florida. Manatees are infrequently found as far west as Texas (Powell and Rathbun, 1984; Rathbun et al., 1990; Schiro et al., 1998). If a catastrophic oil spill reached the Florida coast when manatees were in or near coastal waters, the spill could have population-level effects.

It is possible that manatees could occur in coastal areas where vessels traveling to and from the spill site could affect them. A manatee present where there is vessel traffic could be injured or killed by a vessel strike (Wright et al., 1995). Due to the large number of vessels responding to a catastrophic spill both in coastal waters and traveling through coastal waters to the offshore site, manatees would have an increased risk of collisions with boats. Vessel strikes are the primary cause of death of manatees.

There have been no experimental studies and only a few observations suggesting that oil impacts have harmed any manatees (St. Aubin and Lounsbury, 1990). Types of impacts to manatees and dugongs from contact with oil include (1) asphyxiation due to inhalation of hydrocarbons, (2) acute poisoning due to contact with fresh oil, (3) lowering of tolerance to other stress due to the incorporation of sublethal amounts of petroleum components into body tissues, (4) nutritional stress through damage to food sources, and (5) inflammation or infection and difficulty eating due to oil sticking to the sensory hairs around their mouths (Preen, 1989, in Sadiq and McCain, 1993; Australian Maritime Safety Authority, 2003). For a population whose environment is already under great pressure, even a localized incident could be significant (St. Aubin and Lounsbury, 1990). Spilled oil might affect the quality or availability of aquatic vegetation, including seagrasses, upon which manatees feed. The 2009 Stock Assessment Report (USDOI, FWS, 2009) for the Florida stock of west Indian manatees estimates that there is a minimum population estimate of 3,802 individuals based on a single synoptic survey of warm-water refuges in January 2009. The manatee's potential biological removal (PBR) is the maximum number of animals, not including natural mortalities, that may be removed from the population or stock while allowing that stock to reach or maintain its optimum sustainable population and is approximately 12 individuals. Therefore, if a catastrophic spill and response vessel traffic occurred near manatee habitats in the eastern Gulf of Mexico, population level impacts could occur, because the possibility exists for the number of mortalities to exceed PBR.

Bottlenose dolphins were the most affected species of marine mammals from the Deepwater Horizon oil spill. Ninety to 96 dolphins were collected; 4 bottlenose dolphins were alive, 86 were dead. (The other species of dolphin affected from the Deepwater Horizon spill was spinner dolphins). Bottlenose dolphins can be found throughout coastal waters in the Gulf of Mexico. Like manatees, dolphins could be affected, possibly to population level, by a catastrophic oil spill if it reaches the coast (as well as affecting them in the open ocean), through direct contact, inhalation, ingestion, and stress, as well as through collisions with cleanup vessels.

4.2.2.4. Sea Turtles

Out of the five species of sea turtle that occur in the Gulf of Mexico, only three nest in this area. The largest nesting location for the Kemp's ridley sea turtle is in Rancho Nuevo, Mexico, but they also nest in Texas. Loggerhead sea turtles nest in all states around the Gulf of Mexico. There are also records of nesting colonies of hawksbill sea turtles in the Yucatan Peninsula of Mexico (Plotkin et al., 1995). Kemp's ridley, loggerhead, and hawksbill sea turtles are therefore most likely to be affected by a catastrophic oil spill when there is onshore contact.

Female sea turtles emerge during the warmer summer months to nest Seasonally, females must emerge periodically from the ocean to nest on beaches. Thousands of sea turtles nest along the Gulf Coast, and turtles could build nests on oiled beaches. Nests could also be disturbed or destroyed by cleanup efforts. Untended booms could wash ashore and become a barrier to sea turtles adults and hatchlings (USDOC, NOAA, 2010e). Hatchlings, with a naturally high mortality rate, could walk through oiled sand and swim through oiled water to reach preferred habitats of sargassum floats. Response efforts could include mass movement of eggs from hundreds of nests or thousands of hatchlings from Gulf Coast beaches to the east coast of Florida or to the open ocean to prevent hatchlings entering oiled waters (Jernelöv and Lindén, 1981; USDOI, FWS, 2010e). Due to poorly understood mechanisms that guide female sea turtles back to the beaches where they hatched, it is uncertain if relocated hatchlings would eventually return to the Gulf Coast to nest (Florida Fish and Wildlife Conservation Commission, 2010). Therefore, shoreline oiling and response efforts may affect future population levels and reproduction (USDOI, NPS, 2010). Sea turtle hatchling exposure to, fouling by, or consumption of tarballs persisting in the sea following the dispersal of an oil slick would likely be fatal.

4.2.2.5. Terrestrial Mammals and Reptiles

Beach Mice

Seven subspecies of the field mouse, collectively known as beach mice, live along the Gulf Coast. Five subspecies of beach mice (Alabama, Perdido Key, Choctawhatchee, St. Andrew, and Anastasia Island) are listed as State and federally endangered; the southeastern beach mouse is listed as federally threatened; and the Santa Rosa beach mouse is a Federal species of concern. Beach mice are restricted to the coastal barrier sand dunes along the Gulf Coast of Alabama and Florida. Erosion caused by the loss of vegetation due to oiling would likely cause more damage than the direct oiling of beach mice, due to degradation or loss of habitat. In addition, vehicular traffic and activity associated with cleanup can trample or bury beach mice nests and burrows or cause displacement from preferred habitat. Improperly trained personnel and vehicle and foot traffic during shoreline clean up of a catastrophic spill would disturb beach mouse populations and would degrade or destroy habitat.

The Alabama, Choctawhatchee, St. Andrew, and Perdido Key beach mice are already designated as protected species under the Endangered Species Act (ESA) because of the loss of coastal habitat (USDOI, MMS, 2007). The species' coastal habitat is designated as their critical habitat. For example, the endangered Alabama beach mouse's (*Peromyscus polionotus ammobates*) habitat is 1,211 acres of frontal dunes covering just 10 miles of shoreline designated as critical habitat (USDOI, FWS, 2007). Critical habitat is the specific geographic areas that are essential for the conservation of a threatened or endangered species. With the potential oiling of over 1,000 miles of shoreline, the entire critical habitat for a subspecies of beach mice could be completely oiled. Thus, destruction of the remaining habitat due to a catastrophic spill and cleanup activities would increase the threat of extinction of several subspecies of beach mice.

Diamondback Terrapin

The Texas diamondback terrapin (*Malaclemys terrapin littoralis*) and the Mississippi diamondback terrapin (*Malaclemys terrapin pileata*) are two subspecies of terrapin that occur in the Gulf of Mexico andare Federal species of concern. The former's range runs from Louisiana through Texas, while the latter's includes Louisiana, Mississippi, Alabama, and Florida (USDOI, FWS, 2010f). Terrapins inhabit brackish waters including coastal marshes, tidal flats, creeks, and lagoons behind barrier beaches (Hogan, 2003). Their diet consists of fish, snails, worms, clams, crabs, and marsh plants (Cagle, 1952). Spending most of their lives at the aquatic-terrestrial boundary in estuaries, terrapins are susceptible to habitat destruction from oil spill cleanup efforts as well as direct contact with oil. However, most impacts cannot be quantified at this time. Even after the oil is no longer visible, terrapins may still be exposed while they forage in the salt marshes lining the edges of estuaries where oil may have accumulated under the sediments and within the food chain. Terrapin nests can also be disturbed or destroyed by cleanup efforts. Chronic effects from oil contact including lethal or sublethal oil-related injuries, such as . . . may persist through the generations, potentially reducing population levels.

4.2.2.6. Coastal Habitats

A spill from a catastrophic blowout lasting up to 120 days could impact over 1,000 miles of shoreline. Shoreline oiling would vary between heavy, moderate, light, and occasional tarballs. Due to the length of shoreline that could potentially be oiled and the sensitivity of the Gulf Coast, a high-volume, extended-duration spill could cause extensive habitat degradation. Loss of vegetation could lead to erosion and permanent landloss.

In some previous spills reviewed, a strong storm removed the majority of oil from shore. However, storm surges may carry oil into the coastline and inland as far as the surge reaches. In addition, four significant hurricanes (Katrina, Rita, Gustav, and Ike) have made landfall along the Texas/Louisiana coast in the last 5 years, greatly degrading the coastal beaches, marshes, and barrier islands, making them more susceptible to a catastrophic spill.

Coastal Barrier Beaches and Associated Dunes

Barrier islands make up more than two-thirds of the northern Gulf of Mexico shore. Each of the barrier islands is either high profile or low profile, depending on the elevations and morphology of the island (Morton et al., 2004). The distinguishing characteristics of the high and low profile barriers relates to the width of the islands along with the continuity of the frontal dunes. Low profile barriers are narrow with discontinuous frontal dunes easily overtopped by storm surge which makes the island susceptible to over wash and secondarily to erosion. This over wash can create channels to bring sand onto the island or into lagoons formed on these islands. High profile barriers islands are generally wider than the low profile islands and have continuous, vegetated, frontal dunes with elevations high enough to prevent over wash from major storm surge and therefore are less susceptible to erosion. The sand stored in these high profile dunes allows the island to withstand prolonged erosion and therefore prevent breaching which could result in damaging the island core.

As a result of a catastrophic spill, many of the barrier islands and beaches would receive varying degrees of oiling. Oil disposal on sand and vegetated sand dunes would have little deleterious effects on the existing vegetation or on the recolonization of the oiled sands by plants (Webb, 1988). The depth of oiling would be variable, based on the wave environment and sediment source at a particular beach head. Layering of oil and sand could occur if it was not cleaned before another tidal cycle. However, most areas of oiling are expected to be light and sand removal during cleanup activities should be minimized. In areas designated as natural wilderness areas e.g., Breton National Wildlife National Refuge and Gulf Islands National Seashore land managers may require little to no disruption of the natural system. In these environments it is preferred to let the oil degrade naturally without aggressive and intrusive cleanup procedures. Manual rather than mechanized removal techniques will be used in these areas and only if heavy oiling has occurred. The exceptions occur in areas designated as natural wilderness areas (e.g., Breton National Wildlife National Refuge and Gulf Islands National Seashore) where the land managers want as little disruption to the "natural" system as possible. Thus, these areas may not be treated as thoroughly as other shorelines.

Once oil has reached the beaches and barrier islands and becomes buried or sequestered, it becomes difficult to treat. During wave events when the islands and beaches erode, the oil can become remobilized and transported. Thus, the fate of oil is not as simple as either reaching land, becoming sequestered or being treated, but must be considered in terms of a continuing process of sequestration, remobilization, and transport.

For spilled oil to move onto beaches or across dunes, strong southerly winds must persist for an extended time prior to or immediately after the spill to elevate water levels. Strong winds, however, would reduce the impact severity at a landfall site because they would accelerate the processes of oil-slick dispersal, spill spreading, and oil weathering...

Due to the distance of beaches from deepwater blowout and the combination of weathering and dispersant treatment of the oil offshore, the toxicity of the oil reaching shore should be greatly reduced, thereby minimizing the chances of irreversible damage to the impacted areas. A blowout in shallower waters near shore may have equal or greater impacts due to a shorter period of weathering and dispersion prior to shoreline contact, even though a smaller volume of spilled oil is expected.

Vessel traffic in close proximity to barrier islands has been shown to move considerably more bottom sediment than tidal currents, thus increasing coastal and barrier island erosion rates. If staging areas are in

close proximity to these islands, recovery time of the barrier islands could be greatly extended due to the magnitude of vessels responding to a catastrophic spill.

Wetlands

Coastal wetland habitats in the Gulf of Mexico occur as bands around waterways,, broad expanses of saline, brackish, and freshwater marshes,, mud and sand flats,, and forested wetlands of cypress-tupelo swamps and bottomland hardwoods. A spill from a catastrophic blowout could oil a few to several hundreds of acres of wetlands depending on the depth of inland penetration (Burdeau and Collins, 2010). This would vary from moderate to heavy oiling.

The NOAA Environmental Sensitivity Index (ESI) ranks shorelines according to their sensitivity to oil, the natural persistence of oil, and the expected ease of cleanup after an oil spill. These factors cause oil to persist in coastal and estuarine areas (DOI, MMS, 2010). According to the ESI, the most sensitive shoreline types (i.e., sheltered tidal flats, vegetated low banks, salt/brackish-water marshes, freshwater marshes/swamps, and scrub-shrub wetlands) tend to accumulate oil and are difficult to clean, thus causing oil to persist in these coastal and estuarine areas (USDOI, MMS, 2010).

Precautions such as oil booms, skimmer ships, and barge barriers would be deployed to protect the beaches and the wetlands behind them or on the beach fringe from oil. However, if not maintained, these booms can cause significant harm to fragile wetlands. In most cases, the beach face would take the most oil; however, in areas where the marsh is immediately adjacent to the beach face or embayments, or in the case of small to severe storms, marshes would be oiled. For example, in Alabama, Mississippi and Florida, severe weather could push oil into the tidal pools and back beach areas that support tidal marsh vegetation.

Previous studies of other large spills have shown that when oil has a short residence time in the marsh and it is not incorporated into the sediments, the marsh vegetation has a good chance of survival, even though aboveground die-off of marsh vegetation may occur (Mendelssohn et al., 2002). However, if reoiling occurs after the new shoots from an initial oiling are produced, such that the new shoots are killed, then the marsh plants may not have enough stored energy to produce a second round of new shoots. Longer term damage may result from continued reoiling than from a temporally continuous oiling (Lin et al, 2002; Lin and Mendelssohn, 2009). Other studies noted the utilization of dispersants in the proper dosages results in a reduction in marsh damage from oiling (Lin and Mendelssohn, 2009).). The works of several investigators (Webb et al., 1981 and 1985; Alexander and Webb, 1983 and 1987; Lytle, 1975; Delaune et al., 1979; Fischel et al., 1989) evaluated the effects of potential spills to area wetlands. For wetlands along the central Louisiana coast, the critical oil concentration is assumed to be 0.025 gallon per ft^2 (1.0 liter per m^2) of marsh. Concentrations less than this may cause diebacks for one growing season or less, depending upon the concentration and the season during which contact occurs. The duration and magnitude of a spill resulting from a catastrophic blowout could result in concentrations above this critical level and would result in longer-term effects to wetland vegetation, including some plant mortality and loss of land.

Due to the distance of deep water from shore, the possibility of a spill from a deepwater blowout reaching coastal wetlands with the toxicity to significantly impact the coastal wetlands is low due to the response procedures implemented during a catastrophic spill. The utilization of nearshore booming protection for beaches and wetlands, in combination with offshore skimming, burning, and dispersal treatments for the oil near the spill site, would result in capture and detoxification of the majority of oil reaching shore. Therefore, a spill from a shallow-water blowout is more likely to contribute to wetland damage.

The impact of oil cleanup can result in additional impacts to wetlands, if not done properly. Aggressive onshore and marsh cleanup methods have not yet been utilized and probably would not be initiated until the oil spill has been stopped. Depending on the marsh remediation methods used, further impacts to the wetlands may occur from cleanup activities.

Submerged Vegetation

Approximately 500,000 hectares (1.25 million acres) of submerged seagrass beds are estimated to exist in exposed, shallow coastal waters and embayments of the northern Gulf of Mexico, and over 80 percent of this area is in Florida Bay and Florida coastal waters (Beck et al., 2006; Carlson and Madley, 2006). Submerged vegetation distribution depends on an interrelationship between a number of

environmental factors that include temperature, water depth, turbidity, salinity, turbulence, and substrate suitability (Sheridan and Minello, 2003). Marine seagrass beds generally occur in shallow, relatively clear, protected waters with predominantly sand bottoms (Short et al., 2001). Freshwater submerged aquatic vegetation (SAV) species occur in the low-salinity waters of coastal estuaries (Castellanos and Rozas, 2001). Seagrasses and freshwater SAVs provide important habitat for immature shrimp, black drum, spotted sea trout, juvenile southern flounder, and several other fish species and provide a food source for species of wintering waterfowl (Castellanos and Rozas, 2001; Short et al., 2001; Caldwell, 2003). These areas would have considerable impact from various cleanup efforts, such as increased vessel traffic. Although many of the beds are protected by extensive barrier islands, severe storms can cause inundation and overwashing of these islands, resulting in oiling of the seagrass beds if the storm occurred during an oil spill. In addition, boom anchors could damage seagrass beds (USDOC, NOAA, 2010e). It is assumed that there would be a decrease in submerged vegetation and a negative impact on the bed communities in a highly affected area. If bays and estuaries accrue oil, there is an assumption that there would be a decrease in seagrass cover and negative community impacts. Depending on the species and environmental factors, seagrasses may exhibit minimal impacts from a spill; however, communities within the beds could accrue greater negative outcomes (Jackson et al., 1989; Taylor et al., 2006). Community effects could range from direct mortality due to smothering or indirect mortality from loss of food sources and loss of habitat due to a decrease in ecological performance of the entire system (Zieman et al., 1984).

4.2.3. Socioeconomic Resources

4.2.3.1. Onshore Archaeological Resources

Regardless of the water depth in which the catastrophic blowout occurs, it is assumed that more than 1,000 miles of shoreline could be oiled to some degree. Onshore prehistoric and historic sites would be impacted to some extent by a high-volume spill from a catastrophic blowout that reaches shore. Sites on barrier islands could suffer the heaviest impact (McGimsey, personal communication, 2010). A few prehistoric sites in Louisiana, located inland from the coastline in the marsh and along bayous, could experience some light oiling. As discussed above, impacts would include the loss of ability to accurately date organic material from archeological sites due to contamination. Efforts to prevent coastal cultural resources from becoming contaminated by oil would likely be overwhelmed in the event of a hurricane and by the magnitude of shoreline impacted. The most significant damage to archaeological sites could be related to cleanup and response efforts. Fortunately, important lessons were learned from the *Exxon Valdez* spill in Alaska in 1989, in which the greatest damage to archaeological sites was related to cleanup activities and looting by cleanup crews rather than from the oil itself (Bittner, 1996). As a result, cultural resources were recognized as significant early in the response, and archaeologists are, at present, embedded in Shoreline Cleanup Assessment Techniques (SCAT) teams and are consulting with cleanup crews. Historic preservation representatives are present at both the Joint Incident Command as well as each Area Command under the general oversight of the National Park Service to coordinate response efforts (Odess, personal communication, 2010). Despite these efforts, some archaeological sites suffered damage from looting or from spill clean-up activities (most notably the parade ground at Fort Morgan) (Odess, personal communication, 2011).

4.2.3.2. Commercial Fishing

In addition to closures in Federal waters, portions of individual State waters would also be closed to commercial fishing. The economic impacts of closures on commercial fishing are complicated to predict because it is dependent on season and would vary by fishery. If fishers cannot make up losses in the remainder of the season, a substantial part of their annual income will be lost. In some cases, commercial fishers may move to areas still open to fishing, but at a greater cost due to longer transits.

4.2.3.3. Recreational Fishing

In addition to closures in Federal waters, portions to of individual State waters would also be closed to recreational fishing. More than 67 percent of the total Gulf catch came on trips that fished primarily in inland waters (Pritchard, 2009). In 2008, over 24 million recreational fishing trips were taken, which

generated about $12 billion in sales, over $6 billion in value added impacts, and over 100,000 jobs (USDOC, NOAA, NMFS, 2010b). The majority of recreational fishing occurs in the summer months. During this time, scheduled fishing tournaments are held and would be hard to reschedule. If the spill affected the summer months, normal direct income and indirect income to the communities that host these tournaments would be lost for that year. If a catastrophic spill occurs in the summer, the majority of recreational fishing trips would not occur and economic benefits they generate would be lost for that year.

4.2.3.4. Tourism and Recreational Resources

Tourism and recreation are integral components of the economy of the Gulf of Mexico. Visitors to Texas, Louisiana, Mississippi, Alabama, and Florida spent approximately $145 billion in 2008. (U.S. Travel Association (2008)). This spending helped to support approximately 2.4 million jobs in recreation-based industries statewide (U.S. Dept. of Labor, 2010a). Roughly 600,000 of these jobs are in counties that are directly along the coast, making them particularly vulnerable to a catastrophic event and the likely associated decrease in tourism. Recreation jobs account for 14.8 percent of Gulf Coast employment, greater than the national average of 12.4 percent (QCEW Fact Sheet). The coastal counties and parishes that have the highest concentration of recreation workers (over 10,000 workers) in each state are as follows: Cameron, Nueces, and Galveston Counties (Texas); Jefferson and Orleans Parishes(Louisiana); Harrison County (Mississippi); Mobile and Baldwin Counties (Alabama); and Escambia, Okaloosa, Bay, Pasco, Pinellas, Hillsborough, Manatee, Sarasota, Lee, Collier, Broward, and Miami-Dade Counties (Florida). Gulf Coast recreational employment is reasonably cyclical, with the peak months during the past few years occurring between March and June (U.S. Dept. of Labor, 2010b).

A catastrophic spill has the potential to significantly impact the Gulf Coast recreation and tourism industries. The water-dependent and beach-dependent components of these industries would be particularly vulnerable. This is particularly true for some of the nature parks and island resources directly along the coast, such as Padre Island National Seashore (Texas), Dauphin Island (Alabama), and the Gulf Islands National Seashore (Mississippi/Florida). Kaplan and Whitman (2008) attempt to isolate the economic significance of the recreational resources in the Gulf of Mexico that are particularly relevant to OCS oil and gas activities. They found roughly 60,000 jobs that were dependent on these activities in 2005, although there is uncertainty with this estimate, due to measurement issues and due to events that have occurred since their data collection period (most notably Hurricane Katrina).

In analyzing the potential impacts of a catastrophic spill, one must also consider the range of activities that depend on the base resources that may be affected. For example, the restaurant and lodging industries are particularly important to the Gulf economy. They are also sensitive to general tourism trends in any particular area. However, the economic impacts on these sectors from a spill may be partially offset due to an influx of cleanup and relief workers. Finally, one should consider the economic context in which a catastrophic event occurs. The Deepwater Horizon incident occurred in the context of an economy that was only beginning to recover from a very deep recession. In difficult economic times, recreation workers may be more prone to being laid off in response to a catastrophic event. Workers may also find it more difficult to transition between jobs, which can increase the severity of the economic effects. In a recession, tourism also may be more sensitive both to actual damage and to perceptions of economic problems within a region.

4.2.3.5. Employment and Demographics

By the end of a catastrophic spill, up to 50,000 personnel would be expected to respond to protect the shoreline and wildlife and to cleanup vital coastlines. The degree to which new cleanup jobs offset job losses would vary greatly from county to county (or parish to parish). However, these new jobs would not make up for lost jobs, in terms of dollar revenue. In most cases, cleanup personnel are paid less (e.g., $15-$18 an hour compared with roughly $45 an hour on a drilling rig), resulting in consumers in the region having reduced incomes overall and thus, investing less money in the economy (Aversa, 2010). Permanent demographic impacts are unlikely from these temporary jobs.

There would be additional economic impacts to tourism and both recreational and commercial fishing, as discussed in Sections 4.2.3.2 through 4.2.3.4 above.

4.2.3.6. Land Use and Coastal Infrastructure

In the event of a catastrophic spill, impacts on land use and infrastructure would be temporary and variable in nature. These impacts include land use in staging areas, waste disposal locations and capacities, and potential delays due to vessel decontamination stations near ports, as described below.

Up to 20 staging areas and as many as 50,000 responders would likely result in increased traffic congestion and some possible competing land use issues near the staging areas, depending on the real estate market at the time of the event. Some infrastructure categories, such as vessels, ports, docks and wharves would likely become very engaged in response activities and this could result in a shortage of space and functionality at infrastructure facilities if ongoing drilling activities were simultaneously occurring. However, if a drilling suspension was enacted, like the Deepwater Horizon incident, conflicting demands on infrastructure facilities would likely fail to materialize (Dismukes, personal communication, 2010a).

In the category of waste disposal, the impacts would be more visible as thousands of tons of oily liquid and solid wastes from the oil-spill cleanup are disposed of in onshore landfills. The USEPA the U.S. Coast Guard would likely issue solid waste management directives to address the issue of contaminated materials and solid or liquid wastes that are recovered as a result of cleanup operations (USEPA, 2010d and 2010e).

For navigation and port use, there is also the potential for delays in cargo handling and slow vessel traffic due to decontamination operations at various sites along the marine transportation system (USDOT, 2010). However, most cleanup activities would be complete within a year of the event, so impacts would be expected to be limited in duration (Dismukes, personal communication, 2010b).

4.2.3.7. Environmental Justice

While most coastal populations of along the Gulf of Mexico coast are not generally minority or low income, several communities on the coasts of St. Mary, Lafourche, Terrebonne, St. Bernard, and Plaquemines Parishes have minority or low-income population percentages that are higher than their respective state averages. are predominately Native American, Islaños, or African American. For example, a few counties or parishes along the Gulf Coast have more than a 2-percent Native American population (USDOI, MMS, 2007); about 2,250 Houma Indians (a State of Louisiana recognized tribe) are concentrated in Lafourche Parish, Louisiana comprising 2.4% of the parish's population, and about 800 Chitimacha (a federally recognized tribe) make up 1.6% of St. Mary Parish's population. While these aren't significant numbers on their own, viewed in the context of Louisiana's overall 0.6 percent Native American average, these communities take on greater environmental justice importance.

Gulf Coast minority and low-income groups are particularly vulnerable to the coastal impacts of a catastrophic oil spill due to their dependence on the natural resources in the offshore and coastal environments. Besides their economic reliance on commercial fishing and oystering, coastal low-income and minority groups rely heavily on these fisheries and other traditional subsistence fishing, hunting, trapping, and gathering activities to augment their diets and household incomes (see Hemmerling and Colton, 2003, for an evaluation of environmental justice considerations for south Lafourche Parish). Regular commuting has continued this reliance on the natural resources of the coastal environments even when populations have been forced to relocate because of landloss and the destruction from recent hurricane events.

State fishery closures due to a catastrophic oil spill would disproportionately affect minority and low-income groups. Shoreline impacts would generate additional subsistence-related effects. Therefore, these minority groups would be disproportionately affected if these coastal areas were impacted by a catastrophic spill and the resulting response.

5. POST-SPILL, LONG-TERM RECOVERY (PHASE 4)

5.1. IMPACT-PRODUCING FACTORS AND SCENARIO

During the final phase a catastrophic blowout and spill, it is presumed that the well has been capped or killed and cleanup activities are concluding. While it is assumed that the majority of spilled oil would be dissipated within 30 days of stopping the flow (Inter-agency, 2010a), oil has the potential to persist in

the environment long after a spill event and has been detected in sediment 30 years after a spill (USDOI, FWS, 2004). On sandy beaches, oil can sink deep into the sediments. In tidal flats and salt marshes, oil may seep into the muddy bottoms (USDOI, FWS, 2010g).

5.2. MOST LIKELY AND MOST SIGNIFICANT IMPACTS

At this point in the scenario, the spill has been stopped and long-term recovery begins. There is a great deal of uncertainty regarding the long-term impacts of a catastrophic spill in the Gulf of Mexico. The most likely and most significant impacts, as described below, will likely relate to the continued exposure of organisms to the spilled oil, oil components, and dispersants remaining in the air, water, and sediments, as well as the effects of continued cleanup efforts.

A catastrophic spill can have long-term impacts on Gulf of Mexico ecosystems. An ecosystem is a geographically specified system of organisms, including humans, their environment, and the processes that control their dynamics. Ecosystems involve complex connections between organisms, their environment, and the processes that drive the system (USDOC, NOAA, 2010f). In some cases, marine ecosystems may take decades to fully recover or may recover to alternative states (Ragen, 2010).

5.2.1. Physical Resources

5.2.1.1. Air Quality

There would be some residual air quality impacts after the well is capped or "killed". As most of the oil would have been burned, evaporated, or weathered over time, air quality would return to pre-oil spill conditions. While impacts to air quality are expected to be localized and temporary, as discussed in Sections 2.2.1.1, 3.2.1.1, and 4.2.1.1, adverse effects that may occur from the exposure of humans and wildlife to air pollutants could have long-term consequences.

5.2.1.2. Coastal and Offshore Water Quality

The leading source of contaminants that impairs coastal water quality in the Gulf of Mexico is urban runoff. Urban runoff can include suspended solids, heavy metals, pesticides, oil, grease, and nutrients (such as from lawn fertilizer). Urban runoff increases with population growth, and the Gulf Coast region has experienced a 103 percent population growth since 1970 (USDOC, NOAA, NOS, 2008). Other pollutant source categories include (1) agricultural runoff, (2) municipal point sources, (3) industrial sources, (4) hydromodification (e.g., dredging), and (5) vessel sources (e.g., shipping, fishing, and recreational boating). The NRC (2003; Table I-4, p. 237) estimated that, on average, approximately 26,324 barrels of oil per year entered Gulf waters from petrochemical and oil refinery industries in Louisiana and Texas. The Mississippi River introduced approximately 3,680,938 barrels/year (NRC, 2003; Table I-9, p.242) into the waters of the Gulf. Hydrocarbons also enter the Gulf of Mexico through the result of natural seeps in the Gulf of Mexico at a rate of approximately 980,392 barrels per year (a range of approximately 560,224-1,400,560 barrels/year) (NRC, 2003; p. 191). Produced water (formation water) is, by volume, the largest waste stream from the oil and gas industry that enters Gulf waters. The NRC has estimated the quantity of oil in produced water entering the Gulf per year to be 473,000 bbl (NRC, 2003; p. 200, Table D-8).6 These sources total about 5.5 million barrels of oil per year that routinely enters Gulf of Mexico waters. In comparison, a catastrophic spill of 30,000-60,000 barrels per day for 90-120 days would spill a total of 2.7-7.2 million barrels of oil. When added to the other sources of oil listed above, this would result in a 48- to 129-percent increase in the volume of oil entering the water during the year of the spill. In addition, the oil from a spill will be much more concentrated in some locations than the large number of other activities that release oil into the Gulf of Mexico. Section 3.1.4. of this document discusses the properties and persistence of oil in the environment.

6 These numbers were generated from converting the units reported in the noted reference and do not imply any level of significance.

5.2.2. Biological Resources

As described below, long-term consequences on biological resources can include impaired reproduction, which can potentially impact population levels. Oil has the potential to persist in the environment long after a spill event and has been detected in sediment 30 years after a spill (FWS, 2004). On sandy beaches, oil can sink deep into the sediments. In tidal flats and salt marshes, oil may seep into the muddy bottoms. Oil in these systems has the potential to have long-term impacts on fish and wildlife populations.

Some animals may survive initial exposure to spilled oil but may accumulate high levels of contaminants in their bodies that can be passed on to predators, in a process known as bioaccumulation (USDOI, FWS, 2010g).

5.2.2.1. Coastal and Marine Birds

There is a high probability of underestimating the impacts of oil spills on avian species potentially encountering oil, particularly seabirds. Often overlooked and understudied are the long-term, sublethal, chronic effects due to sublethal exposure to oil. These effects may persist for years after exposure, reducing the capacity of affected individuals within the population to recover, due to effects that may range from minor physiological disorders through damage to vital organs (i.e., liver and kidney) (Alonso-Alvarez et al., 2007). Sublethal effects of oil could ultimately result in reductions in long-term survival or lower reproductive success for some species of birds (Fry et al., 1986; Leighton, 1993; Esler et al., 2000; Golet et al., 2003; Velando et al., 2010). In addition, even light oiling of avian eggs transferred via contact with contaminated breast feathers from an incubating female can be toxic to developing embryos (Albers, 1980; Albers and Heinz, 1983). Effects such as delayed sexual maturity of most seabird species, loss of breeding-age individuals, particularly females, may have long-term, population-level effects. Long-term, sublethal, chronic effects may exceed immediate losses due to direct mortality (i.e., oiled birds) if such residual effects influence a significant proportion of the population or disproportionately impact an important population segment (Newton, 1998; Peterson et al., 2003; Alonso-Alvarez et al., 2007).

5.2.2.2. Fish, Fisheries, and Essential Fish Habitat

In addition to possible small fish kills due to direct impacts (as described under Phases 2 and 3), a catastrophic spill could affect fish populations in the long term. Due to a catastrophic spill, a significant portion of a year class of fish could be absent from the following year's fishery, reducing overall population numbers. However, sublethal impacts, especially for long-lived species (e.g., snapper and grouper), could be masked by reduced fishing pressure due to closures. In addition, healthy fish resources and fishery stocks depend on ideal habitat (EFH) for spawning, breeding, feeding, and growth to maturity. Thus, a catastrophic spill that affects these areas could result in long-term impacts, including destruction to a portion of their habitats.

5.2.2.3. Marine Mammals

Even after the spill is stopped, oilings or deaths of marine mammals would still likely occur due to oil and dispersants persisting in the water, past marine mammal/oil or dispersant interactions, and ingestion of contaminated prey. The animals' exposure to hydrocarbons persisting in the sea may result in sublethal impacts (e.g., decreased health, reproductive fitness, and longevity; and increased vulnerability to disease) and some soft tissue irritation, respiratory stress from inhalation of toxic fumes, food reduction or contamination, direct ingestion of oil and/or tar, and temporary displacement from preferred habitats or migration routes. These long-term impacts could have population-level effects (USDOC, NOAA, NMFS, 2010c).

5.2.2.4. Sea Turtles

Sea turtles take many years to reach sexual maturity. Green sea turtles reach maturity between 20 and 50 years of age; loggerheads may be 35 years old before they are able to reproduce; and hawksbill sea turtles typically reach lengths of 27 inches for males and 31 inches for females before they can reproduce (USDOC, NOAA, NMFS, 2010d). In most foreseeable cases, exposure to hydrocarbons persisting in the sea following the dispersal of an oil slick would result in sublethal impacts (e.g., decreased health,

reproductive fitness, and longevity and increased vulnerability to disease) to sea turtles. As discussed in Section 4.2.2, shoreline oiling and response efforts may affect future population levels and reproduction (USDOI, NPS, 2010). The deaths of subadult and adult sea turtles may also drastically reduce the population.

5.2.2.5. Terrestrial Mammals and Reptiles

Beach Mice

Within the last 20-30 years, the combination of habitat loss due to beachfront development, isolation of remaining beach mouse habitat areas and populations, and destruction of remaining habitat by tropical storms and hurricanes has increased the threat of extinction of several subspecies of beach mice. Destruction of the remaining habitat due to a catastrophic spill and cleanup activities would increase the threat of extinction.

Diamondback Terrapin

Habitat destruction, road construction, and drowning in crab traps are the most recent threats to diamondback terrapins. Tropical storms, hurricanes, and beach erosion threaten their preferred nesting habitats. Destruction of the remaining habitat due to a catastrophic spill and response efforts could drastically affect future population levels and reproduction.

5.2.2.6. Coastal Habitats

Coastal habitats serve important ecological functions, and the loss of vegetation in coastal areas could lead to erosion and permanent land loss.

Coastal Barrier Beaches and Associated Dunes

Oil or its components that remain in the sand after cleanup may be (1) released periodically when storms and high tides resuspend or flush beach sediments, (2) decomposed by biological activity, or (3) volatilized and dispersed.

The protection once afforded to inland marshes by coastal barrier beaches has been greatly reduced due to decreased elevations and the continued effect of subsidence, sea-level rise, and saltwater intrusion. A catastrophic spill has the potential to contribute to this reduction.

The cleanup impacts of a catastrophic spill could result in short-term (up to 2 years) adjustments in beach profiles and configurations as a result of sand removal and disturbance during cleanup operations. Some oil contact to lower areas of sand dunes is expected. These contacts would not result in significant destabilization of the dunes. The long-term stressors to barrier beach communities caused by the physical effects and chemical toxicity of an oil spill may lead to decreased primary production, plant dieback, and hence further erosion.

Wetlands

Wetlands serve a number of important ecological functions. For example, Louisiana's coastal wetlands support more than two-thirds of the wintering waterfowl population of the Mississippi Flyway, including 20-25 percent of North America's puddle duck population. Therefore, loss of wetlands would also impact a significant portion of the waterfowl population.

The duration and magnitude of a spill resulting from a catastrophic blowout could result in high concentrations of oil that would result in long-term effects to wetland vegetation, including some plant mortality and loss of land. This would add to continuing impacts of other factors, such as hurricanes, subsidence, saltwater intrusion, and seB-level rise. The wetlands along the Gulf Coast have already been severely damaged by the 2005 and 2008 hurricane seasons, leaving the mainland less protected. It was estimated in 2000 that coastal Louisiana would continue to lose land at a rate of approximately 2,672 ha/yr (10 mi^2/yr) over the next 50 years. Further, it was estimated that an additional net loss of 132,794 ha (512 mi^2) may occur by 2050, which is almost 10 percent of Louisiana's remaining coastal wetlands (Barras et al., 2003). Barras (2006) indicated an additional 217 mi^2 (562 km^2) of land lost during the 2005

hurricane season. A catastrophic spill occurring nearshore would contribute further to this landloss. Following Hurricanes Katrina and Rita, another series of hurricanes (Gustav and Ike) made landfall along the Louisiana and Texas coasts in September 2008. Hurricane Gustav made landfall as a Category 2 storm near Cocodrie, Louisiana, pushing large surges of saline water into the fresh marshes and coastal swamps of Louisiana from Grand Isle westward. While Hurricane Gustav did not impact the quantity of wetlands that Hurricanes Katrina and Rita impacted, it did have a severe and continuing effect on the coastal barrier islands and the wetlands associated with backshore (back of the island) and foreshore (front of the island). While Hurricane Gustav affected the eastern portion of the Louisiana coast closer to Grand Isle and Houma, Hurricane Ike concentrated on Louisiana's western coast. The Texas coast received the brunt of Hurricane Ike where it made landfall slightly east of Galveston. The storm surge basically removed the dune systems and significantly lowered the beach elevations along the eastern portion of the Texas coast near Galveston and the Bolivar Peninsula. The erosion and wash-over associated with Ike's tidal surge breeched beach ridges opened the inland freshwater ponds and their associated wetlands to the sea. As a result of the four successive storms, the Louisiana and Texas coasts have lost protective elevations, barrier islands, and wetlands and they now have the potential for transitioning to a less productive salt-marsh system in areas where fresh-marsh systems once existed.

In addition, a poorly executed oil cleanup can result in additional impacts. Aggressive onshore and marsh cleanup methods have not yet been utilized and probably would not be initiated until the oil spill has been stopped. Depending on the marsh remediation methods used, further impacts to the wetlands may occur from cleanup activities. Boat traffic in marsh areas from the thousands of response vessels associated with a catastrophic spill would produce an incremental increase in erosion rates, sediment resuspension, and turbidity (i.e., an adverse but not significant impact to coastal wetland and seagrass habitats.)

5.2.2.7. Open Water Habitats

Submerged Vegetation

If bays and estuaries accrue oil, there is an assumption that there would be a decrease in seagrass cover and negative community impacts. Submerged vegetation serves important ecological functions. For example, seagrasses and freshwater SAVs provide important habitat for immature shrimp, black drum, spotted sea trout, juvenile southern flounder, and several other fish species, and they provide a food source for species of wintering waterfowl (Castellanos and Rozas, 2001; Short and Coles, 2001; Caldwell, 2003). Therefore, loss of submerged vegetation would impact these species.

Sargassum

Oceanographic processes that concentrate sargassum into mats and rafts would also concentrate toxic substances. Therefore, it may be assumed that sargassum would be found in areas where oil, dispersants, and other chemicals have accumulated following a catastrophic spill. The ultimate effects oftoxins to sargassum are unclear; however, it is evident that the accumulation provides a toxic environment for associated species, especially those that use the sargassum as areas of refuge for larvae or other developmental stages (Unified Incident Command, 2010d). There would be noticeable effects on species that eat the plant material, such as sea turtles, and the death rate of sargassum may be increased due to toxic substances, which would contribute to a major decline in its biomass. This would decrease available habitat for associated organisms and indirectly affect the survival rate and recruitment for associated fish species. The severity and duration of any toxic effects would be dependent on both the physical properties of the toxic components and their biological effects, such as how long it might take them to degrade, their solubility in water, and the degree that they accumulate in biological tissue.

5.2.2.8. Benthic Habitats

Shelf Habitats

In situations where soft-bottom infaunal communities are negatively impacted, recolonization by populations from neighboring soft-bottom substrate would be expected over a relatively short period. Recolonization would begin with recruitment and immigration of opportunistic species from surrounding

stocks. More complex communities would follow with time. Repopulation could take longer for areas affected by direct oil contact in higher concentrations.

Hard-bottom communities exposed to large amounts of resuspended sediments following a catastrophic, subsurface blowout could be subject to sediment suffocation, exposure to resuspended toxic contaminants, and reduced light penetration. The greatest impacts would occur to communities that exist in clear water with very low turbidity. The consequences of a blowout along, directly on, or near one of these features could be long lasting, although the occurrence of a blowout near such sensitive communities is unlikely because NTL 2009-G39 prevents drilling activity near sensitive hard-bottom habitats. Impacts would more likely be from low level or long-term exposure. This type of exposure has the potential to greatly impact reef coral communities, resulting in impaired reef health. Impacts to a community in more turbid waters would be greatly reduced, as the species are tolerant of suspended sediments, and recovery would occur quicker.

Deepwater Soft-Bottom Benthic Communities

In situations where soft-bottom infaunal communities are negatively impacted, recolonization by populations from neighboring soft-bottom substrate would be expected over a relatively short period of time for all organisms ranging from a matter of days for bacteria and probably less than 1 year for most macrofauna and megafauna species. This could take longer for areas affected by direct oil contact in higher concentrations.

Deepwater Coral Benthic Communities

Deepwater corals are expected to be resistant to oiling, with little effect from low exposure. Many invertebrates associated with deepwater coral communities, particularly the crustaceans, would likely be more susceptible to damage from oil exposure. Recolonization of severely damaged or destroyed communities could take years to decades.

Deepwater Chemosynthetic Benthic Communities

While chemosynthetic communities that receive low quantities of well-dispersed oil undergoing biodegradation would likely experience little negative effect, recolonization of severely damaged or destroyed communities could take years to decades.

5.2.3. Socioeconomic Resources

5.2.3.1. Offshore and Onshore Archaeological Resources

While it is unlikely (Section 2.2.3.1), a known shipwreck could be impacted by the blowout itself or the subsequent oil spill, impacts (i.e., contamination) from the release of large quantities of dispersants associated with a deepwater, catastrophic blowout are possible. Because a site cannot be avoided unless its location in known, undiscovered shipwrecks are at a much higher risk as a result of a blow out. Long-term effects of oiling of prehistoric and historic archaeological resources are poorly understood; however, damage to the protective layer of corals and other organisms on shipwreck sites by oiling could alter the surrounding site dynamics and increase their degradation. In addition, onshore habitat degradation could lead to erosion, which would increase exposure to and subsidence of prehistoric and historic sites. Unlike biological resources that have the potential to recover, damage to archaeological resources from the spill or cleanup activities would be irreversible, leading to loss of important archaeological data needed for proper study and interpretation. Archaeological sites also provide recreational opportunities both offshore and onshore; therefore, the loss of a site would also have impacts on recreation.

5.2.3.2. Commercial Fishing

The Gulf is an important biologic and economic area in terms of seafood production and recreational fishing. According to NOAA, there are 3.2 million recreational fishermen in the Gulf of Mexico region who took 24 million fishing trips in 2008. Commercial fishermen in the Gulf harvested more than 1 billion pounds of finfish and Shellfish in 2008 (USDOC, NOAA, 2010g). The economic impacts of

closures on commercial fishing are complicated to predict because the economic effects are dependent on season and would vary by fishery. If fishers cannot make up losses in the remainder of the season, a substantial part of their annual income could be loss. While the commercial fishing industry of Texas did not sustain measurable direct or indirect economic effects following the 1979 Ixtoc blowout and spill (Restrepo et al., 1982), there is a documented phenomenon that, long after an incident, the perception of tainted fish and Shellfish from the impacted area persists (Keithly and Diop, 2001). It is reasonable to assume that a negative perception could impact the value of commercial fish resources for several seasons.

5.2.3.3. Recreational Fishing

In 2008, over 24 million recreational fishing trips were taken in the Gulf of Mexico, which generated about $12 billion in sales, over $6 billion in value added impacts, and over 100,000 jobs (USDOC, NOAA, NMFS, 2010b). Unlike commercial fishing, recreational fishing is concentrated during the summer months. Therefore, a catastrophic spill occurring at the beginning of the recreational fishing season and continuing through the season would result in the loss of millions of recreational fishing trips and billions in subsequent sales. For example, during the summer months, scheduled fishing tournaments are held that would be hard to reschedule. Normal direct income and indirect income to the communities that host these tournaments would be lost for that year.

5.2.3.4. Tourism and Recreational Resources

The longer-term implications of a catastrophic event on tourism would depend on the extent to which any structural/ecological damage can be repaired, as well as on the extent to which public confidence in the tourism industry can be restored. For example, a catastrophic oil spill would likely affect the fish populations in the affected waters to some extent. The most direct impact of this would be to lessen recreational fishing activity in a region to the extent that the fish population has decreased. However, a region would not fully recover from the event until confidence in fishing is restored and the remaining fish population recovers. In addition, restaurants in the region would be impacted to the extent to which they are perceived to use seafood products caught or raised in contaminated waters. Similarly, although beaches can be decontaminated not long after a spill has been stopped, lingering perceptions can be expected to negatively impact tourism.

Oxford Economics (2010) conducted a study of recent catastrophic events in order to estimate the longer-term economic implications of the Deepwater Horizon Oil Spill. They estimate that the long-term economic damage from the spill could be between $7.6 and $22.7 billion. Analyzing previous oil spills and other catastrophic events, they also suggest that it could take 15-36 months for the tourism industry to recover to pre-spill levels. Given Florida's dependence on fishing and beach activities (as well as the overall size of its economy), this study suggests that the State would bear the majority of the economic damage from the spill. This study also points out the complicated set of economic and psychological forces ultimately determine the extent to which the tourism and recreation industries would recover from a catastrophic oil spill.

5.2.3.5. Employment and Demographics

While a catastrophic spill could immediately impact several Gulf States for several months through fishing closures, loss of tourism, and any suspension of oil and gas activities, anticipating the long-term economic and employment impacts in the Gulf of Mexico is a difficult task. Many of the potentially affected jobs, like fishing charters, are self-employed. Thus, they would not necessarily file for unemployment and will not be included in business establishment surveys used to estimate State unemployment levels. In addition, unemployment numbers in states are based on nonagricultural jobs, and the fishing industry is considered within the agriculture category. On the other side, it is also a challenge to estimate how many of these displaced workers have been hired to clean up the spill. For example, while thousands of vessels of opportunity would be active in the spill response, not all of these would be displaced commercial fishermen from the affected areas. The positive employment impacts related to response activities are likely to be shorter term than the negative impacts discussed above.

Catastrophic spills have a huge regional economic impact, as seen recently in the Deepwater Horizon incident. It is estimated that the total economic consequences of the Deepwater Horizon incident will lead

to a net loss of just under $20 billion for the U.S. economy in 2010, which would lower U.S. economic growth in 2010 by roughly 0.1 percent and would reduce growth to a greater extent in the four states most affected.

5.2.3.6. Land Use and Coastal Infrastructure

Based on the rapid recovery of infrastructure that was heavily damaged by the catastrophic 2005 hurricane season, there are not expected to be any long-term impacts to land use and coastal infrastructure as a result of a catastrophic oil-spill event. However, BOEMRE would continue to monitor the post-spill, long-term recovery phase of the Deepwater Horizon incident for any changes that indicate otherwise. A catastrophic spill could generate up to 60,000 tons of oil-impacted solid materials disposed in landfills along the Gulf Coast. This waste may contain debris, beach or marsh material (sand/silt/clay), vegetation, and personal protection equipment collected during cleanup activities. This would be equivalent to 2-6 years of waste produced from OCS oil and gas activities in the Gulf of Mexico (Dismukes et al., 2007). However, landfill capacity is not expected to be an issue at any phase of the oil-spill event or the long-term recovery. According to USEPA, existing landfills that are receiving oil-spill waste from the Deepwater Horizon incident have plenty of capacity to handle the expected waste volumes. The oil-spill waste that is being disposed in landfills represents less than 7 percent of the total daily waste normally accepted at these landfills (USEPA, 2010a).

It is not expected that any long-term, land-use impacts would arise from properties that are utilized for restoration activities and would somehow have their future economic use compromised. The rise or fall of property values would not be solely a function of some kind of economic impact from a catastrophic oil spill event. There are many other factors that influence the value of property and its best economic use. It is not clear from past experiences whether vegetation loss or erosion created by a spill could result in changes in land use. The amount and location of erosion and vegetation loss can be influenced by the time of year the spill occurs, its location, and weather patterns, including hurricane landfalls (Dismukes, personal communication, 2010a).

5.2.3.7. Environmental Justice

After the spill is stopped, the primary environmental justice concerns relate to possible long-term health impacts to cleanup workers, a predominately minority population, and to possible disposal of oil-impacted solid waste in predominantly minority areas.

Suspension of Oil and Gas Activities

An analysis of socioeconomic characteristics shows that people of Cajun ethnicity in the Gulf states, often found to be of a comparatively low socioeconomic status and work jobs in the textile and oil industries (Henry and Bankston, 1999). Past studies suggest that a healthy offshore petroleum industry also indirectly benefits low-income and minority populations (Tolbert, 1995). One BOEMRE study in Louisiana found income inequality decreased during the oil boom of the 1980's and increased with the decline (Tolbert, 1995). Although we know that many oil- and gas-related service industries are cutting costs and putting off maintenance to defer massive layoffs in response to the oil-spill-caused deepwater drilling suspension and the slowed schedule for shallow-water drilling permits, we do not fully understand their long-term impacts..

Onshore and Offshore Cleanup Workers

By the end of a catastrophic spill, up to 50,000 personnel would be expected to be responding to the spill. The majority of these are field responders (United Incident Command, 2010f). As seen with the Deepwater Horizon incident, the racial composition of cleanup crews was so conspicuous that Ben Jealous, the president of the National Association for the Advancement of Colored People (NAACP), sent a public letter to BP Chief Operations Officer Tony Hayward on July 9, 2010, demanding to know why African Americans were over-represented in "the most physically difficult, lowest paying jobs, with the most significant exposure to toxins" (NAACP, 2010). While regulations require the wearing of protective gear and only a small percentage of cleanup workers suffer immediate illness and injuries (CDC, 2010), exposure could have long-term health impacts (e.g., increased rates of some types of cancer) (Savitz and

Engel, 2010; Kirkeleit et al., 2008). Of the 38 accidents involving supertankers and resulting in large oil spills throughout the world, only seven studies on the repercussions of the exposure of spilled oils on human health have been completed. Aguilera et al. (2010) compiled and reviewed these studies for patterns of health effects and found evidence of the relationship between exposure and "acute physical, psychological, genotoxic, and endocrine effects in the exposed individuals." Acute symptoms from exposure to oil, dispersants, and degreasers include headaches, nausea, vomiting, diarrhea, sore eyes, runny nose, sore throat, cough, nose bleeds, rash, blisters, shortness of breath, and dizziness (Sathiakumar, 2010). USEPA monitoring data has so far shown that the use of dispersants during the DWH event did not result in a presence of chemicals that surpassed human health benchmarks (Trapido, Health Presentation, 2010). Longitudinal epidemiological studies of possible long-term health effects from exposure to either the DWH event oil or dispersants, such as the possible bioaccumulation of toxins in tissues and organs, are lacking and potential for the long-term human health effects are largely unknown (although the National Institutes of Health has proposed such a study).

Prior research on post-spill cleanup efforts, found that the duration of cleaning work was a risk factor for acute toxic symptoms and that seamen had the highest occurrence of toxic symptoms compared to volunteers or paid workers. Therefore, participants in the DWH "Vessels of Opportunity" program, which recruited local boat-owners (including Cajun, Houma Indian, and Vietnamese fishermen) to assist in cleanup efforts, would likely be one of the most exposed groups. African Americans are thought to have made up a high percentage of the cleanup workforce. As seen with the Deepwater Horizon incident, the racial composition of cleanup crews was so conspicuous that Ben Jealous, the president of the National Association for the Advancement of Colored People (NAACP), sent a public letter to BP Chief Operations Officer Tony Hayward on July 9, 2010, demanding to know why African Americans were over-represented in "the most physically difficult, lowest paying jobs, with the most significant exposure to toxins" (NAACP, 2010). The Occupational Safety & Health Administration (OSHA) released two matrices of gear requirements for on- and off-shore Gulf operations that are organized by task (OSHA). Of past oil-spill workers, uninformed and poorly-informed workers were at more risk of exposure and symptoms, demonstrating the importance of education and proper training of workers (Sathiakumar, 2010).

Therefore, a catastrophic spill could disproportionately affect seamen and onshore workers such as Cajuns, Vietnamese, Houma Indian, and African Americans.

During a recent National Institute of Environmental Sciences (NIEHS) workshop regarding the health effects of the BP Deepwater Horizon oil spill, Chairperson Nancy E. Adler pointed to the uncertainty regarding health effects and these types of events, "While studies of previous oil spills provide some basis for identifying and mitigating the human health effects of these exposures, the existing data are insufficient to fully understand and predict the overall impact of hazards from the Deepwater Horizon oil spill on the health of individuals—including workers, volunteers, residents, visitors, and special populations" (Institute of Medicine, 2010). In order to address these data gaps, NIEHS plans to begin a prospective study of the mental and physical health of about 50,000 workers who helped battle the spill.

Solid-Waste Disposal

Following a catastrophic spill, environmental justice concerns related to the disposal of cleanup-related wastes near minority and/or low-income communities (Schleifstein, 2010). It is estimated a catastrophic spill could generate up to 60,000 tons of oil-impacted solid materials that would be disposed in landfills along the Gulf Coast. While no new landfills would be built due to a catastrophic spill, the use of existing landfills might exacerbate existing environmental justice issues. For example, Mobile, Alabama and Miami, Florida are majority minority urban centers with a majority of minority residents living with a 1-mile radius of chosen landfills or liquid processing centers. While only a small percentage of DWH waste was sent to these facilities: 13% of liquid waste to Liquid Environmental Solutions in Mobile and only .28% of the total liquid waste to Cliff Berry in Miami, they could potentially receive more for future spills. For example, of the nine landfills approved by USEPA for oil-impacted solid materials, more than half of the waste was disposed in four landfills that were located in areas where minority groups comprised the majority of the population (Hernandez, 2010). Disposal procedures for the DWH event involved sorting waste materials into standard "waste stream types" at small, temporary stations, and then, sending each type to existing facilities that were licensed to dispose of them. The location of temporary sorting stations was linked to the location of containment and cleanup operations. Hence, future locations of any sorting stations are not predictable since they would be determined by the

needs of cleanup operations. However, waste disposal locations were determined by the specializations of existing facilities and by contractual relationships between them and the cleanup and containment firms. Louisiana received about 82 percent of the DWH liquid waste recovered; of this, 56 percent was manifested to mud facilities located in Venice, Plaquemines Parish, Louisiana, and Port Fourchon, Lafourche Parish, Louisiana, and then transferred to a processing facility in Port Arthur, Texas. The waste remaining after processing was sent to deep well injection landfills located in Fannett and Big Hill, Texas. The sites located in Venice and Port Fourchon, Louisiana, and Port Arthur, Fannett, and Big Hill, Texas, have low minority populations but a few of these areas have substantial poverty rates relative to state and county means. Although, in the case of the DWH event, most of the cleanup occurred in the CPA, disposal occurred in both the CPA and WPA, and this would likely happen should a future event occur.

6. CUMULATIVE ENVIRONMENTAL AND SOCIOECONOMIC IMPACT

Like the recent, devastating hurricane seasons of 2005 and 2008, the Deepwater Horizon incident has changed the environmental baseline of the Gulf of Mexico. Another catastrophic oil spill would make the resources of the Gulf even more susceptible to further impacts, adding to the cumulative effects of an already sensitive ecosystem.

The Gulf Coast has survived major natural and manmade disasters (i.e., hurricanes and oil spills), through which the people and environmental resources of the Gulf of Mexico and the Gulf Coast have repeatedly demonstrated their resiliency. While environmental and socioeconomic resources may recover from a natural or manmade disaster if given enough time between disasters, disasters happening in unison or within short periods of each other would make recovery more difficult.

The magnitude of OCS and non-OCS activity in the Gulf of Mexico is so immense that routine activities associated with a single OCS oil and gas activity (e.g., single lease sale, single well) have a minor to no incremental contribution to the impacts of cumulative activities. However, a catastrophic blowout and spill would have a major contribution to cumulative impacts.

7. SUMMARY OF IMPACTS

7.1. SUMMARY OF IMPACTS FROM PHASE 1 (INITIAL EVENT)

The initial phase of the catastrophic event analyzed in the Gulf of Mexico is a blowout causing an explosion and fire, possibly resulting in the sinking of the drilling rig or platform. Impacts during Phase 1 would be limited to workers on the platform and environmental resources offshore in the immediate vicinity of the blowout. Air quality impacts include the emission of pollutants from the oil and the fire that are hazardous to human health and can possibly be fatal. Water quality impacts include localized water quality effects, which could include the release of a large amount of methane gas and the disturbance of a large amount of sediments over an extended area, if the blowout occurs outside the wellbore, below the seafloor.

An explosion would kill any birds resting on the platform, including birds protected under the Migratory Bird Treaty Act. Eruption of gases and fluids may generate significant pressure waves and noise to injure or kill individual animals in the vicinity, including federally listed threatened and endangered species under the ESA or MMPA. A shock wave under water may also impact commercial and recreational fisheries in the area. Benthic communities beyond avoidance zones could be smothered. In addition to a large number of fatalities and injuries of people on the drilling rig or platform itself, commercial and recreational fishers and divers near the blowout could be injured or killed. The blowout could also damage any unidentified archaeological sites nearby.

7.2. SUMMARY OF IMPACTS FROM PHASE 2 (OFFSHORE SPILL)

The second phase of the catastrophic event analyzed is an extended, offshore spill estimated to last 1-4 months for a blowout in shallow water and 3-5 months for a blowout in deepwater, due to more difficult intervention. A large-scale response effort would be expected for a catastrophic spill, including tens of thousands of responders, several thousand vessels, and the release of a large amount of dispersants.

A catastrophic spill has the potential to cause population level impacts to offshore biological resources. Multiple Federal and State-listed, threatened and endangered species could be impacted in the water column or at the sea surface. In addition, natural processes (e.g., flocculation) and human intervention (i.e., subsea dispersants) could expose benthic communities and archaeological sites to oil. Additionally, known and previously undiscovered archaeological sites and benthic habitats could be damaged by bottom-disturbing activities associated with the response effort, including anchoring of vessels. Pollutants in the spilled oil that are hazardous to response workers without protective equipment would be emitted into the air through evaporation and through in-situ or controlled burns of oil slicks.

Socioeconomic impacts would begin while the spill is still offshore. A large portion of the Gulf of Mexico EEZ and most of State waters could be closed to commercial and recreational fishing for several months, possibly causing the loss of revenue for an entire season or year. These closures may predominately affect minority or ethnic groups. Tourism may also be impacted due to either perceived damage to recreational resources that has not yet materialized or to general hesitation on the part of travelers to visit the overall region due to the spill. Suspension of some oil and gas activities would be possibly follow a catastrophic event, temporarily affecting jobs in the oil and gas industry.

7.3. Summary of Impacts from Phase 3 (Onshore Contact)

The third phase of the catastrophic event analyzed is oiling of the shoreline. Exponential increase of the length of shoreline impacted is expected as the spill would continue over several months, which would likely overwhelm response efforts. Due to longer intervention times, a deepwater blowout and spill could impact over 1,000 miles of shoreline. While a catastrophic spill from a shallow-water blowout is expected to be a lower volume than a deepwater blowout, the site would generally be located closer to shore, allowing less time for oil to be weathered, dispersed, and recovered. This could result in more concentrated and toxic oiling of several hundred miles of shoreline for more than 2 months.

The severity of oiling would vary between heavy, moderate, light, and occasional tarballs. However, due to the length of shoreline that could be potentially oiled and the sensitivity of the Gulf Coast, a catastrophic spill could cause extensive habitat degradation. Loss of vegetation could lead to erosion and permanent landloss. Though response efforts (including the use of skimmers and booms) would decrease the amount of oil contacting the coastline, significant amounts of oil would remain to impact coastal water quality. Gulf of Mexico water quality is already rated as fair to poor, according to USEPA. Depending on timing and location, a catastrophic spill has the potential to cause population-level impacts on biological resources. Dozens of Federal and State-listed, threatened and endangered species could be impacted. Impacts on air quality may have adverse effects on oil spill responders.

While cultural resources were recognized as significant early in the response and archaeologists are at present embedded in SCAT teams and consulting with cleanup crews, efforts to prevent coastal cultural resources from becoming contaminated by oil would likely be overwhelmed by the magnitude of shoreline impacted and/or in the event of a hurricane during the spill cleanup efforts. In addition to closures in Federal waters, portions to all of individual State waters would also be closed to commercial and recreational fishing. The economic impact of these closures would have a disproportional effect on minority and low-income groups, and shoreline impacts would generate additional subsistence-related effects. A catastrophic spill also has the potential to significantly impact the Gulf Coast recreation and tourism industries, particularly water-dependent and beach-dependent components of these industries. An influx of cleanup and relief workers would not fully offset economic impacts. The influx a large number of responders and the creation of staging areas due to a catastrophic spill would have temporary impacts (e.g., increased traffic congestion and some possible competing land use issues) on land use and infrastructure. In addition, there is a potential for delays in cargo handling and slow vessel traffic due to decontamination operations at various sites along the marine transportation system.

7.4. Summary of Impacts from Phase 4 (Long-Term Impacts)

Phase 4 focuses on the long-term impacts of a catastrophic oil spill. While impacts to air and water quality may be shorter term, a catastrophic spill can have impacts on Gulf of Mexico ecosystems long after the well is capped or killed and cleanup activities have concluded. In some cases, marine ecosystems may take decades to fully recover or may recover to alternative states.

Coastal and offshore habitats serve important ecological functions. Onshore, the loss of vegetation could lead to erosion and permanent landloss. Offshore, repopulation of benthic communities could take longer for areas affected by direct oil contact in higher concentrations. For birds, fish, marine mammals and sea turtles, damage of habitats, loss of reproductively capable adults as well as juveniles, and sublethal impacts from oil exposure can lead to impaired reproduction. This can potentially reduce population levels. For example, a catastrophic spill could decrease available habitat for associated organisms and indirectly affect the survival rate and recruitment for associated fish species. In the case of birds, long-term, sublethal, chronic effects may exceed immediate losses due to direct mortality (i.e., oiled birds) if such residual effects influence a significant proportion of the population or disproportionately impact an important population segment. A catastrophic spill could cause the destruction of the remaining habitat of certain onshore species, such as the diamondback terrapin or beach mice.

A catastrophic spill can also have long-term impacts on socioeconomic resources. Positive employment impacts related to response activities are likely to be shorter term than the negative impacts. Catastrophic spills have a huge regional economic impact (billions of dollars) as recently seen with the Deepwater Horizon incident. The longer-term implications for commercial and recreational fishing and tourism depend on the extent and perception of environmental damage. After the spill is stopped, the primary environmental justice concerns would be long-term health impacts of predominately minority workers and the disposal of oil-impacted solid waste in predominantly minority areas. Long-term impacts to land use and coastal infrastructure are not expected. Unlike biological or other socioeconomic resources that have the potential to recover, damage to archaeological resources from the spill or cleanup activities would be irreversible, leading to loss of important archaeological data needed for proper study and interpretation.

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