OCS Report
MMS 2004-039

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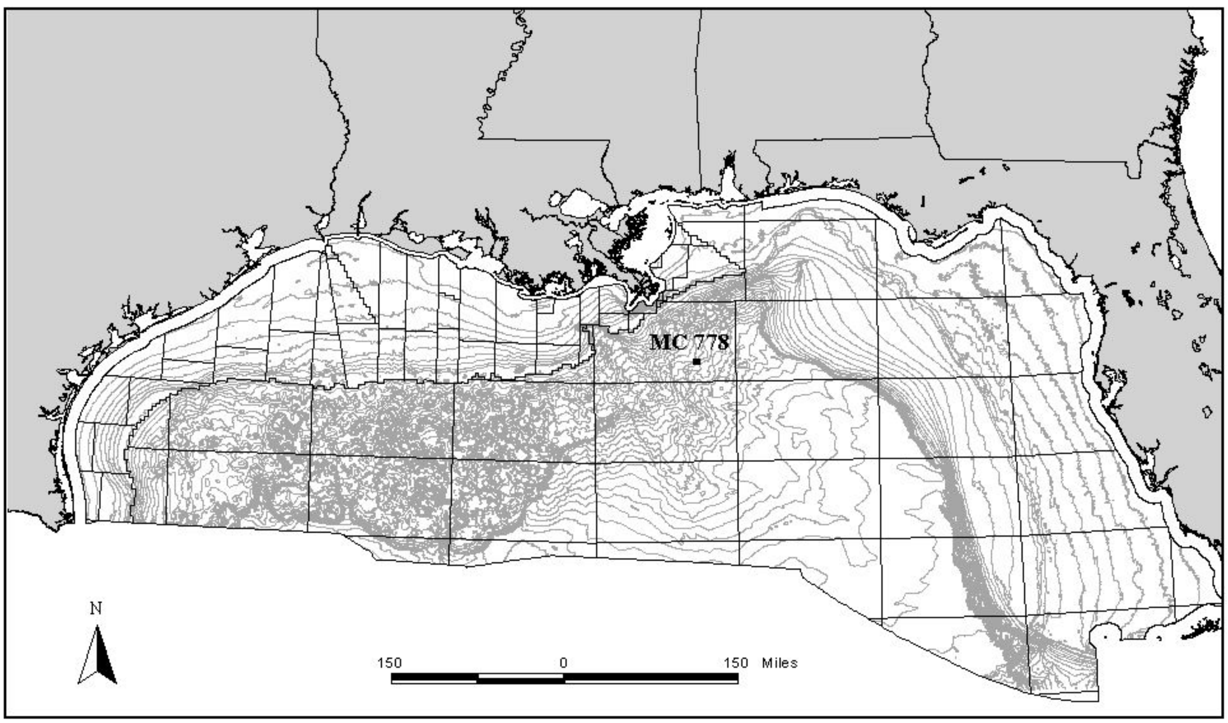

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

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Fate and Effects of a Spill of Synthetic-Based Drilling Fluid at Mississippi Canyon Block 778

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INTRODUCTION

Ultra-deepwater drilling in the Gulf of Mexico (GOM) is a relatively new activity. The challenging conditions of deep water require new technologies and new drilling products (USDOI, MMS, 2002a). As a result, the spill scenarios and potential biological impacts may differ from those that occur in shallower waters. An actual spill associated with ultra-deepwater drilling presented an opportunity to evaluate such spills.

This report describes a spill of 2,450 bbl of synthetic-based drill fluid (SBF), the physical oceanography at the time of the spill, and the potentially affected benthic communities. The spill occurred on May 21, 2003, at Mississippi Canyon Block 778 (MC 778), latitude 28.19° N. and longitude 88.49° W. (Figure 1). It occurred in water with a depth of 6,040 ft as the dynamically positioned *TSF Discoverer Enterprise* was pulling out of the wellhole with bottom location at MC 822. This drilling was occurring on BP's Thunder Horse Project. The riser parted in two places — 1 ft above the lower marine riser package (LMRP) at about 55 ft above the seafloor and at 3,200 ft (RK). Riser joints fell to the seafloor. The SBF escaped from multiple points within the water column. It is not known whether all the SBF in the free-falling joint sections escaped or not. An estimated 2,450 bbl of SBF was released. An investigation of the operational aspects of the riser break and release was concluded on January 9, 2004, and is available through the MMS Public Information Office (1-800-200-GULF).

DISCUSSION

CHARACTERISTICS OF SYNTHETIC-BASED DRILL FLUID

The SBF's were first used in the North Sea in 1990 and in the Gulf of Mexico in 1992 (Neff, 2000). The SBF's are well suited for deepwater use. They promote cuttings suspension, suppress gas hydrate formation, and work well at cold temperatures. Several classes of SBF's are available. In the GOM, SBF usage is limited to esters and internal olefins because they biodegrade within the regulatory time limit.

The SBF's are synthesized rather than refined from crude oil and do not contain polycyclic aromatic hydrocarbons (PAH's). Much of the toxicity related to drilling mud discharges has been attributed to PAH content. The stock base fluid is hydrophobic and emulsifiers and wetting agents are necessary to prepare a drilling fluid. Other components such as lime, barite, and corrosion inhibitors are added to the carrier fluid to achieve a product with optimum qualities.

The operator was using a stock base fluid known as Accolade™, which is marketed by Baroid Corporation. Of the total drill fluid that spilled, 58 percent or 1,421 bbl was the synthetic stock base fluid. The remaining 42 percent included traditional components permitted for discharge when present in water-based drill fluids.

Accolade™ is a 50:50 mix of internal olefin and ester and meets the U.S. Environmental Protection Agency (USEPA) permit requirements for PAH concentration, toxicity, and biodegradation rate (Halliburton Energy Services, Inc., 2003a; Attachment 1). The concentration of mercury and cadmium in the barite was also within the USEPA permitted range (Halliburton Energy Services, Inc., 2003b; Attachment 1). A more detailed description of the Thunder Horse project and its environmental impacts are presented in the Programmatic Environmental Assessment for Grid 16. In a Development Operations Coordination Document (DOCD) for the Thunder Horse project, submitted to MMS prior to drilling, BP estimated that a total of 2,300-3,000 bbl SBF/well would be discharged as SBF-wetted cuttings during the exploratory phase (USDOI, MMS, 2002b). The release on May 21, 2003, discharged a volume roughly equivalent to the volume anticipated for one well.

Because the drill fluid had been down the wellbore, it is assumed that some formation oil may have been mixed into the released fluid. On the basis of the USEPA assumption that formation oil accounts for 0.2 percent of the fluid, the MC 778 spill could have also released 5 bbl of oil. Components in the fluid or the formation oil could have resulted in a surface slick. An overflight conducted within several hours of the release observed no surface slick.

Most literature available focuses on the fate of SBF-wetted cuttings, which settle to the seafloor in heterogeneous piles. In shallower waters, the cuttings settle to the seafloor mostly within 100 m of the well. The MMS has funded studies that are in progress to learn more about cuttings deposition in deeper waters. At MC 778 the accidental spill included fluid and cuttings and would behave differently from permitted cuttings discharge.

PHYSICAL OCEANOGRAPHY

A failure is an expensive incident. The MMS and industry hope to understand the cause of this incident so that similar events can be prevented in the future. Currents were examined as a possible cause of this incident.

The Loop Current is the dominant ocean current in the eastern Gulf of Mexico. This current passes through the Yucatan Channel into the Gulf of Mexico, turns clockwise, and ultimately leaves through the Florida Straits. The geographic position of the Loop Current within the Gulf of Mexico is highly variable, and it can rarely extend as far north as the Mississippi-Alabama shelf. However, from 1993 to 1999 the Loop Current remained south of latitude 28.0^{o} N. (Table 1). Loop Current speeds normally range from 100 to 200 cm/sec (1.9-3.9 kn) but may be as swift as 300 cm/sec (5.8 kn). The Loop Current is generally thought to extend from the surface to approximately 800-1,000 m (2,625-3,281 ft).

Loop Current rings pinch off and are shed at very irregular periods, averaging once every 9-10 months (Hamilton et al., 2000). These rings range from about 300 to 400 km in diameter, and they are also known as warm core eddies. Warm core eddies travel across the Gulf of Mexico at speeds of only about 2-5 km per day. However, water speeds within warm core eddies are much greater, ranging from 50 to 200 cm/sec (1.0-1.9 kn). These warm core eddy currents, like the Loop Current, seldom extend deeper than 1,000 m (3,281 ft).

Past observations of currents in the deepwater Gulf of Mexico have generally revealed consistent decreases in current speed with depth. During late 1999, a limited number of high-speed current events, at times approaching 2 kn, were observed at depths exceeding 1,500 m (4,921 ft) in the northern Gulf of Mexico (Hamilton and Lugo-Fernandez, 2001). In upper continental slope waters, high-speed mid-depth currents that can last as long as a day have been observed (USDOI, MMS, 2002c). However, none of these currents has been observed in waters deeper than 700 m.

Satellite observations of the Loop Current in the Gulf of Mexico on May 21, 2003, (Figure 2) indicate that part of the Loop Current did extend unusually far north at the time of the incident. This is a very rare occurrence. On close examination, although the Loop Current edge is in the proximity of the region of interest, it does not appear to have actually reached the geographic location of the riser break. Although pinching of the Loop Current can be observed in Figure 2, no major, warm-core Loop Current eddy existed in the MC 778 area.

The Loop Current, however, has been observed to tilt as it moves northward. Such tilting might result in currents at 500-1,000 m (1,640-3,281 ft) depths underlying still waters, which might conceivably be missed on casual examination of the altimetry data when the Loop Current appears to be fairly close to the region of interest. *In situ* data can be helpful in such cases in order to completely eliminate the possibility of direct Loop Current influence.

Examination of confidential Acoustic Doppler Current Profiler (ADCP) data taken at MC 778 confirms that the drill site did not experience the influence of swift, deep currents in the upper 1,100 m (3,609 ft), and the deepest level of Loop Current influence is thought to be 800-1,000 m (2,625-3,281 ft). The measurements therefore confirm that there were no high-speed currents directly attributable to the Loop Current. These ADCP data were collected by the operator to meet MMS requirements. However, the data do not extend deeper than approximately 1,100 m (3,609 ft), and it is unknown whether or not strong currents existed between 1,100 and 1,841 m (3,609-6,040 ft) of water.

Video footage was taken immediately after the riser break from an ROV previously deployed at the scene. There appeared to be some currents in deep water in the area, but the strength of these currents was not possible to estimate without measurements.

ENVIRONMENTAL EFFECTS OF THE SBF SPILL

The released SBF would be transported and eventually settle to the seafloor where it would gradually be removed through biological processes. The rate of biodegradation is controlled by many factors including temperature, hydrostatic pressure, and the availability of oxygen. Initially, the dispersed SBF would aerobically biodegrade. At the seafloor, where dissolved oxygen is limited, the sediments would likely become anaerobic as the bacteria utilize the available oxygen to metabolize the SBF. Biodegradation would then proceed anaerobically at a slower rate.

Chemosynthetic Communities

Chemosynthetic communities are persistent, largely sessile assemblages of marine organisms dependent upon symbiotic chemosynthetic bacteria as their primary food source (MacDonald, 1992). Chemosynthetic communities depend on hydrocarbon seepage in the GOM and occur in water depths between 290 and 2,200 m (951 and 7,218 ft) (Roberts et al., 1990; Rosman et al., 1987; MacDonald, 1992).

A review of geological and geophysical data was performed to look for features that could support chemosynthetic communities near MC 778. No areas for potential chemosynthetic communities were identified in the area, including the 457-m (1,500-ft) avoidance distance from the discharging structure required by NTL 2000-G20. No other potential chemosynthetic community areas were identified within 152 m (500 ft) of all 16 anchor locations or anchor chain/cable impacting areas for the semisubmersible drill site.

The closest known chemosynthetic community is located in Viosca Knoll Block 826, more than 72 nmi to the northeast. The likely maximum horizontal distance any drilling mud lost from the riser break would travel would be no more than a few thousand meters in any direction from the well site. Even the area that could have potential chemosynthetic communities, located about 4 nmi to the northwest, would be far beyond the range any drilling muds released at a depth of 975 m (3,200 ft) could travel.

Deepwater Benthos and Sediment Communities

Marine benthic communities include single-celled organisms, invertebrates, and fish. Benthic animals are classified by size into four categories: megafauna (large, mobile, surface organisms), macrofauna, meiofauna, and microfauna (microscopic). The four types are discussed in more detail in Attachment 2.

Through MMS Notice to Lessees (NTL) 2003-G3, “Remotely Operated Vehicle (ROV) Surveys in Deepwater,” BP contracted two separate surveys: one prior to and one immediately after the drilling of the first well in MC 778 very near the same location of the riser failure. During each survey, the ROV filmed six 100-m transects radiating out from a point near the well site. The video records showed close-up views of the seabed and all associated benthic megafauna along these transects. The ROV surveys recorded sparse numbers of megafauna on all six transects. The bottom was flat and generally featureless except for small mounds and depressions remaining from burrowing or impressions of animals. Four major groups of animals were observed but not speciated: fish, sea cucumbers, a probable sea pen, and possible anemones.

The abundance of the smaller fauna is not captured by ROV video. Studies performed at locations both east and west and at depths similar to that of the Thunder Horse project noted a decline in macrofaunal and meiofaunal abundance with depth. This decline has been attributed to the relatively low productivity of the Gulf offshore open waters. About 2,000 macrofaunal individuals per square meter and 300,000-400,000 meiofaunal individuals per square meter would be expected in the Thunder Horse region (USDOI, MMS, 2002b).

The drilling mud release would disturb the benthic community by smothering and displacing it from patches within limited distances of the well site location. Smothering by physical and/or anoxic conditions is the only direct biological effect reported for SBF’s and associated cuttings in the field environment. Anoxia is caused by the rapid biodegradation of the SBF. The various components of the sediment community would be directly impacted relative to the thickness of the drilling mud on top of the initial sediment-water interface.

Invertebrates, many with some degree of mobility, dominate the megafaunal benthic communities at the project depth of around 1,841 m (6,040 ft). Fish, shrimp, crabs, and to some degree, sea cucumbers, would be able to avoid burial because of their mobility. The macrofauna is dominated by deposit-feeding polychaete worms with varying degrees of mobility and tolerance to disturbance. The meiofauna, primarily composed of small nematode worms, is more abundant than macrofauna, and their numbers decline with water depth. Little is known of the microbiota in deep water, but it probably includes hydrocarbon-degrading forms. None of the benthic communities found in Thunder Horse in MC 778 is unique to the area; they appear to be widespread throughout the Gulf where depths, substrates, and other environmental factors are similar.

The affected area would be limited to a small area of the seafloor. Most historical literature (based on the more toxic oil-based mud (OBM) or water-based mud (WBM), which tend to disperse farther) indicate biological effects generally do not occur beyond 500 m (1,640 ft) from the source of a surface discharge, although several papers have noted subtle effects beyond that range. Most relevant is the recent research in the North Sea (Jensen et al., 1999) that studied a number of platforms that used only SBF's. That study found no benthic effects (i.e., benthic effects as measured by subtle community changes) beyond 250 m (820 ft) in most cases, 500 m (1,640 ft) in a few cases. However, one must note that the North Sea is a shallower environment than the deepwater GOM.

Visual evidence of sinking drilling mud was taken from an ROV at the point of the riser break about 10 minutes after the incident (Figure 3). The video showed relatively rapid descent of the mud plume and a lateral movement away from the drill site, indicating some bottom current (Figure 4). There was also a lack of accumulation of material on any of the structures on the seabed as seen in latter parts of the ROV video. The blowout preventer, its framework, and upper surfaces of the fallen riser did not have any appreciable accumulations of drilling mud on their upper surfaces (Figures 5 and 6).

The impact to the sediment communities would be limited to the distance the drifting mud plume traveled during its descent through the remaining 866 m (2,841 ft) of water column between the riser separation and the seabed. Partial recovery of the community would occur within weeks or months of the disturbance, probably followed by a more or less full recovery within 1-2 years. This would not result in a significant impact on the benthic communities.

Fish Resources

The GOM supports a great diversity of fish resources. Ecological factors such as temperature, salinity, primary productivity, bottom types, and many other physical and biological factors determine the distribution and abundance of the fish resources.

Fish can be classified as demersal (bottom-dwelling), oceanic pelagic, or mesopelagic (midwater). Demersal (or benthic) fish have been addressed above under the megafauna descriptions. Common oceanic pelagic species include the large predatory tunas, marlins, sailfish, swordfish, dolphins, wahoo, and sharks and many other lesser known species. The depth of the riser break would not impact the water column where oceanic pelagic species would normally occur. Additional life history information on important commercial invertebrate fish resources of the GOM is contained in USDOI, MMS (2000 and 2002c).

The discharge of drilling mud has the potential to affect fish. However, contaminant levels would reach background levels within a short distance from spill area and be undetectable beyond 3,000 m (9,843 ft) from the site, according to some studies of surface discharges (USDOI, MMS, 2000). The PAH's, which are primarily responsible for the toxicity of oil-based drilling fluids, are below detectable levels in SBF's. Numerous studies have demonstrated that mercury impurities associated with drilling mud barite are not capable of being taken up by marine organisms that might come in contact with discharged drilling fluid solids (Neff et al., 1989).

Very few fish, on the order of less than 10 per hectare (10,000 m^2), were observed *in situ* at the riser incident site during ROV surveys prior to the accident. Adult fish would also tend to swim away from areas that experienced significant deposition of SBF. The effects on bottom fish habitat from SBF would likely be limited to within a few thousand meters of the discharge using the observed lateral movement of SBF exiting the break in the riser, the limited bottom currents at the time, and the separation distance between the break depth and the seabed. Impacts on demersal fish from the drilling mud would be negligible.

Commercial Fisheries

No impact is expected on commercial fishes from the release of SBF resulting from the accidental riser break. There are no commercial fisheries directed at demersal species in the vicinity of the Thunder Horse project. Desirable pelagic fish species may be attracted to the drill ship, but the SBF spill would have no impact on the movements or distribution of commercial pelagic fish species in much shallower water depths above the break location depth of 975 m (3,200 ft).

CONCLUSION

On the basis of the information available, it is concluded that the released SBF dispersed into the water, settled to the seafloor, and biodegraded. The SBF would cause a temporary decrease in dissolved oxygen at the sediment water interface. The released material had been selected for use in the GOM because of its relatively rapid biodegradation rate.

No chemosynthetic communities exist close enough to the release to have been impacted. The less motile animals within the nearby benthic community could have smothered under a layer of SBF or from anoxic conditions resulting from biodegradation. The community would recover as the SBF is biodegraded. Impacts to fish resources and commercial fisheries would be negligible to nonexistent because of their mobility, the dispersion of the SBF, and the absence of toxicity of the released SBF

The Loop Current did not directly affect the MC 778 drill site on May 21, 2003. Currents were weak in the upper 1,100 m (3,609 ft). Current speeds below 1,100 m (3,609 ft) are not known because measurements taken by the operator and made available to MMS did not extend from 1,100 m (3,609 ft) to the seafloor at 1,841 m (6,040 ft).

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Table 1

Loop Current Position Statistics (1/1/1993 — 4/30/1999)

	West Longitude	North Latitude	Length	Area	Volume	Circulation
Mean	87.7^o W.	26.1^o N.	1,390 km	142,000 km^2	2.17x10^{13} m^3	1,271,000 m^2/sec
Std.Dev.	0.97^o W.	0.93^o N.	321 km	28,300 km^2	0.37x10^{13} m^3	321,190 m^2/sec
Maximum	92.0^o W.	28.0^o N.	2,016 km	194,600 km^2	2.81x10^{13} m^3	2,016,200 m^2/sec
Minimum	85.8^o W.	24.1^o N.	593 km	58,600 km^2	0.91$10^{13}$ m^3	593,480 m^2/sec

Source: Hamilton et al., 2000.

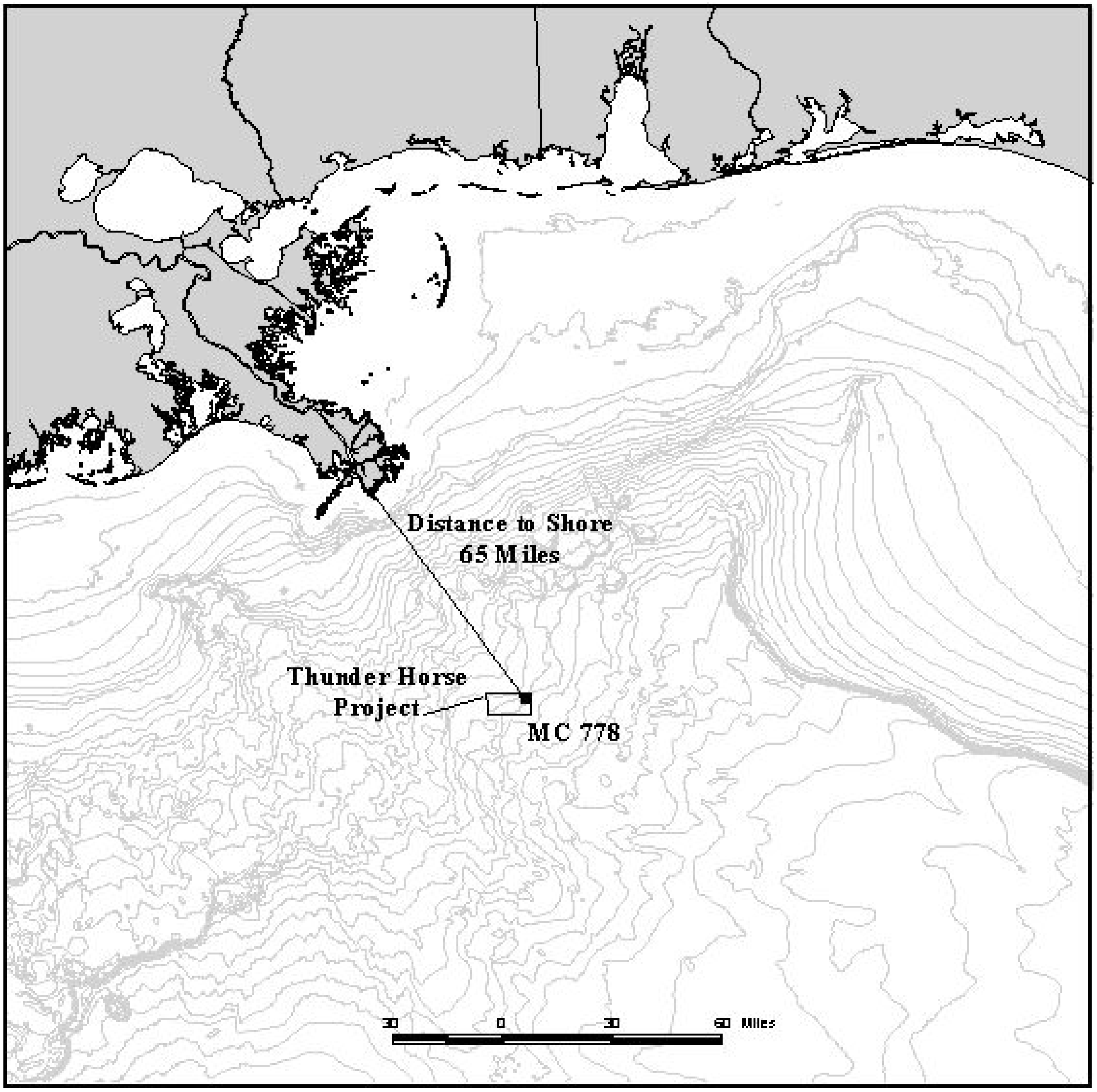

Figure 1. Location of Mississippi Canyon Block 778.

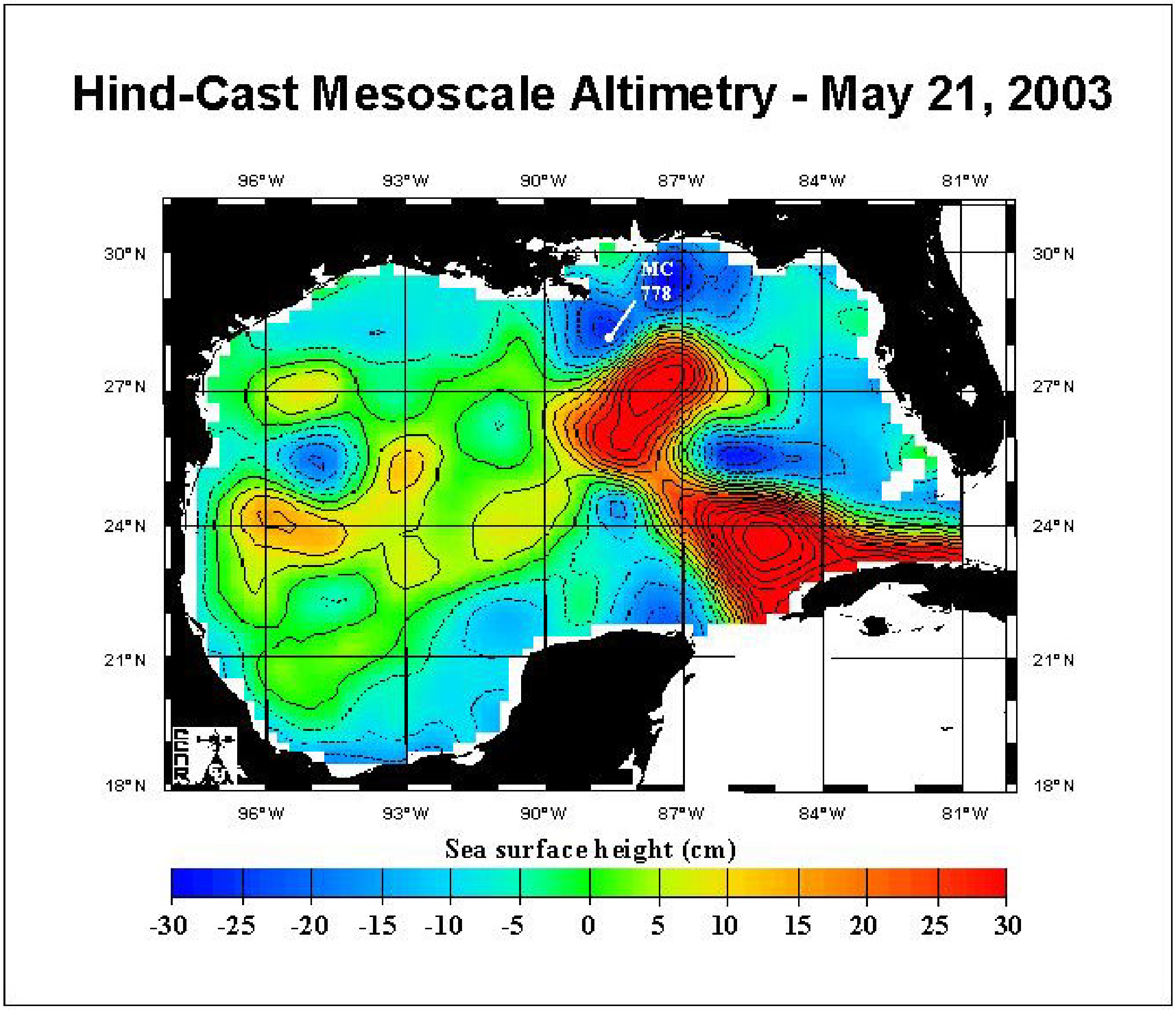

Figure 2. Loop Current position on May 21, 2003 (Leben, 2003).

Figure 3. Mud plume escaping from the parted riser at MC 778 (frame from ROV video, May 21, 2003).

Figure 4. Dispersion of the synthetic-based drilling fluid release at MC 778 (frame from ROV video, May 21, 2003).

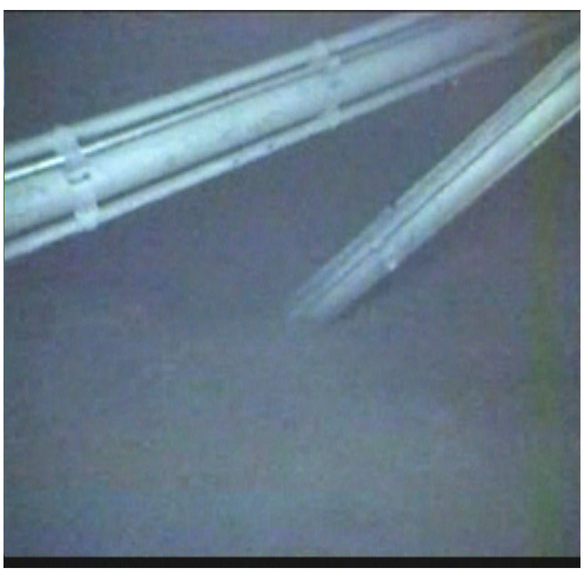

Figure 5. Photograph of riser string resting on the seafloor. The lack of accumulated solids indicates that the current dispersed the released drill fluids (frame from ROV video, May 21, 2003).

Figure 6. Photograph of lower marine riser package after the release. Note the lack of accumulated drilling fluid solids (frame from ROV video, May 21, 2003).

ATTACHMENT 1. CERTIFICATES OF ANALYSIS

HALLIBURTON

CERTIFICATE OF ANALYSIS

ACCOLADE™ BASE

Base Fluid

Customer:
Date of Shipment:
Sales Specification No.: ACCOLAD02
Date: January 29, 2003

Baroid certifies that ACCOLADE™BASE Base Fluid meets the following specifications as shipped from point of manufacture:

Test	Specification	Result	Procedure
Appearance	Colorless to light yellow liquid	PASS	(Visual)
PAH (as Phenanthrene #1), mg/kg	10 Max.	PASS – Below detection limit*	EPA 1654A
Toxicity, BTR (Base Fluid Toxicity Ratio #2)	1.00 Max.	0.6	EPA 66 FR 65209
Biodegradation, BBR (Base Fluid Biodegradation Ratio #3)	1.00 Max.	0.8	EPA 66 FR 65209

*Detection limit ~1 mg/kg.

NOTE: These sales specifications may be revised or updated without prior notice. Customers are requested to reference quality requirements directly on purchase documents as applicable. Please include the sales specification number when referencing quality requirements or making inquiries.

The EPA Stock Limitations data reports are retained on file.
#1. PAH content measured by HPLC method as specified at EPA 1654A.
#2. BTR – Base Fluid Toxicity Ratio = 10-day LC_{50} C16/C18 IO Ref. Material / 10-day LC_{50} ACCOLADE + 0.20 ~ 10-day LC_{50} C16/C18 IO Ref. Material.
#3. BBR = Base Fluid Biodegradation Ratio = % Theoretical gas production of C16/C18 IO Ref. Material / % Theoretical gas production of ACCOLADE + 4%.

1 Company/Rig

2 Well Name

3 Document Number

4 Location

Approved By:

Baroid Quality Department Authorized Representative

™ACCOLADE is a trademark of Halliburton Energy Services, Inc.

Halliburton Energy Services, Inc.
P.O. Box 1675 Houston, Texas 77032

BAROID DRILLING FLUIDS

The Original Mud Company

CERTIFICATE OF ANALYSIS

DATE 4-21-03

ORDER DOCUMENT 24043S3

CUSTOMER NAME BP/Dix Enterprise

WELL NAME 14658 #6, Miss. Canyon 822

DATE SOLD 4-21-03

CERTIFICATION ID. NO.	MERCURY mg/kg	CADMIUM mg/kg
LC3-040	0.575	0.692

A Composite sample from the Mill Stream was taken by Randy Ardoin with BAROID DRILLING FLUIDS 2/28/03 thru 3/30/03 at 7:00. Sample analyzed by W.O.B. of ANALAB Corp. laboratory on 3/27/03 @ 13:00.

Test Reference:
Mercury - Method 7471
Cadmium - Method 3050/7130

Tests Conducted By
Analab Corp.
2600 Dudley Road
Kilgore,TX 75662

CERTIFICATION ID. NO.	SULFIDES mg/l	CARBONATES mg/l
03-065	0	1240

Test Reference
Sulfides - API - 13b - 1
Carbonates - API - 13b - 1

Tests Conducted By:
Baroid Drilling Fluids
Lake Charles, LA

Randy Ardoin

CERTIFIED TO BY
LAKE CHARLES QUALITY CONTROL
3600 Bayou D'Inde Rd. Westlake, LA 70669 (318)882-6460 Fax(318)882-67954

ATTACHMENT 2. DEEPWATER BENTHIC COMMUNITIES/ ORGANISMS

Multiple sources of information have been utilized for this section. Background biological information was recently synthesized for a number of MMS National Environmental Policy Act (NEPA) documents, including the most recent environmental impact statement (EIS) for multiple lease sales in the Central Gulf of Mexico (USDOI, MMS, 2002). Additional direct observations of the benthic environment at the riser break site were made as a requirement of Notice to Lessees (NTL) 2003-G3, *Remotely Operated Vehicle (ROV) Surveys in Deepwater*. Two separate surveys were performed, one prior to and one immediately after the drilling of the first well in MC 778 very near the same location of the riser break.

These ROV surveys were required coincidentally at the Thunder Horse development site as a verification of the effectiveness of existing MMS environmental reviews and mitigations. Surveys were required on a Gulfwide basis and this development was the first to occur in its region. A total of six ROV video transects extended in a radial pattern 100 m from a point near the well site during each of the two surveys. Video records obtained during the transects showed close-up views of the seabed and all associated benthic megafauna along these 100-m transects. This direct visual evidence of benthic animals will be utilized in the descriptions below.

CHEMOSYNTHETIC COMMUNITIES

Chemosynthetic communities are defined as persistent, largely sessile assemblages of marine organisms dependent upon symbiotic chemosynthetic bacteria as their primary food source (MacDonald, 1992). Since the initial discovery in 1984 of chemosynthetic communities dependent on hydrocarbon seepage in the GOM off the west coast of Florida, their geographic range has been found to include the Texas, Louisiana, and Alabama continental slope with a depth range varying from less than 500 m to 2,200 m (Rosman et al., 1987; MacDonald, 1992). Hydrocarbon seep communities in the Central Gulf have been reported to occur at water depths between 290 and 2,200 m (Roberts et al., 1990; MacDonald, 1992). The total number of chemosynthetic communities in the Gulf is now known to exceed 50 (MacDonald, 1992; Boland, personal observations, 2000).

A biological review for the potential occurrence of chemosynthetic communities associated with the Thunder Horse project determined the nearest known chemosynthetic community is located in Viosca Knoll Block 826, approximately 77 nmi from the Thunder Horse development. A reevaluation of geophysical maps of the Thunder Horse area did not show any potential sites for chemosynthetic communities closer than approximately 4 nmi from the riser break position.

DEEPWATER BENTHOS AND SEDIMENT COMMUNITIES

Marine benthic communities consist of a wide variety of single-celled organisms, invertebrates, and fish. Their lifestyles are extremely varied as well and can include absorption of dissolved organic material, symbiosis (e.g., chemosynthetic communities see above), collection of food through filtering, mucous webs, seizing, or other mechanisms.

It is convention in the Gulf of Mexico region to classify benthic animals according to size as megafauna (large, usually mobile animals on the surface), macrofauna (retained on 0.25- to 0.50-mm mesh size sieve), meiofauna (0.063-mm screen; mostly nematode worms), and microfauna (protists and bacteria). The four types are discussed briefly below.

Megafauna

Animals of a size typically caught in trawls and large enough to be easily visible (e.g., crabs, shrimp, benthic fish, etc.) are called megafauna. In the Gulf, most are crustaceans, echinoderms (includes brittle stars, starfish and sea cucumbers), or benthic fish. Benthic megafaunal communities in the Central Gulf appear to be typical of most temperate continental slope assemblages found at depths from 300 to 3,000 m (984 to 9,843 ft) (USDOI, MMS, 2002). Exceptions include the chemosynthetic communities discussed previously.

Megafaunal invertebrate and benthic fish densities decline with depth between the upper slope and the abyssal plain (Pequegnat 1983; Pequegnat et al., 1990). This phenomenon is generally believed to be related to the low productivity in deep, offshore Gulf waters (USDOI, MMS, 2002). Megafaunal communities in the offshore Gulf have historically been zoned by depth strata, which are typified by certain species assemblages (Menzies et al., 1973; Pequegnat, 1983; Gallaway et al., 1988; Pequegnat et al., 1990; USDOI, MMS, 2002). Within this zone system, the Thunder Horse project lies within the Upper Abyssal Zone. With reanalysis of data, these "zones" have more recently been shown to be less defensible (Carney 2001; Gallaway et al. 2003) but are presented here for reference and include the following:

> Shelf/Slope Transition Zone (100-500 m) — Echinoderms, crustaceans, and several species of abundant fish.
>
> Archibenthal Zone (Horizon A) (500-775m) — Galatheid crabs, rat tail fishes, large sea cucumbers, and sea stars are abundant.
>
> Archibenthal Zone (Horizon B) (800-1,000 m) — Galatheid crabs and rat tail fishes are abundant; fishes, echinoderms, and crustaceans decline; characterized by the red crab, *Chaceon quinquedens*.
>
> Upper Abyssal Zone (1,000-2,000 m) — Number of fish species decline while the number of invertebrate species appear to increase; sea cucumbers, *Mesothuria lactea* and *Benthodytes sanguinolenta* are common; galatheid crabs include 12 species of the deep-sea genera Munida and Munidopsis, while the shallow brachyuran crabs decline.
>
> Mesoabyssal Zone (2,300-3,000 m) — Fish species are few and echinoderms continue to dominate the megafauna.
>
> Lower Abyssal Zone (3,200-3,800 m) — Large asteroid, *Dytaster insignis*, is the most common megafaunal species.

Carney et al. (1983) postulated a simpler system of zonation having three zones: (1) a distinct shelf assemblage in the upper 1,000 m; (2) indistinct fauna between 1,000 and 2,000 m; and (3) a distinct slope fauna between 2,000 and 3,000 m. Gallaway et al. (2003) concluded that megafaunal composition changes continually with depth such that a distinct upper slope fauna penetrates to about 1,200-m depths and a distinct deep-slope fauna is present below 2,500 m. A broad transition zone characterized by low abundance and diversity occurs between depths of 1,200 and 2,500 m. The Thunder Horse development lies within this broad transition zone.

Direct observations obtained from ROV surveys conducted as a requirement of NTL 2003-G03 provided an on-site visual record of megafauna in the vicinity of where the riser break occurred in MC 778. NTL 2003-G03 required the operator to conduct ROV video surveys close to the bottom in a radial pattern extending 100 m in six different directions from a well site. General analysis of this video record resulted in expected sparse numbers of megafauna on all six transects. The bottom was flat and generally featureless except for small mounds and depressions remaining from burrowing or impressions of animals.

Species identifications are not possible using this low-resolution video. Only four major groups of animals were observed: fish, sea cucumbers, a probable sea pen, and possible anemones. Only two fish were observed throughout the tape; one was a rat-tail (family macrouridae) and the other was similar in shape but was probably a halosaur (family halosauridae). Both types are common but occur in low numbers at this depth in the Gulf. Sea cucumbers were the most common megafauna group. At least three species were evident; one was dark purple in color and several were seen along each 100-m transect (Figure B-1 (left picture), species not identified). Several individuals of a second species were also present that were white in color and were likely the species *Mesothuria lactea*, reported by Pequegnat (1983) to be the most abundant large sea cucumber in the region (Figure B-1 (right picture)).

A single stalk of a sea pen is present in Figure B-1 (left picture). This was the only individual of this type of animal seen on any transect.

Figure B-1. Video frame images showing a stalked sea pen and two species of sea cucumbers at a depth of 1,915 m (6,281 ft) in MC 778 (taken by ROV for B.P.).

The only other megafauna animals visible in the video were a few anemone-like forms that protruded from below the surface of the sediment. Each had what appeared to be anemone-like tentacles. Only a few of these animals were discernable on the videotape.

Macrofauna

The benthic macrofaunal component of the Northern Gulf of Mexico Continental Slope Study (NGMCS) (Gallaway et. al., 2003) included sampling in nearby areas at similar depths, both to the east and west of the Thunder Horse development. Most all of these data are relevant to the proposed Thunder Horse development because they were taken from the same geographic area and encompass the same depths and substrates.

The NGMCS Study examined 69,933 individual macrofauna from over 1,548 taxa; 1,107 species from 46 major groups were identified (Gallaway et al., 2003). Polychaetes (407 species), mostly deposit-feeding forms (196 taxa), dominated in terms of numbers. Carnivorous polychaetes were more diverse, but less numerous than deposit-feeders, omnivores, or scavengers (Pequegnat et al., 1990; Gallaway et al., 2003). Polychaetes were followed in abundance by nematodes, ostracods, harpacticoid copepods, bivalves, tanaidacids, bryozoans, isopods, amphipods, and others.

In the GOM, macrofaunal density and biomass declines with depth from approximately 5,000 individuals/m^2 on the lower shelf-upper slope to several hundred individuals/m^2 on the abyssal plain (USDOI, MMS, 2002). This decline in benthos has been attributed to the relatively low productivity of the Gulf offshore open waters (USDOI, MMS, 2002). The Thunder Horse region is located at the lower end of this scale and would be expected to have macrofauna densities in the range of 2,000 individuals/m^2.

Meiofauna

Meiofauna (primarily composed of small nematode worms), as with megafauna and macrofauna, also decline in abundance with depth (Pequegnat et al., 1990; Gallaway et al., 2003; USDOI, MMS, 2002). The overall density (mean of 707,000/m^2) of meiofauna is approximately two orders of magnitude greater than the macrofauna throughout the depth range of the slope (Gallaway et al., 1988). These authors reported 43 major groups of meiofauna, with nematodes, harpacticoid copepods (adults and larvae), polychaetes, ostracods, and Kinorhyncha accounting for 98 percent of the total numbers. Nematodes and harpacticoids were dominant in terms of numbers, but polychaetes and ostracods were dominant in terms of biomass, a feature that was remarkably consistent across all stations, regions, seasons, and years

(Gallaway et al., 2003). Meiofaunal densities reported in the NGMCS Study are among the highest recorded worldwide (Gallaway et al., 2003).

The Central Gulf transect appeared to contain a higher abundance of meiofauna than transects in the Eastern or Western Gulf, and, in general, there was a trend of decreasing meiofauna numbers with depth (Gallaway et al., 2003). The Thunder Horse region, at a depth around 1,840 m, would be expected to contain meiofauna densities in the upper sediment layers in the range of 300-500 individuals/10 cm^2 = 300,000-400,000 individuals/m^2.

Microbiota

Less is known about the microbiota than the other groups in the GOM, especially in deep water (USDOI, MMS, 2000). A recent MMS publication (USDOI, MMS, 2002) provides information on this subject. In terms of biomass, data indicate that bacteria are the most important component of the functional infaunal biota. Cruz-Kaegi (1998) developed a carbon cycling budget based on estimates of biomass and metabolic rates in the literature. She discovered that, on the deep slope of the Gulf, the energy from organic carbon in the benthos is cycled through bacteria.

FISH RESOURCES

The GOM supports a great diversity of fish resources. The distribution and abundance of these resources are not random and are governed by a variety of ecological factors such as temperature, salinity, primary productivity, bottom types, and many other physical and biological factors. There are considerable inshore and offshore differences in fish resources.

Fish can be classified as demersal (bottom-dwelling), oceanic pelagic, or mesopelagic (midwater). Demersal (or benthic) fish have been addressed above under the megafauna descriptions. There are no commercial fisheries directed at demersal species in the vicinity of the Thunder Horse Project. Oceanic pelagic fishes are discussed briefly below; however, the depth of the riser break would not impact the water column where oceanic pelagic species would normally occur. Additional life history information on important commercial invertebrate fish resources of the GOM is contained in USDOI, MMS (2000 and 2002).

Oceanic Pelagics (Including Highly Migratory Species)

Common oceanic pelagic species include the large predatory tunas, marlins, sailfish, swordfish, dolphins, wahoo, and sharks. Other pelagics include halfbeaks, flyingfishes, and driftfishes (Stromateidae). Lesser known oceanic pelagics include opah, snake mackerels (Gempylidae), ribbonfishes (Trachipteridae), and escolar.

Oceanic pelagic species occur throughout the GOM, especially at or beyond the shelf edge. Oceanic pelagics are reportedly associated with mesoscale hydrographic features such as fronts, eddies, and discontinuities. Fishers contend that yellowfin tuna aggregate near sea-surface temperature boundaries or frontal zones. Floating objects of all sizes are also known to attract tuna, and offshore structures would similarly be expected to act as a fish attracting device (FAD). Bluefin tuna are not found deeper than about 100 m and yellowfin do not move deeper than around 250 m.

Commercial Fisheries

Commercial fishing in deeper waters, i.e., >200 m (656 ft), of the GOM is characterized by fewer species, and lower landed weights and values than the inshore fisheries. Historically, the deepwater offshore fishery contributes less than 1 percent to the regional total weight and value (USDOI, MMS, 2002). Target species can be classified into three groups: (1) epipelagic fishes, (2) reef fishes, and (3) invertebrates. The Thunder Horse development is beyond the normal depth range of commercial reef fishes and invertebrates.

Epipelagic commercial fishes include dolphin, sharks (silky and tiger; many species of shark are now protected and harvest is prohibited, including mako and thresher), snake mackerels (escolar and oilfish), swordfish, tunas (bigeye, blackfin, bluefin, and yellowfin), and wahoo (USDOI, MMS, 2002). These species are widespread in the Gulf and likely occur in the Thunder Horse development area. Oceanic pelagic fishes were not landed in high quantities relative to other finfish groups during 1983 through 1993 in the Eastern Gulf (very near the Thunder Horse development); however, they were very valuable, ranking second to reef fishes in average dollar value of landings. The most important species, yellowfin tuna and swordfish, were caught primarily by surface longline in oceanic waters offshore the shelf break. The swordfish can be found at water depths up to 800 m.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

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