EXECUTIVE SUMMARY

The need to drill increasingly difficult deepwater and deviated wells, coupled with the economic and safety advantages of ocean discharge of cleaned cuttings, has led the offshore oil and gas industry to develop synthetic based drilling muds (SBMs). Synthetic based muds are drilling muds in which synthetic materials are the carrier fluid. They are designed to be less toxic and degrade faster in marine sediments than oil based drilling muds while providing similar technical advantages in drilling difficult wells.

The U.S. Environmental Protection Agency (USEPA) regulates discharges to water from offshore operations. In 1996, USEPA recognized SBMs as a new class of drilling muds and began reviewing cuttings treatment technologies and the environmental impacts of drill cuttings disposal options. The review provided input for the development of Effluent Limitation Guidelines (ELGs), which include technology-based limitations for the discharge of cuttings generated during drilling with SBMs. In addition to the requirements of the ELGs, a USEPA Region 6 National Pollutant Discharge Elimination System (NPDES) general permit requires operators to either conduct seabed surveys at each location where cuttings drilled with SBM are discharged or, alternatively, participate in a joint industry seabed survey study according to a plan submitted for approval to USEPA Region 6. The Gulf of Mexico Comprehensive Synthetic Based Muds Monitoring Program, documented in this report, meets the latter requirement. The study was sponsored by the SBM Research Group, composed of offshore operators, mud companies, the Minerals Management Service, and the Department of Energy. The objective of this study was to assess the fate and physical, chemical, and biological effects of SBM cuttings discharged from offshore platforms on the benthic environment of the Gulf of Mexico continental shelf and slope.

Four cruises were conducted during the project. Study sites were selected to ensure that all discharges of cuttings were completed prior to the cruises. A Scouting Cruise was performed in June 2000 to evaluate the suitability of ten candidate SBM cuttings discharge sites on the central Gulf of Mexico continental shelf. A Screening Cruise was conducted in August 2000, and geophysical data were collected at eight sites to evaluate the potential presence of substantial cuttings piles. Five of these sites were visited previously during the Scouting Cruise. The remaining three sites were located on the continental slope. Sediment samples were collected at each site and analyzed for a small number of physical, chemical, and biological parameters to document the presence and distribution of SBM cuttings accumulations on the bottom and evaluate the general characteristics of the benthic communities.

Eight sites were surveyed during Sampling Cruises 1 and 2 in May 2001 and May 2002, respectively. Four sites were located on the continental shelf in water depths from 37 to 119 m, and four were located on the continental slope in water depths from 338 to 556 m. Sediment sampling was performed in three zones around each discharge site: near-field (0 to 100 m from the discharge site), mid-field (100 to 250 m from the discharge site), and far-field reference (3,000 to 6,000 m from the discharge site). Surficial sediments were collected at each station for analysis of physical, chemical, and biological parameters. Benthic macroinfauna were counted and identified, and laboratory sediment toxicity tests were conducted on sediments collected at selected sites.

To address the objective of the program, four questions were investigated:

- What is the distribution of SBM cuttings in sediments around the drillsites?
- Are there changes over time in the distributions and concentrations of chemical components of SBM cuttings?
- What physical and chemical changes in sediments are attributable to SBM cuttings accumulations?
- What effects on the benthic community are attributable to SBM cuttings accumulations?

DISTRIBUTION AROUND DISCHARGE SITES

Evidence of drilling discharges was detected at all eight sites. Water based muds and cuttings and SBM cuttings were discharged at each site, and it was not possible to determine if the cuttings detected in the sediments were SBM cuttings. Physical evidence of cuttings in sediments depended primarily on the time since the last cuttings discharge at a site. Cuttings were visible in all near-field zones. Elevated concentrations of barium (Ba) (a tracer of drilling mud), the synthetic chemical (synthetic based fluid [SBF]), and total petroleum hydrocarbons (TPH) were detected in sediments from the near-field and mid-field zones at the sites; however, the distributions of the materials were patchy. Concentrations at far-field stations generally represented background levels. There was a sharp decrease in concentrations of cuttings and chemicals in sediments with distance from the discharge sites, which indicates that drill cuttings solids, especially from SBM cuttings, are deposited close to the discharge site. Most cuttings appeared to be deposited within 100 to 250 m of the discharge site at both continental shelf and continental slope water depths.

Near-field Ba concentrations at the sites were not related to the elapsed time since the last well was drilled or the total number of wells drilled, indicating that the main determinant of Ba concentrations in near-field sediments may be the local current regime and sediment transport. Based on Screening Cruise observations, near-field sediment concentrations of other metals associated with drilling muds were within the range of concentrations for uncontaminated marine sediments. Metals ratios indicated that much of the finer-grained sediments near platforms were from terrigenous (i.e., land-based) sources.

The differences between the concentrations of TPH and SBF in near-field sediments were greater than the differences in far-field sediments. This indicated that the near-field sediments contained hydrocarbons in addition to those counted as SBF, which were defined analytically as C_{16} to C_{18} range hydrocarbons. The presence of additional hydrocarbons not counted as SBF was attributed to factors such as variable concentrations of C_{20} range hydrocarbons in base fluids from different manufacturers, the presence of recent biogenic hydrocarbons in sediments, and changes in the gas-chromatographic fingerprint of sediment hydrocarbons as biodegradation progresses. Gas-chromatographic traces showed that the additional TPH in near-field sediments was not due to the presence of crude oil or petroleum distillate products.

TIME TRENDS

Concentrations of monitored components of SBM cuttings in sediments tended to decrease or return to background values with time after the last cuttings discharge (Figure ES-1). Possible mechanisms of decrease of SBF concentrations with time in surface sediments included microbial biodegradation (breaking down of materials by microorganisms) and burial by natural sediment deposition or bioturbation (reworking of sediments by marine organisms).

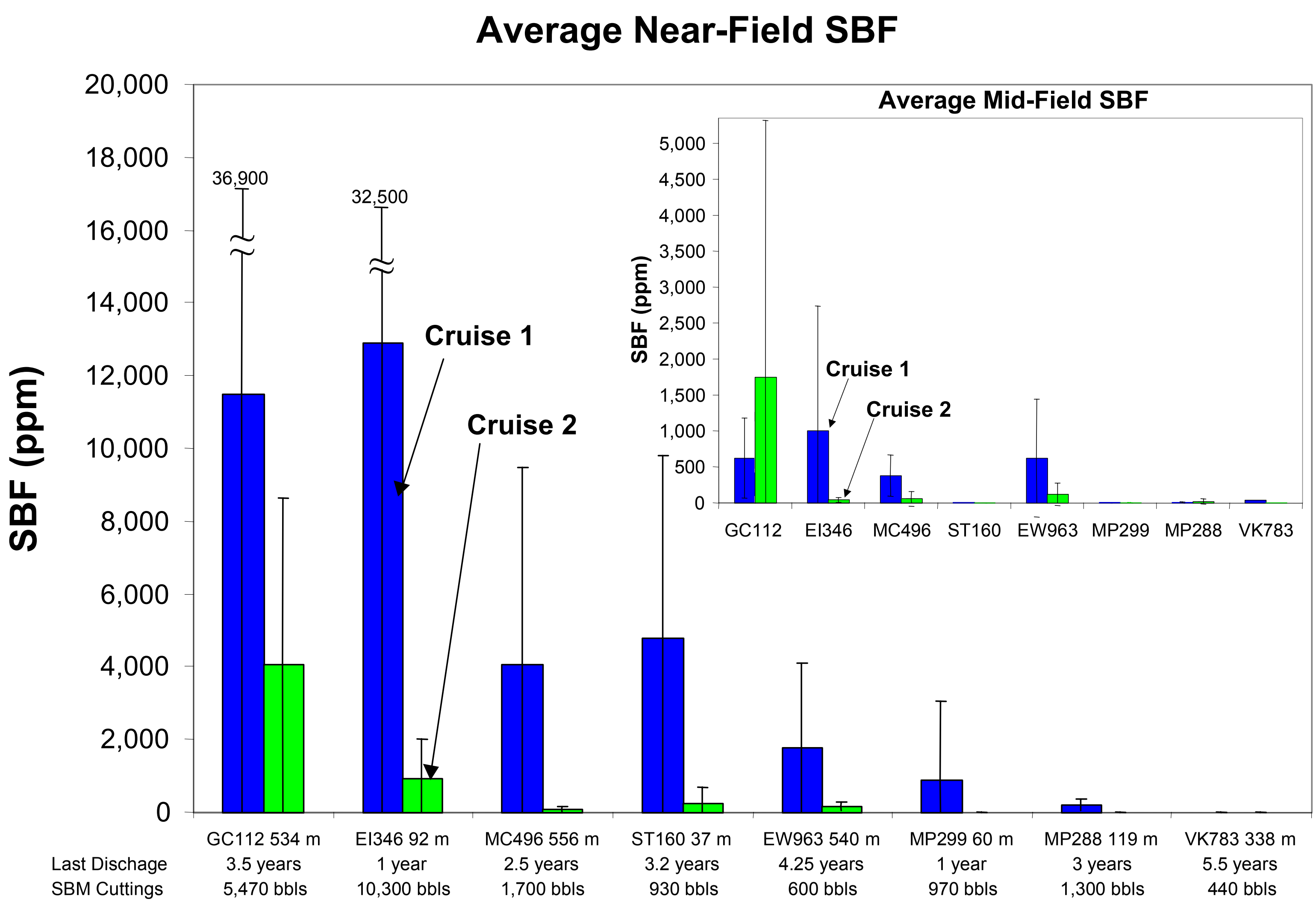

Figure ES-1. Average synthetic based fluid (SBF) base chemical concentrations at all sites for Sampling Cruise 1 (blue columns) and Sampling Cruise 2 (green columns). The error bars show one standard deviation of the measurements at a site and zone.

PHYSICAL AND CHEMICAL DISTURBANCE

A combination of visual, geophysical, and chemical/physical measurements at a total of 15 discharge locations in the Gulf of Mexico indicated that SBM cuttings do not accumulate in large piles, as has been observed in the North Sea for discharges of oil based drilling muds and cuttings. This is reasonable because the North Sea generally has larger reservoirs with many more wells drilled at a single location, compared to the Gulf of Mexico where there are smaller reservoirs with fewer wells at single site. Also, discharges in the North Sea often were shunted to near the seabed, while discharges in the Gulf of Mexico occur near the sea surface at most sites, providing for greater water column dispersion and broader distribution on the seabed.

In general, there was more sand in near-field sediments than in mid-field sediments, and far-field sediments generally contained the least sand and most fine-grained sediments, suggesting that drill cutting solids were deposited in the near-field zone and, to a lesser extent, in the mid-field zone. In general, grain-size distributions were more variable at the continental shelf sites than at the continental slope sites.

Measurements of oxygen, total organic carbon, reduction/oxidation potential, and manganese in sediments, signs of possible SBM cuttings-related organic enrichment, indicated such enrichment near the discharge locations. There was evidence of recovery or decrease over time in the severity of disturbance in the sediments near the discharge locations during the year between the two Sampling Cruises.

BIOLOGICAL DISTURBANCES

Sediment toxicity, which was determined in the laboratory using a standard compliance sediment bioassay utilizing survival of a non-indigenous, coastal benthic amphipod, *Leptocheirus plumulosus,* was restricted to a few locations near the drilling discharges; most of the sediments in the near-field and mid-field (<250 m) were not toxic. Amphipod survival exceeded 75% in all far-field samples at continental shelf and continental slope sites, and therefore these sediment samples were not considered toxic. Of the samples collected within 250 m of the continental shelf and continental slope discharge locations, 73% and 56%, respectively, had amphipod survival exceeding 75% and were considered not toxic. At sites where multiple samples had survival less than 50%, sediment toxicity and SBF concentration were correlated. Changes in sediment chemical composition or physical properties due to cutting deposition were probably responsible for most of the toxicity.

There were substantial differences in the benthic communities at the three sites examined. However, the communities of organisms observed at different zones within a given site were generally similar. At two of the three sites examined, the abundance of organisms in different zones was similar. At the site with the highest SBF concentrations of the three biological study sites, the abundance and diversity of the benthic community were reduced within 250 m of the site center. There was evidence of recovery in the time between the two Sampling Cruises at this site. Near- and mid-field sediments at the other two sites (with lower SBF concentrations) had only moderately disturbed benthic community structure, compared to the corresponding far-field samples. Variability of all benthic community parameters such as diversity and evenness was greatest in the near-field zone and generally much lower in the far-field zone. In the near-field zone, this variability was probably due to variations in sediment textures and patchy distributions of cuttings.

For the three sites where sediment chemistry, benthic faunal community structure, and sediment toxicity were measured, a sediment quality triad analysis was performed to develop an integrated assessment of drill site sediment conditions. This analysis clearly showed reduced sediment quality in the near-field compared to the mid-field. However, the triad analysis showed clear evidence of recovery over the 1-year period between the Sampling Cruises. At two of the three sites analyzed, minimal changes in ecological parameters used in the triad analysis suggested that the habitat quality of the sediments had not been seriously degraded by a long history of discharges at those sites.

In summary, this study was conducted with a diverse set of approaches to assess the fate and effects of discharged SBM cuttings at continental shelf and continental slope sites in the Gulf of Mexico. Key findings of the study are

- no large, multi-meter thick cuttings piles, such as those seen in the North Sea, were detected at any of the 15 sites visited in this study;
- discharges were deposited in a patchy distribution limited to the vicinity of the discharge location (<250 m);
- in general, sediment quality and biological communities were not severely affected, and impacts were limited to the vicinity of the discharge (<250 m); and
- where impacts were observed, progress toward physical, chemical, and biological recovery appeared to occur during the 1-year period between the two Sampling Cruises.