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Water Quality Benefit Analysis For The Proposed Effluent Guidelines For The Coastal Subcategory Of The Oil And Gas Extraction Industry

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WATER QUALITY BENEFITS ANALYSIS FOR THE PROPOSED EFFLUENT GUIDELINES FOR THE COASTAL SUBCATEGORY OF THE OIL AND GAS EXTRACTION INDUSTRY

Final Report

U.S. Environmental Protection Agency
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Office of Science and Technology
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EXECUTIVE SUMMARY

INTRODUCTION

This Water Quality Benefit Analysis (WQBA) assesses the effects of current discharges and the projected benefits of proposed effluent guidelines limitations for the coastal subcategory of the oil and gas extraction industry. The WQBA considers two separate geographic areas: the Gulf of Mexico (Louisiana and Texas) and Cook Inlet, Alaska. The WQBA examines potential impacts from current produced water discharges in both geographic areas, and potential impacts from drilling fluids and drill cuttings discharges in Cook Inlet. Drilling fluids and drill cutting discharges are not assessed for Gulf of Mexico coastal operations because they are prohibited by state authorities and existing NPDES permits. Three types of benefits are analyzed: quantified and non-monetized benefits, quantified and monetized benefits, and non-quantified and non-monetized benefits.

The coastal waters that these proposed guidelines cover maintain diverse ecosystems. These ecosystems serve as spawning grounds, nurseries, and habitat for important estuarine and marine finfish and shellfish species. Many commercial species depend on coastal ecosystems for portions of their life cycle. For example, the commercial fisheries in Texas and Louisiana (finfish, shrimp, crabs, and oysters) were valued at $476 million in 1992; 92% and 98% of the landings in these two states, respectively, consist of species that spend a significant portion of their life cycle in estuaries and bays. Coastal waters also serve as critical habitats for numerous federally-designated endangered and threatened species, including 32 species in coastal areas of Texas and Louisiana.

The regulatory options considered for produced water and evaluated in the WQBA are:

Option 1: (BPT All) - Effluent limitations are equal to existing BPT requirements; oil and grease limited in effluent to 48 mg/l (monthly average) and 72 mg/l (daily maximum).

Option 2: (Gas Flotation All) - All discharges of produced water are required to meet limitations on oil and grease content of 29 mg/l monthly average and a daily maximum of 42 mg/l. The technology basis for these limits is improved operating performance of gas flotation.

Option 3: (Zero Discharge; Cook Inlet BPT) - With the exception of facilities in Cook Inlet, Alaska, all coastal oil and gas facilities are prohibited from discharging produced water; coastal facilities in Cook Inlet are required to comply with existing BPT effluent limitations for oil and grease (48/72 mg/l daily average/daily maximum).

Option 4: (Zero Discharge; Cook Inlet Gas Flotation) - With the exception of facilities in Cook Inlet, Alaska, all coastal oil and gas facilities are prohibited from discharging produced water; coastal facilities in Cook Inlet are required to comply with the oil and grease limitations of 29 mg/l (monthly average) and 42 mg/l (daily maximum) based on improved operating performance of gas flotation.

Option 5: (Zero Discharge All) - Prohibits all discharges of produced water based on reinjection of the produced water.

The options considered for drilling fluids and evaluated in the WQBA are:

Option 1: Zero discharge for all areas except Cook Inlet, Alaska, where discharge limitations require toxicity of no less than 30,000 ppm (SPP); no discharge of free oil and diesel oil; and no more than 1 mg/l mercury and 3 mg/l cadmium in the stock barite.

Option 2: Zero discharge for all areas except for Cook Inlet, Alaska, where discharge limitations are the same as Option 1, except toxicity would meet a limitation of 1 million ppm (SPP).

Option 3: Zero discharge of drilling fluids in all areas.

Although all the above options were evaluated, this Executive Summary presents findings developed for the current baseline and the selected options only. For produced water, the selected option is Option 4 (Zero Discharge; Cook Inlet Gas Flotation). For drilling fluids and cuttings, the two co-selected options are Options 2 (Zero Discharge, except Cook Inlet) and Option 3 (Zero Discharge). Results for other considered options are presented in the main body of this report.

QUANTIFIED, NON-MONETIZED BENEFITS, GULF OF MEXICO

Review of Case Studies

A total of 25 case study sites (12 sites in Louisiana and 13 sites in Texas) are summarized. Of these 25 study sites, 13 sites are in relatively low energy locations (marshes, canals) and 12 sites are in relatively high energy areas (bayous, river distributaries, open bays/lakes). Also, 12 wetlands locations were included in the 25 study sites, 6 saltmarsh sites and 6 fresh or brackish marsh sites. Water depth is reported for 19 study sites; 15 sites are located in water depths less than 3 meters; 4 sites are located in waters greater than 3 meters.

Documented impacts show elevated hydrocarbons and metals in water column and sediments, and reveal impacts on biota up to 1,000 meters from the produced water discharge site. Salinity effects are typically detected up to 300 meters from the discharge, and up to 800 meters in dead-end canals. Benthic dead zones (i.e., areas with no benthic fauna) are documented out to 15 meters from discharges. Severely depressed benthic communities (>75% reductions) are noted to 150 meters from produced water outfalls.

Radiochemical impacts were variable, but generally of limited spatial scale. Indigenous biota were generally found to have detectable levels of Ra-226 and Ra-228. Background levels in these studies were generally not known and not easily estimated. No pre- versus post-discharge sampling has been conducted to establish temporal relationships between the discharge of produced water radium and sediment or biotic accumulations. Spacial data are ambiguous and not easily interpreted, in terms of establishing background

levels in sediments or biota. However, caged organisms deployed for 14 days have been shown to bioaccumulate radium as far as 350 meters from a produced water discharge.

Water Quality Benefits

In this WQBA, plume dispersion modeling is performed to project in-stream concentrations of 66 pollutants (representing subcategory-wide produced water discharge) at the edge of the state-prescribed mixing zones for Texas and Louisiana at one- and three-meter water depths. Texas has standards for 12 of these pollutants, while Louisiana has standards for 14. For both of the Gulf of Mexico states analyzed, three discharge rate scenarios are modeled: mean discharge rate by outfall; median discharge rate by outfall (i.e., 50% of outfall flows are greater or less than the median flow); and median discharge rate by flow (i.e., 50% of the total produced water volume is discharged at greater or lesser flow rates). Assessment of compliance with state standards was conducted in accordance with state implementation guidance of both Texas and Louisiana.

At the mean discharge rate, one pollutant (silver) in Texas exceeds its chronic standard at the one meter depth. In Louisiana at the one meter depth, one pollutant (copper) exceeds two acute standards (daily average and maximum), two pollutants (copper and lead) exceed two chronic standards, and one pollutant (benzene) exceeds two human health standards at the one meter depth, and at three meter depth one pollutant (copper) exceeds its acute standard, and one pollutant (benzene) exceeds two human health standards. The proposed BAT zero discharge option would eliminate all projected exceedances.

Reduction of Point Source Toxic Loadings to Texas and Louisiana

The watershed pollutant loadings from produced water are compared to other industrial and municipal point sources (i.e., excluding pollutant loadings from nonpoint sources and atmospheric deposition) for Texas and Louisiana estuarine drainage systems. Produced water loadings are calculated and compared to estimates for other industrial and municipal point sources using the same methodology presented in a report prepared by EPA's Office of Research and Development (ORD) for the Gulf of Mexico Program. At the current (BPT) discharge level, and only considering the 34 pollutants found in produced water that also were identified in this ORD report, produced water in Texas contributes about 17% and in Louisiana about 58% of total point source pollutant loadings into their respective watersheds. Toxic unit loadings also were assessed. For the 34 current BPJ pollutants assessed, produced water toxic unit loadings approximated 94% in Texas and 87% in Louisiana of the total point source toxic unit loadings. The proposed zero discharge option would eliminate produced water pollutant loading contributions to Texas and Louisiana coastal watersheds.

QUANTIFIED AND MONETIZED BENEFITS, GULF OF MEXICO

Projected Cancer Risk Reduction Benefits

A first-order assessment of potential human health impacts from ingestion of seafood contaminated with radium from discharged produced water is developed. Upper bound individual cancer risks from consuming fish contaminated with Ra^{226} and Ra^{228} from current produced water discharges are estimated for recreational and subsistence anglers. Risks are estimated using two types of data: (1) measured field seafood data (i.e., because background radium levels could not be adequately determined, average Ra^{226} and Ra^{228} levels were used, based on field samples of fish, crabs, and oysters collected within 3,000 meters of produced water discharges in coastal subcategory areas of Louisiana), and (2) modeled effluent data (i.e., using current subcategory-wide produced water concentrations of Ra^{226} and Ra^{228} and plume dispersion modeling to estimate Ra^{226} and Ra^{228} levels in seafood). Risks are calculated using standard EPA methodology. Resulting carcinogenic risks from all seafood categories are adjusted, also as per EPA methodology, by factors of 0.20 and 0.75, to account for ingestion of seafood from locations that are not contaminated. These reductions are applied to both field data and modeling approaches.

Projected individual cancer risks for both risk assessment approaches are at 10^{-5} and 10^{-4} level for subsistence anglers (147 grams per day seafood consumption), and at 10^{-6} level for recreational anglers (15 grams per day seafood consumption). The proposed zero discharge of produced water will eliminate these estimated cancer risks over time. Using a range of $2 million to $10 million per lifetime and measured field data, the monetized benefits from cancer cases avoidance for the selected BAT option are projected to range from $2.3 to $43 million, with a range of midpoint values of $7 million to $26 million. Using the same lifetime cost range and the modeling approach, the selected BAT option is projected to result in monetized benefits of $2.4 to $46 million per year with a range of midpoint values of $7 million to $26 million.

The temporal dynamics of both impacts and benefits assessments is relevant to the human health risk assessment. For the assessments of cancer reduction benefits, the methodology is consistent with estimating costs for the rule, using a one-year, "snap-shot" approach. Allocating the full value of annual benefits within one year following cessation of produced water discharges may appear to over-estimate potential annual benefits in cases where incomplete recovery has occurred. However, in such cases where impacts are incompletely recovered, a consideration of total impact would need to include any impacts expected to occur beyond that year. This analysis does not attempt to identify or allocate benefits on a year-by-year basis, but merely averages total benefits so that monetized benefits may be compared to costs that are developed using the same approach.

Projected Ecological Benefits

A potential ecological benefit of zero discharge of produced water in Texas and Louisiana coastal areas is projected from a Trinity Bay case study. Assuming that zero discharge of produced water would result in a recovery of ecosystems around platforms, a monetary value could be assigned to the estimated acreage impacted

around the study platform currently affected by produced water discharges. A case study of a produced water outfall to a coastal embayment is used to develop estimates of ecological impact associated with this outfall. Sediment benthic community analyses and sediment total naphthalenes analyses were performed monthly for 21 months. The sieve size used for benthic infaunal sorting was changed during the course of the study, so two sets of analyses are performed, one for each sieve size.

For 0.50 mm mesh size data, benthic abundance and species richness are respectively reduced 23% and 21% within a 3,963-meter impact radius, amounting to 2,817 and 2,501 equivalent acres affected. For 0.25 mm mesh size data, species richness was reduced 7% within a 3,963-meter impact radius for 814 equivalent acres affected; benthic abundance was reduced 9% within a 1,677-meter impact radius for 200 equivalent acres affected. A Galveston Bay National Estuary Program study that monetized recreational values to create a range of total values and the estimated acreage of Galveston Bay is used to estimate per-acre ecological values ($336 to $730 per acre, with a midpoint value of $533/acre) for the Trinity Bay case study.

These per-acre ecological values are applied to the Trinity Bay case study's estimates of equivalent area affected to estimate the monetized ecological benefit of the zero discharge option for this case study. The estimated ecological benefits for the Trinity Bay study based on the minimum impact area and resource valuation estimate and the maximum impact area and resource valuation estimate range from $67,200 to $2,056,410.

To estimate benefits on a Gulf-wide basis, a review conducted for MMS of wetland valuations that includes Louisiana valuations is used. Based on this review, wetland values range from $57 to $940 per acre per year (median value of $410 per acre per year) in 1990 dollars. Based on those estimations, the projected monetized ecological benefits for the preferred regulatory option is $0.8 million to $184 million for Gulf of Mexico coastal area in 1990 dollars ($1.0 million to $210 million in 1994 dollars). Value estimates used in this analysis are net estimates, and do not include resource costs.

To project Gulf of Mexico benefits on a subcategory-wide basis, the approach scaled the data available for the Trinity Bay case study assuming a linear relationship among all parameters (i.e., flow, environmental impact, and costs). The total current BPT flow for the coastal subcategory in Texas is projected at 73,318 bpd (10.4-fold greater than the Trinity Bay case study flow). For Louisiana, the total BPT flow is projected 415,919 bpd (59-fold greater than the Trinity Bay case study flow). Thus, the total Texas and Louisiana acreage affected ranges from 11,799 acres to 166,191 acres, with a midpoint of 89,024 acres.

QUANTIFIED, NON-MONETIZED BENEFITS, COOK INLET, ALASKA

Produced Water

In this WQBA, plume dispersion modeling is performed to project in-stream concentrations of 20 pollutants at the edge of the mixing zones for the eight outfalls currently discharging produced water to Cook Inlet. Facility specific flow and environmental data were used in the model scenarios evaluated. Alaska state

requirements do not have spatially-defined mixing zones, so the WQBA assessed the extent of the mixing zone required for compliance with all applicable state standards. For the eight outfalls modeled, the distance from each facility where all state standards are met ranges from within 15.2 meters (50 feet) to 2,500 meters at the current (BPT) pollutant level, and from within 15.2 meters (50 feet) to 2,000 meters at the proposed BAT pollutant level.

Drilling Fluids and Drill Cuttings

Discharges of drilling fluids and drill cuttings are modeled using in-stream concentrations of 17 pollutants in the water column at the edge of a 100-meter mixing zone. The discharge rates are modeled in accordance with the maximum discharge rates allowable under the existing NPDES general permit for Cook Inlet. The modeling results show two standards are exceeded (drinking water standards for aluminum and iron) at the 40 meter water depth and at the 20 meters water depth; and three standards are exceeded at the 10 meters water depth (drinking water standards for aluminum, antimony, and iron) at both current BPT discharge and the alternative BAT Option 2 which would allow discharge of drilling fluids and drill cuttings with certain limitations. The co-proposed zero discharge option (BAT Option 3) will eliminate all projected exceedances.

NON-QUANTIFIED BENEFITS, GULF OF MEXICO AND COOK INLET, ALASKA

The WQBA attempts to quantify, and whenever appropriate, to monetize specific environmental benefits that may result from the options proposed for this rule. However, some potential benefits could not be quantified or monetized because of a lack of data or insufficient information to define causal relationships between coastal oil and gas production activities and environmental effects.

Environmental Equity Issues

An analysis of potential exposure among socioeconomic and ethnic groups in coastal areas of Texas and Louisiana, indicates that subsistence and personal use of fisheries may be appreciable. This subsistence usage indicates potential environmental equity concerns for low income subsistence and personal use anglers. Zero discharge limits and standards for produced water would eliminate concern for these users.

Threatened and Endangered Species

The proposed regulation may also have beneficial effects on 32 threatened and endangered species in coastal areas of Texas and Louisiana. Zero discharge of produced water would eliminate these concerns.

Revisions to the WQBA in Response to EPA Region 6 Final NPDES Permits

EPA Region 6 has recently published final NPDES general permits covering oil and gas production facilities discharging to the coastal subcategory in the States of Louisiana and Texas (60 FR 2387; January 9,

1995). These permits prohibit the discharge of produced water and produced sand derived from these facilities to waters of the U.S., with the exception of produced water discharges derived from offshore subcategory sources that are discharged into certain deltaic passes of the Mississippi or Atchafalaya River. These excluded facilities, however, are covered under the proposed effluent guidelines. Because of the close timing of the publication of these final permits and the proposed effluent guidelines, little opportunity for re-analysis of impacts and benefits developed in this WQBA occurred. The approach used to revise the WQBA in response to the publication of the final permits is to proportionate impacts and benefits based on a simple flow proportion, based on the 29% share of produced water flow attributable to the facilities excluded from coverage under the final general permits.

This is a simplistic approach that is required because of the lack of time to react to the changes in the industry profile used to develop the coastal subcategory effluent guidelines. This approach entails the continuing use of a number of assumptions that, although defensible for the analyses developed for the entire coastal subcategory in Louisiana and Texas may not be fully applicable to only the facilities excluded from coverage by the Region 6 general permit in Louisiana. For the final rule a new WQBA will be conducted that is based on a revised industry profile.

Preliminary estimates of environmental benefits revised analyses to address the Region 6 final general permits are as follows:

- Produced water flows in Louisiana are reduced to 52 million barrels per year; flows in Texas are reduced to zero.

- Revised Louisiana watershed mass loadings from produced water discharges from facilities excluded from coverage under the Region 6 final general permit are projected to be 2.0 million pounds per year or 17% of the mass load from industrial and municipal point sources (includes ORD report pollutants only) to 6.0 million pounds per year or 23% of Louisiana's point source mass load (all produced water pollutants included).

- Reduced toxic unit loadings from produced water discharges from facilities excluded from coverage under the Region 6 final permit are estimated to represent 25% of the point source toxic loadings in Louisiana.

- Revisions to water quality compliance, resource valuations, and exposed population estimates cannot be projected at this time for the reduced flow that results from issuance of the Region 6 NPDES permits.

- Based on a reduced flow estimate of 29% of the original flow estimate, the monetized benefit estimate is reduced to potential benefits due to cancer risk reductions. For these proposed effluent guidelines those benefits range from $0.7 to $13.3 million annually.

- Based on a reduced flow estimate of 29% of the pre-permit flow estimate, the monetized ecological benefit due to ecological improvement from these proposed effluent guidelines is $1.4 to $41.5 million annually.

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1. INTRODUCTION

1.1 Background

This water quality benefits analysis (WQBA) is part of the U.S. Environmental Protection Agency's (EPA) rulemaking package for proposed effluent guidelines for the coastal subcategory of the oil and gas extraction industry. EPA developed proposed guidelines based on a variety of data collected and analyzed by the Agency, including a Request for Comments (54 FR 46919; November 8, 1989), an Information Collection Request (ICR) conducted by the Agency during July of 1993, and information collected in response to a public meeting on this rulemaking held on July 19, 1994 in New Orleans, Louisiana. As part of the rulemaking package, EPA seeks to describe and assess the potential ecological and human health impacts associated with current ("baseline") discharges from coastal oil and gas operations and the benefits associated with the regulatory options under consideration.

On January 9, 1995, Region 6 issued final NPDES general permits covering discharges from production facilities in coastal Louisiana and Texas (60 FR 2387). Those permits require that all coastal produced water be reinjected, thereby significantly changing the facility characterization for this analysis upon which all further analyses are based. Because of the short time between issuance of those permits and finalization of this analysis, revisions to this WQBA were not possible. A preliminary, first order assessment of the impact of these Region 6 permits has been developed and is included in Section 11 of this document based solely on linear estimations of flow reduction attributable to these permits. The remainder of this document reflects the original facility characterizations and subsequent assessments. Any changes resulting from the issuance of these permits and from comments received as a result of the proposal will be reflected in the final WQBA.

1.2 Purpose

The purpose of this WQBA is to quantify and to monetize, wherever possible, the benefits that are projected to accrue from the regulatory options under consideration in the proposed rule. The WQBA presents several types of characterizations and assessments for this purpose:

- Waste stream characterizations of produced water discharge volumes, pollutant composition, and toxicity (Section 2)

- A watershed assessment that compares produced water pollutant mass loadings and toxic loadings from coastal oil and gas operations to other industrial and municipal point source loadings for individual estuarine drainage systems in Texas and Louisiana (Section 3)

- Water quality compliance assessments for produced water for Texas, Louisiana, and Cook Inlet, Alaska that compare receiving water pollutant concentrations projected from surface water dispersion modeling for state mixing zones to state numeric water quality standards (Section 4)

- Water quality compliance assessments for drilling fluids discharged to Cook Inlet that compare receiving water pollutant concentrations projected from surface water dispersion modeling to state numeric water quality standards (Section 5)

- Valuations of resources at risk in the Gulf of Mexico, including recreational and commercial fisheries, non-consumptive and other recreational uses, and endangered and threatened species (Section 6)

- Analyses of populations indirectly exposed to produced water pollutants and environmental equity issues, i.e., estimates of exposed low income and subsistence populations, as well as seafood consumption rates and patterns (Section 7)

- A carcinogenic risk assessment for produced water radionuclides for average rate and high rate seafood consumption, based on seafood radionuclide contamination levels observed in field data and projected from modeling (Section 8)

- A case study of projected, monetized ecological benefits resulting from regulation of produced water, based on a field study in Trinity Bay, Texas and acreage valuations derived in Section 6 for Gulf of Mexico coastal areas (Section 9)

- A literature review of field studies of produced water impacts in Texas and Louisiana (Section 10)

- A preliminary discussion of revised analyses as a result of the recently issued Region 6 NPDES general permits covering coastal production discharges (Section 11).

1.3 Geographic Scope

The WQBA considers operations and impacts in two geographic areas: the Gulf of Mexico (primarily analyses for Texas and Louisiana) and Upper Cook Inlet, Alaska. The overwhelming majority of operations affected by this rule (i.e., those still discharging after July, 1996, which is the projected final promulgation date of these effluent guidelines) are located in Texas and Louisiana. EPA projects that 96% of coastal oil and gas production facilities (216 facilities) are located in these two coastal Gulf of Mexico states; the remaining 8 facilities are located in Cook Inlet, Alaska. The WQBA does not consider any environmental impacts associated with coastal oil and gas operations in Mississippi, Alabama, Florida, California, or North Slope of Alaska because these facilities are currently controlled under state regulations that require zero discharge for both drilling and production wastes.

1.4 Waste Streams

Gulf of Mexico Operations

Drilling fluids and cuttings associated with Gulf of Mexico coastal operations are currently prohibited from discharge by state authorities and existing NPDES permits. Therefore, drilling wastes are not considered for Gulf of Mexico operations in this WQBA. The only waste stream considered in this WQBA for Gulf of Mexico operations is produced water. Produced water volumes are based on individual outfall flow data, aggregated to state-wide estimates for both Texas and Louisiana. These volume estimates include consideration of compliance schedules for attaining zero discharge limitations under existing state permits.

Produced water pollutant concentrations for the current baseline condition (i.e., the Best Practicable Treatment, or BPT level of treatment technology) are average values for Texas and Louisiana facilities based on an EPA sampling and analysis survey of ten coastal facilities in these states. Produced water pollutant concentrations for gas flotation (Best Available Technology Economically Achievable, or BAT) options are based on pollutant levels in produced water effluent from this treatment technology based on facilities in the offshore subcategory of this industry. Produced water toxicity for Gulf of Mexico operations is based on data obtained from effluent studies conducted for both Texas and Louisiana facilities.

Cook Inlet, Alaska Operations

Produced water volumes for Cook Inlet operations are based on the individual flows from the eight currently authorized outfalls. Produced water BPT pollutant concentrations for the baseline condition are flow-weighted averages, based on data supplied by Cook Inlet operators. Gas flotation (BAT) produced water pollutant concentrations are the same as those used for Gulf of Mexico operations.

Drilling fluid pollutant concentrations are based on data developed for the offshore guidelines rulemaking. Specific pollutant concentrations have been adjusted to reflect actual Cook Inlet practices.

1.5 Regulatory History

The proposed effluent guidelines apply to discharges from coastal oil and gas extraction facilities, including exploration, development and production operations. The processes and operations of the coastal oil and gas subcategory are currently regulated under 40 CFR Part 435, Subpart D. The regulations are being proposed pursuant to a Consent Decree entered in Natural Resouces Defense Council (NRDC) et al. v. Reilly (DDC No. 89-2980, January 31, 1992) and are consistent with EPA's latest Effluent Guidelines Plan under section 304(m) of the Clean Water Act (CWA). (See 59 FR, 44234, August 24, 1994)

The existing effluent limitations guidelines are based on the achievement of best practicable control technology currently available (BPT). Coastal subcategory effluent limitations were proposed on October 13, 1976 (41 FR 44943). On April 13, 1979 (44 FR 22069) BPT effluent limitations guidelines were promulgated

for all subcategories under the oil and gas category, but action on Best Available Technology (BAT) and New Source Performance Standards (NSPS) regulations was deferred. On November 8, 1989, EPA published a notice of information and request for comments on the Coastal Oil and Gas subcategory effluent limitations guidelines (54 FR 46919). The notice presented the current information about control and treatment technologies applicable to oil and gas wastes, and the Agency's anticipated approach to effluent limitations guidelines development for BAT, BCT, and NSPS. EPA solicited comments on the information presented and the limitations development approach and also requested additional information where available.

To further public participation on this rule, on July 19, 1994, EPA held a public meeting about the content and status of the proposed regulation. The meeting was announced in the Federal Register (59 FR 31186; June 17, 1994) and gave interested parties an opportunity to provide information, data, and ideas to EPA on key issues. EPA will assess all comments and data received at that public meeting, all comments and data received as a result of this proposal, and any information submitted in response to the 1989 Notice of Information, prior to promulgation of the final regulation.

During the development of the proposed coastal guidelines, EPA also sent a questionnaire to industry under authority of section 308 of the CWA. During its design, EPA met with industry trade associations (on March 19, 1992) to discuss its plans to issue a questionnaire. Following the March meeting, EPA distributed a draft of the questionnaire to NRDC, industry representatives, and trade associations for review and comment. A final questionnaire was subsequently completed, reviewed, approved by the Office of Management and Budget (OMB), and sent to coastal oil and gas operators on August 30, 1993. Results of that questionnaire have been used for development of the proposed regulations and supporting analyses wherever applicable.

1.6 BAT Regulatory Options

1.6.1 Produced Water

EPA considered five BAT options for regulating produced water in the development of this rulemaking package. These options are the following:

Option 1: BPT All. This option is the least onerous on the industry, requiring all facilities to continue to meet the exisitng BPT level of treatment for oil and grease in produced water (48 mg/l oil and grease as a monthly average and 72 mg/l oil and grease as a daily maximum).

Option 2: Gas Flotation All. This option requires all coastal facilities to meet the same BAT (gas flotation technology) oil and grease limitations for produced water that were promulgated for the offshore subcategory of this industry (29 mg/l oil and grease as a monthly average and 42 mg/l oil and grease as a daily maximum).

Option 3: Zero Discharge All, except BPT Limits for All Cook Inlet Facilities. This option requires zero discharge of produced water for all operators except those in Cook Inlet, Alaska, who would be required to comply with the BPT level of treatment (48/72 mg/l oil and grease, monthly average/daily maximum).

Option 4: Zero Discharge All, except Gas Flotation for All Cook Inlet Facilities. **This option is the preferred option for these proposed effluent guidelines.** This option requires zero discharge of produced water for all operators except those in Cook Inlet, Alaska, who would be required to comply with the offshore level of treatment (29/42 mg/l oil and grease monthly average/daily maximum).

Option 5: Zero Discharge All. This option requires all facilities to comply with a zero discharge limitation on produced water.

1.6.2 Drilling Wastes

EPA considered three options for drilling wastes in the development of this rulemaking package. All three options include a zero discharge of dewatering effluent that is sometimes produced from drilling fluids solids control systems. The three options considered are:

Option 1: Zero Discharge All, except Offshore Limits for Cook Inlet Facilities. This option requires no additional regulatory requirements beyond those already in place.

Option 2: Zero Discharge All, except Offshore Limits and a More Stringent Toxicity Limit for Cook Inlet Facilities. This option retains the existing zero discharge requirement for Gulf of Mexico operations, but imposes a more stringent toxicity limit (1,000,000 ppm Suspended Particulate Phase, or SPP) on Cook Inlet facilities compared to the current toxicity limitation in the BAT offshore guidelines (30,000 ppm SPP).

Option 3: Zero Discharge All. This option requires all operators to achieve a zero discharge standard, including Cook Inlet operations.

2. PRODUCED WATER CHARACTERIZATIONS

2.1 Background

The discharge volume and pollutant concentration data used for this water quality benefits analysis (WQBA) were derived from state and NPDES permit data and from data collected by the Engineering and Analysis Division (EAD) of EPA's Office of Science and Technology for this proposed rulemaking. Their collection, derivation, and analyses are presented in greater detail in the Development Document for this proposed rule (EPA, 1994a).

The discharge volume data used to characterize those operators in Texas, Louisiana, and Cook Inlet who are affected by the proposed guidelines were obtained by EAD from state and EPA Regional permits issued to oil and gas production facilities. Discharge monitoring reports (DMRs) from facilities in Texas and Louisiana were used to document the location and volume of those discharges. Discharge volume data are presented separately for Texas, Louisiana, and Cook Inlet operators.

The pollutant concentration data used for this analysis also are presented in greater detail in the Development Document for the proposed rulemaking. These data were collected from state regulatory agencies, EPA sampling and analysis efforts, and industry documents. Produced water pollutant data are presented in this document for both current (BPT) technologies and for improved gas flotation (BAT) technology. Pollutant data are presented separately for Gulf of Mexico facilities and Cook Inlet facilities.

The volume, pollutant, and toxicity data summarized and presented in this chapter are used for the further analyses that are conducted and presented in this WQBA.

2.2 Characterization of Produced Water Discharge Volumes

2.2.1 Texas

The Texas Railroad Commission is the state agency charged with regulating the discharge of wastes from oil and gas exploration and production facilities in Texas. Tidal disposal permits issued for produced water discharges require monthly monitoring and quarterly reporting of discharge volumes and oil and grease concentrations. The permit data are tracked by a database maintained at the Railroad Commission Headquarters in Austin. This database was used for the characterization of Texas coastal discharges.

For BPT analyses, Texas facilities include those current discharges that are permitted by the Railroad Commission to discharge after June, 1996. For gas flotation BAT options, small dischargers (defined for Texas as discharges of less than 80 barrels of produced water per day) are assumed to haul their produced water to commercial disposal facilities rather than investing in improved technology. The list of Texas operators and discharge volumes for both the BPT baseline and BAT options are presented in Exhibit 2-1.

Exhibit 2–1. Texas Coastal Produced Water Outfalls

Permit No./ Outfall	Operator	Volume (bpd) Current BPT	Gas Flot'n (BAT)
1	Neumin Production Co.	88	88
4	PI Energy Inc.	75	
8	Brown, Clifford L., Jr.	25	
13	Ensenjay Petroleum Corp.	1,193	1,193
14	PI Energy, Inc.	20	
19 A	Apache Corp.	440	440
19 B	Apache Corp.	685	685
19 C	Apache Corp.	560	560
20	Texaco Exploration and Production Inc.	275	275
26	Exxon Corp. – Houston	7,495	7,495
47	United Texas Corp. (A)	150	150
60	Cedar Point Oil Co.	1,200	1,200
64	Coastal Oil & Gas Corp.	40	
68 A	Orange Petroleum Co.	2,900	2,900
68 B	Orange Petroleum Co.	696	696
68 D	Orange Petroleum Co.	151	151
68 E	Orange Petroleum Co.	2,012	2,012
71	Ebb Tide Oil Co.	4	
80	Exxon Corp.	1,948	1,948
81	Exxon Co. U.S.A.	888	888
85	Texaco Producing Co.	112	112
89	Goodrich Operating Co., Inc.	137	137
90	Brown, George R., Parnership	3,670	3,670
102	Karbuhn Oil Co.	46	
104	Ebb Tide Oil Co.	55	
105 A	Brown, Clifford L., Jr.	1,300	1,300
105 B	Brown, Clifford L., Jr.	90	90
105 C	Brown, Clifford L., Jr.	130	130
105 D	Brown, Clifford L., Jr.	430	430
105 E	Brown, Clifford L., Jr.	170	170
105 G	Brown, Clifford L., Jr.	250	250
111	Marshall Petroleum, Inc.	10	
113	Brown, George R., Parnership	3,000	3,000
119	M.K. McDaniel	44	
122	Kilmarnock Oil Co.	200	200
124 A	S&S Energy, Inc.	404	404
124 B	S&S Energy, Inc.	379	379
127	Shelton, Charles H.	420	420
132	Shelton, Charles H.	154	154
134	Headington Oil Co.	400	400
136	American Exploration Co.	4,476	4,476
152	Keplinger Operating Co.	80	80
155	Texaco, Inc.	1,660	1,660
156	Texaco Exploration and Production Inc.	2,746	2,746
157	Texaco Exploration and Production Inc.	479	479
163	Ace Productions	450	450

Exhibit 2–1. Texas Coastal Produced Water Outfalls (Continued)

Permit No./ Outfall	Operator	Volume (bpd) Current BPT	Gas Flot'n (BAT)
165	Unocal	144	144
166	Petro Vest, Inc.	100	100
167	Petro Vest, Inc.	400	400
170	Westland Oil Development Corp.	1	
176	S.S.C. Gas Producing Co.	60	
177	Texas Petroleum Co.	1,500	1,500
184	La Parrita Oil & Gas, Inc.	12	
189	Tierra Mineral Development	2,045	2,045
195	Bristol Resources Corp.	16	
197	Bristol Resources Corp.	32	
201	Tierra Mineral Development	1	
202	Fort Worth Oil and Gas, Inc.	84	84
206	Midcon Offshore, Inc.	10	
207	Miresco, Inc.	1,033	1,033
214	Brown, George R. Partnership	22	
219	Zinn Petroleum Co.	300	300
238	Merrico Resources, Inc.	34	
241	Dewbre Petroleum Corp.	155	155
242	PI Energy Inc.	600	600
249	Killam Oil Co.	3,755	3,755
264	Live Oak Reserves, Inc.	775	775
276	Pearl, Bill H. Production, Inc.	375	375
282	Redfish Bay Operating Corp.	110	110
547	Wainoco Oil & Gas Co.	2	
552	Wilson Hydrocarbon, Inc.	60	
577	Paton Oil Corp.	682	682
580	Lundy Vacuum Service, Inc.	100	100
582	Lamar Oil & Gas, Inc.	70	
587	Linda Production, Inc.	80	80
590 A	BKN Oil & Gas, Inc.	32	
590 B	BKN Oil & Gas, Inc.	775	775
590 C	BKN Oil & Gas, Inc.	13	
590 D	BKN Oil & Gas, Inc.	375	375
590 E	BKN Oil & Gas, Inc.	35	
590 F	BKN Oil & Gas, Inc.	40	
590 G	BKN Oil & Gas, Inc.	68	
590 H	BKN Oil & Gas, Inc.	1,200	1,200
590 I	BKN Oil & Gas, Inc.	86	86
590 J	BKN Oil & Gas, Inc.	43	
590 K	BKN Oil & Gas, Inc.	50	
595	Poynor Corp.	72	
605	Whittington Operating Co.	245	245
613	Redfish Bay Operating Corp.	600	600
616	Crest Resources & Exploration	400	400
627	Haps Oil & Gas Corp.	185	185
628	Convest Energy Corp.	15	

Exhibit 2–1. Texas Coastal Produced Water Outfalls (Continued)

Permit No./ Outfall	Operator	Volume (bpd) Current BPT	Gas Flot'n (BAT)
632	Kansas Oil & Gas Co.	904	904
635	Gulf Vacuum Service	1,290	1,290
637	Denovo Oil & Gas, Inc.	652	652
638	Pinell, H.P. Trustee	24	
645	Oil Lease Operating Co.	10	
649	Dynamic Production, Inc.	80	80
655	Bay Operating Co., Inc.	15	
659	Lone Oak Disposal Co.	248	248
663	Amoco Production Co.	15	
666	American Exploration Co.	335	335
672	King Oil	120	120
673	BWS Vacuum Sevice, Inc.	130	130
674	TD Operating Co.	200	200
675	Chain Oil & Gas, Inc.	210	210
680	Zilka Energy Co.	110	110
684	Brandes Petroleum Inc.	250	250
685	SNR Oilfield Services, Inc.	600	600
693	Brymer Contracting Co.	436	436
694	Crest Resources & Exploration	180	180
708	Corpus Christi Oil & Gas Co.	8	
710	Dan J. Harrison III & F.H. Bruce	150	150
723 B	Corpus Christi Oil & Gas Co.	15	
739	Graham Royalty, Ltd.	330	330
744	Scana Exploration Co.	1,200	1,200
747	Cavalla Energy Exploration Co.	43	
752	Houston Oil Production Enterprises, Inc.	10	
753	Houston Oil Production Enterprises, Inc.	29	
789	Pax Petroleum Corp.	350	350
792	Corpus Christi Leaseholds, Inc.	4	
822	Poynor Corp.	1,000	1,000
854	Texana Operating Co.	185	185
857	Claron Corp.	175	175
885	Houston Oil & Minerals Corp.	168	168
904	Coastal Oil & Gas Corp.	4,839	4,839
905	Coastal Oil & Gas Corp.	74	
Facility Count		127	86
Total Texas Volume (bpd)		73,318	72,064
Total Texas Volume (bpy)		26,761,070	26,303,360
Average Texas Discharge Rate (bpd)		577	838
Median Flow by Outfall (bpd)		162	379
Median Flow by Flow (bpd)		1,957	1,978

Source: EPA, 1994a.

For the current BPT baseline, there are 127 produced water outfalls documented in coastal Texas with a total discharge of 73,318 barrels per day (bpd), or 26.8 million barrels per year (bpy). Discharge rates range from 1 bpd to 7,495 bpd. The average discharge rate is 577 bpd; the median discharge rate by outfall (i.e., 50% of the outfalls discharge at a greater rate) is 162 bpd; and the median discharge rate by flow (i.e., 50% of the volume is discharged at a greater rate) is 1,957 bpd.

For the gas flotation option (BAT Option 2), there are 86 outfalls documented as discharging at greater than the 80 bpd minimum discharge limit, with a total discharge of 72,064 bpd, or 26.3 million bpy. Discharge rates range from 80 bpd to 7,495 bpd. The average discharge rate is 838 bpd; the median discharge rate by outfall is 379 bpd; and the median discharge rate by flow is 1,978 bpd.

2.2.2 Louisiana

The Louisiana Department of Environmental Quality (DEQ) also issues permits for discharges of oil and gas production wastes in state waters. Through these permits, state regulations require that produced water discharges be phased out. The state has identified a series of termination dates that group and order permits by receiving water type. Fresh water areas were phased out earliest and brackish/saline water areas are phased out last. Nearly all discharges must cease by 1997, with only a few facilities discharging to main passes of the Mississippi and Atchafalaya Rivers permitted to continue discharging.

Discharge data for this rulemaking were collected from state files, verified by responses to EAD's Section 308 questionnaire, and compiled for analysis. Those outfalls scheduled to cease discharge prior to June, 1996 were removed from the database for analyses for the proposed rulemaking. For gas flotation (BAT Option 2), small dischargers (defined in Louisiana as discharges of less than 70 bpd) are assumed to haul their waste to commercial disposal facilities. The final list of operators and discharge volumes presented in Exhibit 2-2 were supplied by EAD for this analysis.

For current BPT discharges, there are 94 produced water outfalls documented in coastal Louisiana with a total discharge of 415,919 bpd, or 152 million barrels per year (bpy). Discharge rates range from 1 bpd to 144,000 bpd. The average discharge rate is 4,425 bpd; the median discharge rate by outfall (i.e., 50% of the outfalls discharge at a greater rate) is 950 bpd; and the median discharge rate by flow (i.e., 50% of the volume is discharged at a greater rate) is 15,100 bpd.

For gas flotation (BAT Option 2), there are 84 outfalls documented as discharging at greater than the 70 bpd minimum discharge limit, with a total discharge of 415,740 bpd, or 152 million bpy. Discharge rates range from 72 bpd to 144,000 bpd. The average discharge rate is 4,949 bpd; the median discharge rate by outfall is 1,125 bpd; and the median discharge rate by flow is 15,100 bpd.

Exhibit 2–2. Louisiana Coastal Produced Water Outfalls

Permit No./ Outfall	Operator	Volume (bpd) Current BPT	Gas Flot'n (BAT)
3040 001	Alliance Operating Corp.	1,678	1,678
3650 001	Alltex Exploration, Inc.	465	465
3408 001	Amerada Hess Corp.	3,662	3,662
2184 001	Ashlawn Energy, Inc.	3,143	3,143
2184 002	Ashlawn Energy, Inc.	3,143	3,143
2184 003	Ashlawn Energy, Inc.	3,143	3,143
3795 001	Atlas Production Services, Inc.	152	152
3795 002	Atlas Production Services, Inc.	152	152
2858 001	BKE–A, LLC	1	
3686 001	Bois d'Arc Operating Corp.	925	925
3870 001	Bois d'Arc Operating Corp.	1,010	1,010
3086 001	Burk Royalty Co.	450	450
1901 001–2	Callon Offshore Production, Inc.	15,100	15,100
1901 001–3a	Callon Offshore Production, Inc.	15,100	15,100
1901 002–2	Callon Offshore Production, Inc.	15,100	15,100
1901 002–3	Callon Offshore Production, Inc.	15,100	15,100
1934 001–1	Callon Offshore Production, Inc.	14,443	14,443
2142 001–1	Callon Offshore Production, Inc.	12,076	12,076
2672 001–2	Callon Offshore Production, Inc.	9,175	9,175
2859 001	Callon Offshore Production, Inc.	11,290	11,290
2860 003	Callon Offshore Production, Inc.	7,120	7,120
2699 001	Carl Oil & Gas Co.	30	
3074 001	Cashco Oil Co.	72	72
1863 001	Chevron U.S.A., Inc.	27,856	27,856
1896 001	Chevron U.S.A., Inc.	35,652	35,652
1857 001	Chevron U.S.A., Inc.	2,073	2,073
1857 003	Chevron U.S.A., Inc.	2,073	2,073
1857 004	Chevron U.S.A., Inc.	2,073	2,073
1857 005	Chevron U.S.A., Inc.	2,073	2,073
1857 006	Chevron U.S.A., Inc.	2,073	2,073
1857 008	Chevron U.S.A., Inc.	2,073	2,073
1857 009	Chevron U.S.A., Inc.	2,073	2,073
1857 010	Chevron U.S.A., Inc.	2,073	2,073
1857 011	Chevron U.S.A., Inc.	2,073	2,073
1861 001	Chevron U.S.A., Inc.	4,600	4,600
2945 001	Claron Corp.	15	
3853 001	Cliffs Oil & Gas Co.	245	245
3038 001	CXY Energy, Inc.	500	500
3067 000	Denovo Oil and Gas, Inc.	200	200
3459 000	Desco Oil Co.	34	
3133 001	DKM Resources, Inc.	22	
2185 001	Energy Development Corp.	700	700
2785 001	Energy Development Corp.	250	250
2779 001	Graham Royalty, Ltd.	950	950
4029 001	Hilcorp Energy Co.	3,522	3,522
4467 001	Houma Production Co.	400	400
2368 001	Hunt Petroleum Co.	1,125	1,125
2368 002	Hunt Petroleum Co.	1,125	1,125
2368 003	Hunt Petroleum Co.	1,125	1,125
2368 005	Hunt Petroleum Co.	1,125	1,125
2368 006	Hunt Petroleum Co.	1,125	1,125

Exhibit 2–2. Louisiana Coastal Produced Water Outfalls (Continued)

Permit No./ Outfall	Operator	Volume (bpd) Current BPT	Gas Flot'n (BAT)
2704 001	Hunt Petroleum Co.	75	75
3008 001	Hunt Petroleum Co.	266	266
3029 001	James A. Whitson, Jr.	300	300
2956 000	Japex (U.S.) Corp.	13	
3081 001	Konantz, Inc.	613	613
2408 001	Linder Oil Co.	20	
2710 001	Linder Oil Co.	904	904
1853 001	LLECO Holdings, Inc.	324	324
3746 001	Marblehead Energy Corp.	1,250	1,250
2164 001–1	Oryx Energy Co.	150	150
3223 001	Pel–Tex Oil Co.	186	186
3407 001	Pennzoil Exploration & Production Co.	6,300	6,300
2838 001	Petro Corp.	1,500	1,500
2227 001	Quintana	600	600
2299 001	Quintana	2	
2626 001	Samedan Oil Corp.	100	100
2071 001	Shell	144,000	144,000
2084 001	Texaco, Inc.	1,716	1,716
2084 003–1	Texaco, Inc.	1,716	1,716
2084 005	Texaco, Inc.	1,716	1,716
2084 012	Texaco, Inc.	1,716	1,716
2084 015	Texaco, Inc.	1,716	1,716
2084 016	Texaco, Inc.	1,716	1,716
2816 011	Texaco, Inc.	291	291
2825 001–2	Texaco, Inc.	666	666
2825 002–2	Texaco, Inc.	666	666
2825 003–2	Texaco, Inc.	666	666
2882 001	Texaco, Inc.	747	747
2882 002	Texaco, Inc.	747	747
2970 001	Texaco, Inc.	500	500
2971 001–2	Texaco, Inc.	2,650	2,650
2971 002	Texaco, Inc.	2,650	2,650
3032 001	Texoil Co.	939	939
2547 001	Torch Operating Co.	109	109
2708 001	Torch Operating Co.	278	278
1950 001	Warren Petroleum Co.	1,680	1,680
2138 001	Whiting Petroleum Co.	21	
2138 002	Whiting Petroleum Co.	21	
3039 001	Wichita River Oil Corp.	270	270
2909 001	WRT Energy Corp.	3,252	3,252
2118 001	W.W.F. Oil Corp.	370	370
2118 002	W.W.F. Oil Corp.	370	370
2118 003	W.W.F. Oil Corp.	370	370
Facility Count		94	84
Total Louisiana Volume (bpd)		415,919	415,740
Total Louisiana Volume (bpy)		151,810,581	151,745,246
Average Louisiana Discharge Rate (bpd)		4,425	4,949
Median Flow by Outfall (bpd)		950	1,125
Median Flow by Flow (bpd)		15,100	15,100

Source: EPA, 1994a.

2.2.3 Alaska

Discharges of produced water to Cook Inlet are covered by a NPDES general permit issued by EPA Region 10. Because there are only eight produced water outfalls in Cook Inlet, individual facility discharge volumes were used to assess loadings and water quality impacts for individual outfalls rather than average values, as were used for Gulf of Mexico analyses. The discharge volumes of the eight outfalls are presented in Exhibit 2-3.

Alaska discharges from eight outfalls average 16,748 bpd with a total discharge volume of 133,982 bpd, or 48.9 million bpy. The discharge rates range from 30 bpd to 126,072 bpd for the eight outfalls. These volumes and flow rates are used for Cook Inlet operations in analyses for all options considered.

2.3 Produced Water Pollutant Characterization

2.3.1 Texas and Louisiana

Pollutant data for current BPT discharges were provided by EAD for Gulf of Mexico facilities based on sampling conducted on coastal facilities in Texas and Louisiana. BAT effluent concentrations for gas flotation technology also were provided by EAD based on sampling of offshore produced water discharges. Because the sampling and analyses for BPT and BAT were conducted independently, the list of pollutants for each technology differ. The concentrations of the 68 pollutants for the current BPT level of treatment and the proposed gas flotation technology (BAT Option 2) are presented in Exhibit 2-4.

BPT pollutant concentrations represent the average concentration of the ten facilities sampled. Pollutants reported at less than the detection limit are treated as one-half of the detection limit reported. Only pollutants detected in one or more samples are included in the analysis. Gas Flotation (BAT) pollutant concentrations are based on samples taken at offshore facilities using gas flotation technology. The derivation of these values is presented in the development document for the proposed coastal effluent guidelines (EPA, 1994a).

2.3.2 Alaska

Pollutant concentration data for current BPT discharges from Cook Inlet facilities were provided by EAD based on an EPA study of the six produced water outfalls over one year. Current BPT and gas flotation (BAT) pollutant data for Alaska are presented in Exhibit 2-5.

Exhibit 2–3. Cook Inlet Produced Water Outfalls

Operator	Facility	Discharge Distance from Shore (miles)	Average Discharge (bpd)
Marathon	Trading Bay	1.9	126,072
Shell Western	East Foreland	0.15	3,100
Amoco	Dillon	3.7	2,650
Unocal	Anna	2.5	1,500
Marathon	Granite Point	1.9	300
Phillips	NCIU Tyonek A	5.5	170
Unocal	Bruce	1.5	160
Unocal	Baker	7.5	30
Facility Count			8
Total Alaska Volume (bpd)			133,982
Total Alaska Volume (bpy)			48,903,430
Average Alaska Discharge Rate (bpd)			16,748

Source: EPA, 1994a.

Exhibit 2–4. Produced Water Pollutant Concentrations for Texas and Louisiana Analyses

Pollutant	Mean Concentration (ug/l) Current BPT	Gas Flotation (BAT Option 2)
1,2:3,4–Diepoxybutane	71.1	71.1
2–Butanone	122	122
2–Hexanone	35.81	35.81
2–Methylnaphthalene	67.2	67.2
2,4–Dimethylphenol	117	117
Acetone	913	913
Aluminum	1,072	49.93
Ammonia, as Nitrogen	65,773	65,773
Antimony	166	166
Arsenic	10.8	10.8
Barium	52,573	35,560.8
Benzene	4,285	1,225.9
Benzoic Acid	3,813	3,813
Benzyl Alcohol	49.5	49.5
Beryllium	5.56	5.56
Bis(2–ethylhexyl)phthalate	46.0	46.0
Boron	20,244	16,473.8
Cadmium	22.8	14.47
Calcium	2,501,000	2,501,000
Carbon Disulfide	8.48	8.48
Chlorides	65,111,000	65,111,000
Chloromethane	28.6	28.6
Chromium	128	128
Cobalt	83.6	83.6
Copper	180	180
Di–n–butyl Phthalate	36.6	6.43
Ethylbenzene	115	62.18
Hexanoic Acid	790	790
Iron	15,492	3,146.2
Lead	515	124.86
Magnesium	615,699	615,699
Manganese	1,301	74.16
Methylene Chloride	170	170
Molybdenum	86.9	86.9
Naphthalene	144	92.02
n–Decane	139	139
n–Docosane	38.0	38.0
n–Dodecane	225	225
n–Eicosane	68.0	68.0
n–Hexadecane	283	283

Exhibit 2–4. Produced Water Pollutant Concentrations for Texas and Louisiana Analyses (Continued)

Pollutant	Mean Concentration (ug/l) Current BPT	Gas Flotation (BAT Option 2)
n–Hexosane	36.1	36.1
Nickel	109	109
n–Octacosane	35.2	35.2
n–Octadecane	82.9	82.9
n–Tetracosane	38.2	38.2
n–Tetradecane	119	119
n–Triacontane	35.0	35.0
o–Cresol	121	121
Oil and Grease	52,956	23500
p–Cresol	149	149
Phenol	553	536
Radium 226	0.000172	0.000204
Radium 228	0.000228	0.000249
Selenium	250	250
Silver	252	252
Strontium	205,500	205,500
Sulfur	9,683	9,683
Thallium	180	180
Tin	305	305
Titanium	32.4	4.48
Toluene	3,370	827.8
Total Suspended Solids (TSS)	133,063	30,000
Total Xylenes	222.1	222.1
Trichlorofluoromethane	294	294
Vanadium	96.6	96.6
Vinyl Acetate	29.4	29.4
Yttrium	25.0	25.0
Zinc	329	133.85

Source: EPA, 1994a.

Exhibit 2–5. Produced Water Pollutant Concentrations for Alaska Analyses

Pollutant	Mean Concentration (ug/l) Current BPT	Gas Flotation (BAT)
2–Butanone	1,029.0	411.6
2,4–Dimethylphenol	514.7	250.0
Aluminum	78.0	49.9
Anthracene	25.3	7.40
Arsenic	114.2	73.1
Barium	55,563.8	35,560.8
Benzene	3,386.1	1,225.9
Benzo(a)pyrene	10.6	4.65
Boron	25,740.3	16,473.8
Cadmium	22.6	14.5
Chlorobenzene	8.05	7.79
Copper	444.7	284.6
Di–n–butylphthalate	16.1	6.43
Ethylbenzene	157.7	62.2
Iron	4,915.9	3,146.2
Lead	195.1	124.9
Manganese	115.9	74.2
n–Alkanes	1,641.5	656.6
Naphthalene	933.5	92.0
Nickel	1,705.5	1,091.5
p–Chloro–m–cresol	25.2	10.1
Phenol	431.5	536.0
Radium–226	0.00000139	0.000204
Radium–228	0.00000312	0.000249
Steranes	77.5	31.0
Titanium	7.00	4.48
Toluene	1,507.4	827.8
Total Xylenes	542.5	378.0
Triterpanes	78.0	31.2
Zinc	44.8	133.9

Source: EPA, 1994a.

2.4 Produced Water Toxicity

2.4.1 Texas

Texas Railroad Commission produced water discharge permits do not require toxicity testing. Therefore, whole effluent toxicity data for Texas coastal outfalls were obtained from literature sources. The toxicity data identified for Texas are summarized in Exhibit 2-6.

Texas lethal toxicity values range from 2.7% to 80% effluent (48-hr LC50s) for silverside minnows and grass shrimp, respectively. The mean 48-hour LC50 value for all species is 22.7% effluent for 10 reported values. The mean 96-hour LC50 is 42% effluent for 7 reported values. Chronic values (EC50s) range from <2.7% to 27.2% effluent for 3 reported tests.

2.3.2 Louisiana

Louisiana coastal discharge permits require that operators conduct acute and chronic toxicity tests using mysids and sheepshead minnows and submit the results within six months of initiating produced water discharges. These toxicity data for coastal outfalls were compiled from the DEQ permit files and are summarized for 222 outfalls in Exhibit 2-7.

Louisiana produced water toxicity tests report an average acute toxicity of 12.4% effluent for mysids (range of 0.048% to 100% effluent) and 27.4% effluent for sheepshead minnows (range of 1.17% to 100% effluent). The average chronic EC50 values range from 4.69% to 6.23% effluent for mysids and 8.25% to 8.54% effluent for sheepshead minnows.

2.4.3 Alaska

As part of a study conducted for Alaska oil and gas companies and EPA (Ebasco Environmental, 1990), six production facilities were sampled in winter and summer. The toxicity data are presented in Exhibit 2-8. The mean seasonal 96-hour LC50s range from 0.91% effluent to 63.39% effluent, with an overall mean of 23.6% effluent for the six facilities.

Exhibit 2-6. Texas Coastal Produced Water Toxicity Data

Species	Test Endpoint	Produced Water Concentration	Reference
Sheepshead minnow	96-hour LC50	52% (with seawater) 35% (with DI water)	Andreason and Spears, 1983
Pinfish		51%	
Atlantic croaker		46%	
White mullet		37%	
Brown shrimp		37%	
White shrimp		36%	
Microtox	EC50	15%	Cain, undated
Mysids	N/A	3% - 30%	Caudle, 1993
Sea urchin	EC50 (fertilization)	<2.7% - 17.7%	Chapman, undated
	EC50 (normal development)	7.3% - 27.2%	
Brown shrimp	48-hour LC50	24.5% - 26.5% 18% - 21.5%	Heffernan, 1971
White shrimp		26% - 30% 13.5%	
Crab megalops		21%	
Grass shrimp	48-hour LC50	15% 80%	Mackin and Conte, 1971
Silverside minnows		2.7% 10%	
Fathead minnows	24-hour LC50	17% (1-day old sample) 35% (2-day old sample)	Sauer et al., 1992
Ceriodaphnia		8% (1-day old sample) 11% (2-day old sample)	
Pin perch	48-hour LC50	11.5%	Spears, 1960

Exhibit 2-7. Louisiana Coastal Produced Water Toxicity Data

	Mysids (*Mysidopsis bahia*)				Sheepshead Minnows (*Cyprinodon variegatus*)		
	96-hr LC50 (% effluent	LOEL Survival (% effluent)	LOEL Growth (% effluent)	LOEL Fecundity (% effluent)	96-hr LC50 (% effluent)	LOEL Survival (% effluent)	LOEL Growth (% effluent)
Mean	12.4	4.69	6.23	6.04	27.4	8.25	8.54
Median	8.24	2.27	2.30	3.00	18.3	4.17	5.15
Minimum	0.048	0.040	0.063	0	1.17	0.14	0.15
Maximum	100	100	100	100	100	100	100
Lower 95th %ile	1.29	0.17	0.35	0.23	2.68	0.59	0.59
No. of Outfalls	222	210	205	140	222	206	203

Source: *Avanti* Corp., 1994.

Exhibit 2-8. Cook Inlet Produced Water Toxicity Data

Facility	Mean 96-hour LC50 for *Mysidopsis bahia* (% Effluent)	Annual Mean LC50 (% Effluent)
Amoco Platform Bruce		
Winter	1.5	0.91
Summer	0.3	
Marathon Granite Point		
Winter	8.5	13.5
Summer	18.5	
Marathon Trading Bay		
Winter	12.1	18.0
Summer	23.9	
Shell East Forelands		
Winter	13.9	21.66
Summer	29.4	
Amoco Platform Baker		
Winter	20.5	
Summer	29.3	23.99
Winter	32.4	
Summer	13.8	
Phillips Platform A		
Winter	78.2	63.69
Summer	49.2	

Source: Ebasco Environmental, 1990.

3. PRODUCED WATER WATERSHED LOADINGS AND QUANTIFIED BENEFITS, TEXAS AND LOUISIANA

As one assessment of the potential impact of coastal produced water discharges and the potential benefit of their regulation, an analysis of the relative contribution of this waste stream to the total pollutant loadings to Texas and Louisiana watersheds has been conducted for this water quality benefits analysis (WQBA). To conduct such an analysis, an assessment of loadings from other point sources is needed. Such an assessment has been developed for the Gulf of Mexico Program for the five Gulf of Mexico coastal states. Data developed for Texas and Louisiana serve as the basis for the analysis developed in this WQBA.

3.1 Methodology

Watershed loadings from both produced water and other industrial and municipal sources are derived for 14 Texas and Louisiana estuarine drainage systems (EDSs). The delineation of EDSs and the estimated loadings for industrial and municipal point sources were developed in the EPA Office of Research and Development (ORD) report entitled: "Comparison of Gulf of Mexico Drainage Systems: Input of Toxic Chemicals and Potential Ecological Effects" (EPA, 1994b). For Texas and Louisiana, the names and physical extent of these EDSs are provided in Exhibit 3-1; a map is provided as Exhibit 3-2. Coastal subcategory produced water dischargers have been assigned to these EDSs, located according to information obtained in Texas and Louisiana permit files.

Flow and effluent pollutant data for produced water, based on the EPA characterizations described in Section 2 of this WQBA, are used to derive produced water pollutant loading estimates. As was also developed in the ORD report for other point sources, produced water pollutant loadings are developed for both mass loadings (total pounds of pollutants) and toxic unit loadings (a measure of the relative toxic potentials of pollutants, derived from the mass loading of an individual pollutant divided by an estimate of its relative toxicity). Mass loadings are calculated as the product of flow and pollutant concentration data on an EDS-specific basis, and aggregated for state-wide total loadings. The mass loadings of produced water-derived pollutants are then compared to estimates of mass loadings from other industrial and municipal point sources developed in the ORD report. EDS-specific produced water flows are developed from individual outfall flow and location data, and are presented for Texas and Louisiana discharges in Exhibits 3-3 and 3-4, respectively.

In deriving mass loading estimates, the pollutants identified and included in the loadings calculations in the ORD report and those observed in coastal produced water are not the same. Total mass loadings for other industrial and municipal point sources, as identified in the ORD report, include 189 pollutants (Exhibit 3-5), of which 34 were found in current BPT and gas flotation (BAT Option 2) produced water effluent. Based on the pollutant data for produced water, 32 pollutants detected in the production effluent are not included in the mass or toxic unit loadings calculations of the ORD report.

Exhibit 3-1. EPA Office of Research and Development Report Estuarine Drainage Systems for Texas and Louisiana

EDS No.	EDS Name	Volume (acre-ft)	Surface Area (acres)
2	Laguna Madre	2,998,376	519,060
3	Corpus Christi Bay	1,281,814	120,155
4	Aransas Bay	1,097,464	111,528
5	San Antonio Bay	531,428	120,820
6	Matagorda Bay	2,627,112	278,510
7	Brazos River	15,015	1,930
8	Galveston Bay	2,196,773	342,275
9	Sabine Lake	351,433	61,253
10	Calcasieu Lake	610,137	101,198
11	Atchafalaya/Vermilion Bays	15,087,793	430,980
12	Mississippi Delta Region	9,815,891	1,330,793
13	Mississippi Sound	5,298,075	555,938
13a	Lake Pontchartrain	5,249,662	470,928
13b	Lake Borgne	1,546,866	189,005

Source: EPA, 1994b.

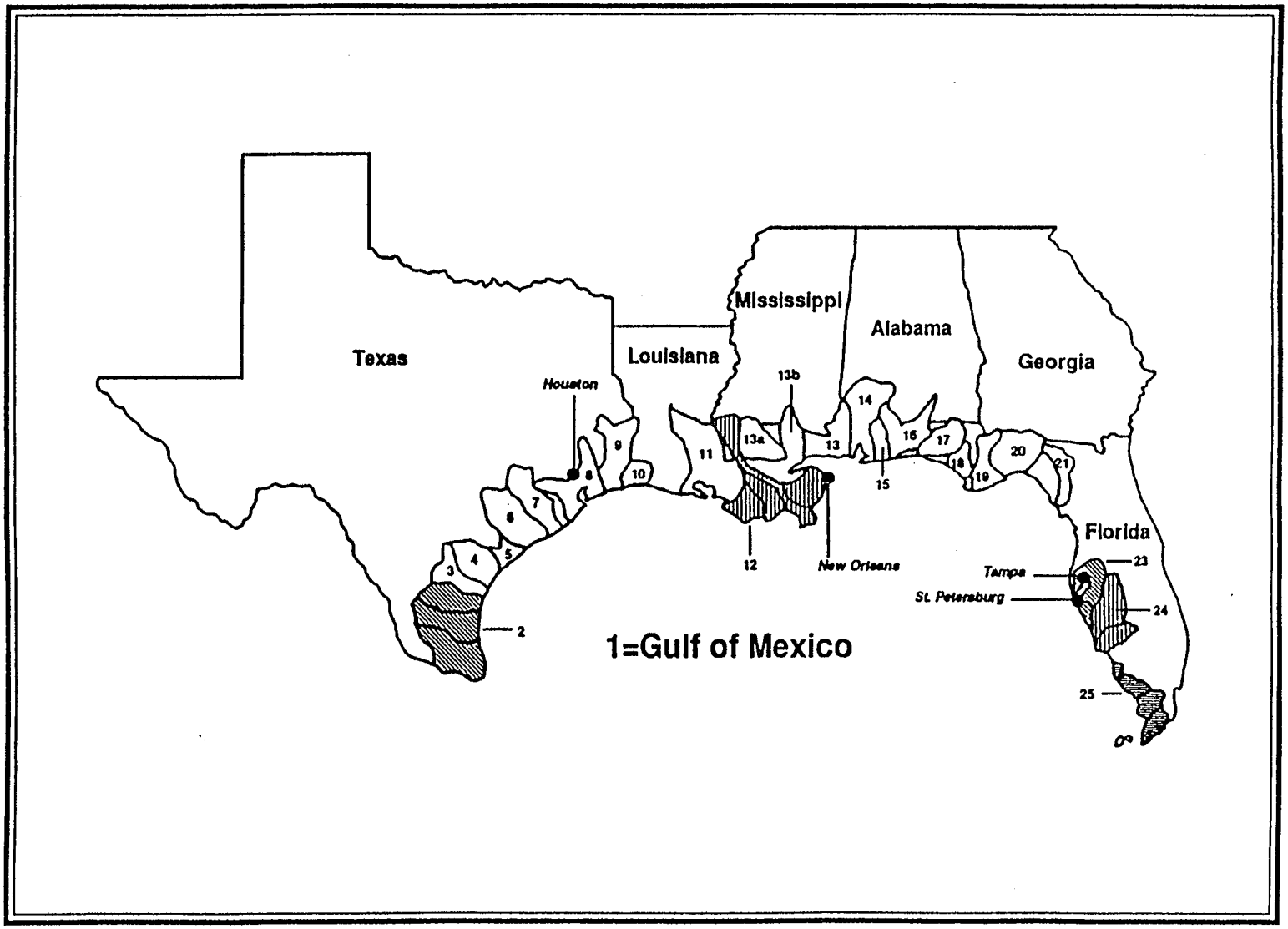


Exhibit 3-2. Map of Gulf of Mexico Estuarine Drainage Systems (Source: EPA, 1994b)

Exhibit 3–3. Texas Outfalls Used for Watershed Loadings Analyses Sorted by EDS

Permit No.	EDS No.	Operator	Volume (bpd) Current BPT		Volume (bpd) Gas Flotation (BAT)	
241	2	Dewbre Petroleum Corp.	155		155	
627	2	Haps Oil & Gas Corp.	185		185	
184	2	La Parrita Oil & Gas, Inc.	12			
582	2	Lamar Oil & Gas, Inc.	70			
638	2	Pinell, H.P. Trustee	24			
176	2	S.S.C. Gas Producing Co.	60			
547	2	Wainoco Oil & Gas Co.	2			
605	2	Whittington Operating Co.	245		245	
680	2	Zilka Energy Co.	110		110	
219	2	Zinn Petroleum Co.	300		300	
EDS 2 Subtotal				1,163		995
655	3	Bay Operating Co., Inc.	15			
195	3	Bristol Resources Corp.	16			
197	3	Bristol Resources Corp.	32			
214	3	Brown, George R. Partnership	22			
792	3	Corpus Christi Leaseholds, Inc.	4			
202	3	Fort Worth Oil and Gas, Inc.	84		84	
249	3	Killam Oil Co.	3,755		3,755	
238	3	Merrico Resources, Inc.	34			
206	3	Midcon Offshore, Inc.	10			
577	3	Paton Oil Corp.	682		682	
242	3	PI Energy Inc.	600		600	
4	3	PI Energy Inc.	75			
282	3	Redfish Bay Operating Corp.	110		110	
613	3	Redfish Bay Operating Corp.	600		600	
685	3	SNR Oilfield Services, Inc.	600		600	
177	3	Texas Petroleum Co.	1,500		1,500	
189	3	Tierra Mineral Development	2,045		2,045	
201	3	Tierra Mineral Development	1			
EDS 3 Subtotal				10,185		9,976
693	4	Brymer Contracting Co.	436		436	
628	4	Convest Energy Corp.	15			
264	4	Live Oak Reserves, Inc.	775		775	
207	4	Miresco, Inc.	1,033		1,033	
276	4	Pearl, Bill H. Production, Inc.	375		375	
EDS 4 Subtotal				2,634		2,619
747	5	Cavalla Energy Exploration Co.	43			
708	5	Corpus Christi Oil & Gas Co.	8			
14	5	PI Energy, Inc.	20			
20	5	Texaco Exploration and Production Inc.	275		275	
EDS 5 Subtotal				346		275
19 A	6	Apache Corp.	440		440	
19 B	6	Apache Corp.	685		685	
19 C	6	Apache Corp.	560		560	
590 A	6	BKN Oil & Gas, Inc.	32			

Exhibit 3–3. Texas Outfalls Used for Watershed Loadings Analyses Sorted by EDS (Continued)

Permit No.	EDS No.	Operator	Volume (bpd) Current BPT		Volume (bpd) Gas Flotation (BAT)	
590 B	6	BKN Oil & Gas, Inc.	775		775	
590 C	6	BKN Oil & Gas, Inc.	13			
590 D	6	BKN Oil & Gas, Inc.	375		375	
590 E	6	BKN Oil & Gas, Inc.	35			
590 F	6	BKN Oil & Gas, Inc.	40			
590 G	6	BKN Oil & Gas, Inc.	68			
590 H	6	BKN Oil & Gas, Inc.	1,200		1,200	
590 I	6	BKN Oil & Gas, Inc.	86		86	
590 J	6	BKN Oil & Gas, Inc.	43			
590 K	6	BKN Oil & Gas, Inc.	50			
673	6	BWS Vacuum Sevice, Inc.	130		130	
723 B	6	Corpus Christi Oil & Gas Co.	15			
13	6	Ensenjay Petroleum Corp.	1,193		1,193	
26	6	Exxon Corp. – Houston	7,495		7,495	
739	6	Graham Royalty, Ltd.	330		330	
885	6	Houston Oil & Minerals Corp.	168		168	
580	6	Lundy Vacuum Service, Inc.	100		100	
1	6	Neumin Production Co.	88		88	
85	6	Texaco Producing Co.	112		112	
552	6	Wilson Hydrocarbon, Inc.	60			
EDS 6 Subtotal				14,093		13,737
663	7	Amoco Production Co.	15			
152	7	Keplinger Operating Co.	80		80	
EDS 7 Subtotal				95		80
163	8	Ace Productions	450		450	
136	8	American Exploration Co.	4,476		4,476	
666	8	American Exploration Co.	335		335	
684	8	Brandes Petroleum Inc.	250		250	
60	8	Cedar Point Oil Co.	1,200		1,200	
675	8	Chain Oil & Gas, Inc.	210		210	
857	8	Claron Corp.	175		175	
904	8	Coastal Oil & Gas Corp.	4,839		4,839	
905	8	Coastal Oil & Gas Corp.	74			
64	8	Coastal Oil & Gas Corp.	40			
616	8	Crest Resources & Exploration	400		400	
694	8	Crest Resources & Exploration	180		180	
710	8	Dan J. Harrison III & F.H. Bruce	150		150	
637	8	Denovo Oil & Gas, Inc.	652		652	
649	8	Dynamic Production, Inc.	80		80	
104	8	Ebb Tide Oil Co.	55			
71	8	Ebb Tide Oil Co.	4			
80	8	Exxon Corp.	1,948		1,948	
81	8	Exxon Co. U.S.A.	888		888	
635	8	Gulf Vacuum Service	1,290		1,290	
134	8	Headington Oil Co.	400		400	
753	8	Houston Oil Production Enterprises, Inc.	29			
632	8	Kansas Oil & Gas Co.	904		904	

Exhibit 3–3. Texas Outfalls Used for Watershed Loadings Analyses Sorted by EDS (Continued)

Permit No.	EDS No.	Operator	Volume (bpd) Current BPT		Volume (bpd) Gas Flotation (BAT)	
587	8	Linda Production, Inc.	80		80	
659	8	Lone Oak Disposal Co.	248		248	
111	8	Marshall Petroleum, Inc.	10			
119	8	M.K. McDaniel	44			
645	8	Oil Lease Operating Co.	10			
789	8	Pax Petroleum Corp.	350		350	
167	8	Petro Vest, Inc.	400		400	
166	8	Petro Vest, Inc.	100		100	
822	8	Poynor Corp.	1,000		1,000	
595	8	Poynor Corp.	72			
744	8	Scana Exploration Co.	1,200		1,200	
127	8	Shelton, Charles H.	420		420	
132	8	Shelton, Charles H.	154		154	
124 A	8	S&S Energy, Inc.	404		404	
124 B	8	S&S Energy, Inc.	379		379	
674	8	TD Operating Co.	200		200	
854	8	Texana Operating Co.	185		185	
165	8	Unocal	144		144	
47	8	United Texas Corp. (A)	150		150	
EDS 8 Subtotal				24,579		24,241
105 A	9	Brown, Clifford L., Jr.	1,300		1,300	
105 B	9	Brown, Clifford L., Jr.	90		90	
105 C	9	Brown, Clifford L., Jr.	130		130	
105 D	9	Brown, Clifford L., Jr.	430		430	
105 E	9	Brown, Clifford L., Jr.	170		170	
105 G	9	Brown, Clifford L., Jr.	250		250	
8	9	Brown, Clifford L., Jr.	25			
90	9	Brown, George R., Parnership	3,670		3,670	
113	9	Brown, George R., Parnership	3,000		3,000	
89	9	Goodrich Operating Co., Inc.	137		137	
752	9	Houston Oil Production Enterprises, Inc.	10			
102	9	Karbuhn Oil Co.	46			
122	9	Kilmarnock Oil Co.	200		200	
672	9	King Oil	120		120	
68 A	9	Orange Petroleum Co.	2,900		2,900	
68 B	9	Orange Petroleum Co.	696		696	
68 D	9	Orange Petroleum Co.	151		151	
68 E	9	Orange Petroleum Co.	2,012		2,012	
156	9	Texaco Exploration and Production Inc.	2,746		2,746	
157	9	Texaco Exploration and Production Inc.	479		479	
155	9	Texaco, Inc.	1,660		1,660	
170	9	Westland Oil Development Corp.	1			
EDS 9 Subtotal				20,223		20,141
Facility Count			127		86	
Total Texas Volume (bpd)			73,318		72,064	
Total Texas Volume (bpy)			26,761,070		26,303,360	
Average Texas Discharge Rate (bpd)			577		838	

Exhibit 3–4. Louisiana Outfalls Used for Watershed Loadings Analyses Sorted by EDS

Permit No.	EDS	Operator	Volume (bpd) Current BPT		Volume (bpd) Gas Flotation (BAT)	
3040 001	10	Alliance Operating Corp.	1,678		1,678	
3650 001	10	Alltex Exploration, Inc.	465		465	
3853 001	10	Cliffs Oil & Gas Co.	245		245	
2909 001	10	WRT Energy Corp.	3,252		3,252	
2118 003	10	W.W.F. Oil Corp.	370		370	
2118 002	10	W.W.F. Oil Corp.	370		370	
2118 001	10	W.W.F. Oil Corp.	370		370	
EDS #10 Subtotal				6,750		6,750
3408 001	11	Amerada Hess Corp.	3,662		3,662	
3074 001	11	Cashco Oil Co.	72		72	
2956 000	11	Japex (U.S.) Corp.	13			
3223 001	11	Pel–Tex Oil Co.	186		186	
2838 001	11	Petro Corp.	1,500		1,500	
2626 001	11	Samedan Oil Corp.	100		100	
2971 002	11	Texaco, Inc.	2,650		2,650	
2971 001–2	11	Texaco, Inc.	2,650		2,650	
2882 002	11	Texaco, Inc.	747		747	
2882 001	11	Texaco, Inc.	747		747	
2825 001–2	11	Texaco, Inc.	666		666	
2825 002–2	11	Texaco, Inc.	666		666	
2825 003–2	11	Texaco, Inc.	666		666	
2970 001	11	Texaco, Inc.	500		500	
EDS #11 Subtotal				14,826		14,813
2184 001	12	Ashlawn Energy, Inc.	3,143		3,143	
2184 002	12	Ashlawn Energy, Inc.	3,143		3,143	
2184 003	12	Ashlawn Energy, Inc.	3,143		3,143	
3795 001	12	Atlas Production Services, Inc.	152		152	
3795 002	12	Atlas Production Services, Inc.	152		152	
2858 001	12	BKE–A, LLC	1			
3686 001	12	Bois d'Arc Operating Corp.	925		925	
3870 001	12	Bois d'Arc Operating Corp.	1,010		1,010	
3086 001	12	Burk Royalty Co.	450		450	
1901 001–2	12	Callon Offshore Production, Inc.	15,100		15,100	
1901 001–3a	12	Callon Offshore Production, Inc.	15,100		15,100	
1901 002–2	12	Callon Offshore Production, Inc.	15,100		15,100	
1901 002–3	12	Callon Offshore Production, Inc.	15,100		15,100	
1934 001–1	12	Callon Offshore Production, Inc.	14,443		14,443	
2142 001–1	12	Callon Offshore Production, Inc.	12,076		12,076	
2672 001–2	12	Callon Offshore Production, Inc.	9,175		9,175	
2859 001	12	Callon Offshore Production, Inc.	11,290		11,290	
2860 003	12	Callon Offshore Production, Inc.	7,120		7,120	
2699 001	12	Carl Oil & Gas Co.	30			
1857 001	12	Chevron U.S.A., Inc.	2,073		2,073	
1857 003	12	Chevron U.S.A., Inc.	2,073		2,073	
1857 004	12	Chevron U.S.A., Inc.	2,073		2,073	
1857 005	12	Chevron U.S.A., Inc.	2,073		2,073	
1857 006	12	Chevron U.S.A., Inc.	2,073		2,073	
1857 008	12	Chevron U.S.A., Inc.	2,073		2,073	
1857 009	12	Chevron U.S.A., Inc.	2,073		2,073	
1857 010	12	Chevron U.S.A., Inc.	2,073		2,073	

Exhibit 3–4. Louisiana Outfalls Used for Watershed Loadings Analyses Sorted by EDS (Continued)

Permit No.	EDS	Operator	Volume (bpd) Current BPT		Volume (bpd) Gas Flotation (BAT)	
1857 011	12	Chevron U.S.A., Inc.	2,073		2,073	
1861 001	12	Chevron U.S.A., Inc.	4,600		4,600	
1863 001	12	Chevron U.S.A., Inc.	27,856		27,856	
1896 001	12	Chevron U.S.A., Inc.	35,652		35,652	
2945 001	12	Claron Corp.	15			
3038 001	12	CXY Energy, Inc.	500		500	
3067 000	12	Denovo Oil and Gas, Inc.	200		200	
3459 000	12	Desco Oil Co.	34			
3133 001	12	DKM Resources, Inc.	22			
2185 001	12	Energy Development Corp.	700		700	
2785 001	12	Energy Development Corp.	250		250	
2779 001	12	Graham Royalty, Ltd.	950		950	
4029 001	12	Hilcorp Energy Co.	3,522		3,522	
4467 001	12	Houma Production Co.	400		400	
2368 001	12	Hunt Petroleum Co.	1,125		1,125	
2368 002	12	Hunt Petroleum Co.	1,125		1,125	
2368 003	12	Hunt Petroleum Co.	1,125		1,125	
2368 005	12	Hunt Petroleum Co.	1,125		1,125	
2368 006	12	Hunt Petroleum Co.	1,125		1,125	
2704 001	12	Hunt Petroleum Co.	75		75	
3008 001	12	Hunt Petroleum Co.	266		266	
3029 001	12	James A. Whitson, Jr.	300		300	
3081 001	12	Konantz, Inc.	613		613	
2408 001	12	Linder Oil Co.	20			
2710 001	12	Linder Oil Co.	904		904	
1853 001	12	LLECO Holdings, Inc.	324		324	
3746 001	12	Marblehead Energy Corp.	1,250		1,250	
2164 001–1	12	Oryx Energy Co.	150		150	
3407 001	12	Pennzoil Exploration & Production Co.	6,300		6,300	
2227 001	12	Quintana	600		600	
2299 001	12	Quintana	2			
2071 001	12	Shell	144,000		144,000	
2084 001	12	Texaco, Inc.	1,716		1,716	
2084 003–1	12	Texaco, Inc.	1,716		1,716	
2084 005	12	Texaco, Inc.	1,716		1,716	
2084 012	12	Texaco, Inc.	1,716		1,716	
2084 015	12	Texaco, Inc.	1,716		1,716	
2084 016	12	Texaco, Inc.	1,716		1,716	
2816 011	12	Texaco, Inc.	291		291	
3032 001	12	Texoil Co.	939		939	
2547 001	12	Torch Operating Co.	109		109	
2708 001	12	Torch Operating Co.	278		278	
1950 001	12	Warren Petroleum Co.	1,680		1,680	
2138 001	12	Whiting Petroleum Co.	21			
2138 002	12	Whiting Petroleum Co.	21			
3039 001	12	Wichita River Oil Corp.	270		270	
EDS #12 Subtotal				394,343		394,177
Facility Count			94		84	
Total Louisiana Volume (bpd)			415,919		415,740	
Total Louisiana Volume (bpy)			151,810,581		151,745,246	
Average Louisiana Discharge Rate (bpd)			4,425		4,949	

Exhibit 3-5. Pollutants Included in the EPA ORD Report

1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dimethyl Hydrazine
1,2,4-Trichlorobenzene
1,2,4-Trimethylbenzene
1,2-Butylene Oxide
1,2-Dibromoethane
1,2-Dichlorobenzene
1,2-Dichloroethane
1,2-Dichloroethylene
1,2-Dichloropropane
1,3-Butadiene
1,3-Dichlorobenzene
1,3-Dichloropropylene
1,4-Dichlorobenzene
1,4-Dioxane
2,4-D
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Ethoxyethanol
2-Methyloxyethanol
2-Nitropropane
4,4'-Isopropylidenediphenol
4,4'-Methylenebis(2-Chloraniline)
4,4'-Methylenedianiline
4,6-Dinitro-o-cresol
4-Nitrophenol
Acetaldehyde
Acetone
Acetonitrile
Acrolein
Acrylamide
Acrylic Acid
Acrylonitrile
Aluminum
Aluminum Oxide
Ammonia
Ammonium Nitrate
Ammonium Sulfate
Aniline
Anthracene
Antimony
Arsenic
Asbestos
Barium
Benzene
Benzoyl Chloride
Benzoyl Peroxide
Benzyl Chloride
Bis(2-Chloro-1-Methylethyl) Ether
Bis(2-Chloroethyl) Ether
Bromoform
Bromoethane
Butyl Acrylate
Butyl Benzyl Phthalate
Butylaldehyde
Cadmium
Captan
Carbaryl
Carbon Disulfide
Carbon Tetrachloride
Carbonyl Sulfide
Catechol
Chloramben
Chlorodane
Chlorine
Chlorine Dioxide
Chloroacetic Acid
Chlorobenze
Chloroethane
Chloroform
Chloromethane
Chlorophenols
Chloroprene
Chlorothalonil
Chromium
Cobalt
Copper
Cresol
Cumene
Cumene Hydroperoxide
Cupferron
Cyclohexane
Decabromodiphenyl Oxide
Di(2-Ethylhexyl) Phthalate
Diaminotoluene
Dibenzofuran
Dibutyl Phthalate
Dichlorobenzene
Dichloromethane
Dichlorovos
Diiethanolamine
Diethyl Phthalate
Diethyl Sulfate
Dimethyl Phthalate
Epichlorohydrin
Ethyl Acrylate
Ethyl Chloroformate
Ethylbenzene
Ethylene
Ethylene Glycol
Ethylene Oxide
Formaldehyde
Freon 113
Glycol Ethers
Hexachloro-1,3-Butadiene
Hexachlorobenzene
Hexachlorocyclopentadiene
Hexachloroethane
Hydrazine
Hydrazine Sulfate
Hydrochloric Acid
Hydrogen Cyanide
Hydrogen Flouride
Hydroquinone
Isobutyraldehyde
Isopropyl Alcohol
Lead
Lindane
m-Xylene
Maleic Anhydride
Manganese
Mercury
Methanol
Methyl Acrylate
Methyl Ethyl Ketone
Methyl Iodide
Methyl Isobutyl Ketone
Methyl Isocyanate
Methyl Methacrylate
Methyl tert-Butyl Ether
Mehtylenebis(Phenylisocyanate)
Molybdenum Trioxide
N,N-Dimethylaniline
n-Butyl Alcohol
n-Dioctyl Phthalate
Naphthalane
Nickel
Nitric Acid
Nitrilotriacetic Acid
Nitrobenzene
Nitroglycerin
o-Anisidine
o-Cresol
o-Toluidine
o-Xylene
p-Cresol
p-Phenylenediamine
p-Xylene
Parathion
Pentachlorophenol
Phenol
Phosgene
Phosphoric Acid
Phosphorus
Phthalic Anhydride
Picric Acid
Polychlorinated Biphenyls
Propionaldehyde
Propoxur
Propylene
Propylene Oxide
Pyridine
Quinoline
Quionone
sec-Butyl Alcohol
Silver
Styrene
Sulfuric Acid
Terephthalic Acid
tert-Butyl Alcohol
Tetrachloroethylene
Titanium Tetrachloride
Toluene
Toluene-2,4-Diisocyanate
Toluene-2,6-Diisocyanate
Trichloroethylene
Urethane
Vanadium
Vinyl Acetate
Vinyl Chloride
Vinylidene Chloride
Xylene
Zinc
Zineb

To develop the estimates of relative watershed mass loadings of produced water pollutants in this WQBA, all of the pollutants identified in the ORD report are included in pollutant loadings for other industrial and municipal point sources. However, for produced water loadings estimates, the loadings are calculated both using all of the produced water pollutants and using only produced water pollutants that are included in the ORD report.

The relative contribution of produced water toxic unit loadings also are analyzed in this WQBA using the same methodology as the ORD report. Mass loadings of the 34 individual produced water pollutants found in the ORD report are divided by their respective toxicity criterion to obtain toxic units (TU) per year. These toxicity criteria (Exhibit 3-6), developed according to a scheme defined in the ORD report, are based on demonstrated or estimated criterion continuous concentrations (ccc) from federal ambient water quality criteria. A toxicity index (TI) is obtained by dividing the total TUs for each EDS by the EDS volume (acre feet). An adjusted TI is obtained by dividing the final TI by 1,000. Although mass loadings are developed for produced water pollutants not on the list of pollutants identified in the ORD report, because of the potential time and effort required to develop toxic criteria for these pollutants, no toxicity criteria or toxic unit loadings are developed for the 32 produced water pollutants not included in the ORD report.

Exhibit 3-7 presents the mass and toxic unit loadings developed in the ORD report. These loadings are the industrial and municipal loadings to EDSs in Texas and Louisiana to which produced water loadings are compared.

3.2 Current BPT Produced Water Effluent

3.2.1 Mass Loadings

For 34 produced water pollutants identified in the ORD report, projected mass loadings for Texas current BPT produced water effluent are 1.25 million pounds (Exhibit 3-8), ranging from 1,621 to 345,101 pounds on an EDS-specific basis. Projected pollutant mass loadings for Louisiana current BPT produced water effluent are 7.10 million pounds, ranging from 115,187 to 6.73 million pounds on an EDS-specific basis (Exhibit 3-9).

Mass loadings of produced water pollutants not included in the ORD report amounted to 2.42 million pounds annually in Texas (Exhibit 3-8) and 13.7 million pounds annually in Louisiana (Exhibit 3-9), nearly double the loadings of produced water pollutants included in the ORD report.

3.2.2 Toxic Unit Loadings

Projected toxic unit loadings for current BPT produced water effluent pollutants amount to a total adjusted TI of 11,721 in Texas (Exhibit 3-10), ranging from 92 to 7,002 on an EDS-specific basis. Projected toxic unit loadings for current BPT produced water effluent pollutants amount to a total adjusted TI of 6,358 in Louisiana, ranging from 120 to 4,891 on an EDS-specific basis (Exhibit 3-11).

Exhibit 3-6. Toxic Criteria for Produced Water Effluent Pollutants

Chemical	Toxic Criteria (ppb)	Comments[a]
2-Butanone	19,500	LC50 (Brine shrimp)
2,4-Dimethylphenol	21.2	Fresh water c.c.c./FAWQC
Acetone	41,000	LC50 (Bay Shrimp)
Aluminum	87.0	Freshwater c.c.c./FAWQC
Ammonia	340	Salt water c.c.c./FAWQC
Antimony	160	Salt water c.c.c./FAWQC
Arsenic	36.0	Salt water c.c.c./FAWQC
Barium	2,600	EC50 (Duckweed)
Benzene	109	Salt water c.c.c./FAWQC
Bis(2-ethylhexyl)phthalate	3,000	LC50 (Harpacticoid copepod)
Cadmium	9.30	Salt water c.c.c./FAWQC
Carbon Disulfide	2,100	EC50 (Green algae)
Chloromethane	2,700	LC50 (Inland silverside)
Chromium	50.0	Salt water c.c.c./FAWQC
Cobalt	100	LC50 (Sticklebacks)
Copper	2.90	Salt water c.c.c./FAWQC
Di-n-butylphthalate	6.00	LC50 (Dinoflagellate)
Ethylbenzene	4.30	Salt water c.c.c./FAWQC
Lead	5.60	Salt water c.c.c./FAWQC
Manganese	3,100	EC50 (Duckweed)
Methylene chloride	4,830	"No effect" (30 day chronic level)
Molybdenum	540	Molybdenum trioxide LC50; USFWS, 1985
Naphthalene	23.5	Salt water c.c.c./FAWQC
Nickel	8.30	Salt water c.c.c./FAWQC

[a] c.c.c: criterion continuous concentration
FAWQC: Federal Ambient Water Quality Criteria
Where criteria are not available, the lowest observed chronic value divided by a factor of 10 was used and the test organism reported.

Exhibit 3-6. Toxic Criteria for Produced Water Effluent Pollutants (Continued)

Chemical	Toxic Criteria (ppb)	Comments[a]
o-Cresol	0.300	Fresh water c.c.c./FAWQC
o-Xylene	41.0	LC50 (Sea urchin)
p-Cresol	50.0	Fresh water c.c.c./FAWQC
p-Xylene	20.0	LC50 (Bay shrimp)
Phenol	58.0	Salt water c.c.c./FAWQC
Selenium	71.0	Salt water c.c.c./FAWQC
Silver	0.230	Salt water c.c.c./FAWQC
Toluene	37.0	Salt water c.c.c./FAWQC
Vanadium	180	EC50 (Dinoflagellate)
Vinyl acetate	450	LC50 (Brine shrimp)
Zinc	86.0	Salt water c.c.c./FAWQC

Source: EPA, 1994b.

Exhibit 3–7. Total Industrial and Municipal Loadings for the Gulf of Mexico by Estuarine Drainage System

EDS No.	EDS Name	Mass Loadings (lb/yr) [a] Industrial Sources	Municipal Sources [c]	Total Sources	Toxic Indices (TU/EDS Vol) [a, b] Industrial Sources	Municipal Sources [c]	Total Sources
2	Laguna Madre	0	0	0	0	0	0
3	Corpus Christi Bay	796,573	237	796,810	176.04	0	176.0
4	Aransas Bay	0	0	0	0	0	0
5	San Antonio Bay	11,332	0	11,332	0.99	0	0.99
6	Matagorda Bay	7,731	0	7,731	0.04	0	0.04
7	Brazos River	886,005	0	886,005	387.63	0	387.6
8	Galveston Bay	2,068,545	1,170,582	3,239,127	62.60	15.01	77.6
9	Sabine Lake	1,149,277	0	1,149,277	172.24	0	172.2
10	Calcasieu Lake	3,180,119	98	3,180,217	939.81	0	939.8
11	Atchafalaya/Vermilion Bays	563,160	0	563,160	2.85	0	2.85
12	Mississippi Delta Region	1,352,090	13,167	1,365,257	0.36	0	0.36
13	Mississippi Sound	610,181	904	611,085	0.46	0.02	0.48
13a	Lake Pontchartrain	1,000	0	1,000	0	0	0
13b	Lake Borgne	1,080	0	1,080	0.01	0	0.01
14	Mobile Bay	843,317	1,307	844,624	5.39	0.02	5.41
15	Perdido Bay	224,500	0	224,500	3.83	0	3.83
16	Escambia Bay	343,750	1,119	344,869	18.29	0.02	18.3
17	Choctawhatchee Bay	0	0	0	0	0	0
18	St Andrew Bay	0	103,204	103,204	0	0.08	0.08
19	Apalachicola Bay	0	74,648	74,648	0	0.01	0.01
20	Apalachee Bay	22,927	0	22,927	0.04	0	0.04
21	Suwannee River	0	0	0	0	0	
22	Withlacoochee Bay	5,767	0	5,767	0.76	0	0.76
23	Tampa Bay	3,433	32,907	36,340	0.01	0.04	0.05
24	Charlotte Harbour	0	0	0	0	0	0
25	Ten Thousand Islands	0	0	0	0	0	0
Gulf of Mexico Total (lb/yr)		12,070,787	1,398,173	13,468,960	1,771.35	15.20	1,786.55
Louisiana Subtotal (lb/yr)		5,707,630	14,169	5,721,799	943.49	0.02	943.51
Texas Subtotal (lb/yr)		4,919,463	1,170,819	6,090,282	799.54	15.01	814.55
Louisiana and Texas Total (lb/yr)		10,627,093	1,184,988	11,812,081	1,743.03	15.03	1,758.06

[a] Source: EPA, 1994b.
[b] TU/EDS Volume derived as: 10^{-3} x mass load/toxic criterion/EDS volume.
[c] Reduced loadings based on influent loadings and engineering estimates of POTW treatment efficiencies.

Exhibit 3–8. Texas Produced Water Mass Loadings – Current BPT Effluent

Pollutant	Mean Conc. (ug/l)	Mass Loading by Watershed (lbs/yr)								Total Loading (lbs/yr)	% of Total Loading	Cum'ltive % of Loading
		EDS #2	EDS #3	EDS #4	EDS #5	EDS #6	EDS #7	EDS #8	EDS #9			
Pollutants identified in the EPA ORD Report:												
Ammonia, as Nitrogen	65,773	9,787	85,709	22,166	2,912	118,595	799	206,837	170,180	616,984	49.3%	49.3%
Barium	52,573	7,823	68,508	17,717	2,327	94,794	639	165,327	136,027	493,162	39.4%	88.7%
Benzene	4,285	638	5,584	1,444	190	7,726	52.1	13,475	11,087	40,194	3.21%	91.9%
Toluene	3,370	501	4,392	1,136	149	6,077	41.0	10,599	8,720	31,615	2.53%	94.5%
Manganese	1,301	194	1,695	438	57.6	2,346	15.8	4,092	3,367	12,205	0.98%	95.4%
Aluminum	1,072	160	1,397	361	47.5	1,934	13.0	3,373	2,775	10,060	0.80%	96.2%
Acetone	913	136	1,190	308	40.4	1,646	11.1	2,871	2,362	8,564	0.68%	96.9%
Phenol	553	82.3	721	186	24.5	998	6.72	1,740	1,432	5,190	0.41%	97.3%
Lead	515	76.7	671	174	22.8	929	6.26	1,620	1,333	4,833	0.39%	97.7%
Zinc	329	49.0	429	111	14.6	594	4.00	1,035	852	3,088	0.25%	98.0%
Silver	252	37.4	328	84.8	11.1	454	3.06	791	651	2,360	0.19%	98.2%
Selenium	250	37.1	325	84.1	11.0	450	3.03	785	646	2,341	0.19%	98.4%
Xylenes	222	33.0	289	74.8	9.83	400	2.70	698	575	2,083	0.17%	98.5%
Copper	180	26.8	235	60.8	7.98	325	2.19	567	467	1,691	0.14%	98.7%
Methylene Chloride	170	25.3	221	57.2	7.51	306	2.06	534	439	1,592	0.13%	98.8%
Antimony	166	24.6	216	55.8	7.33	298	2.01	520	428	1,553	0.12%	98.9%
p–Cresol	149	22.1	194	50.1	6.58	268	1.81	467	384	1,393	0.11%	99.0%
Naphthalene	144	21.5	188	48.7	6.40	261	1.76	454	374	1,355	0.11%	99.1%
Chromium	128	19.0	166	43.0	5.65	230	1.55	401	330	1,197	0.10%	99.2%
2–Butanone	122	18.2	159	41.1	5.40	220	1.48	384	316	1,144	0.09%	99.3%
o–Cresol	121	18.1	158	40.9	5.37	219	1.48	382	314	1,139	0.09%	99.4%
2,4–Dimethylphenol	117	17.4	152	39.3	5.16	210	1.42	367	302	1,094	0.09%	99.5%
Ethylbenzene	115	17.1	150	38.8	5.09	207	1.40	362	298	1,079	0.09%	99.6%
Nickel	109	16.2	141	36.6	4.81	196	1.32	341	281	1,018	0.08%	99.7%
Vanadium	96.6	14.4	126	32.5	4.28	174	1.17	304	250	906	0.07%	99.7%
Molybdenum	86.9	12.9	113	29.3	3.85	157	1.06	273	225	815	0.07%	99.8%
Cobalt	83.6	12.4	109	28.2	3.70	151	1.02	263	216	784	0.06%	99.9%
Bis(2–ethylhexyl)phthalate	46.0	6.85	60.0	15.5	2.04	83.0	0.56	145	119	432	0.03%	99.9%
Di–n–butylphthalate	36.6	5.45	47.7	12.3	1.62	66.0	0.45	115	94.8	344	0.03%	99.9%
Vinyl Acetate	29.4	4.38	38.4	9.92	1.30	53.1	0.36	92.5	76.1	276	0.02%	100%
Chloromethane	28.6	4.25	37.3	9.63	1.27	51.6	0.35	89.9	74.0	268	0.02%	100%
Cadmium	22.8	3.39	29.7	7.68	1.01	41.1	0.28	71.7	59.0	214	0.02%	100%
Arsenic	10.8	1.61	14.1	3.64	0.48	19.5	0.13	33.9	27.9	101	0.01%	100%
Carbon Disulfide	8.48	1.26	11.1	2.86	0.38	15.3	0.10	26.7	21.9	79.5	0.01%	100%
Total for 34 ORD Pollutants (lbs/yr)		19,846	173,805	44,949	5,904	240,494	1,621	419,436	345,101	1,251,157		

Exhibit 3–8. Texas Produced Water Mass Loadings – Current BPT Effluent (Continued)

Pollutant	Mean Conc. (ug/l)	Mass Loadings by Watershed (lbs/yr)								Total Loading (lbs/yr)	% of ORD Total Loading	Cum'ltive % of Loading
		EDS #2	EDS #3	EDS #4	EDS #5	EDS #6	EDS #7	EDS #8	EDS #9			
Pollutants not identified in the EPA ORD Report:												
Chlorides	65,111,000	9,688,377	84,846,189	21,942,549	2,882,355	117,401,801	791,398	204,755,472	168,467,794	610,775,936	48817%	
Calcium	2,501,000	372,143	3,259,055	842,842	110,715	4,509,559	30,399	7,864,930	6,471,072	23,460,715	1875%	
Magnesium	615,699	91,615	802,318	207,492	27,256	1,110,168	7,484	1,936,197	1,593,056	5,775,585	462%	
Strontium	205,500	30,578	267,787	69,254	9,097	370,538	2,498	646,239	531,709	1,927,700	154%	
Boron	20,244	3,012	26,379	6,822	896	36,501	246	63,660	52,378	189,896	15.2%	
Iron	15,492	2,305	20,187	5,221	686	27,933	188	48,717	40,083	145,321	11.6%	
Sulfur	9,683	1,441	12,618	3,263	429	17,460	118	30,451	25,054	90,833	7.26%	
Benzoic Acid	3,813	567	4,968	1,285	169	6,875	46.3	11,990	9,865	35,765	2.86%	
Hexanoic Acid	790	118	1,029	266	35.0	1,424	9.60	2,484	2,043	7,408	0.59%	
Tin	305	45.4	397	103	13.5	550	3.71	959	789	2,861	0.23%	
Trichlorofluoromethane	294	43.8	383	99.1	13.0	530	3.58	925	761	2,759	0.22%	
n–Hexadecane	283	42.1	368	95.3	12.5	510	3.44	889	732	2,652	0.21%	
n–Dodecane	225	33.5	294	76.0	9.98	407	2.74	709	583	2,115	0.17%	
Thallium	180	26.8	235	60.7	7.97	325	2.19	566	466	1,689	0.13%	
n–Decane	139	20.7	181	46.9	6.15	251	1.69	437	360	1,304	0.10%	
n–Tetradecane	119	17.7	155	40.2	5.28	215	1.45	375	308	1,118	0.09%	
n–Octadecane	82.9	12.3	108	27.9	3.67	149	1.01	261	214	778	0.06%	
1,2:3,4–Diepoxybutane	71.1	10.6	92.7	24.0	3.15	128	0.86	224	184	667	0.05%	
n–Eicosane	68.0	10.1	88.6	22.9	3.01	123	0.83	214	176	638	0.05%	
2–Methylnaphthalene	67.2	10.0	87.6	22.7	2.98	121	0.82	211	174	631	0.05%	
Benzyl Alcohol	49.5	7.36	64.5	16.7	2.19	89.2	0.60	156	128	464	0.04%	
n–Tetracosane	38.2	5.69	49.8	12.9	1.69	68.9	0.46	120	98.9	359	0.03%	
n–Docosane	38.0	5.66	49.5	12.8	1.68	68.5	0.46	120	98.3	357	0.03%	
n–Hexosane	36.1	5.37	47.0	12.2	1.60	65.1	0.44	114	93.4	339	0.03%	
2–Hexanone	35.8	5.32	46.6	12.1	1.58	64.5	0.43	113	92.6	336	0.03%	
n–Octacosane	35.2	5.23	45.8	11.8	1.56	63.4	0.43	111	91.0	330	0.03%	
n–Triacontane	35.0	5.21	45.6	11.8	1.55	63.2	0.43	110	90.6	329	0.03%	
Titanium	32.4	4.82	42.2	10.9	1.43	58.4	0.39	102	83.8	304	0.02%	
Yttrium	25.0	3.73	32.6	8.44	1.11	45.1	0.30	78.7	64.8	235	0.02%	
Beryllium	5.56	0.83	7.24	1.87	0.25	10.0	0.07	17.5	14.4	52.1	0.004%	
Radium 228	0.0002	0.00003	0.0003	0.0001	0.00001	0.0004	0.000003	0.0007	0.0006	0.0021	0.0000%	
Radium 226	0.0002	0.00003	0.0002	0.0001	0.000008	0.0003	0.000002	0.0005	0.0004	0.0016	0.0000%	
Total for Non ORD Pollutants (lb/yr) [a]		38,343	335,792	86,841	11,407	464,635	3,132	810,351	666,737	2,417,238		
Total for All Pollutants (lb/yr)		10,210,325	89,417,159	23,124,673	3,037,637	123,726,658	834,033	215,786,386	177,543,760	643,680,631		

[a] Total excludes the three common ions Cl^-, Ca^{++}, Mg^{++}.

Table 3–9. Louisiana Produced Water Mass Loadings – Current BPT Effluent

Pollutant	Mean Conc. (ug/l)	Mass Loadings by Watershed (lbs/yr) EDS #10	EDS #11	EDS #12	Total Loading (lbs/yr)	% of Total Loading	Cum'ltive % of Loading
Pollutants identified in the EPA ORD Report:							
Ammonia	65,773	56,802	124,763	3,318,473	3,500,038	49.3%	49.3%
Barium	52,573	45,403	99,724	2,652,488	2,797,615	39.4%	88.7%
Benzene	4,285	3,700	8,128	216,185	228,013	3.21%	91.9%
Toluene	3,370	2,911	6,393	170,043	179,346	2.53%	94.5%
Manganese	1,301	1,124	2,468	65,646	69,238	0.98%	95.4%
Aluminum	1,072	926	2,034	54,108	57,069	0.80%	96.2%
Acetone	913	788	1,732	46,064	48,584	0.68%	96.9%
Phenol	553	478	1,049	27,901	29,427	0.41%	97.3%
Lead	515	445	977	25,997	27,419	0.39%	97.7%
Zinc	329	284	624	16,609	17,517	0.25%	98.0%
Silver	252	217	477	12,693	13,388	0.19%	98.2%
Selenium	250	216	473	12,591	13,280	0.19%	98.4%
Xylenes	222	192	421	11,206	11,819	0.17%	98.5%
Copper	180	156	342	9,098	9,596	0.14%	98.7%
Methylene Chloride	170	147	322	8,563	9,031	0.13%	98.8%
Antimony	166	143	314	8,351	8,807	0.12%	98.9%
p–Cresol	149	128	282	7,495	7,905	0.11%	99.0%
Naphthalene	144	125	274	7,290	7,689	0.11%	99.1%
Chromium	128	110	242	6,439	6,792	0.10%	99.2%
2–Butanone	122	105	231	6,155	6,492	0.09%	99.3%
o–Cresol	121	105	230	6,125	6,460	0.09%	99.4%
2,4–Dimethylphenol	117	101	221	5,885	6,207	0.09%	99.5%
Ethylbenzene	115	99	218	5,805	6,123	0.09%	99.6%
Nickel	109	94	206	5,477	5,776	0.08%	99.7%
Vanadium	96.6	83	183	4,873	5,139	0.07%	99.7%
Molybdenum	86.9	75	165	4,385	4,625	0.07%	99.8%
Cobalt	83.6	72	158	4,216	4,446	0.06%	99.9%
Bis(2–ethylhexyl)phthalate	46.0	40	87	2,323	2,450	0.03%	99.9%
Di–n–butylphthalate	36.6	32	69	1,847	1,948	0.03%	99.9%
Vinyl Acetate	29.4	25	56	1,485	1,566	0.02%	99.9%
Chloromethane	28.6	25	54	1,442	1,521	0.02%	100%
Cadmium	22.8	20	43	1,150	1,213	0.02%	100%
Arsenic	10.8	9.3	20	544	574	0.008%	100%
Carbon Disulfide	8.48	7.3	16	428	451	0.006%	100%
Total for 34 ORD Pollutants (lb/yr)		115,187	253,000	6,729,378	7,097,566		

Exhibit 3–9. Louisiana Produced Water Mass Loadings – Current BPT Effluent (Continued)

Pollutant	Mean Conc. (ug/l)	Mass Loadings by Watershed (lbs/yr) EDS #10	EDS #11	EDS #12	Total Loading (lbs/yr)	% of ORD Tot: Loading	Cum'ltive % of Loading
Pollutants not identified in the EPA ORD Report:							
Chloride	65,111,000	56,230,906	123,507,228	3,285,080,339	3,464,818,473	48817%	
Calcium	2,501,000	2,159,904	4,744,077	126,184,300	133,088,280	1875%	
Magnesium	615,699	531,728	1,167,902	31,064,193	32,763,823	462%	
Strontium	205,500	177,473	389,807	10,368,202	10,935,482	154%	
Boron	20,244	17,483	38,400	1,021,362	1,077,244	15.2%	
Iron	15,492	13,379	29,386	781,612	824,376	11.6%	
Sulfur	9,683	8,363	18,368	488,548	515,278	7.26%	
Benzoic Acid	3,813	3,293	7,232	192,366	202,891	2.86%	
Hexanoic Acid	790	682	1,498	39,846	42,026	0.59%	
Tin	305	263	579	15,390	16,232	0.23%	
Trichlorofluoromethane	294	254	558	14,840	15,652	0.22%	
n–Hexadecane	283	244	536	14,266	15,047	0.21%	
n–Dodecane	225	195	428	11,374	11,997	0.17%	
Thallium	180	155	342	9,084	9,581	0.13%	
n–Decane	139	120	264	7,015	7,398	0.10%	
n–Tetradecane	119	103	226	6,013	6,342	0.09%	
n–Octadecane	82.9	71.6	157	4,182	4,411	0.06%	
1,2:3,4–Diepoxybutane	71.1	61.4	135	3,587	3,784	0.05%	
n–Eicosane	68.0	58.7	129	3,431	3,619	0.05%	
2–Methylnaphthalene	67.2	58.1	128	3,393	3,578	0.05%	
Benzyl Alcohol	49.5	42.7	93.8	2,495	2,632	0.04%	
n–Tetracosane	38.2	33.0	72.5	1,929	2,035	0.03%	
n–Docosane	38.0	32.8	72.1	1,917	2,022	0.03%	
n–Hexosane	36.1	31.2	68.5	1,821	1,921	0.03%	
2–Hexanone	35.8	30.9	67.9	1,805	1,904	0.03%	
n–Octacosane	35.2	30.4	66.7	1,774	1,871	0.03%	
n–Triacontane	35.0	30.3	66.4	1,767	1,864	0.03%	
Titanium	32.4	28.0	61.4	1,634	1,724	0.02%	
Yttrium	25.0	21.6	47.5	1,263	1,332	0.02%	
Beryllium	5.56	4.80	10.5	280	296	0.004%	
Radium 228	0.000228	0.00020	0.00043	0.0115	0.012	0.0000%	
Radium 226	0.000172	0.00015	0.00033	0.0087	0.0092	0.0000%	
Total for Non ORD Pollutants (lb/yr) [a]		222,542	488,798	13,001,200	13,712,541		
Total for All Pollutants (lb/yr)		59,260,267	130,161,006	3,462,059,410	3,651,480,683		

[a] Total excludes the three common ions Cl^-, Ca^{++}, and Mg^{++}.

Exhibit 3–10. Texas Produced Water Toxic Unit Loadings – Current BPT Effluent

Pollutant	Mean Conc. (ug/l)	Toxicity Criterion (ug/l)	Toxic Unit Loadings by Watershed (TU/yr) EDS #2	EDS #3	EDS #4	EDS #5	EDS #6	EDS #7	EDS #8	EDS #9	Total Loading (TU/yr)	% of Total Loading	Cum'ltive % of Loading
Silver	252	0.23	7.38E+10	6.47E+11	1.67E+11	2.20E+10	8.95E+11	6.03E+09	1.56E+12	1.28E+12	4.65E+12	52.2%	52.2%
o–Cresol	121	0.30	2.73E+10	2.39E+11	6.19E+10	8.13E+09	3.31E+11	2.23E+09	5.77E+11	4.75E+11	1.72E+12	19.3%	71.5%
Ammonia, as Nitrogen	65,773	340	1.31E+10	1.14E+11	2.96E+10	3.88E+09	1.58E+11	1.07E+09	2.76E+11	2.27E+11	8.23E+11	9.23%	80.7%
Lead	515	5.6	6.21E+09	5.44E+10	1.41E+10	1.85E+09	7.53E+10	5.07E+08	1.31E+11	1.08E+11	3.92E+11	4.39%	85.1%
Toluene	3,370	37	6.15E+09	5.38E+10	1.39E+10	1.83E+09	7.45E+10	5.02E+08	1.30E+11	1.07E+11	3.88E+11	4.34%	89.4%
Copper	180	2.9	4.20E+09	3.68E+10	9.50E+09	1.25E+09	5.09E+10	3.43E+08	8.87E+10	7.30E+10	2.65E+11	2.97%	92.4%
Benzene	4,285	109	2.65E+09	2.32E+10	6.01E+09	7.89E+08	3.22E+10	2.17E+08	5.61E+10	4.61E+10	1.67E+11	1.87%	94.3%
Ethylbenzene	115	4.3	1.81E+09	1.58E+10	4.09E+09	5.37E+08	2.19E+10	1.48E+08	3.82E+10	3.14E+10	1.14E+11	1.28%	95.5%
Barium	52,573	2,600	1.36E+09	1.20E+10	3.09E+09	4.06E+08	1.65E+10	1.11E+08	2.88E+10	2.37E+10	8.60E+10	0.96%	96.5%
Nickel	109	8.3	8.83E+08	7.73E+09	2.00E+09	2.63E+08	1.07E+10	7.21E+07	1.87E+10	1.53E+10	5.56E+10	0.62%	97.1%
Aluminum	1,072	87	8.32E+08	7.29E+09	1.88E+09	2.48E+08	1.01E+10	6.80E+07	1.76E+10	1.45E+10	5.25E+10	0.59%	97.7%
Phenol	553	58	6.44E+08	5.64E+09	1.46E+09	1.92E+08	7.80E+09	5.26E+07	1.36E+10	1.12E+10	4.06E+10	0.45%	98.2%
Naphthalene	144	23.5	4.15E+08	3.63E+09	9.40E+08	1.23E+08	5.03E+09	3.39E+07	8.77E+09	7.22E+09	2.62E+10	0.29%	98.5%
Di–n–butylphthalate	36.6	6.0	4.12E+08	3.61E+09	9.33E+08	1.23E+08	4.99E+09	3.37E+07	8.71E+09	7.16E+09	2.60E+10	0.29%	98.8%
2,4–Dimethylphenol	117	21.2	3.71E+08	3.25E+09	8.41E+08	1.10E+08	4.50E+09	3.03E+07	7.85E+09	6.46E+09	2.34E+10	0.26%	99.0%
Zinc	329	86	2.58E+08	2.26E+09	5.85E+08	7.69E+07	3.13E+09	2.11E+07	5.46E+09	4.49E+09	1.63E+10	0.18%	99.2%
Selenium	250	71	2.37E+08	2.08E+09	5.37E+08	7.06E+07	2.87E+09	1.94E+07	5.01E+09	4.13E+09	1.50E+10	0.17%	99.4%
p–Cresol	149	50	2.01E+08	1.76E+09	4.54E+08	5.97E+07	2.43E+09	1.64E+07	4.24E+09	3.49E+09	1.26E+10	0.14%	99.5%
Chromium	128	50	1.72E+08	1.51E+09	3.90E+08	5.13E+07	2.09E+09	1.41E+07	3.64E+09	3.00E+09	1.09E+10	0.12%	99.6%
Cadmium	22.8	9.3	1.65E+08	1.45E+09	3.75E+08	4.92E+07	2.00E+09	1.35E+07	3.50E+09	2.88E+09	1.04E+10	0.12%	99.7%
Xylenes	136	74	1.24E+08	1.08E+09	2.80E+08	3.68E+07	1.50E+09	1.01E+07	2.62E+09	2.15E+09	7.80E+09	0.09%	99.8%
Antimony	166	160	6.98E+07	6.11E+08	1.58E+08	2.08E+07	8.46E+08	5.70E+06	1.48E+09	1.21E+09	4.40E+09	0.05%	99.9%
Cobalt	83.6	100	5.64E+07	4.94E+08	1.28E+08	1.68E+07	6.83E+08	4.61E+06	1.19E+09	9.81E+08	3.56E+09	0.04%	99.9%
Vanadium	96.6	180	3.62E+07	3.17E+08	8.20E+07	1.08E+07	4.39E+08	2.96E+06	7.65E+08	6.30E+08	2.28E+09	0.03%	100%
Manganese	1,301	3,100	2.83E+07	2.48E+08	6.42E+07	8.43E+06	3.43E+08	2.31E+06	5.99E+08	4.93E+08	1.79E+09	0.02%	100%
Arsenic	10.8	36	2.02E+07	1.77E+08	4.58E+07	6.02E+06	2.45E+08	1.65E+06	4.28E+08	3.52E+08	1.28E+09	0.01%	100%
Molybdenum	86.9	540	1.09E+07	9.51E+07	2.46E+07	3.23E+06	1.32E+08	8.87E+05	2.30E+08	1.89E+08	6.85E+08	0.008%	100%
Vinyl Acetate	29.4	450	4.41E+06	3.87E+07	1.00E+07	1.31E+06	5.35E+07	3.61E+05	9.33E+07	7.68E+07	2.78E+08	0.003%	100%
Methylene Chloride	170	4,830	2.37E+06	2.08E+07	5.37E+06	7.06E+05	2.87E+07	1.94E+05	5.01E+07	4.12E+07	1.50E+08	0.002%	100%
Acetone	913	41,000	1.50E+06	1.32E+07	3.40E+06	4.47E+05	1.82E+07	1.23E+05	3.18E+07	2.61E+07	9.48E+07	0.001%	100%
Bis(2–ethylhexyl)phthalate	46.0	3,000	1.04E+06	9.07E+06	2.35E+06	3.08E+05	1.26E+07	8.46E+04	2.19E+07	1.80E+07	6.53E+07	0.001%	100%
Chloromethane	28.6	2,700	7.15E+05	6.26E+06	1.62E+06	2.13E+05	8.66E+06	5.84E+04	1.51E+07	1.24E+07	4.51E+07	0.001%	100%
2–Butanone	122	19,500	4.22E+05	3.70E+06	9.56E+05	1.26E+05	5.12E+06	3.45E+04	8.92E+06	7.34E+06	2.66E+07	0.000%	100%
Carbon Disulfide	8.48	2,100	2.73E+05	2.39E+06	6.17E+05	8.11E+04	3.30E+06	2.23E+04	5.76E+06	4.74E+06	1.72E+07	0.000%	100%
Total for 34 ORD Pollutants (TUs/yr)[a]			1.42E+11	1.24E+12	3.21E+11	4.21E+10	1.71E+12	1.16E+10	2.99E+12	2.46E+12	8.92E+12		
EDS Volume (acre feet)			1,281,814	1,097,464	531,428	458,215	2,627,112	15,015	2,196,773	351,433	8,559,254		
Toxicity Indices (TIs = TUs/EDS Vol)			110,409	1,129,326	603,142	91,887	652,790	769,922	1,361,531	7,002,474	11,721,480		
Adjusted Toxicity Indices (TIs/1,000)			110	1,129	603	91.9	653	770	1,362	7,002	11,721		

[a] Calculated as: pollutant concentration * EDS produced water volume/toxicity criterion.

Exhibit 3–11. Louisiana Produced Water Toxic Unit Loadings – Current BPT Effluent

Pollutant	Mean Conc. (ug/l)	Toxicity Criterion (ug/l)	Toxic Unit Loading by Watershed (TU/yr) EDS #10	EDS #11	EDS #12	Total Loading (TU/yr)	% of Total Loading	Cum'ltive % of Loading
Silver	252	0.23	4.28E+11	9.41E+11	2.50E+13	2.64E+13	52.1%	52.1%
o–Cresol	121	0.30	1.59E+11	3.48E+11	9.26E+12	9.77E+12	19.3%	71.4%
Ammonia	65,773	340	7.58E+10	1.66E+11	4.43E+12	4.67E+12	9.22%	80.6%
Lead	515	5.6	3.60E+10	7.92E+10	2.11E+12	2.22E+12	4.39%	85.0%
Toluene	3,370	37	3.57E+10	7.84E+10	2.08E+12	2.20E+12	4.34%	89.4%
Copper	180	2.9	2.44E+10	5.35E+10	1.42E+12	1.50E+12	2.96%	92.3%
Benzene	4,285	109	1.54E+10	3.38E+10	9.00E+11	9.49E+11	1.87%	94.2%
Ethylbenzene	115	4.3	1.05E+10	2.30E+10	6.12E+11	6.46E+11	1.28%	95.5%
Barium	52,573	2,600	7.92E+09	1.74E+10	4.63E+11	4.88E+11	0.96%	96.5%
Nickel	109	8.3	5.12E+09	1.13E+10	2.99E+11	3.16E+11	0.62%	97.1%
Aluminum	1,072	87	4.83E+09	1.06E+10	2.82E+11	2.98E+11	0.59%	97.7%
Phenol	553	58	3.74E+09	8.21E+09	2.18E+11	2.30E+11	0.45%	98.1%
Naphthalene	144	23.5	2.41E+09	5.29E+09	1.41E+11	1.48E+11	0.29%	98.4%
Di–n–butylphthalate	36.6	6.0	2.39E+09	5.25E+09	1.40E+11	1.47E+11	0.29%	98.7%
2,4–Dimethylphenol	117	21.2	2.16E+09	4.73E+09	1.26E+11	1.33E+11	0.26%	99.0%
Zinc	329	86	1.50E+09	3.29E+09	8.76E+10	9.24E+10	0.18%	99.1%
Selenium	250	71	1.38E+09	3.02E+09	8.04E+10	8.48E+10	0.17%	99.3%
Xylenes	222	74	1.18E+09	2.58E+09	6.87E+10	7.24E+10	0.14%	99.5%
p–Cresol	149	50	1.16E+09	2.56E+09	6.80E+10	7.17E+10	0.14%	99.6%
Chromium	128	50	1.00E+09	2.20E+09	5.84E+10	6.16E+10	0.12%	99.7%
Cadmium	22.8	9.3	9.60E+08	2.11E+09	5.61E+10	5.92E+10	0.12%	99.8%
Antimony	166	160	4.05E+08	8.90E+08	2.37E+10	2.50E+10	0.05%	99.9%
Cobalt	83.6	100	3.27E+08	7.19E+08	1.91E+10	2.02E+10	0.04%	99.9%
Vanadium	96.6	180	2.10E+08	4.62E+08	1.23E+10	1.30E+10	0.03%	100%
Manganese	1,301	3,100	1.64E+08	3.61E+08	9.61E+09	1.01E+10	0.02%	100%
Arsenic	10.8	36	1.17E+08	2.58E+08	6.86E+09	7.23E+09	0.01%	100%
Molybdenum	86.9	540	6.31E+07	1.38E+08	3.68E+09	3.89E+09	0.008%	100%
Vinyl Acetate	29.4	450	2.56E+07	5.63E+07	1.50E+09	1.58E+09	0.003%	100%
Methylene Chloride	170	4,830	1.38E+07	3.02E+07	8.04E+08	8.48E+08	0.002%	100%
Acetone	913	41,000	8.72E+06	1.92E+07	5.10E+08	5.38E+08	0.001%	100%
Bis(2–ethylhexyl)phthalate	46.0	3,000	6.01E+06	1.32E+07	3.51E+08	3.70E+08	0.001%	100%
Chloromethane	28.6	2,700	4.15E+06	9.11E+06	2.42E+08	2.56E+08	0.001%	100%
2–Butanone	122	19,500	2.45E+06	5.38E+06	1.43E+08	1.51E+08	0.000%	100%
Carbon Disulfide	8.48	2,100	1.58E+06	3.47E+06	9.24E+07	9.75E+07	0.000%	100%
Total for 34 ORD Pollutants (TUs/yr)[a]			8.22E+11	1.81E+12	4.80E+13	5.06E+13		
EDS Volume (acre feet)			610,137	15,087,793	9,815,891	25,513,821		
Toxicity Indices (TIs = TUs/EDS Vol)			1,346,997	119,643	4,891,422	6,358,061		
Adjusted Toxicity Indices (TIs/1,000)			1,347	119.6	4,891	6,358		

[a] Calculated as: pollutant concentration * EDS produced water volume/toxicity criterion.

3.3 Gas Flotation Produced Water Effluent (BAT Option 2)

3.3.1 Mass Loadings

For the 34 produced water pollutants identified in the ORD report, projected mass loadings for Texas gas flotation (BAT Option 2) effluent are 993,658 pounds (Exhibit 3-12), ranging from 1,103 to 334,248 pounds on an EDS-specific basis. Projected pollutant mass loadings for Louisiana gas flotation (BAT Option 2) effluent are 15,705 pounds, ranging from 255 to 14,891 pounds on an EDS-specific basis (Exhibit 3-13).

Mass loadings of gas flotation (BAT Option 2) produced water pollutants not included in the ORD report total 2.23 million pounds in Texas and 35,200 pounds in Louisiana. Again, this amount is nearly double the mass loading reported for those pollutants found in the ORD report.

3.3.2 Toxic Unit Loadings

Projected toxic unit loadings for produced water gas flotation (BAT Option 2) effluent pollutants amount to an adjusted total TI of 10,344 in Texas (Exhibit 3-14), ranging from 66 to 6,287 on an EDS-specific basis. Projected toxic unit loadings for produced water gas flotation (BAT Option 2) effluent pollutants amount to an adjusted total TI of 5,729 in Louisiana, ranging from 108 to 4,407 total toxic unit loadings on an EDS-specific basis (Exhibit 3-15).

3.4 Contributions of Produced Water Loadings to Total Watershed Loadings

Based on the loadings estimates for industrial and municipal point sources presented in the ORD report, comparisons of both current BPT baseline and gas flotation (BAT Option 2) produced water pollutant mass loadings and toxic unit loadings are developed on a watershed and state-wide basis for Texas and Louisiana. Results are summarized in Exhibit 3-16 and discussed further in sections 3.4.1 and 3.4.2 below.

3.4.1 Current BPT Effluent

Considering only the loadings of pollutants listed in the ORD report, the mass loading of 34 current BPT produced water pollutants in Texas approximates 17% of the total point source mass load of pollutants; on a watershed basis, current BPT produced water pollutants range from 0.2% to 100% (Exhibit 3-17). Based on loadings of all 66 toxic pollutants detected in current BPT produced water discharges, the mass loadings represent 38% of the total loadings; on a watershed basis, current BPT produced water pollutant loadings range from 0.5% to 100%.

The mass loading of 34 current BPT produced water pollutants in Louisiana that are listed in the ORD report approximates 58% of the total point source mass loadings; on a watershed basis, current BPT produced water pollutants range from 0% to 83% (Exhibit 3-18). The mass loading of all current BPT

Exhibit 3–12. Texas Produced Water Mass Loadings – Gas Flotation Effluent (BAT Option 2)

Pollutant	Mean Conc. (ug/l)	Mass Loading by Watershed (lbs/yr)								Total Loading (lbs/yr)	% of Total Loading	Cum'ltive % of Loading
		EDS #2	EDS #3	EDS #4	EDS #5	EDS #6	EDS #7	EDS #8	EDS #9			
Pollutants identified in the EPA ORD report:												
Ammonia	65,773	8,373	83,950	22,039	2,314	115,600	673	203,993	169,491	606,433	61.0%	61.0%
Barium	35,561	4,527	45,388	11,916	1,251	62,500	364	110,291	91,637	327,874	33.0%	94.0%
Benzene	1,226	156	1,565	411	43.1	2,155	12.5	3,802	3,159	11,303	1.14%	95.2%
Acetone	913	116	1,165	306	32.1	1,605	9.34	2,832	2,353	8,418	0.85%	96.0%
Toluene	828	105	1,057	277	29.1	1,455	8.47	2,567	2,133	7,632	0.77%	96.8%
Phenol	536	68.2	684	180	18.9	942	5.49	1,662	1,381	4,942	0.50%	97.3%
Silver	252	32.1	322	84.4	8.87	443	2.58	782	649	2,323	0.23%	97.5%
Selenium	250	31.8	319	83.8	8.80	439	2.56	775	644	2,305	0.23%	97.7%
Xylenes	222	28.3	283	74.4	7.81	390	2.27	689	572	2,048	0.21%	97.9%
Copper	180	22.9	230	60.3	6.33	316	1.84	558	464	1,660	0.17%	98.1%
Methylene Chloride	170	21.6	217	57.0	5.98	299	1.74	527	438	1,567	0.16%	98.3%
Antimony	166	21.1	212	55.6	5.84	292	1.70	515	428	1,531	0.15%	98.4%
p–Cresol	149	19.0	190	49.9	5.24	262	1.53	462	384	1,374	0.14%	98.6%
Zinc	134	17.0	171	44.9	4.71	235	1.37	415	345	1,234	0.12%	98.7%
Chromium	128	16.3	163	42.9	4.50	225	1.31	397	330	1,180	0.12%	98.8%
Lead	125	15.9	159	41.8	4.39	219	1.28	387	322	1,151	0.12%	98.9%
2–Butanone	122	15.5	156	40.9	4.29	214	1.25	378	314	1,125	0.11%	99.0%
o–Cresol	121	15.4	154	40.5	4.26	213	1.24	375	312	1,116	0.11%	99.2%
2,4–Dimethylphenol	117	14.9	149	39.2	4.12	206	1.20	363	301	1,079	0.11%	99.3%
Nickel	109	13.9	139	36.5	3.84	192	1.12	338	281	1,005	0.10%	99.4%
Vanadium	96.6	12.3	123	32.4	3.40	170	0.99	300	249	891	0.09%	99.4%
Naphthalene	92.0	11.7	117	30.8	3.24	162	0.94	285	237	848	0.09%	99.5%
Molybdenum	86.9	11.1	111	29.1	3.06	153	0.89	270	224	801	0.08%	99.6%
Cobalt	83.6	10.6	107	28.0	2.94	147	0.86	259	215	771	0.08%	99.7%
Manganese	74.2	9.44	94.7	24.8	2.61	130	0.76	230	191	684	0.07%	99.8%
Ethylbenzene	62.2	7.92	79.4	20.8	2.19	109	0.64	193	160	573	0.06%	99.8%
Aluminum	49.9	6.36	63.7	16.7	1.76	87.8	0.51	155	129	460	0.05%	99.9%
Bis(2–ethylhexyl)phthalate	46.0	5.86	58.7	15.4	1.62	80.8	0.47	143	119	424	0.04%	99.9%
Vinyl Acetate	29.4	3.74	37.5	9.85	1.03	51.7	0.30	91.2	75.8	271	0.03%	99.9%
Chloromethane	28.6	3.64	36.5	9.58	1.01	50.3	0.29	88.7	73.7	264	0.03%	100%
Cadmium	14.5	1.84	18.5	4.85	0.51	25.4	0.15	44.9	37.3	133	0.01%	100%
Arsenic	10.8	1.37	13.8	3.62	0.38	19.0	0.11	33.5	27.8	100	0.01%	100%
Carbon Disulfide	8.48	1.08	10.8	2.84	0.30	14.9	0.087	26.3	21.9	78	0.01%	100%
Di–n–butylphthalate	6.43	0.82	8.21	2.15	0.23	11.3	0.066	19.9	16.6	59	0.01%	100%
Total for 34 ORD Pollutants (lb/yr)		13,720	137,555	36,112	3,792	189,413	1,103	334,248	277,715	993,658		

Exhibit 3–12. Texas Produced Water Mass Loadings – Gas Flotation Effluent (BAT Option 2; Continued)

Pollutant	Mean Conc. (ug/l)	Mass Loading by Watershed (lbs/yr) EDS #2	EDS #3	EDS #4	EDS #5	EDS #6	EDS #7	EDS #8	EDS #9	Total Loading (lbs/yr)	% of ORD Total Loading	Cum'ltive % of Loading
Pollutants not identified in the EPA ORD report:												
Chlorides	65,111,000	8,288,852	83,105,114	21,817,592	2,290,889	114,436,142	666,440	201,939,762	167,784,693	600,329,483	60416%	
Calcium	2,501,000	318,386	3,192,178	838,043	87,996	4,395,644	25,599	7,756,775	6,444,833	23,059,453	2321%	
Magnesium	615,699	78,381	785,854	206,310	21,663	1,082,125	6,302	1,909,571	1,586,596	5,676,802	571%	
Strontium	205,500	26,161	262,292	68,860	7,230	361,177	2,103	637,352	529,553	1,894,729	191%	
Boron	16,474	2,097	21,026	5,520	580	28,954	169	51,093	42,451	151,890	15.3%	
Sulfur	9,683	1,233	12,359	3,245	341	17,018	99.1	30,032	24,952	89,278	8.98%	
Benzoic Acid	3,813	485	4,867	1,278	134	6,702	39.0	11,826	9,826	35,156	3.54%	
Iron	3,146	401	4,016	1,054	111	5,530	32.2	9,758	8,107	29,008	2.92%	
Hexanoic Acid	790.0	101	1,008	265	27.8	1,388	8.09	2,450	2,036	7,284	0.73%	
Tin	305	38.8	389	102	10.7	536	3.12	946	786	2,812	0.28%	
Trichlorofluoromethane	294	37.4	375	98.5	10.3	517	3.01	912	758	2,711	0.27%	
n–Hexadecane	283	36.0	361	94.8	10.0	497	2.90	878	729	2,609	0.26%	
n–Dodecane	225	28.6	287	75.4	7.92	395	2.30	698	580	2,075	0.21%	
Thallium	180	22.9	230	60.3	6.33	316	1.84	558	464	1,660	0.17%	
n–Decane	139	17.7	177	46.6	4.89	244	1.42	431	358	1,282	0.13%	
n–Tetradecane	119	15.1	152	39.9	4.19	209	1.22	369	307	1,097	0.11%	
n–Octadecane	82.9	10.6	106	27.8	2.92	146	0.85	257	214	764	0.08%	
1,2:3,4–Diepoxybutane	71.1	9.05	90.7	23.8	2.50	125	0.73	221	183	656	0.07%	
n–Eicosane	68	8.66	86.8	22.8	2.39	120	0.70	211	175	627	0.06%	
2–Methylnaphthalene	67.2	8.55	85.8	22.5	2.36	118	0.69	208	173	620	0.06%	
Benzyl Alcohol	49.5	6.30	63.2	16.6	1.74	87.0	0.51	154	128	456	0.05%	
n–Tetracosane	38.2	4.86	48.8	12.8	1.34	67.1	0.39	118	98.4	352	0.04%	
n–Docosane	38	4.84	48.5	12.7	1.34	66.8	0.39	118	97.9	350	0.04%	
n–Hexosane	36.1	4.60	46.1	12.1	1.27	63.4	0.37	112	93.0	333	0.03%	
2–Hexanone	35.81	4.56	45.7	12.0	1.26	62.9	0.37	111	92.3	330	0.03%	
n–Octacosane	35.2	4.48	44.9	11.8	1.24	61.9	0.36	109	90.7	325	0.03%	
n–Triacontane	35	4.46	44.7	11.7	1.23	61.5	0.36	109	90.2	323	0.03%	
Yttrium	25	3.18	31.9	8.38	0.88	43.9	0.26	77.5	64.4	231	0.02%	
Beryllium	5.56	0.71	7.10	1.86	0.20	9.77	0.057	17.2	14.3	51.3	0.01%	
Titanium	4.48	0.57	5.72	1.50	0.16	7.87	0.046	13.9	11.5	41.3	0.004%	
Radium 226	0.00025	0.00003	0.00032	0.00008	0.00001	0.00044	0.000003	0.00077	0.00064	0.0023	0.00000%	
Radium 228	0.00020	0.00003	0.00026	0.00007	0.00001	0.00036	0.000002	0.00063	0.00053	0.0019	0.00000%	
Total for Non ORD Pollutants (lb/yr) [a]		30,749	308,296	80,937	8,499	424,525	2,472	749,138	622,433	2,227,049		
Total for All Pollutants (lb/yr)		8,730,087	87,528,996	22,978,994	2,412,838	120,527,849	701,917	212,689,494	176,716,270	632,286,445		

[a] Total excludes the three common ions Cl^-, Ca^{++}, Mg^{++}.

Exhibit 3–13. Louisiana Produced Water Mass Loadings – Gas Flotation Effluent (BAT Option 2)

Pollutant	Mean Conc. (ug/l)	Mass Loading by Watershed (lb/yr) EDS #10	EDS #11	EDS #12	Total Loading (lbs/yr)	% of Total Loading	Cum'ltive % of Loading
Pollutants identified in the EPA ORD report:							
Ammonia	65,773	156	342	9,088	9,585	61.03%	61.0%
Barium	35,561	84.1	185	4,913	5,182	33.00%	94.0%
Benzene	1,226	2.90	6.37	169	178.7	1.14%	95.2%
Acetone	913	2.16	4.74	126	133.1	0.85%	96.0%
Toluene	828	1.96	4.30	114	120.6	0.77%	96.8%
Phenol	536	1.27	2.78	74.1	78.1	0.50%	97.3%
Silver	252	0.60	1.31	34.8	36.7	0.23%	97.5%
Selenium	250	0.59	1.30	34.5	36.4	0.23%	97.7%
Xylenes	222	0.53	1.15	30.7	32.4	0.21%	97.9%
Copper	180	0.43	0.93	24.9	26.2	0.17%	98.1%
Methylene Chloride	170	0.40	0.88	23.5	24.8	0.16%	98.3%
Antimony	166	0.39	0.86	22.9	24.2	0.15%	98.4%
p–Cresol	149	0.35	0.77	20.6	21.7	0.14%	98.6%
Zinc	134	0.32	0.69	18.5	19.5	0.12%	98.7%
Chromium	128	0.30	0.66	17.7	18.7	0.12%	98.8%
Lead	125	0.30	0.65	17.3	18.2	0.12%	98.9%
2–Butanone	122	0.29	0.63	16.9	17.8	0.11%	99.0%
o–Cresol	121	0.29	0.63	16.7	17.6	0.11%	99.2%
2,4–Dimethylphenol	117	0.28	0.61	16.2	17.1	0.11%	99.3%
Nickel	109	0.26	0.57	15.1	15.9	0.10%	99.4%
Vanadium	96.6	0.23	0.50	13.3	14.1	0.09%	99.4%
Naphthalene	92.0	0.22	0.48	12.7	13.4	0.09%	99.5%
Molybdenum	86.9	0.21	0.45	12.0	12.7	0.08%	99.6%
Cobalt	83.6	0.20	0.43	11.6	12.2	0.08%	99.7%
Manganese	74.2	0.18	0.39	10.2	10.8	0.07%	99.8%
Ethylbenzene	62.2	0.15	0.32	8.59	9.06	0.06%	99.8%
Aluminum	49.9	0.12	0.26	6.90	7.28	0.05%	99.9%
Bis(2–ethylhexyl)phthalate	46.0	0.11	0.24	6.36	6.70	0.04%	99.9%
Vinyl Acetate	29.4	0.070	0.15	4.06	4.28	0.03%	99.9%
Chloromethane	28.6	0.068	0.15	3.95	4.17	0.03%	100%
Cadmium	14.5	0.034	0.075	2.00	2.11	0.01%	100%
Arsenic	10.8	0.026	0.056	1.49	1.57	0.01%	100%
Carbon Disulfide	8.48	0.020	0.044	1.17	1.24	0.01%	100%
Di–n–butylphthalate	6.43	0.015	0.033	0.89	0.94	0.01%	100%
Total for 34 ORD Pollutants (lb/yr)		255	560	14,891	15,705		

Exhibit 3–13. Louisiana Produced Water Mass Loadings – Gas Flotation Effluent (BAT Option 2; Continued)

Pollutant	Mean Conc. (ug/l)	Mass Loading by Watershed (lb/yr) EDS #10	EDS #11	EDS #12	Total Loading (lbs/yr)	% of ORD Total Loading	Cum'ltive % of Loading
Pollutants not identified in the EPA ORD Report:							
Chloride	65,111,000	154,057	338,079	8,996,431	9,488,568	60416%	
Calcium	2,501,000	5,918	12,986	345,565	364,469	2321%	
Magnesium	615,699	1,457	3,197	85,072	89,725	571%	
Strontium	205,500	486	1,067	28,394	29,947	191%	
Boron	16,474	39.0	85.5	2,276	2,401	15.3%	
Sulfur	9,683	22.9	50.3	1,338	1,411	8.98%	
Benzoic Acid	3,813	9.02	19.8	527	556	3.54%	
Iron	3,146	7.44	16.3	435	458	2.92%	
Hexanoic Acid	790	1.87	4.10	109	115	0.73%	
Tin	305	0.72	1.58	42.1	44.4	0.28%	
Trichlorofluoromethane	294	0.70	1.53	40.6	42.8	0.27%	
n–Hexadecane	283	0.67	1.47	39.1	41.2	0.26%	
n–Dodecane	225	0.53	1.17	31.1	32.8	0.21%	
Thallium	180	0.43	0.93	24.9	26.2	0.17%	
n–Decane	139	0.33	0.72	19.2	20.3	0.13%	
n–Tetradecane	119	0.28	0.62	16.4	17.3	0.11%	
n–Octadecane	82.9	0.20	0.43	11.5	12.1	0.08%	
1,2:3,4–Diepoxybutane	71.1	0.17	0.37	9.82	10.4	0.07%	
n–Eicosane	68.0	0.16	0.35	9.40	9.91	0.06%	
2–Methylnaphthalen	67.2	0.16	0.35	9.29	9.79	0.06%	
Benzyl Alcohol	49.5	0.12	0.26	6.84	7.21	0.05%	
n–Tetracosane	38.2	0.090	0.20	5.28	5.57	0.04%	
n–Docosane	38.0	0.090	0.20	5.25	5.54	0.04%	
n–Hexosane	36.1	0.085	0.19	4.99	5.26	0.03%	
2–Hexanone	35.8	0.085	0.19	4.95	5.22	0.03%	
n–Octacosane	35.2	0.083	0.18	4.86	5.13	0.03%	
n–Triacontane	35.0	0.083	0.18	4.84	5.10	0.03%	
Yttrium	25.0	0.059	0.13	3.45	3.64	0.02%	
Beryllium	5.56	0.013	0.029	0.77	0.81	0.01%	
Titanium	4.48	0.011	0.023	0.62	0.65	0.004%	
Radium 226	0.000249	0.0000006	0.000001	0.00003	0.00004	0.0000%	
Radium 228	0.000204	0.0000005	0.000001	0.00003	0.00003	0.0000%	
Total of Non ORD Pollutants (lb/yr) [a]		572	1,254	33,374	35,200		
Total for All Pollutants (lb/yr)		162,258	356,076	9,475,333	9,993,667		

[a] Total excludes the three common ions Cl^-, Ca^{++}, and Mg^{++}.

Exhibit 3-14. Texas Produced Water Toxic Unit Loadings – Gas Flotation Effluent (BAT Option 2)

Pollutant	Mean Conc. (ug/l)	Toxic Criterion (ug/l)	Toxic Unit Loadings by Watershed (TU/yr)								Total Loading (TU/yr)	% of Total Loading	Cum'ltive % of Loading
			EDS #2	EDS #3	EDS #4	EDS #5	EDS #6	EDS #7	EDS #8	EDS #9			
Silver	252	0.23	6.3E+10	6.3E+11	1.7E+11	1.7E+10	8.7E+11	5.1E+09	1.5E+12	1.3E+12	4.6E+12	58%	58.0%
o-Cresol	121	0.30	2.3E+10	2.3E+11	6.1E+10	6.4E+09	3.2E+11	1.9E+09	5.7E+11	4.7E+11	1.7E+12	21%	79.3%
Ammonia	65,773	340	1.1E+10	1.1E+11	2.9E+10	3.1E+09	1.5E+11	9.0E+08	2.7E+11	2.3E+11	8.1E+11	10%	89.5%
Copper	180.0	2.9	3.6E+09	3.6E+10	9.4E+09	9.9E+08	4.9E+10	2.9E+08	8.7E+10	7.3E+10	2.6E+11	3.28%	92.8%
Toluene	828	37	1.3E+09	1.3E+10	3.4E+09	3.6E+08	1.8E+10	1.0E+08	3.1E+10	2.6E+10	9.4E+10	1.18%	94.0%
Lead	125	5.6	1.3E+09	1.3E+10	3.4E+09	3.6E+08	1.8E+10	1.0E+08	3.1E+10	2.6E+10	9.3E+10	1.18%	95.2%
Ethylbenzene	62.2	4.3	8.4E+08	8.4E+09	2.2E+09	2.3E+08	1.2E+10	6.7E+07	2.0E+10	1.7E+10	6.0E+10	0.77%	95.9%
Barium	35,561	2,600	7.9E+08	7.9E+09	2.1E+09	2.2E+08	1.1E+10	6.4E+07	1.9E+10	1.6E+10	5.7E+10	0.72%	96.7%
Nickel	109	8.3	7.6E+08	7.6E+09	2.0E+09	2.1E+08	1.0E+10	6.1E+07	1.8E+10	1.5E+10	5.5E+10	0.69%	97.4%
Benzene	1,226	109	6.5E+08	6.5E+09	1.7E+09	1.8E+08	9.0E+09	5.2E+07	1.6E+10	1.3E+10	4.7E+10	0.59%	98.0%
Phenol	536	58	5.3E+08	5.4E+09	1.4E+09	1.5E+08	7.4E+09	4.3E+07	1.3E+10	1.1E+10	3.9E+10	0.49%	98.4%
2,4-Dimethylphenol	117	21.2	3.2E+08	3.2E+09	8.4E+08	8.8E+07	4.4E+09	2.6E+07	7.8E+09	6.5E+09	2.3E+10	0.29%	98.7%
Naphthalene	92	23.5	2.3E+08	2.3E+09	6.0E+08	6.2E+07	3.1E+09	1.8E+07	5.5E+09	4.6E+09	1.6E+10	0.21%	98.9%
Selenium	250	71	2.0E+08	2.0E+09	5.4E+08	5.6E+07	2.8E+09	1.6E+07	5.0E+09	4.1E+09	1.5E+10	0.19%	99.1%
Xylenes	222	74	1.7E+08	1.7E+09	4.6E+08	4.8E+07	2.4E+09	1.4E+07	4.2E+09	3.5E+09	1.3E+10	0.16%	99.3%
p-Cresol	149	50	1.7E+08	1.7E+09	4.5E+08	4.8E+07	2.4E+09	1.4E+07	4.2E+09	3.5E+09	1.2E+10	0.16%	99.5%
Chromium	128	50	1.5E+08	1.5E+09	3.9E+08	4.1E+07	2.0E+09	1.2E+07	3.6E+09	3.0E+09	1.1E+10	0.14%	99.6%
Zinc	134	86	9.0E+07	9.0E+08	2.4E+08	2.5E+07	1.2E+09	7.2E+06	2.2E+09	1.8E+09	6.5E+09	0.08%	99.7%
Cadmium	14.5	9.3	9.0E+07	9.0E+08	2.4E+08	2.5E+07	1.2E+09	7.2E+06	2.2E+09	1.8E+09	6.5E+09	0.08%	99.8%
Di-n-butylphthalate	6.43	6.0	6.2E+07	6.2E+08	1.6E+08	1.7E+07	8.5E+08	5.0E+06	1.5E+09	1.3E+09	4.5E+09	0.06%	99.8%
Antimony	166	160	6.0E+07	6.0E+08	1.6E+08	1.7E+07	8.3E+08	4.8E+06	1.5E+09	1.2E+09	4.3E+09	0.05%	99.9%
Cobalt	83.6	100	4.8E+07	4.8E+08	1.3E+08	1.3E+07	6.7E+08	3.9E+06	1.2E+09	9.8E+08	3.5E+09	0.04%	99.9%
Aluminum	49.93	87	3.3E+07	3.3E+08	8.7E+07	9.2E+06	4.6E+08	2.7E+06	8.1E+08	6.7E+08	2.4E+09	0.03%	99.9%
Vanadium	96.6	180	3.1E+07	3.1E+08	8.2E+07	8.6E+06	4.3E+08	2.5E+06	7.5E+08	6.3E+08	2.2E+09	0.03%	100%
Arsenic	10.8	36	1.7E+07	1.7E+08	4.6E+07	4.8E+06	2.4E+08	1.4E+06	4.2E+08	3.5E+08	1.3E+09	0.02%	100%
Molybdenum	86.9	540	9.3E+06	9.3E+07	2.4E+07	2.6E+06	1.3E+08	7.5E+05	2.3E+08	1.9E+08	6.7E+08	0.009%	100%
Vinyl Acetate	29.4	450	3.8E+06	3.8E+07	9.9E+06	1.0E+06	5.2E+07	3.0E+05	9.2E+07	7.6E+07	2.7E+08	0.003%	100%
Methylene Chloride	170	4,830	2.0E+06	2.0E+07	5.3E+06	5.6E+05	2.8E+07	1.6E+05	5.0E+07	4.1E+07	1.5E+08	0.002%	100%
Manganese	74	3,100	1.4E+06	1.4E+07	3.6E+06	3.8E+05	1.9E+07	1.1E+05	3.4E+07	2.8E+07	1.0E+08	0.001%	100%
Acetone	913	41,000	1.3E+06	1.3E+07	3.4E+06	3.6E+05	1.8E+07	1.0E+05	3.1E+07	2.6E+07	9.3E+07	0.001%	100%
Bis(2-ethylhexyl)phthalate	46	3,000	8.9E+05	8.9E+06	2.3E+06	2.4E+05	1.2E+07	7.1E+04	2.2E+07	1.8E+07	6.4E+07	0.001%	100%
Chloromethane	28.6	2,700	6.1E+05	6.1E+06	1.6E+06	1.7E+05	8.4E+06	4.9E+04	1.5E+07	1.2E+07	4.4E+07	0.001%	100%
2-Butanone	122	19,500	3.6E+05	3.6E+06	9.5E+05	1.0E+05	5.0E+06	2.9E+04	8.8E+06	7.3E+06	2.6E+07	0.000%	100%
Carbon Disulfide	8.48	2,100	2.3E+05	2.3E+06	6.1E+05	6.4E+04	3.2E+06	1.9E+04	5.7E+06	4.7E+06	1.7E+07	0.000%	100%
Total for 34 ORD Pollutants (TU/yr)[a]			1.09E+11	1.09E+12	2.87E+11	3.02E+10	1.51E+12	8.78E+09	2.66E+12	2.21E+12	7.91E+12		
EDS Volume (acre feet)			1,281,814	1,097,464	531,428	458,215	2,627,112	15,015	2,196,773	351,433	8,559,254		
Toxicity Indices (TIs = TU/EDS Vol)			85,154	997,180	540,628	65,837	573,615	584,483	1,210,522	6,287,033	10,344,451		
Adjusted Toxicity Indices (TIs/1,000)			85.2	997	541	65.8	574	584	1,211	6,287	10,344		

[a] Calculated as: pollutant concentration * EDS produced water volume/toxicity criterion.

Exhibit 3–15. Louisiana Produced Water Toxic Unit Loadings – Gas Flotation Effluent (BAT Option 2)

Pollutant	Mean Conc. (ug/l)	Toxicity Criterion (ug/l)	Toxic Unit Loading by Watershed (TU/yr) EDS #10	EDS #11	EDS #12	Total Loading (TU/Yr)	% of Total Loading	Cum'ltive % of Loading
Silver	252	0.23	4.29E+11	9.43E+11	2.51E+13	2.64E+13	58.0%	58.0%
o–Cresol	121	0.30	1.58E+11	3.47E+11	9.23E+12	9.74E+12	21.3%	79.3%
Ammonia	65,773	340	7.58E+10	1.66E+11	4.43E+12	4.67E+12	10.2%	89.5%
Copper	180	2.9	2.43E+10	5.34E+10	1.42E+12	1.50E+12	3.28%	92.8%
Toluene	828	37	8.76E+09	1.93E+10	5.12E+11	5.40E+11	1.18%	94.0%
Lead	125	5.6	8.73E+09	1.92E+10	5.10E+11	5.38E+11	1.18%	95.2%
Ethylbenzene	62.2	4.3	5.66E+09	1.24E+10	3.31E+11	3.49E+11	0.77%	95.9%
Barium	35,561	2,600	5.36E+09	1.18E+10	3.13E+11	3.30E+11	0.72%	96.7%
Nickel	109	8.3	5.14E+09	1.13E+10	3.01E+11	3.17E+11	0.69%	97.4%
Benzene	1,226	109	4.41E+09	9.68E+09	2.57E+11	2.71E+11	0.59%	98.0%
Phenol	536	58.0	3.62E+09	7.95E+09	2.11E+11	2.23E+11	0.49%	98.4%
2,4–Dimethylphenol	117	21.2	2.16E+09	4.75E+09	1.26E+11	1.33E+11	0.29%	98.7%
Naphthalene	92.0	23.5	1.53E+09	3.37E+09	8.96E+10	9.45E+10	0.21%	98.9%
Selenium	250	71.0	1.38E+09	3.03E+09	8.06E+10	8.50E+10	0.19%	99.1%
Xylenes	222	74.0	1.18E+09	2.58E+09	6.87E+10	7.24E+10	0.16%	99.3%
p–Cresol	149	50.0	1.17E+09	2.56E+09	6.82E+10	7.19E+10	0.16%	99.5%
Chromium	128	50.0	1.00E+09	2.20E+09	5.86E+10	6.18E+10	0.14%	99.6%
Zinc	134	86.0	6.10E+08	1.34E+09	3.56E+10	3.76E+10	0.08%	99.7%
Cadmium	14.5	9.3	6.10E+08	1.34E+09	3.56E+10	3.76E+10	0.08%	99.8%
Di–n–butylphthalate	6.43	6.0	4.20E+08	9.22E+08	2.45E+10	2.59E+10	0.06%	99.8%
Antimony	166	160	4.06E+08	8.93E+08	2.37E+10	2.50E+10	0.05%	99.9%
Cobalt	83.6	100	3.27E+08	7.19E+08	1.91E+10	2.02E+10	0.04%	99.9%
Aluminum	49.9	87.0	2.25E+08	4.94E+08	1.31E+10	1.39E+10	0.03%	99.9%
Vanadium	96.6	180	2.10E+08	4.62E+08	1.23E+10	1.30E+10	0.03%	100%
Arsenic	10.8	36.0	1.18E+08	2.58E+08	6.87E+09	7.24E+09	0.02%	100%
Molybdenum	86.9	540	6.30E+07	1.38E+08	3.68E+09	3.88E+09	0.01%	100%
Vinyl Acetate	29.4	450	2.56E+07	5.62E+07	1.50E+09	1.58E+09	0.003%	100%
Methylene Chloride	170	4,830	1.38E+07	3.03E+07	8.06E+08	8.50E+08	0.002%	100%
Manganese	74.2	3,100	9.37E+06	2.06E+07	5.47E+08	5.77E+08	0.001%	100%
Acetone	913	41,000	8.72E+06	1.92E+07	5.10E+08	5.38E+08	0.001%	100%
Bis(2–ethylhexyl)phthalate	46.0	3,000	6.01E+06	1.32E+07	3.51E+08	3.70E+08	0.001%	100%
Chloromethane	28.6	2,700	4.15E+06	9.11E+06	2.42E+08	2.56E+08	0.001%	100%
2–Butanone	122	19,500	2.45E+06	5.38E+06	1.43E+08	1.51E+08	0.0003%	100%
Carbon Disulfide	8.48	2,100	1.58E+06	3.47E+06	9.24E+07	9.75E+07	0.0002%	100%
Total for 34 ORD Pollutants (TU/yr)[a]			7.40E+11	1.63E+12	4.33E+13	4.56E+13		
EDS Volume (acre feet)			610,137	15,087,793	9,815,891	25,513,821		
Toxicity Indices (TIs = TU/EDS Vol)			1,213,623	107,796	4,407,093	5,728,512		
Adjusted Toxicity Indices (TIs/1,000)			1,214	108	4,407	5,729		

[a] Calculated as: pollutant concentration * EDS produced water volume/toxicity criterion.

Exhibit 3-16. Summary of Relative Contribution of Produced Water Mass and Toxic Unit Loadings to Total Watershed Loadings from ORD Report

	Texas		Louisiana	
	Mass Load	Toxic Unit Load	Mass Load	Toxic Unit Load
Current Produced Water (BPT)				
ORD Pollutants	17%	94%	58%	87%
All Pollutants	38%	--	80%	--
Gas Flotation Effluent (BAT Option 2)				
ORD Pollutants	14%	93%	0.31%	86%
All Pollutants	35%	--	1.0%	--

Exhibit 3–17. Texas Industrial, Municipal, and Produced Water Pollutant Mass Loadings
Current BPT Effluent

EDS No.	EDS Name	EDS Volume (acre feet)	Pollutant Loadings (lbs/yr)[a] Industrial Sources		Municipal Sources[b]		Produced Water Sources: ORD Pollutants		Produced Water Sources: All BPT Pollutants[c]		All Point Sources: ORD	All Point Sources: All BPT
2	Laguna Madre	1,281,814	0	0%	0	0%	19,846	100%	58,190	100%	19,846	58,190
3	Corpus Christi Bay	1,097,464	796,573	82%	237	0.02%	173,805	18%	509,597	39%	970,615	1,306,407
4	Aransas Bay	531,428	0	0%	0	0%	44,949	100%	131,790	100%	44,949	131,790
5	San Antonio Bay	458,215	11,332	66%	0	0%	5,904	34%	17,312	60%	17,236	28,644
6	Matagorda Bay	2,627,112	7,731	3.1%	0	0%	240,494	97%	705,130	99%	248,225	712,861
7	Brazos River	15,015	886,005	100%	0	0%	1,621	0.2%	4,753	0.5%	887,626	890,758
8	Galveston Bay	2196773	2,068,545	57%	1,170,582	32%	419,436	11%	1,229,786	28%	3,658,563	4,468,913
9	Sabine Lake	351433	1,149,277	77%	0	0%	345,101	23%	1,011,838	47%	1,494,378	2,161,115
	Texas Total	8,559,254	4,919,463	67%	1,170,819	16%	1,251,157	17%	3,668,395	38%	7,341,439	9,758,677

[a] The EPA ORD report (EPA, 1994b) estimates based on mass loadings (lb/yr)/toxicity criterion (ug/l)/EDS volume (acre feet)/1,000.
[b] Source: EPA ORD report; reduced loadings based on influent loadings and engineering estimates of POTW treatment efficiencies.
[c] Excluding the common ions Cl^-, Ca^{++}, and Mg^{++}; the total including these produced water pollutants is 643,680,631 pounds.

Exhibit 3–18. Louisiana Industrial, Municipal, and Produced Water Pollutant Mass Loadings
Current BPT Effluent

EDS No.	EDS Name	EDS Volume (acre feet)	Pollutant Loadings (lbs/yr)[a]									
			Industrial Sources		Municipal Sources[b]		Produced Water Sources				All Point Sources	
							ORD Pollutants		All BPT Pollutants[c]		ORD	All BPT
10	Calcasieu Lake	610,137	3,180,119	97%	98	0.00%	115,187	3.5%	337,729	9.6%	3,295,404	3,517,946
11	Atchafalaya/Vermilion Bays	15,087,793	563,160	69%	0	0%	253,000	31%	741,799	57%	816,160	1,304,959
12	Mississippi Delta Region	9,815,891	1,352,090	17%	13,167	0.2%	6,729,378	83%	19,730,578	94%	8,094,635	21,095,835
13a	Lake Pontchartrain	5,249,662	1,000	100%	0	0%	0	0%	0	0%	1,000	1,000
13b	Lake Borgne	1,546,866	1,080	100%	0	0%	0	0%	0	0%	1,080	1,080
	Louisiana Totals	32,310,349	5,097,449	42%	13,265	0.11%	7,097,566	58%	20,810,107	80%	12,208,280	25,920,821

[a] From EPA ORD report (EPA, 1994b) estimates based on mass loadings (lbs/yr)/toxicity criterion (ug/l)/EDS volume (acre feet)/1,000.
[b] Source: EPA ORD report; reduced loadings based on influent loadings and engineering estimates of POTW treatment efficiencies.
[c] Excluding the common ions Cl^-, Ca^{++}, and Mg^{++}; the total including these produced water pollutants is 3,651,480,683 pounds.

produced water toxic pollutants represents 80% of the total point source mass loadings; on a watershed basis, current BPT produced water pollutants range from 0% to 94%.

Toxic unit loadings are compared only for 34 produced water pollutants listed in the ORD report. The toxic unit loading of current BPT produced water pollutants in Texas approximates 94% of the total toxic unit loadings; on a watershed basis, current BPT produced water pollutants range from 67% to 100% (Exhibit 3-19). In Louisiana, the toxic unit loading of current BPT produced water pollutants approximates 87% of the total toxic unit loading; on a watershed basis, current BPT produced water pollutants range from 0% to 100% (Exhibit 3-20).

3.4.2 Gas Flotation Effluent (BAT Option 2)

The mass loading of 34 pollutants in gas flotation effluent (BAT Option 2) pollutants that are listed in the ORD report approximates 14% of the total point source mass loading in the state of Texas; on a watershed basis, gas flotation effluent pollutants range from 0.12% to 100% (Exhibit 3-21). For all 66 toxic pollutants detected in gas flotation effluent, the mass loading represents 35% of the total loading; on a watershed basis, gas flotation effluent loadings range from 0.40% to 100%. In Louisiana, mass loading of 34 gas flotation (BAT Option 2) pollutants listed in the ORD report approximates 0.31% of the total point source mass loading; on a watershed basis, produced water BAT pollutants range from 0% to 1.08% of the EDS totals (Exhibit 3-22). For all pollutants detected in gas flotation effluent, the mass loading represents 1.0%; on a watershed basis, produced water BAT pollutants range from 0% to 3.41% of the EDS totals.

The toxic unit loading of gas flotation (BAT Option 2) produced water pollutants in Texas approximates 93% of the total toxic unit load of pollutants; on a watershed basis, produced water pollutants range from 60% to 100% of the EDS totals (Exhibit 3-23). In Louisiana, toxic unit loading of gas flotation produced water pollutants approximates 86% of the total toxic unit load of pollutants; on a watershed basis, produced water gas flotation pollutants range from 0% to 100% of the EDS totals (Exhibit 3-24).

Exhibit 3–19. Texas Industrial, Municipal, and Produced Water Pollutant Toxic Unit Loadings Current BPT Effluent

EDS No.	EDS Name	EDS Volume (acre feet)	Toxic Unit Loadings (TU/yr)[a] Industrial Sources	Municipal Sources [b]	Produced Water Sources[c]		All Point Sources
2	Laguna Madre	1,281,814	0.0	0.0	110	100%	110
3	Corpus Christi Bay	1,097,464	176.0	0.0	1,129	87%	1,305
4	Aransas Bay	531,428	0.0	0.0	603	100%	603
5	San Antonio Bay	458,215	0.99	0.0	91.9	99%	92.9
6	Matagorda Bay	2,627,112	0.04	0.0	653	100%	653
7	Brazos River	15,015	387.6	0.0	770	67%	1,158
8	Galveston Bay	2,196,773	62.6	15.0	1,362	95%	1,439
9	Sabine Lake	351,433	172.2	0.0	7,002	98%	7,175
	Texas Totals	8,559,254	800	15.0	11,721	93.5%	12,536

[a] The EPA ORD report (EPA, 1994b) estimates based on mass loadings (lbs/yr)/toxicity criterion (ug/l)/ EDS Volume (acre feet)/1,000.

[b] Source: EPA ORD report; reduced loadings based on influent loadings and engineering estimates of POTW treatment efficiencies.

[c] Toxic units are calculated only for pollutants in the EPA ORD report.

Exhibit 3–20. Louisiana Industrial, Municipal, and Produced Water Pollutant Toxic Unit Loadings Current BPT Effluent

EDS No.	EDS Name	EDS Volume (acre feet)	Toxic Unit Loadings (TU/yr)[a] Industrial Sources	Municipal Sources[b]	Produced Water Sources[c]		All Point Sources
10	Calcasieu Lake	610,137	940	0.0	1,347	59%	2,287
11	Atchafalaya/Vermilion Bays	15,087,793	2.9	0.0	120	98%	122
12	Mississippi Delta Region	9,815,891	0.36	0.0	4,891	100%	4,892
13a	Lake Pontchartrain	5,249,662	0.01	0.0	0.0	0.0%	0.01
13b	Lake Borgne	1,546,866	0.01	0.0	0.0	0.0%	0.01
	Louisiana Total	32,310,349	943	0.0	6,358	87.1%	7,301

[a] From the EPA ORD report estimates based on mass loadings (lbs/yr)/toxicity criterion (ug/l)/ EDS volume (acre feet)/1,000.
[b] Source: EPA ORD report; reduced loadings based on influent loadings and engineering estimates of POTW treatment efficiencies.
[c] Toxic units are calculated only for pollutants included in the EPA ORD report.

Exhibit 3–21. Texas Industrial, Municipal, and Produced Water Pollutant Mass Loadings
Gas Flotation Effluent (BAT Option 2)

EDS No.	EDS Name	EDS Volume (acre feet)	Pollutant Loadings (lbs/yr)[a]									
			Industrial Sources		Municipal Sources[b]		Produced Water Sources				All Point Sources	
							ORD Pollutants		All BAT Pollutants[c]		ORD	All BAT
2	Laguna Madre	1,281,814	0	0%	0	0%	13,720	100%	44,469	100%	13,720	44,469
3	Corpus Christi Bay	1,097,464	796,573	85%	237	0.03%	137,555	15%	445,850	36%	934,365	1,242,660
4	Aransas Bay	531,428	0	0%	0	0%	36,112	100%	117,049	100%	36,112	117,049
5	San Antonio Bay	458,215	11,332	75%	0	0%	3,792	25%	12,290	52%	15,124	23,622
6	Matagorda Bay	2,627,112	7,731	3.9%	0	0%	189,413	96%	613,938	99%	197,144	621,669
7	Brazos River	15,015	886,005	100%	0	0%	1,103	0.12%	3,575	0.40%	887,108	889,580
8	Galveston Bay	2,196,773	2,068,545	58%	1,170,582	33%	334,248	9.4%	1,083,386	25%	3,573,375	4,322,513
9	Sabine Lake	351,433	1,149,277	81%	0	0%	277,715	19%	900,148	44%	1,426,992	2,049,425
	Texas Total	8,559,254	4,919,463	69%	1,170,819	17%	993,658	14%	3,220,707	35%	7,083,940	9,310,989

[a] The EPA ORD report (EPA, 1994b) estimates based on mass loadings (lb/yr)/toxicity criterion (ug/l)/EDS volume (acre feet)/1,000.
[b] Source: EPA ORD report; reduced loadings based on influent loadings and engineering estimates of POTW treatment efficiencies.
[c] Excluding the common ions Cl^-, Ca^{++}, and Mg^{++}; the total including these produced water pollutants is 632,286,445 pounds.

Exhibit 3–22. Louisiana Industrial, Municipal, and Produced Water Pollutant Mass Loadings
Gas Flotation Effluent (BAT Option 2)

EDS No.	EDS Name	EDS Volume (acre feet)	Pollutant Loadings (lbs/yr)[a] Industrial Sources		Municipal Sources[b]		Produced Water Sources ORD Pollutants		Produced Water Sources All BAT Pollutants[c]		All Point Sources ORD	All Point Sources All BAT
10	Calcasieu Lake	610,137	3,180,119	100%	98	0.003%	255	0.008%	827	0.026%	3,180,472	3,181,044
11	Atchafalaya/Vermilion Bays	15,087,793	563,160	100%	0	0%	560	0.10%	1,814	0.32%	563,720	564,974
12	Mississippi Delta Region	9,815,891	1,352,090	98%	13,167	1.0%	14,891	1.08%	48,265	3.41%	1,380,148	1,413,522
13a	Lake Pontchartrain	5,249,662	1,000	100%	0	0%	0	0%	0	0%	1,000	1,000
13b	Lake Borgne	1,546,866	1,080	100%	0	0%	0	0%	0	0%	1,080	1,080
	Louisiana Total	32,310,349	5,097,449	99%	13,265	0.3%	15,705	0.31%	50,905	1.0%	5,126,419	5,161,619

[a] From EPA ORD report (EPA, 1994b) estimates based on mass loadings (lbs/yr)/toxicity criterion (ug/l)/EDS volume (acre feet)/1,000.
[b] Source: EPA ORD report; reduced loadings based on influent loadings and engineering estimates of POTW treatment efficiencies.
[c] Excluding the common ions Cl^-, Ca^{++}, and Mg^{++}; the total including these produced water pollutants is 9,993,667 pounds.

Exhibit 3–23. Texas Industrial, Municipal, and Produced Water Pollutant Toxic Unit Loadings Gas Flotation Effluent (BAT Option 2)

EDS No.	EDS Name	EDS Volume (acre feet)	Toxic Unit Loadings (TU/yr) [a] Industrial Sources	Municipal Sources [b]	Produced Water Sources [c]		All Point Sources
2	Laguna Madre	1,281,814	0.0	0.0	85	100%	85
3	Corpus Christi Bay	1,097,464	176.0	0.0	997	85%	1,173
4	Aransas Bay	531,428	0.0	0.0	541	100%	541
5	San Antonio Bay	458,215	0.99	0.0	66	99%	67
6	Matagorda Bay	2,627,112	0.04	0.0	574	100%	574
7	Brazos River	15,015	387.6	0.0	584	60%	972
8	Galveston Bay	2196773	62.6	15.0	1,211	94%	1,288
9	Sabine Lake	351433	172.2	0.0	6,287	97%	6,459
	Texas Total	8,559,254	800	15.0	10,344	93%	11,159

[a] The EPA ORD report (EPA, 1994b) estimates based on mass loadings (lbs/yr)/toxicity criterion (ug/l)/ EDS volume (acre feet)/1,000.

[b] Source: EPA ORD reduced loadings based on influent loadings and engineering estimates of POTW treatment efficiencies.

[c] Toxic units are calculated only for pollutants in the EPA ORD report.

Exhibit 3–24. Louisiana Industrial, Municipal, and Produced Water Pollutant Toxic Unit Loadings Gas Flotation Effluent (BAT Option 2)

EDS No.	EDS Name	EDS Basin (acre feet)	Toxic Unit Loadings (TU/yr)[a] Industrial Sources	Municipal Sources[b]	Produced Water Sources[c]		All Point Sources
10	Calcasieu Lake	610,137	940	0.0	1,214	56%	2,153
11	Atchafalaya/Vermilion Bays	15,087,793	2.9	0.0	108	97%	111
12	Mississippi Delta Region	9,815,891	0.36	0.0	4,407	100%	4,407
13a	Lake Pontchartrain	5,249,662	0.01	0.0	0.0	0%	0.01
13b	Lake Borgne	1,546,866	0.01	0.0	0.0	0%	0.01
	Louisiana Total	32,310,349	943	0.0	5,729	86%	6,672

[a] From the EPA ORD report estimates based on mass loadings (lbs/yr)/toxicity criterion (ug/l)/ EDS volume (acre feet)/1,000.
[b] Source: EPA ORD report; reduced loadings based on influent loadings and engineering estimates of POTW treatment efficiencies.
[c] Toxic units are calculated only for pollutants included in the EPA ORD report.

4. WATER QUALITY COMPLIANCE ASSESSMENTS FOR PRODUCED WATER

4.1 Methodology

The current BPT and BAT pollutant concentrations for the produced water waste stream are compared to the water quality standards of Texas, Louisiana, and Alaska to determine compliance with those standards. State water quality implementation guidance documents are followed in applying waste load allocation models for calculating the appropriate daily average and daily maximum limitations for the Texas and Louisiana state standards. Because Alaska does not require application of a waste load allocation model, standards are compared to the effluent concentrations projected by the modeling at the edge of various mixing zones comparable to those of Texas and Louisiana.

4.1.1 Surface Water Modeling

Water quality assessments are conducted separately for Texas, Louisiana, and Cook Inlet operations. Plume dispersion modeling was performed using the CORMIX expert system (Version 2.10; Doneker and Jirka, 1993). For both of the Gulf of Mexico states, three discharge rate scenarios are modeled: mean discharge rate by outfall; median discharge rate by outfall (i.e., 50% of outfall flows are greater or lesser than the median flow); and median discharge rate by flow (i.e., 50% of the total produced water volume is discharged at greater or lesser flow rates). The median rate by outfall is useful in assessing the number or fraction of outfalls or facilities complying with water quality standards, whereas the median rate by flow is more useful for assessing the fraction or proportion of produced water being discharged that is complying with state standards. Because only a few outfalls account for most of the discharge volume, the median discharge by flow is higher than the mean or median rate by outfall. For Cook Inlet operations, outfall-specific flows are modeled for the eight outfalls currently discharging. Effluent pollutant concentrations used in these analyses are those presented previously in Section 2 (Exhibits 2-4 and 2-5).

The modeling input parameters for the Gulf of Mexico facilities are derived from published literature and DMR data from coastal operators. The water depths used are 1 and 3 meters with ambient current speeds of 5 cm/sec; an average determined from published literature for the Gulf of Mexico (Texas A&M, 1991). Ambient density data also are derived from temperature and salinity data in published literature (Temple et al., 1977). For Texas, ambient densities of 1,000 kg/m^3 (summer) and 1,004 kg/m^3 (winter) are modeled; for Louisiana, 1,005 kg/m^3 is used. The water column is assumed to be mixed because of the shallow depths.

The discharge configurations simulated for the Gulf of Mexico outfalls are surface discharges from a 5-inch diameter pipe. These two configuration parameters were determined by responses to the Section 308 questionnaire submitted to EPA by coastal operators. The produced water effluent density is determined from temperature and chlorides data submitted on DMRs. For Texas, only chlorides data are available, so the Louisiana temperature data are used for both states. The resulting effluent densities are 1,031 kg/m^3 for Texas and 1,020 kg/m^3 for Louisiana.

The discharge configurations simulated for Cook Inlet outfalls are based on site-specific data collected for each outfall. Ambient density and current data, outfall configurations, and effluent density data were provided by a Region 10 modeling study for the same outfalls (Schurr, 1986). Most discharges are from submerged pipes. Where site-specific data are not provided in the Region 10 study, averages are used (e.g., pipe diameter and pipe depth).

4.1.2 State Water Quality Standards

For Texas, waste load allocations and soluble metal transformations are applied in the analysis of water quality at 50 feet (the acute standard mixing zone); at 200 feet (the chronic standard mixing zone); and at 400 feet (the human health standard mixing zone). The waste load allocation model uses the predicted mixing that will occur in the water column and the state standards to calculate allowable end-of-pipe limitations. The effluent pollutant concentrations presented in Chapter 2 of this document are compared to those calculated limitations to determine compliance with state standards. The standards used to calculate the Texas water quality-based, end-of-pipe limitations are presented in Exhibit 4-1.

In accordance with the Texas implementation guidance, the waste load allocation was calculated in the following manner. First, as part of the state waste load allocation model, four metals require calculation of a dissolved fraction to determine the amount that may be present in the water column. The calculation of these dissolved fractions is presented in Exhibit 4-2. For all other metals and organic pollutants, the dissolved fraction is assumed to be 1 for the calculations. To calculate the waste load allocation (WLA), each state standard is divided by the fractional percentage of effluent at the edge of the prescribed mixing zone (1/number of dilutions predicted by the model) and multiplied by the dissolved fraction appropriate to each specific pollutant.

This waste load allocation is then used to calculate the long-term average (LTA) limitations for each pollutant (0.32 x WLA for acute limits, 0.61 x WLA for chronic limits, and 0.93 x WLA for human health limits). From these LTA limitations, daily average and daily maximum limitations are calculated for acute, chronic, and human health standards (daily average limitations are 1.47 x LTA and daily maximum limitations are 3.11 x LTA). For water quality compliance analyses, these daily average and daily maximum limitations are used as end of pipe limitations. These limitations are compared to average produced water pollutant concentrations for current BPT and gas flotation (BAT Option 2) produced water effluents to assess compliance with state water quality standards.

For Louisiana, similar waste load allocations and soluble metal transformations are applied in the analysis of water quality at 50 feet (the acute standard mixing zone) and at 200 feet (the chronic and human health standard mixing zone). The Louisiana standards used to calculate the state water quality limitations are presented in Exhibit 4-3.

The waste load allocation model required for Louisiana is the same as Texas with a few variations. The Louisiana soluble metal transformations are the same as Texas. However, Louisiana standards do not

Exhibit 4-1. Texas Water Quality Standards

Parameter	Water Quality Standards (ug/l)		
	Marine Acute	Marine Chronic	Human Health
Arsenic	149	78	
Benzene			208
Cadmium	45.62	10.02	
Chromium (hex)	1,100	50	
Copper	16.27	4.37	
Cresols			31,111
Lead	140	5.6	3.85
Mercury	2.1	1.1	0.025
Nickel	119	13.2	
Selenium	564	136	
Silver	7.2	0.92	
Zinc	98	89	
2-Butanone			591,111

Source: Texas Water Commission, 1991.

Exhibit 4-2. Calculation of the Fraction of Dissolved Metal

Metal	Slope (m)	Texas Linear Partition Coefficients		Louisiana Linear Partition Coefficients	
		Partition Coefficient (K_{po})	K_p[a]	Intercept (b)	K_D[b]
Copper	-0.72	70,000	13,330	4.86	13,804
Lead	-0.85	1,150,000	162,000	6.06	162,181
Silver	-0.74	720,000	131,000		
Zinc	-0.52	230,000	69,500	5.36	69,183

[a] $K_p = K_{po} \times TSS^m$

[b] $K_D = 10^b \times TSS^m$

Where TSS = 10 mg/l for both Texas and Louisiana; as recommended for bays in the Texas Implementation Guidance (Louisiana guidance does not specify TSS)

$$\text{Fraction of Dissolved Metal} = \frac{1}{1 + (K_p \text{ or } K_D \times TSS \times 10^{-6})}$$

Metal	Dissolved Fraction	
	Texas	Louisiana
Copper	0.882	0.878
Lead	0.382	0.381
Silver	0.433	NA[a]
Zinc	0.590	0.591

[a] No dissolved fraction for silver in Louisiana

Exhibit 4-3. Louisiana Water Quality Standards

Parameter	Surface Water Quality Standards (ug/l)			Oil and Gas Standards (ug/l)
	Marine Acute	Marine Chronic	Human Health	
Arsenic	69	36		
Benzene	2,700	1,350	12.5	12.5
Cadmium	45.62	10.0		
Chloromethane			70	
Chromium (tri)	515	103		
Chromium (hex)	1,100	50		
Copper	4.37	4.37		
Ethylbenzene	8,760	4,380	8,100	4,380
Lead	220	8.5		
Mercury	2.1	0.025		
Methylene Chloride	25,600	12,800	87	
Nickel	75	8.3		
Phenol	580	290	50	
Toluene	950	475	69,300	475
Zinc	95	86		
Radium				60 pCi/l
Chlorides	Range of 835 - 1,600 mg/l for estuarine water bodies			10-fold dilution
Oil and grease				15 mg/l
TOC				50 mg/l
TSS				45 mg/l

Source: Louisiana DEQ, 1991.

require use of a dissolved fraction for silver; it is assumed to be 1. The waste load allocation (WLA) is calculated the same as for Texas and the long term average (LTA) limitation is calculated in the same manner as Texas with different multipliers (1.31 x WLA for acute; 0.53 x WLA for chronic; and 1.0 x WLA for human health). The daily average and daily maximum limitations also are calculated the same as Texas with different multipliers (1.31 x LTA for acute, 3.11 x LTA for chronic, and 1.0 x LTA for human health daily average and 2.38 x LTA for human health daily maximum). In addition to state water quality standards, Louisiana has performance-based effluent standards for oil and gas exploration and production facilities. These standards are also presented in Exhibit 4-3 and represent effluent limitations that must be met prior to any dilution of the effluent.

Water quality assessments for Cook Inlet are conducted according to state standards for Alaska (ADEC, 1989; 1994). The Alaska marine water quality standards for toxics and other deleterious organic and inorganic substances in discharges to waters used for growth and propagation of fish, shellfish, aquatic life, and wildlife require compliance with EPA Quality Criteria for Water and Alaska Drinking Water Standards. The water quality limitations used for this analysis are presented in Exhibit 4-4.

The approach to assess compliance with state standards for Alaska fundamentally differs from that of Texas and Louisiana. Alaska regulations do not specify spatially-defined mixing zones. Rather, the extent of the mixing zone needed to achieve compliance with water quality standards is determined and evaluated for reasonableness. Thus, for this analysis the spatial extent of mixing zones needed for each outfall to meet all of the state standards is calculated. However, to assess Alaskan water quality compliance in a manner that would allow comparison with Gulf of Mexico operations, the analysis performed for Cook Inlet facilities also uses 50-foot and 200-foot mixing zones.

4.2 Texas Water Quality Compliance Assessment

The results of the CORMIX modeling for both the current BPT and BAT (Option 2) discharges in Texas coastal waters are presented in Exhibit 4-5 for both 1- and 3-meter water depths for the mean, median by outfall, and median by flow discharge rates. The results are expressed as the number of dilutions projected by the model at the edge of the specified mixing zone in 1- and 3-meter water depths.

The projected dilutions at the edge of the mixing zones for each discharge rate and water depth are used as input in the waste load allocation models. The results of these waste load allocation calculations are used to calculate the long term average limitations and the daily average and daily maximum limitations that are then compared to effluent concentrations. The mean produced water pollutant concentrations are presented on the exhibits and effluent values that exceed the calculated limitations are outlined.

Exhibits 4-6 through 4-8 present the waste load allocation and limitations calculations for current BPT discharges for 1-meter water depths and Exhibits 4-9 through 4-11 present calculations for discharges to 3-meter water depths. For gas flotation (BAT Option 2), the waste load allocation and limitations calculations are presented in Exhibits 4-12 through 4-14 for discharges to 1-meter water depths and in Exhibits 4-15 through 4-17 for discharges to 3-meter water depths.

Exhibit 4–4. Alaska Water Quality Standards[a]

Parameter	Drinking Water Standards (ug/l)	Federal Water Quality Criteria (ug/l)		
		Acute	Chronic	HH
Aluminum	200	–	–	–
Anthracene	–	–	–	0.0311
Antimony	6.0	–	–	–
Arsenic	50	–	–	1.4
Barium	2,000	–	–	–
Benzene	5.0	5,100	700	710
Benzo(a)pyrene	–	–	–	0.311
Beryllium	4.0	–	–	–
Cadmium	5.0	43	9.3	–
Chlorobenzene	–	–	–	21,000
Chromium	100	–	–	–
Copper	1,000	2.9	–	–
Di–n–butylphthalate	–	–	–	12,000
Ethylbenzene	700	430	–	29,000
Iron	300	–	–	–
Lead	–	220	5.6	–
Manganese	50	–	–	–
Mercury	100	–	–	–
Naphthalene	–	2,350	–	–
Nickel	100	75	8.3	100
Phenol	–	5,800	–	–
Radium–226 and –228	5 pCi/l (total) (5E–6 ug/l)	–	–	–
Selenium	50	–	–	–
Silver	100	–	–	–
Thallium	2.0	–	–	–
Toluene	1,000	6,300	5,000	424,000
Xylenes (total)	10,000	–	–	–
Zinc	5,000	95	86	–

[a] Alaska state water quality standards for marine waters – growth and propagation of fish, shellfish, aquatic life, and wildlife – requre that toxic and other deleterious organic and inorganic substances not exceed criteria cited in EPA Quality Criteria for Water or Alaska Drinking Water Standards.

Exhibit 4–5. Cormix Results for Texas Produced Water Discharges

Current (BPT)

Discharge Rate (bpd)	Number of Dilutions at Edge of Mixing Zone								
	Acute (50 ft)			Chronic (200 ft)			Human Health (400 ft)		
1 Meter Water Depth									
	Summer	Winter	Average	Summer	Winter	Average	Summer	Winter	Average
162	157	159	158	357	352	354	1,054	1,017	1,036
577	40.7	40.8	40.8	81.7	80.4	81.1	210	203	206
1,957	15.5	15.5	15.5	25.1	24.8	25.0	49.9	48.4	49.2
3 Meter Water Depth									
	Summer	Winter	Average	Summer	Winter	Average	Summer	Winter	Average
162	895	911	903	1,313	1,325	1,319	2,126	2,111	2,118
577	304	247	276	418	334	376	591	499	545
1,957	82.6	83.4	83.0	106	107	107	145	144	144

Median discharge by outfall 162 bpd
Mean discharge 577 bpd
Median discharge by flow 1,957 bpd

Gas Flotation (BAT Option 2)

Discharge Rate (bpd)	Number of Dilutions at Edge of Mixing Zone								
	Acute (50 ft)			Chronic (200 ft)			Human Health (400 ft)		
1 Meter Water Depth									
	Summer	Winter	Average	Summer	Winter	Average	Summer	Winter	Average
379	58.1	58.4	58.3	127	125	126	355	341	348
838	29.9	30.1	30.0	55.9	55.2	55.6	134	129	131
1,978	15.4	15.4	15.4	24.9	24.6	24.8	49.3	47.8	48.6
3 Meter Water Depth									
	Summer	Winter	Average	Summer	Winter	Average	Summer	Winter	Average
379	431	439	435	605	612	608	891	890	890
838	175	176	176	233	234	234	342	338	340
1,978	107	108	108	136	136	136	177	176	177

Median discharge by outfall 379 bpd
Mean discharge 838 bpd
Median discharge by flow 1,978 bpd

Exhibit 4–6. Waste Load Allocation Calculation for Texas Water Quality Analysis – 1 Meter Water Depth
Current BPT; Median Discharge Rate by Outfall (162 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	0.633	0.282	0.097			591,111			612,095,440
Arsenic	1	0.633	0.282	0.097	149	78		23,542	27,651	
Benzene	1	0.633	0.282	0.097			208			215,384
Cadmium	1	0.633	0.282	0.097	45.62	10.02		7,208	3,552	
Chromium	1	0.633	0.282	0.097	1,100	50		173,800	17,725	
Copper	0.88	0.633	0.282	0.097	16.27	4.37		2,921	1,760	
Cresols	1	0.633	0.282	0.097			31,111			32,215,440
Lead	0.38	0.633	0.282	0.097	140	5.6	3.85	58,211	5,224	10,491
Nickel	1	0.633	0.282	0.097	119	13.2		18,802	4,679	
Selenium	1	0.633	0.282	0.097	564	136		89,112	48,212	
Silver	0.43	0.633	0.282	0.097	7.2	0.92		2,646	758	
Zinc	0.59	0.633	0.282	0.097	98	89		26,244	53,475	

[a] Dissolved fraction calculated according to Texas Natural Resource Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	158
	200 ft	355
	400 ft	1,036

Exhibit 4–6. (Continued)
Current BPT; Median Discharge Rate by Outfall (162 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
2–Butanone			569,248,760			836,795,677			1,770,363,643	122
Arsenic	7,533	16,867		11,074	24,795		23,429	52,457		10.8
Benzene			200,307			294,451			622,955	4,285
Cadmium	2307	2167		3,391	3,185		7,173	6,739		22.8
Chromium	55,616	10,812		81,756	15,894		172,966	33,626		128
Copper	935	1,074		1,374	1,579		2,907	3,340		180
Cresols			29,960,360			44,041,729			93,176,719	270
Lead	18,627	3,187	9,757	27,382	4,685	14,343	57,931	9,911	30,344	515
Nickel	6,017	2,854		8,844	4,196		18,712	8,877		109
Selenium	28,516	29,409		41,918	43,232		88,684	91,463		250
Silver	847	463		1,244	680		2,633	1,439		252
Zinc	8,398	32,620		12,345	47,951		26,118	101,448		329

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The mean Current BPT effluent concentrations do not exceed any of the daily average or maximum limitations.

Exhibit 4–7. Waste Load Allocation Calculation for Texas Water Quality Analysis – 1 Meter Water Depth
Current BPT; Mean Discharge Rate (577 bpd)

Pollutant	Dissolved Fraction[a]	Mean % Effluent[b] at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Standards (ug/l)[c] Marine Acute	Marine Chronic	Human Health	Waste Load Allocation (ug/l)[d] Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	2.45	1.23	0.485			591,111			121,768,866
Arsenic	1	2.45	1.23	0.485	149	78		6,079	6,326	
Benzene	1	2.45	1.23	0.485			208			42,848
Cadmium	1	2.45	1.23	0.485	45.62	10.02		1,861	813	
Chromium	1	2.45	1.23	0.485	1,100	50		44,880	4,055	
Copper	0.88	2.45	1.23	0.485	16.27	4.37		754	403	
Cresols	1	2.45	1.23	0.485			31,111			6,408,866
Lead	0.38	2.45	1.23	0.485	140	5.6	3.85	15,032	1,195	2,087
Nickel	1	2.45	1.23	0.485	119	13.2		4,855	1,071	
Selenium	1	2.45	1.23	0.485	564	136		23,011	11,030	
Silver	0.43	2.45	1.23	0.485	7.2	0.92		683	174	
Zinc	0.59	2.45	1.23	0.485	98	89		6,777	12,234	

[a] Dissolved fraction calculated according to Texas Natural Resource Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	40.8
	200 ft	81.1
	400 ft	206

Exhibit 4–7. (Continued)
Current BPT; Mean Discharge Rate (577 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
2–Butanone			113,245,045			166,470,217			352,192,091	122
Arsenic	1,945	3,859		2,860	5,672		6,050	12,001		10.8
Benzene			39,849			58,578			123,929	4,285
Cadmium	596	496		876	729		1,852	1,542		22.8
Chromium	14,362	2,474		21,112	3,636		44,665	7,693		128
Copper	241	246		355	361		751	764		180
Cresols			5,960,245			8,761,561			18,536,363	270
Lead	4,810	729	1,941	7,071	1,072	2,853	14,959	2,267	6,037	515
Nickel	1,554	653		2,284	960		4,832	2,031		109
Selenium	7,364	6,728		10,824	9,890		22,901	20,924		250
Silver	219	106		321	156		680	329		252 [f]
Zinc	2,169	7,463		3,188	10,970		6,744	23,209		329

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The outlined mean BPT Current effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of silver exceeds the daily average chronic limitation by a factor of 1.6.

Exhibit 4–8. Waste Load Allocation Calculation for Texas Water Quality Analysis – 1 Meter Water Depth
Current BPT; Median Discharge Rate by Flow (1,978 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	6.45	4.00	2.03			591,111			29,082,661
Arsenic	1	6.45	4.00	2.03	149	78		2,310	1,950	
Benzene	1	6.45	4.00	2.03			208			10,234
Cadmium	1	6.45	4.00	2.03	45.62	10.02		707	250	
Chromium	1	6.45	4.00	2.03	1,100	50		17,050	1,250	
Copper	0.88	6.45	4.00	2.03	16.27	4.37		287	124	
Cresols	1	6.45	4.00	2.03			31,111			1,530,661
Lead	0.38	6.45	4.00	2.03	140	5.6	3.85	5,711	368	498
Nickel	1	6.45	4.00	2.03	119	13.2		1,845	330	
Selenium	1	6.45	4.00	2.03	564	136		8,742	3,400	
Silver	0.43	6.45	4.00	2.03	7.2	0.92		260	53.5	
Zinc	0.59	6.45	4.00	2.03	98	89		2,575	3,771	

[a] Dissolved fraction calculated according to Texas Natural Resource Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	15.5
	200 ft	25.0
	400 ft	49.2

Exhibit 4–8. (Continued)
Current BPT; Median Discharge Rate by Flow (1,978 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
2–Butanone			27,046,875			39,758,906			84,115,781	122
Arsenic	739	1,190		1,086	1,749		2,298	3,699		10.8
Benzene			9,517			13,990			29,599	4,285
Cadmium	226	153		333	225		704	475		22.8
Chromium	5,456	763		8,020	1,121		16,968	2,371		128
Copper	91.7	75.7		135	111		285	236		180 [f]
Cresols			1,423,515			2,092,567			4,427,131	270
Lead	1,827	225	464	2,686	330	681	5,683	699	1,442	515 [g]
Nickel	590	201		868	296		1,836	626		109
Selenium	2,797	2,074		4,112	3,049		8,700	6,450		250
Silver	83.1	32.6		122	48.0		258	101		252 [h]
Zinc	824	2,300		1,211	3,382		2,562	7,154		329

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The outlined mean BPT Current effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of copper exceeds the daily average acute and chronic limitations by factors of 1.3 and 1.6, respectively.
[g] The mean effluent concentration of lead exceeds the daily average chronic limitation by a factor of 1.6.
[h] The mean effluent concentration of silver exceeds the daily average acute and chronic limitations by factors of 2.1 and 5.3, respectively; and the daily maximum chronic limitation by a factor of 2.5.

Exhibit 4–9. Waste Load Allocation Calculation for Texas Water Quality Analysis – 3 Meter Water Depth
Current BPT; Median Discharge Rate by Outfall (162 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	0.111	0.076	0.047			591,111			1,251,973,098
Arsenic	1	0.111	0.076	0.047	149	78		134,547	102,882	
Benzene	1	0.111	0.076	0.047			208			440,544
Cadmium	1	0.111	0.076	0.047	45.62	10.02		41,195	13,216	
Chromium	1	0.111	0.076	0.047	1,100	50		993,300	65,950	
Copper	0.88	0.111	0.076	0.047	16.27	4.37		16,695	6,550	
Cresols	1	0.111	0.076	0.047			31,111			65,893,098
Lead	0.38	0.111	0.076	0.047	140	5.6	3.85	332,684	19,438	21,459
Nickel	1	0.111	0.076	0.047	119	13.2		107,457	17,411	
Selenium	1	0.111	0.076	0.047	564	136		509,292	179,384	
Silver	0.43	0.111	0.076	0.047	7.2	0.92		15,120	2,822	
Zinc	0.59	0.111	0.076	0.047	98	89		149,990	198,968	

[a] Dissolved fraction calculated according to Texas Natural Resource Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	903
	200 ft	1,319
	400 ft	2,118

Exhibit 4–9. (Continued)
Current BPT; Median Discharge Rate by Outfall (162 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l)[d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
2–Butanone			1,164,334,981			1,711,572,422			3,621,081,791	
Arsenic	43,055	62,758		63,291	92,254		133,901	195,177		10.8
Benzene			409,706			602,268			1,274,185	4,285
Cadmium	13182	8062		19,378	11,851		40,997	25,073		22.8
Chromium	317,856	40,230		467,248	59,137		988,532	125,114		128
Copper	5,342	3,996		7,853	5,873		16,615	12,426		180
Cresols			61,280,581			90,082,454			190,582,607	270
Lead	106,459	11,857	19,957	156,495	17,430	29,336	331,087	36,876	62,065	515
Nickel	34,386	10,621		50,548	15,612		106,941	33,030		109
Selenium	162,973	109,424		239,571	160,854		506,847	340,309		250
Silver	4,838	1,721		7,112	2,531		15,047	5,354		252
Zinc	47,997	121,370		70,555	178,414		149,270	377,462		329

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The mean Current BPT effluent concentrations do not exceed any of the daily average or maximum limitations.

Exhibit 4–10. Waste Load Allocation Calculation for Texas Water Quality Analysis – 3 Meter Water Depth
Current BPT; Mean Discharge Rate (577 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	0.362	0.266	0.183			591,111			322,155,495
Arsenic	1	0.362	0.266	0.183	149	78		41,124	29,328	
Benzene	1	0.362	0.266	0.183			208			113,360
Cadmium	1	0.362	0.266	0.183	45.62	10.02		12,591	3,768	
Chromium	1	0.362	0.266	0.183	1,100	50		303,600	18,800	
Copper	0.88	0.362	0.266	0.183	16.27	4.37		5,103	1,867	
Cresols	1	0.362	0.266	0.183			31,111			16,955,495
Lead	0.38	0.362	0.266	0.183	140	5.6	3.85	101,684	5,541	5,522
Nickel	1	0.362	0.266	0.183	119	13.2		32,844	4,963	
Selenium	1	0.362	0.266	0.183	564	136		155,664	51,136	
Silver	0.43	0.362	0.266	0.183	7.2	0.92		4,621	804	
Zinc	0.59	0.362	0.266	0.183	98	89		45,844	56,719	

[a] Dissolved fraction calculated according to Texas Natural Resource Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	276
	200 ft	376
	400 ft	545

Exhibit 4–10. (Continued)
Current BPT; Mean Discharge Rate (577 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
2–Butanone			299,604,610			440,418,777			931,770,338	122
Arsenic	13,160	17,890		19,345	26,298		40,927	55,638		10.8
Benzene			105,425			154,974			327,871	4,285
Cadmium	4029	2298		5,923	3,378		12,531	7,147		22.8
Chromium	97,152	11,468		142,813	16,858		302,143	35,665		128
Copper	1,633	1,139		2,400	1,674		5,078	3,542		180
Cresols			15,768,610			23,179,857			49,040,378	270
Lead	32,539	3,380	5,135	47,832	4,969	7,549	101,196	10,512	15,970	515
Nickel	10,510	3,028		15,450	4,451		32,686	9,416		109
Selenium	49,812	31,193		73,224	45,854		154,917	97,010		250
Silver	1,479	491		2,174	721		4,599	1,526		252
Zinc	14,670	34,598		21,565	50,860		45,624	107,601		329

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The mean Current BPT effluent concentrations do not exceed any of the daily average or maximum limitations.

Exhibit 4–11. Waste Load Allocation Calculation for Texas Water Quality Analysis – 3 Meter Water Depth
Current BPT; Median Discharge Rate by Flow (1,957 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	1.20	0.935	0.694			591,111			85,119,984
Arsenic	1	1.20	0.935	0.694	149	78		12,367	8,346	
Benzene	1	1.20	0.935	0.694			208			29,952
Cadmium	1	1.20	0.935	0.694	45.62	10.02		3,786	1,072	
Chromium	1	1.20	0.935	0.694	1,100	50		91,300	5,350	
Copper	0.88	1.20	0.935	0.694	16.27	4.37		1,535	531	
Cresols	1	1.20	0.935	0.694			31,111			4,479,984
Lead	0.38	1.20	0.935	0.694	140	5.6	3.85	30,579	1,577	1,459
Nickel	1	1.20	0.935	0.694	119	13.2		9,877	1,412	
Selenium	1	1.20	0.935	0.694	564	136		46,812	14,552	
Silver	0.43	1.20	0.935	0.694	7.2	0.92		1,390	229	
Zinc	0.59	1.20	0.935	0.694	98	89		13,786	16,141	

[a] Dissolved fraction calculated according to Texas Natural Resource Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	83.0
	200 ft	107
	400 ft	144

Exhibit 11. (Continued)
Current BPT; Median Discharge Rate by Flow (1,957 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
2–Butanone			79,161,585			116,367,530			246,192,530	122
Arsenic	3,957	5,091		5,817	7,484		12,308	15,833		10.8
Benzene			27,855			40,947			86,630	4,285
Cadmium	1212	654		1,781	961		3,768	2,034		22.8
Chromium	29,216	3,264		42,948	4,797		90,862	10,149		128
Copper	491	324		722	476		1,527	1,008		180
Cresols			4,166,385			6,124,586			12,957,458	270
Lead	9,785	962	1,357	14,384	1,414	1,995	30,432	2,991	4,220	515
Nickel	3,161	862		4,646	1,266		9,830	2,679		109
Selenium	14,980	8,877		22,020	13,049		46,587	27,607		250
Silver	445	140		654	205		1,383	434		252 [f]
Zinc	4,412	9,846		6,485	14,473		13,720	30,620		329

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The outlined mean BPT Current effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of silver exceeds the daily average chronic limitation by a factor of 1.2.

Exhibit 4–12. Waste Load Allocation Calculation for Texas Water Quality Analysis – 1 Meter Water Depth
Gas Flotation (BAT Option 2); Median Discharge Rate by Outfall (379 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	1.72	0.794	0.287			591,111			205,706,628
Arsenic	1	1.72	0.794	0.287	149	78		8,687	9,828	
Benzene	1	1.72	0.794	0.287			208			72,384
Cadmium	1	1.72	0.794	0.287	45.62	10.02		2,660	1,263	
Chromium	1	1.72	0.794	0.287	1,100	50		64,130	6,300	
Copper	0.88	1.72	0.794	0.287	16.27	4.37		1,075	624	
Cresols	1	1.72	0.794	0.287			31,111			10,826,628
Lead	0.38	1.72	0.794	0.287	140	5.6	3.85	21,366	1,847	3,507
Nickel	1	1.72	0.794	0.287	119	13.2		6,938	1,663	
Selenium	0.43	1.72	0.794	0.287	564	136		75,938	39,575	
Silver	1	1.72	0.794	0.287	7.2	0.92		420	116	
Zinc	0.59	1.72	0.794	0.287	98	89		9,684	19,007	

[a] Dissolved fraction calculated according to Texas Natural Resource Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	58.3
	200 ft	126
	400 ft	348

Exhibit 4–12. (Continued)
Gas Flotation (BAT Option 2); Median Discharge Rate by Outfall (379 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
2–Butanone			191,307,164			281,221,531			594,965,280	122
Arsenic	2,780	5,995		4,086	8,813		8,645	18,645		10.8
Benzene			67,317			98,956			209,356	1,226
Cadmium	851	770		1,251	1,132		2,647	2,395		14.5
Chromium	20,522	3,843		30,167	5,649		63,822	11,952		128
Copper	344	381		506	560		1,070	1,184		180
Cresols			10,068,764			14,801,083			31,313,856	270
Lead	6,837	1,127	3,262	10,051	1,656	4,795	21,264	3,504	10,144	125
Nickel	2,220	1,015		3,263	1,491		6,904	3,155		109
Selenium	24,300	24,141		35,721	35,487		75,574	75,078		250
Silver	134	70.7		197	104		418	220		252 [f]
Zinc	3,099	11,594		4,555	17,043		9,637	36,058		134

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of silver exceeds the daily average acute and chronic limitations by factors of 1.3 and 2.4, respectively; and the daily maximum chronic limitation by a factor of 1.1.

Exhibit 4–13. Waste Load Allocation Calculation for Texas Water Quality Analysis – 1 Meter Water Depth
Gas Flotation (BAT Option 2); Mean Discharge Rate (838 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	3.33	1.80	0.763			591,111			77,435,541
Arsenic	1	3.33	1.80	0.763	149	78		4,470	4,337	
Benzene	1	3.33	1.80	0.763			208			27,248
Cadmium	1	3.33	1.80	0.763	45.62	10.02		1,369	557	
Chromium	1	3.33	1.80	0.763	1,100	50		33,000	2,780	
Copper	0.88	3.33	1.80	0.763	16.27	4.37		555	276	
Cresols	1	3.33	1.80	0.763			31,111			4,075,541
Lead	0.38	3.33	1.80	0.763	140	5.6	3.85	11,053	819	1,327
Nickel	1	3.33	1.80	0.763	119	13.2		3,570	734	
Selenium	1	3.33	1.80	0.763	564	136		16,920	7,562	
Silver	1	3.33	1.80	0.763	7.2	0.92		216	51.2	
Zinc	0.59	3.33	1.80	0.763	98	89		4,983	8,387	

[a] Dissolved fraction calculated according to Texas Natural Resource Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	30.0
	200 ft	55.6
	400 ft	131

Exhibit 13. (Continued)
Gas Flotation (BAT Option 2); Mean Discharge Rate (838 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
2–Butanone			72,015,053			105,862,128			223,966,815	122
Arsenic	1,430	2,645		2,103	3,889		4,449	8,227		10.8
Benzene			25,341			37,251			78,809	1,226
Cadmium	438	340		644	500		1,362	1,057		14.5
Chromium	10,560	1,696		15,523	2,493		32,842	5,274		128
Copper	177	168		261	248		552	524		180
Cresols			3,790,253			5,571,672			11,787,687	270
Lead	3,537	500	1,234	5,199	735	1,814	11,000	1,554	3,839	125
Nickel	1,142	448		1,679	658		3,553	1,392		109
Selenium	5,414	4,613		7,959	6,780		16,839	14,345		250
Silver	69.1	31.2		102	45.9		215	97.0		252 [f]
Zinc	1,595	5,116		2,344	7,521		4,959	15,911		134

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of silver exceeds the daily average acute and chronic limitations by factors of 2.5 and 5.5, respectively; and the daily maximum acute and chronic limitations by factors of 1.2 and 2.6, respectively.

Exhibit 4–14. Waste Load Allocation Calculation for Texas Water Quality Analysis – 1 Meter Water Depth
Gas Flotation (BAT Option 2); Median Discharge Rate by Flow (1,978 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	6.49	4.03	2.06			591,111			28,727,995
Arsenic	1	6.49	4.03	2.06	149	78		2,295	1,934	
Benzene	1	6.49	4.03	2.06			208			10,109
Cadmium	1	6.49	4.03	2.06	45.62	10.02		703	248	
Chromium	1	6.49	4.03	2.06	1,100	50		16,940	1,240	
Copper	0.88	6.49	4.03	2.06	16.27	4.37		285	123	
Cresols	1	6.49	4.03	2.06			31,111			1,511,995
Lead	0.38	6.49	4.03	2.06	140	5.6	3.85	5,674	365	492
Nickel	1	6.49	4.03	2.06	119	13.2		1,833	327	
Selenium	1	6.49	4.03	2.06	564	136		8,686	3,373	
Silver	1	6.49	4.03	2.06	7.2	0.92		111	22.8	
Zinc	0.59	6.49	4.03	2.06	98	89		2,558	3,741	

[a] Dissolved fraction calculated according to Texas Natural Resource Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	15.4
	200 ft	24.8
	400 ft	48.6

Exhibit 4–14. (Continued)
Gas Flotation (BAT Option 2); Median Discharge Rate by Flow (1,978 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
2–Butanone			26,717,035			39,274,041			83,089,979	122
Arsenic	734	1,180		1,079	1,735		2,284	3,670		10.8
Benzene			9,401			13,820			29,238	1,226
Cadmium	225	152		330	223		699	471		14.5
Chromium	5421	756		7,969	1,112		16,859	2,352		128
Copper	91.1	75.1		134	110		283	234		180 [f]
Cresols			1,406,155			2,067,048			4,373,142	270
Lead	1,816	223	458	2,669	328	673	5,646	693	1,424	125
Nickel	586	200		862	294		1,824	621		109
Selenium	2,779	2,057		4,086	3,024		8,644	6,399		250
Silver	35.5	13.9		52.2	20.5		110	43.3		252 [g]
Zinc	819	2,282		1,203	3,355		2,546	7,097		134

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[e] The mean effluent concentration of copper exceeds the daily average acute and chronic limitations by factors of 1.3 and 1.6, respectively.
[f] The mean effluent concentration of silver exceeds the daily average acute and chronic limitations by factors of 4.8 and 12, respectively; and the daily maximum acute and chronic limitations by factors of 2.3 and 5.8, respectively.

Exhibit 4–15. Waste Load Allocation Calculation for Texas Water Quality Analysis – 3 Meter Water Depth
Gas Flotation (BAT Option 2); Median Discharge Rate by Outfall (379 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	0.230	0.164	0.112			591,111			526,088,790
Arsenic	1	0.230	0.164	0.112	149	78		64,815	47,424	
Benzene	1	0.230	0.164	0.112			208			185,120
Cadmium	1	0.230	0.164	0.112	45.62	10.02		19,845	6,092	
Chromium	1	0.230	0.164	0.112	1,100	50		478,500	30,400	
Copper	0.88	0.230	0.164	0.112	16.27	4.37		8,043	3,019	
Cresols	1	0.230	0.164	0.112			31,111			27,688,790
Lead	0.38	0.230	0.164	0.112	140	5.6	3.85	160,263	8,960	9,017
Nickel	1	0.230	0.164	0.112	119	13.2		51,765	8,026	
Selenium	1	0.230	0.164	0.112	564	136		245,340	82,688	
Silver	1	0.230	0.164	0.112	7.2	0.92		3,132	559	
Zinc	0.59	0.230	0.164	0.112	98	89		72,254	91,715	

[a] Dissolved fraction calculated according to Texas Natural Resources Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	435
	200 ft	608
	400 ft	890

Exhibit 4–15. (Continued)
Gas Flotation (BAT Option 2); Median Discharge Rate by Outfall (379 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l)[d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
2–Butanone			489,262,575			719,215,985			1,521,606,607	122
Arsenic	20,741	28,929		30,489	42,525		64,504	89,968		10.8
Benzene			172,162			253,078			535,423	4,285
Cadmium	6,350	3,716		9,335	5,463		19,749	11,557		22.8
Chromium	153,120	18,544		225,086	27,260		476,203	57,672		128
Copper	2,574	1,842		3,783	2,707		8,004	5,728		180
Cresols			25,750,575			37,853,345			80,084,287	270
Lead	51,284	5,466	8,386	75,388	8,034	12,327	159,494	16,998	26,080	515
Nickel	16,565	4,896		24,350	7,197		51,517	15,225		109
Selenium	78,509	50,440		115,408	74,146		244,162	156,867		250
Silver	1,002	341		1,473	502		3,117	1,061		252
Zinc	23,121	55,946		33,988	82,241		71,907	173,993		329

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The mean BAT Option 2 effluent concentrations do not exceed any of the daily average or maximum limitations.

Exhibit 4-16. Waste Load Allocation Calculation for Texas Water Quality Analysis – 3 Meter Water Depth
Gas Flotation (BAT Option 2); Mean Discharge Rate (838 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2-Butanone	1	0.568	0.427	0.294			591,111			200,977,740
Arsenic	1	0.568	0.427	0.294	149	78		26,224	18,252	
Benzene	1	0.568	0.427	0.294			208			70,720
Cadmium	1	0.568	0.427	0.294	45.62	10.02		8,029	2,345	
Chromium	1	0.568	0.427	0.294	1,100	50		193,600	11,700	
Copper	0.88	0.568	0.427	0.294	16.27	4.37		3,254	1,162	
Cresols	1	0.568	0.427	0.294			31,111			10,577,740
Lead	0.38	0.568	0.427	0.294	140	5.6	3.85	64,842	3,448	3,445
Nickel	1	0.568	0.427	0.294	119	13.2		20,944	3,089	
Selenium	1	0.568	0.427	0.294	564	136		99,264	31,824	
Silver	1	0.568	0.427	0.294	7.2	0.92		1,267	215	
Zinc	0.59	0.568	0.427	0.294	98	89		29,234	35,298	

[a] Dissolved fraction calculated according to Texas Natural Resources Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50-ft zone of initial dilution (ZID); chronic criteria at a 200-ft mixing zone, and human health criteria at a 400-ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	176
	200 ft	234
	400 ft	340

Exhibit 4–16. (Continued)
Gas Flotation (BAT Option 2); Mean Discharge Rate (838 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
2–Butanone			186,909,298			274,756,668			581,287,917	122
Arsenic	8,392	11,134		12,336	16,367		26,098	34,626		10.8
Benzene			65,770			96,681			204,543	4,285
Cadmium	2,569	1,430		3,777	2,102		7,991	4,448		22.8
Chromium	61,952	7,137		91,069	10,491		192,671	22,196		128
Copper	1,041	709		1,531	1,042		3,238	2,204		180
Cresols			9,837,298			14,460,828			30,593,997	270
Lead	20,749	2,104	3,204	30,502	3,092	4,709	64,531	6,542	9,963	515
Nickel	6,702	1,884		9,852	2,770		20,843	5,860		109
Selenium	31,764	19,413		46,694	28,537		98,788	60,373		250
Silver	406	131		596	193		1,261	408		252 [f]
Zinc	9,355	21,532		13,752	31,652		29,094	66,964		329

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean concentration of silver exceeds the daily average chronic limitation by a factor of 1.3.

Exhibit 4–17. Waste Load Allocation Calculation for Texas Water Quality Analysis – 3 Meter Water Depth
Gas Flotation (BAT Option 2); Median Discharge Rate by Flow (1,978 bpd)

		Mean % Effluent [b]			Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	at Mix Zone (400 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 400 ft)
2–Butanone	1	0.926	0.735	0.565			591,111			104,626,647
Arsenic	1	0.926	0.735	0.565	149	78		16,092	10,608	
Benzene	1	0.926	0.735	0.565			208			36,816
Cadmium	1	0.926	0.735	0.565	45.62	10.02		4,927	1,363	
Chromium	1	0.926	0.735	0.565	1,100	50		118,800	6,800	
Copper	0.88	0.926	0.735	0.565	16.27	4.37		1,997	675	
Cresols	1	0.926	0.735	0.565			31,111			5,506,647
Lead	0.38	0.926	0.735	0.565	140	5.6	3.85	39,789	2,004	1,793
Nickel	1	0.926	0.735	0.565	119	13.2		12,852	1,795	
Selenium	1	0.926	0.735	0.565	564	136		60,912	18,496	
Silver	1	0.926	0.735	0.565	7.2	0.92		778	125	
Zinc	0.59	0.926	0.735	0.565	98	89		17,939	20,515	

[a] Dissolved fraction calculated according to Texas Natural Resources Conservation Commission, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic criteria at a 200–ft mixing zone, and human health criteria at a 400–ft mixing zone.
[c] Source: Texas Surface Water Quality Standards Chapter 307.6.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).

Dilutions available:		
	50 ft	108
	200 ft	136
	400 ft	177

Exhibit 4–17. (Continued)
Gas Flotation (BAT Option 2); Median Discharge Rate by Flow (1,978 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l)[d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
2–Butanone			97,302,782			143,035,089			302,611,651	122
Arsenic	5,149	6,471		7,570	9,512		16,015	20,124		10.8
Benzene			34,239			50,331			106,483	4,285
Cadmium	1,577	831		2,318	1,222		4,903	2,585		22.8
Chromium	38,016	4,148		55,884	6,098		118,230	12,900		128
Copper	639	412		939	606		1,987	1,281		180
Cresols			5,121,182			7,528,137			15,926,875	270
Lead	12,733	1,223	1,668	18,717	1,797	2,452	39,598	3,802	5,187	515
Nickel	4,113	1,095		6,046	1,610		12,790	3,406		109
Selenium	19,492	11,283		28,653	16,585		60,620	35,089		250
Silver	249	76.3		366	112		774	237		252 [f]
Zinc	5,740	12,514		8,438	18,396		17,853	38,919		329

[a] Long–term averages calculated as 0.32 * WLA (acute); 0.61 * WLA (chronic); and 0.93 * WLA (human health).
[b] Daily Average calculated as 1.47 * long–term averages for acute, chronic, and human health.
[c] Daily Maximum calculated as 3.11 * long–term averages for acute, chronic, and human health.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean concentration of silver exceeds the daily average and daily maximum chronic limitations by factors of 2.3 and 1.1, respectively.

4.3 Louisiana Water Quality Compliance Assessment

The results of the CORMIX modeling for both the current BPT and gas flotation (BAT Option 2) discharges in Louisiana coastal waters are presented in Exhibit 4-18 for 1- and 3-meter water depths for the mean, median by outfall, and median by flow discharge rates. The results are expressed as the number of dilutions projected by the model at the edge of the specified mixing zones.

The projected dilutions at the edge of the mixing zones are used as input in the waste load allocation models. The results of these waste load allocation calculations are used to calculate the long term average limitations and the daily average and daily maximum limitations that are then compared to effluent concentrations. The mean produced water pollutant concentrations are presented on the exhibits and effluent values that exceed the calculated limitations are outlined.

Exhibits 4-19 through 4-21 present the waste load allocation and limitations calculations for current BPT discharges for 1-meter water depths and Exhibits 4-22 through 4-24 present calculations for discharges to 3-meter water depths. For gas flotation (BAT Option 2), the waste load allocation and limitations calculations are presented in Exhibits 4-25 through 4-27 for discharges to 1-meter water depths and in Exhibits 4-28 through 4-30 for discharges to 3-meter water depths.

The Louisiana oil and gas rule limitations are compared to the current BPT and gas flotation (BAT Option 2) effluent concentrations in Exhibit 4-31. These are end-of-pipe limitations that must be met before any dilution has occurred.

4.4 Cook Inlet, Alaska Water Quality Compliance Assessment

The results of the surface water modeling for Cook Inlet are presented in Exhibit 4-32 as the number of dilutions projected at the edge of each mixing zone. The current BPT and gas flotation (BAT Options 2 and 4) mean pollutant concentrations are divided by these predicted dilutions to determine the pollutant concentrations at the edge of the mixing zones modeled. For the eight outfalls, the water quality analyses are presented in Exhibits 4-33 through 4-40. The resulting pollutant concentrations for current BPT and gas flotation (BAT Options 2 and 4) effluent at the edge of the mixing zones are compared to the state standards. On each table, those pollutant concentrations that exceed state standards are outlined.

4.5 Summary of Water Quality Compliance Assessments for Produced Water

4.5.1 Gulf of Mexico - Current BPT

The summary of the water quality analyses for Texas and Louisiana current BPT discharges in 1 meter and 3 meters of water are presented in Exhibit 4-41. The median discharge rate by outfall results in 5 exceedances (all in Louisiana) at the 1 meter depth (3 daily average limitations - copper acute, copper chronic, and benzene human health; and 2 daily maximum limitations - copper acute and benzene human

Exhibit 4–18. Cormix Results for Louisiana Produced Water Discharges

Current (BPT)

Discharge Rate (bpd)	Number of Dilutions at Edge of Mixing Zone	
	50 ft	200 ft
1 Meter Water Depth		
950	27.6	40.7
4,425	11.1	13.9
15,100	5.30	7.00
3 Meter Water Depth		
950	166	208
4,425	48.1	52.9
15,100	12.7	16.2

Median discharge by outfall 950 bpd
Mean discharge 4,425 bpd
Median discharge by flow 15,100 bpd

Gas Flotation (BAT Option 2)

Discharge Rate (bpd)	Number of Dilutions at Edge of Mixing Zone	
	50 ft	200 ft
1 Meter Water Depth		
1,125	24.5	39.3
4,949	9.90	12.4
15,100	5.30	7.00
3 Meter Water Depth		
1,125	142	181
4,949	41.0	47.7
15,100	12.7	16.2

Median discharge by outfall 1,125 bpd
Mean discharge 4,949 bpd
Median discharge by flow 15,100 bpd

Exhibit 4–19. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 1 Meter Water Depth
Current BPT; Median Discharge Rate by Outfall (950 bpd)

Pollutant	Dissolved Fraction[a]	Mean % Effluent [b] at ZID (50 feet)	Mean % Effluent [b] at Mix Zone (200 feet)	Standards (ug/l) [c] Marine Acute	Standards (ug/l) [c] Marine Chronic	Standards (ug/l) [c] Human Health	Waste Load Allocation (ug/l) [d] Acute (at ZID)	Waste Load Allocation (ug/l) [d] Chronic (at 200 ft)	Waste Load Allocation (ug/l) [d] Health (at 200 ft)
Arsenic	1	3.62	2.46	69	36		1,904	1,465	
Benzene	1	3.62	2.46	2,700	1,350	12.5	74,520	54,945	509
Cadmium	1	3.62	2.46	45.62	10.0		1,259	407	
Chlorides	1	3.62	2.46	835 – 1,600 mg/l [e]					
Chloromethane	1	3.62	2.46			70			2,849
Chromium (tri)	1	3.62	2.46	515	103		14,214	4,192	
Chromium (hex)	1	3.62	2.46	1,100	50		30,360	2,035	
Copper	0.88	3.62	2.46	4.37	4.37		137	202	
Ethylbenzene	1	3.62	2.46	8,760	4,380	8,100	241,776	178,266	329,670
Lead	0.38	3.62	2.46	220	8.5		15,979	910	
Methylene Chloride	1	3.62	2.46	25,600	12,800	87	706,560	520,960	3,541
Nickel	1	3.62	2.46	75	8.3		2,070	338	
Phenol	1	3.62	2.46	580	290	50	16,008	11,803	2,035
Toluene	1	3.62	2.46	950	475	69,300	26,220	19,333	2,820,510
Zinc	0.59	3.62	2.46	95	86		4,444	5,933	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 27.6 and 200 ft – 40.7

Exhibit 4–19. (Continued)
Current BPT; Median Discharge Rate by Outfall (950 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
Arsenic	609	777		798	1,017		1,895	2,415		10.8
Benzene	23,846	29,121	509	31,239	38,148	509	74,162	90,566	1,211	4,285 [f]
Cadmium	403	216		528	283		1,253	671		22.8
Chlorides (mg/l)							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			2,849			2,849			6,781	28.6
Chromium (tri)	4,548	2,222		5,959	2,911		14,146	6,910		128
Chromium (hex)	9,715	1,079		12,727	1,413		30,214	3,354		128
Copper	43.9	107		57.5	140		136	333		180 [h]
Ethylbenzene	77,368	94,481	329,670	101,352	123,770	329,670	240,615	293,836	784,615	115
Lead	5,113	483		6,698	632		15,902	1,501		515
Methylene Chloride	226,099	276,109	3,541	296,190	361,703	3,541	703,169	858,698	8,427	170
Nickel	662	179		868	235		2,060	557		109
Phenol	5,123	6,256	2,035	6,711	8,195	2,035	15,931	19,455	4,843	553
Toluene	8,390	10,246	2,820,510	10,991	13,423	2,820,510	26,094	31,866	6,712,814	3,370
Zinc	1,422	3,144		1,863	4,119		4,423	9,779		329

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BPT Current effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 8.4 and 3.5, respectively.
[g] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[h] The mean concentration of copper exceeds the daily average acute and chronic limitations by factors of 3.1 and 1.3, respectively; and the daily maximum acute limitation by a factor of 1.3.

Exhibit 4–20. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 1 Meter Water Depth
Current BPT; Mean Discharge Rate (4,425 bpd)

Pollutant	Dissolved Fraction[a]	Mean % Effluent[b] at ZID (50 feet)	Mean % Effluent[b] at Mix Zone (200 feet)	Standards (ug/l)[c] Marine Acute	Standards (ug/l)[c] Marine Chronic	Standards (ug/l)[c] Human Health	Waste Load Allocation (ug/l)[d] Acute (at ZID)	Waste Load Allocation (ug/l)[d] Chronic (at 200 ft)	Waste Load Allocation (ug/l)[d] Health (at 200 ft)
Arsenic	1	9.01	7.19	69	36		766	500	
Benzene	1	9.01	7.19	2,700	1,350	12.5	29,970	18,765	174
Cadmium	1	9.01	7.19	45.62	10.0		506	139	
Chlorides	1	9.01	7.19	835 – 1,600 mg/l[e]					
Chloromethane	1	9.01	7.19			70			973
Chromium (tri)	1	9.01	7.19	515	103		5,716	1,432	
Chromium (hex)	1	9.01	7.19	1,100	50		12,210	695	
Copper	0.88	9.01	7.19	4.37	4.37		55.1	69.0	
Ethylbenzene	1	9.01	7.19	8,760	4,380	8,100	97,236	60,882	112,590
Lead	0.38	9.01	7.19	220	8.5		6,426	311	
Methylene Chloride	1	9.01	7.19	25,600	12,800	87	284,160	177,920	1,209
Nickel	1	9.01	7.19	75	8.3		832	115	
Phenol	1	9.01	7.19	580	290	50	6,438	4,031	695
Toluene	1	9.01	7.19	950	475	69,300	10,545	6,602	963,270
Zinc	0.59	9.01	7.19	95	86		1,787	2,026	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 11.1; 200 ft – 13.9

Exhibit 4–20. (Continued)
Current BPT; Mean Discharge Rate (4,425 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
Arsenic	245	265		321	347		762	825		10.8
Benzene	9,590	9,945	174	12,563	13,029	174	29,826	30,930	414	4,285 [f]
Cadmium	162	74		212	96.5		504	229		22.8
Chlorides (mg/l)							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			973			973			2,316	28.6
Chromium (tri)	1,829	759		2,396	994		5,689	2,360		128
Chromium (hex)	3,907	368		5,118	483		12,151	1,146		128
Copper	17.6	36.6		23.1	47.9		54.9	114		180 [h]
Ethylbenzene	31,116	32,267	112,590	40,761	42,270	112,590	96,769	100,352	267,964	115
Lead	2,056	165		2,694	216		6,395	512		515 [i]
Methylene Chloride	90,931	94,298	1,209	119,120	123,530	1,209	282,796	293,266	2,878	170
Nickel	266	61		349	80.1		829	190		109
Phenol	2,060	2,136	695	2,699	2,799	695	6,407	6,644	1,654	553
Toluene	3,374	3,499	963,270	4,420	4,584	963,270	10,494	10,883	2,292,583	3,370
Zinc	572	1,074		749	1,407		1,779	3,340		329

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BPT Current effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 25 and 10, respectively.
[g] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[h] The mean concentration of copper exceeds the daily average acute and chronic limitations by factors of 7.8 and 3.8, respectively; and the daily maximum acute limitation by a factor of 3.3.
[i] The mean concentraion of lead exceeds the daily average chronic limitation by a factor of 2.4.

Exhibit 4–21. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 1 Meter Water Depth
Current BPT; Median Discharge Rate by Flow (15,100 bpd)

Pollutant	Dissolved Fraction[a]	Mean % Effluent [b] at ZID (50 feet)	Mean % Effluent [b] at Mix Zone (200 feet)	Standards (ug/l) [c] Marine Acute	Standards (ug/l) [c] Marine Chronic	Standards (ug/l) [c] Human Health	Waste Load Allocation (ug/l) [d] Acute (at ZID)	Waste Load Allocation (ug/l) [d] Chronic (at 200 ft)	Waste Load Allocation (ug/l) [d] Health (at 200 ft)
Arsenic	1	18.9	14.3	69	36		366	252	
Benzene	1	18.9	14.3	2,700	1,350	12.5	14,310	9,450	87.5
Cadmium	1	18.9	14.3	45.62	10.0		242	70	
Chlorides	1	18.9	14.3	835 – 1,600 mg/l [e]					
Chloromethane	1	18.9	14.3			70			490
Chromium (tri)	1	18.9	14.3	515	103		2,730	721	
Chromium (hex)	1	18.9	14.3	1,100	50		5,830	350	
Copper	0.88	18.9	14.3	4.37	4.37		26.3	34.8	
Ethylbenzene	1	18.9	14.3	8,760	4,380	8,100	46,428	30,660	56,700
Lead	0.38	18.9	14.3	220	8.5		3,068	157	
Methylene Chloride	1	18.9	14.3	25,600	12,800	87	135,680	89,600	609
Nickel	1	18.9	14.3	75	8.3		398	58.1	
Phenol	1	18.9	14.3	580	290	50	3,074	2,030	350
Toluene	1	18.9	14.3	950	475	69,300	5,035	3,325	485,100
Zinc	0.59	18.9	14.3	95	86		853	1,020	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 5.30; 200 ft – 7.00

Exhibit 4–21. (Continued)
Current BPT; Median Discharge Rate by Flow (15,100 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
Arsenic	117	134		153	175		364	415		10.8
Benzene	4,579	5,009	87.5	5,999	6,561	87.5	14,241	15,576	208	4,285 [f]
Cadmium	77.4	37.1		101	48.6		241	115		22.8
Chlorides (mg/l)							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			490			490			1,166	28.6
Chromium (tri)	873	382		1,144	501		2,716	1,188		128
Chromium (hex)	1,866	186		2,444	243		5,802	577		128
Copper	8.4	18.4		11.0	24.1		26.2	57.3		180 [h]
Ethylbenzene	14,857	16,250	56,700	19,463	21,287	56,700	46,205	50,537	134,946	115
Lead	982	83		1,286	109		3,054	258		515 [i]
Methylene Chloride	43,418	47,488	609	56,877	62,209	609	135,029	147,688	1,449	170
Nickel	127	30.8		167	40.3		396	95.8		109 [j]
Phenol	984	1,076	350	1,289	1,409	350	3,059	3,346	833	553 [k]
Toluene	1,611	1,762	485,100	2,111	2,309	485,100	5,011	5,481	1,154,538	3,370 [l]
Zinc	273	541		358	708		849	1,682		329

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BPT Current effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 49 and 21, respectively.
[g] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[h] The mean concentration of copper exceeds the daily average acute and chronic limitations by factors of 16 and 7.5, respectively; and the daily maximum acute and chronic limitations by factors of 6.9 and 3.1.
[i] The mean concentraion of lead exceeds the daily average and daily maximum chronic limitations by factors of 4.7 and 2.0, respectively.
[j] The mean concentration of nickel exceeds the daily average and daily maximum chronic limitations by factors of 2.7 and 1.1, respectively.
[k] The mean concentration of phenol exceeds the daily average human health limitaiton by a factor of 1.6.
[l] The mean concentration of toluene exceeds the daily average acute and chronic limitations by factors of 1.6 and 1.5, respectively.

Exhibit 4–22. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 3 Meter Water Depth
Current BPT; Median Discharge Rate by Outfall (950 bpd)

Pollutant	Dissolved Fraction[a]	Mean % Effluent[b] at ZID (50 feet)	Mean % Effluent[b] at Mix Zone (200 feet)	Standards (ug/l)[c] Marine Acute	Standards (ug/l)[c] Marine Chronic	Standards (ug/l)[c] Human Health	Waste Load Allocation (ug/l)[d] Acute (at ZID)	Waste Load Allocation (ug/l)[d] Chronic (at 200 ft)	Waste Load Allocation (ug/l)[d] Health (at 200 ft)
Arsenic	1	0.602	0.481	69	36		11,454	7,488	
Benzene	1	0.602	0.481	2,700	1,350	12.5	448,200	280,800	2,600
Cadmium	1	0.602	0.481	45.62	10.0		7,573	2,080	
Chlorides	1	0.602	0.481	835 – 1,600 mg/l[e]					
Chloromethane	1	0.602	0.481			70			14,560
Chromium (tri)	1	0.602	0.481	515	103		85,490	21,424	
Chromium (hex)	1	0.602	0.481	1,100	50		182,600	10,400	
Copper	0.88	0.602	0.481	4.37	4.37		824	1,033	
Ethylbenzene	1	0.602	0.481	8,760	4,380	8,100	1,454,160	911,040	1,684,800
Lead	0.38	0.602	0.481	220	8.5		96,105	4,653	
Methylene Chloride	1	0.602	0.481	25,600	12,800	87	4,249,600	2,662,400	18,096
Nickel	1	0.602	0.481	75	8.3		12,450	1,726	
Phenol	1	0.602	0.481	580	290	50	96,280	60,320	10,400
Toluene	1	0.602	0.481	950	475	69,300	157,700	98,800	14,414,400
Zinc	0.59	0.602	0.481	95	86		26,729	30,319	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 166; 200 ft – 208

Exhibit 4–22. (Continued)
Current BPT; Median Discharge Rate by Outfall (950 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
Arsenic	3,665	3,969		4,802	5,199		11,399	12,342		10.8
Benzene	143,424	148,824	2,600	187,885	194,959	2,600	446,049	462,843	6,188	4,285 [f]
Cadmium	2,423	1,102		3,175	1,444		7,537	3,428		22.8
Chlorides (mg/l)							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			14,560			14,560			34,653	28.6
Chromium (tri)	27,357	11,355		35,837	14,875		85,080	35,313		128
Chromium (hex)	58,432	5,512		76,546	7,221		181,724	17,142		128
Copper	264	547		346	717		820	1,703		180
Ethylbenzene	465,331	482,851	1,684,800	609,584	632,535	1,684,800	1,447,180	1,501,667	4,009,824	115
Lead	30,754	2,466		40,287	3,230		95,644	7,669		515
Methylene Chloride	1,359,872	1,411,072	18,096	1,781,432	1,848,504	18,096	4,229,202	4,388,434	43,068	170
Nickel	3,984	915		5,219	1,199		12,390	2,846		109
Phenol	30,810	31,970	10,400	40,361	41,880	10,400	95,818	99,425	24,752	553
Toluene	50,464	52,364	14,414,400	66,108	68,597	14,414,400	156,943	162,852	34,306,272	3,370
Zinc	8,553	16,069		11,205	21,050		26,601	49,974		329

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BPT Current effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of benzene exceeds the daily average human health limitation by a factor of 1.6.
[g] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.

Exhibit 4–23. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 3 Meter Water Depth
Current BPT; Mean Discharge Rate (4,425 bpd)

Pollutant	Dissolved Fraction[a]	Mean % Effluent[b] at ZID (50 feet)	Mean % Effluent[b] at Mix Zone (200 feet)	Standards (ug/l)[c] Marine Acute	Standards (ug/l)[c] Marine Chronic	Standards (ug/l)[c] Human Health	Waste Load Allocation (ug/l)[d] Acute (at ZID)	Waste Load Allocation (ug/l)[d] Chronic (at 200 ft)	Waste Load Allocation (ug/l)[d] Health (at 200 ft)
Arsenic	1	2.08	1.89	69	36		3,319	1,904	
Benzene	1	2.08	1.89	2,700	1,350	12.5	129,870	71,415	661
Cadmium	1	2.08	1.89	45.62	10.0		2,194	529	
Chlorides	1	2.08	1.89	835 – 1,600 mg/l[e]					
Chloromethane	1	2.08	1.89			70			3,703
Chromium (tri)	1	2.08	1.89	515	103		24,772	5,449	
Chromium (hex)	1	2.08	1.89	1,100	50		52,910	2,645	
Copper	0.88	2.08	1.89	4.37	4.37		239	263	
Ethylbenzene	1	2.08	1.89	8,760	4,380	8,100	421,356	231,702	428,490
Lead	0.38	2.08	1.89	220	8.5		27,847	1,183	
Methylene Chloride	1	2.08	1.89	25,600	12,800	87	1,231,360	677,120	4,602
Nickel	1	2.08	1.89	75	8.3		3,608	439	
Phenol	1	2.08	1.89	580	290	50	27,898	15,341	2,645
Toluene	1	2.08	1.89	950	475	69,300	45,695	25,128	3,665,970
Zinc	0.59	2.08	1.89	95	86		7,745	7,711	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 48.1; 200 ft – 52.9

Exhibit 4–23. (Continued)
Current BPT; Mean Discharge Rate (4,425 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
Arsenic	1,062	1,009		1,391	1,322		3,303	3,139		10.8
Benzene	41,558	37,850	661	54,442	49,583	661	129,247	117,713	1,574	4,285 [f]
Cadmium	702	280		920	367		2,184	872		22.8
Chlorides (mg/l)							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			3,703			3,703			8,813	28.6
Chromium (tri)	7,927	2,888		10,384	3,783		24,653	8,981		128
Chromium (hex)	16,931	1,402		22,180	1,836		52,656	4,360		128
Copper	76.4	139		100	182		238	433		180 [h]
Ethylbenzene	134,834	122,802	428,490	176,632	160,871	428,490	419,333	381,914	1,019,806	115
Lead	8,911	627		11,674	822		27,714	1,950		515
Methylene Chloride	394,035	358,874	4,602	516,186	470,124	4,602	1,225,449	1,116,097	10,953	170
Nickel	1,154	233		1,512	305		3,590	724		109
Phenol	8,927	8,131	2,645	11,695	10,651	2,645	27,764	25,287	6,295	553
Toluene	14,622	13,318	3,665,970	19,155	17,446	3,665,970	45,476	41,418	8,725,009	3,370
Zinc	2,478	4,087		3,247	5,354		7,708	12,710		329

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BPT Current effluent concentrations exceed the outlined daily average and maximum limitations.
[e] The mean effluent concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 6.5 and 2.7, repectively.
[f] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[g] The mean effluent concentration of copper exceeds the daily average acute limitation by a factor of 1.8.

Exhibit 4–24. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 3 Meter Water Depth
Current BPT; Median Discharge Rate by Flow (15,100 bpd)

Pollutant	Dissolved Fraction[a]	Mean % Effluent[b] at ZID (50 feet)	Mean % Effluent[b] at Mix Zone (200 feet)	Standards (ug/l)[c] Marine Acute	Standards (ug/l)[c] Marine Chronic	Standards (ug/l)[c] Human Health	Waste Load Allocation (ug/l)[d] Acute (at ZID)	Waste Load Allocation (ug/l)[d] Chronic (at 200 ft)	Waste Load Allocation (ug/l)[d] Health (at 200 ft)
Arsenic	1	7.87	6.17	69	36		876	583	
Benzene	1	7.87	6.17	2,700	1,350	12.5	34,290	21,870	202
Cadmium	1	7.87	6.17	45.62	10.0		579	162	
Chlorides	1	7.87	6.17	835 – 1,600 mg/l[e]					
Chloromethane	1	7.87	6.17			70			1,134
Chromium (tri)	1	7.87	6.17	515	103		6,540	1,669	
Chromium (hex)	1	7.87	6.17	1,100	50		13,970	810	
Copper	0.88	7.87	6.17	4.37	4.37		63.1	80.4	
Ethylbenzene	1	7.87	6.17	8,760	4,380	8,100	111,252	70,956	131,220
Lead	0.38	7.87	6.17	220	8.5		7,353	362	
Methylene Chloride	1	7.87	6.17	25,600	12,800	87	325,120	207,360	1,409
Nickel	1	7.87	6.17	75	8.3		952	134	
Phenol	1	7.87	6.17	580	290	50	7,366	4,698	810
Toluene	1	7.87	6.17	950	475	69,300	12,065	7,695	1,122,660
Zinc	0.59	7.87	6.17	95	86		2,045	2,361	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 12.7; 200 ft – 16.2

Exhibit 4–24. (Continued)
Current BPT; Median Discharge Rate by Flow (15,100 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Current BPT [e]
Arsenic	280	309		367	405		872	961		10.8
Benzene	10,973	11,591	202	14,374	15,184	202	34,125	36,048	482	4,285 [f]
Cadmium	185	85.9		243	112		577	267		22.8
Chlorides (mg/l)							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			1,134			1,134			2,699	28.6
Chromium (tri)	2,093	884		2,742	1,159		6,509	2,750		128
Chromium (hex)	4,470	429		5,856	562		13,903	1,335		128
Copper	20.2	42.6		26.4	55.9		62.8	133		180 [h]
Ethylbenzene	35,601	37,607	131,220	46,637	49,265	131,220	110,718	116,957	312,304	115
Lead	2,353	192		3,082	252		7,317	597		515 [i]
Methylene Chloride	104,038	109,901	1,409	136,290	143,970	1,409	323,559	341,791	3,354	170
Nickel	305	71.3		399	93.4		948	222		109 [j]
Phenol	2,357	2,490	810	3,088	3,262	810	7,331	7,744	1,928	553
Toluene	3,861	4,078	1,122,660	5,058	5,343	1,122,660	12,007	12,684	2,671,931	3,370
Zinc	654	1,252		857	1,639		2,035	3,892		329

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BPT Current effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 21 and 8.9, repectively.
[g] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[h] The mean effluent concentration of copper exceeds the daily average acute and chronic limitations by factors of 6.8 and 3.2, respectively; and the daily maximum acute and chronic limitations by factors of 2.9 and 1.4, respectively.
[i] The mean effluent concentration of lead exceeds the daily average chronic limitation by a factor of 2.0.
[j] The mean effluent concentration of nickel exceeds the daily average chronic limitation by a factor of 1.2.

Exhibit 4–25. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 1 Meter Water Depth
Gas Flotation (BAT Option 2); Median Discharge Rate by Outfall (1,125 bpd)

		Mean % Effluent [b]		Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 200 ft)
Arsenic	1	4.08	2.54	69	36		1,690	1,415	
Benzene	1	4.08	2.54	2,700	1,350	12.5	66,150	53,055	491
Cadmium	1	4.08	2.54	45.62	10.0		1,118	393	
Chlorides	1	4.08	2.54	85 – 1,600 mg/l [e]					
Chloromethane	1	4.08	2.54			70			2,751
Chromium (tri)	1	4.08	2.54	515	103		12,617	4,048	
Chromium (hex)	1	4.08	2.54	1,100	50		26,950	1,965	
Copper	0.88	4.08	2.54	4.37	4.37		122	195	
Ethylbenzene	1	4.08	2.54	8,760	4,380	8,100	214,620	172,134	318,330
Lead	0.38	4.08	2.54	220	8.5		14,184	879	
Methylene Chloride	1	4.08	2.54	25,600	12,800	87	627,200	503,040	3,419
Nickel	1	4.08	2.54	75	8.3		1,837	326	
Phenol	1	4.08	2.54	580	290	50	14,210	11,397	1,965
Toluene	1	4.08	2.54	950	475	69,300	23,275	18,668	2,723,490
Zinc	0.59	4.08	2.54	95	86		3,945	5,728	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 24.5 and 200 ft – 39.3

Exhibit 4–25. (Continued)
Gas Flotation (BAT Option 2); Median Discharge Rate by Outfall (1,125 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
Arsenic	541	750		709	982		1,682	2,332		10.8
Benzene	21,168	28,119	491	27,730	36,836	491	65,832	87,451	1,169	1,226 [f]
Cadmium	358	208		469	273		1,112	648		14.5
Chlorides (mg/l)							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			2,751			2,751			6,547	28.6
Chromium (tri)	4,038	2,145		5,289	2,810		12,557	6,672		128
Chromium (hex)	8,624	1,041		11,297	1,364		26,821	3,239		128
Copper	38.9	103		51.0	135		121	322		180 [h]
Ethylbenzene	68,678	91,231	318,330	89,969	119,513	318,330	213,590	283,728	757,625	62.2
Lead	4,539	466		5,946	610		14,116	1,449		125
Methylene Chloride	200,704	266,611	3,419	262,922	349,261	3,419	624,189	829,161	8,137	170
Nickel	588	173		770	226		1,829	538		109
Phenol	4,547	6,040	1,965	5,957	7,913	1,965	14,142	18,786	4,677	536
Toluene	7,448	9,894	2,723,490	9,757	12,961	2,723,490	23,163	30,770	6,481,906	828
Zinc	1,262	3,036		1,654	3,977		3,926	9,442		134

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 2.5 and 1.05, respectively.
[g] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[h] The mean concentration of copper exceeds the daily average acute and chronic limitations by factors of 5.6 and 2.1, respectively; and the daily maximum chronic limitation by a factor of 2.4.

Exhibit 4–26. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 1 Meter Water Depth
Gas Flotation (BAT Option 2); Mean Discharge Rate (4,949 bpd)

		Mean % Effluent [b]		Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 200 ft)
Arsenic	1	10.1	8.06	69	36		683	446	
Benzene	1	10.1	8.06	2,700	1,350	12.5	26,730	16,740	155
Cadmium	1	10.1	8.06	45.62	10.0		452	124	
Chlorides	1	10.1	8.06	85 – 1,600 mg/l [e]					
Chloromethane	1	10.1	8.06			70			868
Chromium (tri)	1	10.1	8.06	515	103		5,099	1,277	
Chromium (hex)	1	10.1	8.06	1,100	50		10,890	620	
Copper	0.88	10.1	8.06	4.37	4.37		49.2	62	
Ethylbenzene	1	10.1	8.06	8,760	4,380	8,100	86,724	54,312	100,440
Lead	0.38	10.1	8.06	220	8.5		5,732	277	
Methylene Chloride	1	10.1	8.06	25,600	12,800	87	253,440	158,720	1,079
Nickel	1	10.1	8.06	75	8.3		743	103	
Phenol	1	10.1	8.06	580	290	50	5,742	3,596	620
Toluene	1	10.1	8.06	950	475	69,300	9,405	5,890	859,320
Zinc	0.59	10.1	8.06	95	86		1,594	1,807	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 9.90; 200 ft – 12.4

Exhibit 26. (Continued)
Gas Flotation (BAT Option 2); Mean Discharge Rate (4,949 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
Arsenic	219	237		286	310		680	736		10.8
Benzene	8,554	8,872	155	11,205	11,623	155	26,602	27,593	369	1,226 [f]
Cadmium	145	65.7		189	86.1		449	204		14.5
Chlorides							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			868			868			2,066	28.6
Chromium (tri)	1,632	677		2,137	887		5,074	2,105		128
Chromium (hex)	3,485	329		4,565	430		10,838	1,022		128
Copper	15.7	32.6		20.6	42.8		48.9	101		180 [h]
Ethylbenzene	27,752	28,785	100,440	36,355	37,709	100,440	86,308	89,522	239,047	62.2
Lead	1,834	147		2,403	193		5,704	457		125
Methylene Chloride	81,101	84,122	1,079	106,242	110,199	1,079	252,223	261,618	2,568	170
Nickel	238	54.5		311	71.5		739	170		109 [i]
Phenol	1,837	1,906	620	2,407	2,497	620	5,714	5,927	1,476	536
Toluene	3,010	3,122	859,320	3,943	4,089	859,320	9,360	9,708	2,045,182	828
Zinc	510	958		668	1,255		1,586	2,979		134

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[e] The mean concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 7.9 and 3.3, respectively.
[f] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[g] The mean concentration of copper exceeds the daily average acute and chronic limitations by factors of 8.8 and 4.2, respectively; and the daily maximum acute and chronic limitations by factors of 3.7 and 1.8, respectively.
[h] The mean concentration of nickel exceeds the daily average chronic limitation by a factor of 1.5.

Exhibit 4–27. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 1 Meter Water Depth
Gas Flotation (BAT Option 2); Median Discharge Rate by Flow (15,100 bpd)

		Mean % Effluent [b]		Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 200 ft)
Arsenic	1	18.9	14.3	69	36		366	252	
Benzene	1	18.9	14.3	2,700	1,350	12.5	14,310	9,450	87.5
Cadmium	1	18.9	14.3	45.62	10.0		242	70.0	
Chlorides	1	18.9	14.3	85 – 1,600 mg/l [e]					
Chloromethane	1	18.9	14.3			70			490
Chromium (tri)	1	18.9	14.3	515	103		2,730	721	
Chromium (hex)	1	18.9	14.3	1,100	50		5,830	350	
Copper	0.88	18.9	14.3	4.37	4.37		26.3	34.8	
Ethylbenzene	1	18.9	14.3	8,760	4,380	8,100	46,428	30,660	56,700
Lead	0.38	18.9	14.3	220	8.5		3,068	157	
Methylene Chloride	1	18.9	14.3	25,600	12,800	87	135,680	89,600	609
Nickel	1	18.9	14.3	75	8.3		398	58.1	
Phenol	1	18.9	14.3	580	290	50	3,074	2,030	350
Toluene	1	18.9	14.3	950	475	69,300	5,035	3,325	485,100
Zinc	0.59	18.9	14.3	95	86		853	1,020	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 5.30; 200 ft – 7.00

Exhibit 4–27. (Continued)
Gas Flotation (BAT Option 2); Median Discharge Rate by Flow (15,100 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
Arsenic	117	134		153	175		364	415		10.8
Benzene	4,579	5,009	87.5	5,999	6,561	87.5	14,241	15,576	208	1,226 [f]
Cadmium	77.4	37.1		101	48.6		241	115		14.5
Chlorides							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			490			490			1,166	28.6
Chromium (tri)	873	382		1,144	501		2,716	1,188		128
Chromium (hex)	1,866	186		2,444	243		5,802	577		128
Copper	8.42	18.4		11.0	24.1		26.2	57.3		180 [h]
Ethylbenzene	14,857	16,250	56,700	19,463	21,287	56,700	46,205	50,537	134,946	62.2
Lead	982	83		1,286	109		3,054	258		125 [i]
Methylene Chloride	43,418	47,488	609	56,877	62,209	609	135,029	147,688	1,449	170
Nickel	127	30.8		167	40.3		396	95.8		109 [j]
Phenol	984	1,076	350	1,289	1,409	350	3,059	3,346	833	536 [k]
Toluene	1,611	1,762	485,100	2,111	2,309	485,100	5,011	5,481	1,154,538	828
Zinc	273	541		358	708		849	1,682		134

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 11 and 4.7, respectively.
[g] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[h] The mean concentration of copper exceeds the daily average acute and chronic limitations by factors of 16 and 7.5, respectively; and the daily maximum acute and chronic limitations by factors of 6.9 and 3.1, respectively.
[i] The mean concentration of lead exceeds the daily average chronic limitation by a factor of 1.1.
[j] The mean concentration of nickel exceeds the daily average and daily maximum chronic limitations by factors of 2.7 and 1.1, respectively.
[k] The mean concentration of phenol exceeds the daily average human health limitation by a factor of 1.5.

Exhibit 4–28. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 3 Meter Water Depth
Gas Flotation (BAT Option 2); Median Discharge Rate by Outfall (1,125 bpd)

		Mean % Effluent [b]		Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 200 ft)
Arsenic	1	0.704	0.552	69	36		9,798	6,516	
Benzene	1	0.704	0.552	2,700	1,350	12.5	383,400	244,350	2,263
Cadmium	1	0.704	0.552	45.62	10.0		6,478	1,810	
Chlorides	1	0.704	0.552	835 – 1,600 mg/l [e]					
Chloromethane	1	0.704	0.552			70			12,670
Chromium (tri)	1	0.704	0.552	515	103		73,130	18,643	
Chromium (hex)	1	0.704	0.552	1,100	50		156,200	9,050	
Copper	0.88	0.704	0.552	4.37	4.37		705	899	
Ethylbenzene	1	0.704	0.552	8,760	4,380	8,100	1,243,920	792,780	1,466,100
Lead	0.38	0.704	0.552	220	8.5		82,211	4,049	
Methylene Chloride	1	0.704	0.552	25,600	12,800	87	3,635,200	2,316,800	15,747
Nickel	1	0.704	0.552	75	8.3		10,650	1,502	
Phenol	1	0.704	0.552	580	290	50	82,360	52,490	9,050
Toluene	1	0.704	0.552	950	475	69,300	134,900	85,975	12,543,300
Zinc	0.59	0.704	0.552	95	86		22,864	26,383	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 142; 200 ft – 181

Exhibit 4–28. (Continued)
Gas Flotation (BAT Option 2); Median Discharge Rate by Outfall (1,125 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
Arsenic	3,135	3,453		4,107	4,524		9,751	10,740		10.8
Benzene	122,688	129,506	2,263	160,721	169,652	2,263	381,560	402,762	5,385	1,226
Cadmium	2,073	959		2,716	1,257		6,447	2,983		14.5
Chlorides							Range of 835 – 1,600 mg/l			65,111 [f]
Chloromethane			12,670			12,670			30,155	28.6
Chromium (tri)	23,402	9,881		30,656	12,944		72,779	30,729		128
Chromium (hex)	49,984	4,797		65,479	6,283		155,450	14,917		128
Copper	226	476		296	624		702	1,482		180
Ethylbenzene	398,054	420,173	1,466,100	521,451	550,427	1,466,100	1,237,949	1,306,739	3,489,318	62.2
Lead	26,307	2,146		34,463	2,811		81,816	6,673		125
Methylene Chloride	1,163,264	1,227,904	15,747	1,523,876	1,608,554	15,747	3,617,751	3,818,781	37,478	170
Nickel	3,408	796		4,464	1,043		10,599	2,476		109
Phenol	26,355	27,820	9,050	34,525	36,444	9,050	81,965	86,519	21,539	536
Toluene	43,168	45,567	12,543,300	56,550	59,692	12,543,300	134,252	141,713	29,853,054	828
Zinc	7,317	13,983		9,585	18,318		22,755	43,487		134

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.

Exhibit 4–29. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 3 Meter Water Depth
Gas Flotation (BAT Option 2); Mean Discharge Rate (4,949 bpd)

Pollutant	Dissolved Fraction[a]	Mean % Effluent[b] at ZID (50 feet)	Mean % Effluent[b] at Mix Zone (200 feet)	Standards (ug/l)[c] Marine Acute	Standards (ug/l)[c] Marine Chronic	Standards (ug/l)[c] Human Health	Waste Load Allocation (ug/l)[d] Acute (at ZID)	Waste Load Allocation (ug/l)[d] Chronic (at 200 ft)	Waste Load Allocation (ug/l)[d] Health (at 200 ft)
Arsenic	1	2.44	2.10	69	36		2,829	1,717	
Benzene	1	2.44	2.10	2,700	1,350	12.5	110,700	64,395	596
Cadmium	1	2.44	2.10	45.62	10.0		1,870	477	
Chlorides	1	2.44	2.10	835 – 1,600 mg/l[e]					
Chloromethane	1	2.44	2.10			70			3,339
Chromium (tri)	1	2.44	2.10	515	103		21,115	4,913	
Chromium (hex)	1	2.44	2.10	1,100	50		45,100	2,385	
Copper	0.88	2.44	2.10	4.37	4.37		204	237	
Ethylbenzene	1	2.44	2.10	8,760	4,380	8,100	359,160	208,926	386,370
Lead	0.38	2.44	2.10	220	8.5		23,737	1,067	
Methylene Chloride	1	2.44	2.10	25,600	12,800	87			4,150
Nickel	1	2.44	2.10	75	8.3		3,075	396	
Phenol	1	2.44	2.10	580	290	50	23,780	13,833	2,385
Toluene	1	2.44	2.10	950	475	69,300	38,950	22,658	3,305,610
Zinc	0.59	2.44	2.10	95	86		6,602	6,953	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 41.0; 200 ft – 47.7

Exhibit 4–29. (Continued)
Gas Flotation (BAT Option 2); Mean Discharge Rate (4,949 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
Arsenic	905	910		1,186	1,192		2,815	2,830		10.8
Benzene	35,424	34,129	596	46,405	44,709	596	110,169	106,142	1,419	1,226 [f]
Cadmium	599	253		784	331		1,861	786		14.5
Chlorides							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			3,339			3,339			7,947	28.6
Chromium (tri)	6,757	2,604		8,851	3,411		21,014	8,098		128
Chromium (hex)	14,432	1,264		18,906	1,656		44,884	3,931		128
Copper	65.2	126		85.4	164		203	390		180 [h]
Ethylbenzene	114,931	110,731	386,370	150,560	145,057	386,370	357,436	344,373	919,561	62.2
Lead	7,596	565		9,950	741		23,623	1,759		125
Methylene Chloride			4,150			4,150			9,877	170
Nickel	984	210		1,289	275		3,060	653		109
Phenol	7,610	7,331	2,385	9,969	9,604	2,385	23,666	22,801	5,676	536
Toluene	12,464	12,008	3,305,610	16,328	15,731	3,305,610	38,763	37,346	7,867,352	828
Zinc	2,113	3,685		2,767	4,827		6,570	11,460		134

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 2.1.
[g] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[h] The mean concentration of copper exceeds the daily average acute and chronic limitations by factors of 2.1 and 1.1, respectively.

Exhibit 4–30. Waste Load Allocation Calculation for Louisiana Water Quality Analysis – 3 Meter Water Depth
Gas Flotation (BAT Option 2); Median Discharge Rate by Flow (15,100 bpd)

		Mean % Effluent [b]		Standards (ug/l) [c]			Waste Load Allocation (ug/l) [d]		
Pollutant	Dissolved Fraction[a]	at ZID (50 feet)	at Mix Zone (200 feet)	Marine Acute	Marine Chronic	Human Health	Acute (at ZID)	Chronic (at 200 ft)	Health (at 200 ft)
Arsenic	1	7.87	6.17	69	36		876	583	
Benzene	1	7.87	6.17	2,700	1,350	12.5	34,290	21,870	202
Cadmium	1	7.87	6.17	45.62	10.0		579	162	
Chlorides	1	7.87	6.17	835 – 1,600 mg/l [e]					
Chloromethane	1	7.87	6.17			70			1,134
Chromium (tri)	1	7.87	6.17	515	103		6,540	1,669	
Chromium (hex)	1	7.87	6.17	1,100	50		13,970	810	
Copper	0.88	7.87	6.17	4.37	4.37		63.1	80.4	
Ethylbenzene	1	7.87	6.17	8,760	4,380	8,100	111,252	70,956	131,220
Lead	0.38	7.87	6.17	220	8.5		7,353	362	
Methylene Chloride	1	7.87	6.17	25,600	12,800	87	325,120	207,360	1,409
Nickel	1	7.87	6.17	75	8.3		952	134	
Phenol	1	7.87	6.17	580	290	50	7,366	4,698	810
Toluene	1	7.87	6.17	950	475	69,300	12,065	7,695	1,122,660
Zinc	0.59	7.87	6.17	95	86		2,045	2,361	

[a] Dissolved fraction calculated according to Louisiana DEQ, 1993.
[b] Effluent concentration at the edge of the mixing zone after dilution (100/no. of dilutions). For bays and estuaries, acute criteria must be met at a 50–ft zone of initial dilution (ZID); chronic and human health criteria must be met at a 200–ft mixing zone.
[c] Source: Louisiana Surface Water Quality Standards Chapter 11.
[d] Calculated as: criterion/(% effluent at edge of mixing zone * the dissolved fraction).
[e] Range of criteria for estuarine waters.

Dilutions available: 50 ft – 12.7; 200 ft – 16.2

Exhibit 4–30. (Continued)
Gas Flotation (BAT Option 2); Median Discharge Rate by Flow (15,100 bpd)

Pollutant	Long–Term Average Limitation (ug/l) [a]			Daily Average Limitation (ug/l) [b]			Daily Maximum Limitation (ug/l) [c]			Effluent Conc. (ug/l) [d]
	Acute	Chronic	Health	Acute	Chronic	Health	Acute	Chronic	Health	Gas Flot'n (BAT) [e]
Arsenic	280	309		367	405		872	961		10.8
Benzene	10,973	11,591	202	14,374	15,184	202	34,125	36,048	482	1,226 [f]
Cadmium	185	86		243	112		577	267		14.5
Chlorides							Range of 835 – 1,600 mg/l			65,111 [g]
Chloromethane			1,134			1,134			2,699	28.6
Chromium (tri)	2,093	884		2,742	1,159		6,509	2,750		128
Chromium (hex)	4,470	429		5,856	562		13,903	1,335		128
Copper	20.2	42.6		26.4	55.9		62.8	133		180 [h]
Ethylbenzene	35,601	37,607	131,220	46,637	49,265	131,220	110,718	116,957	312,304	62.2
Lead	2,353	192		3,082	252		7,317	597		125
Methylene Chloride	104,038	109,901	1,409	136,290	143,970	1,409	323,559	341,791	3,354	170
Nickel	305	71.3		399	93.4		948	222		109 [i]
Phenol	2,357	2,490	810	3,088	3,262	810	7,331	7,744	1,928	536
Toluene	3,861	4,078	1,122,660	5,058	5,343	1,122,660	12,007	12,684	2,671,931	828
Zinc	654	1,252		857	1,639		2,035	3,892		134

[a] Long–term averages (LTA) calculated as 0.32 * WLA (acute); 0.53 * WLA (chronic); and LTA = WLA (human health).
[b] Daily Average calculated as 1.31 x LTA for acute and chronic; human health = LTA.
[c] Daily Maximum calculated as 3.11 x LTA for acute and chronic; human health = 2.38 x LTA.
[d] Source: EPA, 1994a.
[e] The outlined mean BAT Option 2 effluent concentrations exceed the outlined daily average and maximum limitations.
[f] The mean concentration of benzene exceeds the daily average and daily maximum human health limitations by factors of 6.1 and 2.5.
[g] The mean effluent concentration of chlorides exceeds the range of allowable concentrations by a factor of 41.
[h] The mean concentration of copper exceeds the daily average acute and chronic limitations by factors of 6.8 and 3.2, respectively; and the daily maximum acute and chronic limitations by factors of 2.9 and 1.4, respectively.
[i] The mean concentration of nickel exceeds the daily average chronic limitation by a factor of 1.2.

Exhibit 4–31. Assessment of Compliance with Louisiana Oil and Gas Effluent Limitations

Parameter	Oil and Gas Standards	Current BPT Concentration	Gas Flotation (BAT Option 2) Concentration
Benzene (ug/l)	12.5 [a]	4,285	1,226
Ethylbenzene (ug/l)	4,380	115	62.2
Toluene (ug/l)	475 [b]	3,370	828
Radium (pCi/l)	60 [c]	400	453
Oil and Grease (mg/l)	15 [d]	53.0	23.5
TOC (mg/l)	50	NA	NA
TSS (mg/l)	45 [e]	133	30.0

[a] The benzene oil and gas standard is exceeded by the BPT concentration by a factor of 343; and by the BAT Option 2 concentration by a factor of 98.

[b] The toluene oil and gas standard is exceeded by the BPT concentration by a factor of 7.1; and by the BAT Option 2 concentration by a factor of 1.7.

[c] The radium oil and gas standard is exceeded by the BPT concentration by a factor of 6.7; and by the BAT Option 2 concentration by a factor of 7.6.

[d] The oil and grease standard is exceeded by the BPT concentration by a factor of 3.5; and by the BAT Option 2 concentration by a factor of 1.6.

[e] The TSS oil and gas standard is exceeded by the BPT concentration by a factor of 3.0.

Exhibit 4–32. Cormix Results for Alaska Produced Water Discharges

Operator	Facility	Water Depth (ft)	Discharge Rate (bpd)	Number of Dilutions at Edge of Mixing Zone (m)							
				15.2	61	100	500	750	1,000	2,000	2,500
Marathon	Trading Bay	35	126,072	4.2	16.9	27.7	139		244	477	
Shell Western	East Foreland	35	3,100	4.0	16	26.3	132	708	1,286		
Amoco	Dillon	92	2,650	83	332	544	2,720				
Unocal	Anna	77	1,500	11	43	71	356		2,873		
Marathon	Granite Point	45	300	1.9	7.9	13.1	65.1	119	173	479	671
Phillips	NCIU Tyonek A	70	170	39	156	256	1,282				
Unocal	Bruce	62	160	538	2,154						
Unocal	Baker	102	30	9,120							

Exhibit 4–33. Water Quality Analysis for Trading Bay (11 m water depth, 126,072 bpd)

Pollutant	Effluent Concentration (ug/l)		50–ft		200–ft		1,000–m		2,000–m		Drinking Water Standards (ug/l)	Federal Water Quality Criteria (ug/l)		
	BPT	BAT[a]	BPT	BAT	BPT	BAT	BPT	BAT	BPT	BAT		Acute	Chronic	HH
Aluminum	78	49.9	25	16	6.3	4.0	0.38	0.24	0.16	0.10	200			
Anthracene	25	7.4	**8.1**	**2.4**	**2.0**	**0.60**	**0.12**	**0.036**	**0.051**	0.015				0.0311
Benzene	3,386	1,226	**1,092**	**395**	**273**	**99**	**17**	**6.0**	**6.8**	2.5	5.0	5,100	700	710
Benzo(a)pyrene	11	4.7	**3.4**	**1.5**	**0.85**	**0.38**	0.052	0.023	0.021	0.009				0.311
Chlorobenzene	8.1	7.8	2.6	2.5	0.65	0.63	0.039	0.038	0.016	0.016				21,000
Di–n–butyl–phthalate	16	6.4	5.2	2.1	1.3	0.52	0.08	0.032	0.032	0.013				12,000
Ethylbenzene	158	62	51	20	13	5.0	0.77	0.30	0.32	0.13	700	430		29,000
Naphthalene	934	92	301	30	75	7.4	4.6	0.45	1.9	0.19		2,350		
Phenol	431	536	139	173	35	43	2.1	2.6	0.87	1.1		5,800		
Toluene	1,507	828	486	267	122	67	7.4	4.1	3.0	1.7	1,000	6,300	5,000	424,000
Xylenes (total)	543	378	175	122	44	30	2.7	1.9	1.1	0.76	10,000			
Arsenic	114	73	**37**	**24**	**9.2**	**5.9**	0.56	0.36	0.23	0.15	50			1.4
Barium	55,564	35,561	**17,924**	**11,471**	**4,481**	**2,868**	272	174	112	72	2,000			
Cadmium	23	14	**7.3**	4.7	1.8	1.2	0.11	0.071	0.046	0.029	5.0	43	9.3	
Copper	445	285	**143**	**92**	**36**	**23**	2.2	1.4	0.90	0.57	1,000	2.9		
Iron	4,916	3,146	**1,586**	**1,015**	**396**	254	24	15	9.9	6.3	300			
Lead	195	125	**63**	**40**	**16**	**10**	1.0	0.61	0.39	0.25		220	5.6	
Manganese	116	74	37	24	9.3	6.0	0.57	0.36	0.23	0.15	50			
Nickel	1,705	1,091	**550**	**352**	**138**	**88**	**8.4**	5.4	3.4	2.2	100	75	8.3	100
Zinc	45	134	14	43	3.6	11	0.22	0.66	0.090	0.27	5,000	95	86	
Radium–226	1.4E–06	2.0E–04	1E–06	**1E–04**	4E–07	**4E–05**	2E–08	2E–06	1E–06	1E–06	5 pCi/l (total)			
Radium–228	3.1E–06	2.5E–04	(Totals)								(5E–6 ug/l)			
Total of Water Quality Exceedances:			15	13	12	10	3	2	2	0				
Breakdown of Standards Exceeded:														
Acute			2	2	2	2	–	–	–	–				
Chronic			3	2	2	2	1	–	–	–				
Human Health			5	4	4	3	1	1	1	–				
Drinking Water			5	5	4	3	1	1	1	–				

[a] BAT Options 2 and 4.

All state standards are met by the BPT–level concentrations by 2.5 km.

Exhibit 4–34. Water Quality Analysis for East Foreland (11 m water depth; 3,100 bpd)

Pollutant	Effluent Concentration (ug/l)		Effluent Concentration at Edge of Mixing Zone (ug/l)										Drinking Water Standards (ug/l)	Federal Water Quality Criteria (ug/l)		
			50–ft		200–ft		100–m		500–m		750–m					
	BPT	BAT [a]	BPT	BAT	BPT	BAT	BPT	BAT	BPT	BAT	BPT	BAT		Acute	Chronic	HH
Aluminum	78	50	20	12	4.9	3.1	3.0	1.9	0.6	0.4	0.11	0.07	200			
Anthracene	25	7.4	6.3	1.9	1.6	0.46	0.96	0.28	0.19	0.056	0.036	0.010				0.0311
Benzene	3,386	1,226	847	306	212	77	129	47	26	9.3	4.8	1.7	5.0	5,100	700	710
Benzo(a)pyrene	11	4.7	2.6	1.2	0.66	0.29	0.40	0.18	0.080	0.035	0.015	0.007				0.311
Chlorobenzene	8.1	7.8	2.0	1.9	0.50	0.49	0.31	0.30	0.061	0.059	0.011	0.011				21,000
Di–n–butyl–phthalate	16	6.4	4.0	1.6	1.0	0.40	0.61	0.24	0.12	0.049	0.023	0.009				12,000
Ethylbenzene	158	62	39	16	10	3.9	6.0	2.4	1.2	0.47	0.22	0.088	700	430		29,000
Naphthalene	934	92	233	23	58	5.8	35	3.5	7.1	0.70	1.3	0.13		2,350		
Phenol	431	536	108	134	27	34	16	20	3.3	4.1	0.61	0.76		5,800		
Toluene	1,507	828	377	207	94	52	57	31	11	6.3	2.1	1.2	1,000	6,300	5,000	424,000
Xylenes (total)	543	378	136	95	34	24	21	14	4	2.9	0.8	0.5	10,000			
Arsenic	114	73	29	18	7.1	4.6	4.3	2.8	0.87	0.55	0.16	0.10	50			1.4
Barium	55,564	35,561	13,891	8,890	3,473	2,223	2,113	1,352	421	269	78	50	2,000			
Cadmium	23	14	5.7	3.6	1.4	0.90	0.86	0.55	0.17	0.11	0.032	0.020	5.0	43	9.3	
Copper	445	285	111	71	28	18	17	10.8	3.4	2.2	0.63	0.40	1,000	2.9		
Iron	4,916	3,146	1,229	787	307	197	187	120	37	24	6.9	4.4	300			
Lead	195	125	49	31	12	7.8	7.4	4.7	1.5	0.95	0.28	0.18		220	5.6	
Manganese	116	74	29	19	7.2	4.6	4.4	2.8	0.88	0.56	0.16	0.10	50			
Nickel	1,705	1,091	426	273	107	68	65	42	13	8.3	2.4	1.5	100	75	8.3	100
Zinc	45	134	11	33	2.8	8.4	1.7	5.1	0.34	1.0	0.063	0.19	5,000	95	86	
Radium–226	1E–06	2E–04	1E–06	1E–04	3E–07	3E–05	2E–07	2E–05	3E–08	3E–06	6E–09	6E–07	5 pCi/l (total)			
Radium–228	3E–06	2E–04											(5E–6 ug/l)			
Total Water Quality Exceedances:			14	13	12	8	7	6	4	2	1	0				
Breakdown of Standards Exceeded:																
Acute			2	2	2	1	1	1	1	–	–	–				
Chronic			3	2	2	2	2	1	1	–	–	–				
Human Health			4	4	4	2	3	2	1	1	1	–				
Drinking Water			5	5	4	3	1	2	1	1	–	–				

[a] BAT Options 2 and 4.
All state standards are met by the BPT–level concentrations by 1 km.

Exhibit 4–35. Water Quality Analysis for Platform Dillon (28 m water depth; 2,650 bpd)

Pollutant	Effluent Concentration (ug/l)		Effluent Concentration at Edge of Mixing Zone (ug/l)				Drinking Water Standards (ug/l)	Federal Water Quality Criteria (ug/l)		
			50–ft		200–ft					
	BPT	BAT [a]	BPT	BAT	BPT	BAT		Acute	Chronic	HH
Aluminum	78	50	0.94	0.60	0.0028	0.0018	200			
Anthracene	25	7.4	**0.30**	**0.089**	0.00092	0.00027				0.0311
Benzene	3,386	1,226	**40.8**	**14.8**	0.12	0.044	5.0	5,100	700	710
Benzo(a)pyrene	11	4.7	0.13	0.056	0.00038	0.00017				0.311
Chlorobenzene	8.1	7.8	0.097	0.094	0.00029	0.00028				21,000
Di–n–butyl–phthalate	16	6.4	0.19	0.077	0.00058	0.00023				12,000
Ethylbenzene	158	62	1.90	0.75	0.0057	0.0023	700	430		29,000
Naphthalene	934	92	11.2	1.11	0.034	0.0033		2,350		
Phenol	431	536	5.20	6.46	0.016	0.019		5,800		
Toluene	1,507	828	18.2	9.97	0.055	0.030	1,000	6,300	5,000	424,000
Xylenes (total)	543	378	6.54	4.55	0.020	0.014	10,000			
Arsenic	114	73	1.38	0.88	0.0041	0.0027	50			1.4
Barium	55,564	35,561	669	428	2.02	1.29	2,000			
Cadmium	23	14	0.27	0.17	0.0008	0.00053	5.0	43	9.3	
Copper	445	285	**5.36**	**3.43**	0.016	0.010	1,000	2.9		
Iron	4,916	3,146	59.2	37.9	0.18	0.11	300			
Lead	195	125	2.35	1.50	0.0071	0.0045		220	5.6	
Manganese	116	74	1.40	0.89	0.0042	0.0027	50			
Nickel	1,705	1,091	**20.5**	**13.2**	0.062	0.040	100	75	8.3	100
Zinc	45	134	0.54	1.61	0.0016	0.0049	5,000	95	86	
Radium–226	1.4E–06	2.0E–04	5.4E–08	**5.5E–06**	1.4E–08	1.4E–06	5 pCi/l (total)			
Radium–228	3.1E–06	2.5E–04	(Totals)				(5E–6 ug/l)			
Total Water Quality Exceedances:			4	5	0	0				
Breakdown of Standards Exceeded:										
Acute			1	1	–	–				
Chronic			1	1	–	–				
Human Health			1	1	–	–				
Drinking Water			1	2	–	–				

[a] BAT Options 2 and 4.

Exhibit 4–36. Water Quality Analysis for Platform Anna (23.5 m water depth; 1,500 bpd)

Pollutant	Effluent Concentration (ug/l)		Effluent Concentration at Edge of Mixing Zone (ug/l)								Drinking Water Standards (ug/l)	Federal Water Quality Criteria (ug/l)		
			50–ft		200–ft		100–m		500–m					
	BPT	BAT [a]	BPT	BAT	BPT	BAT	BPT	BAT	BPT	BAT		Acute	Chronic	HH
Aluminum	78	50	7.09	4.54	1.81	1.16	1.10	0.70	0.22	0.14	200			
Anthracene	25	7.4	**2.30**	**0.67**	**0.59**	**0.17**	**0.36**	**0.10**	**0.071**	0.021				0.0311
Benzene	3,386	1,226	**308**	**111**	**78.7**	**28.5**	**47.7**	**17.3**	**9.51**	3.44	5.0	5,100	700	710
Benzo(a)pyrene	11	4.7	**0.96**	**0.42**	0.25	0.11	0.15	0.065	0.030	0.013				0.311
Chlorobenzene	8.1	7.8	0.73	0.71	0.19	0.18	0.11	0.11	0.023	0.022				21,000
Di–n–butyl–phthalate	16	6.4	1.46	0.58	0.37	0.15	0.23	0.091	0.045	0.018				12,000
Ethylbenzene	158	62	14.3	5.65	3.67	1.45	2.22	0.88	0.44	0.17	700	430		29,000
Naphthalene	934	92	84.9	8.37	21.7	2.14	13.1	1.30	2.62	0.26		2,350		
Phenol	431	536	39.2	48.7	10.0	12.5	6.08	7.55	1.21	1.51		5,800		
Toluene	1,507	828	137	75.3	35.1	19.3	21.2	11.7	4.23	2.33	1,000	6,300	5,000	424,000
Xylenes (total)	543	378	49.3	34.4	12.6	8.79	7.64	5.32	1.52	1.06	10,000			
Arsenic	114	73	**10.4**	**6.64**	**2.66**	**1.70**	**1.61**	1.03	0.32	0.21	50			1.4
Barium	55,564	35,561	**5,051**	**3,233**	1,292	827	783	501	156	99.9	2,000			
Cadmium	23	14	2.06	1.32	0.53	0.34	0.32	0.20	0.064	0.041	5.0	43	9.3	
Copper	445	285	**40.4**	**25.9**	**10.3**	**6.62**	**6.26**	**4.01**	1.25	0.80	1,000	2.9		
Iron	4,916	3,146	**447**	286	114	73.2	69.2	44.3	13.8	8.84	300			
Lead	195	125	**17.7**	**11.4**	4.54	2.90	2.75	1.76	0.55	0.35		220	5.6	
Manganese	116	74	10.5	6.74	2.69	1.72	1.63	1.04	0.33	0.21	50			
Nickel	1,705	1,091	**155**	**99.2**	**39.7**	**25.4**	**24.0**	**15.4**	4.79	3.07	100	75	8.3	100
Zinc	45	134	4.07	12.2	1.04	3.11	0.63	1.89	0.13	0.38	5,000	95	86	
Radium–226	1.4E–06	2.0E–04	4E–07	**4E–05**	1E–07	**1E–05**	6E–08	**6E–06**	1E–08	1E–06	5 pCi/l (total) (5E–6 ug/l)			
Radium–228	3.1E–06	2.5E–04												
Total Water Quality Exceedances:			12	10	5	6	5	5	2	0				
Breakdown of Standards Exceeded:														
Acute			2	2	1	1	1	1	–	–				
Chronic			2	2	1	1	1	1	–	–				
Human Health			4	3	2	2	2	1	1	–				
Drinking Water			4	3	1	2	1	2	1	–				

[a] BAT Options 2 and 4.

All state standards are met by the BPT–level concentrations by 1 km.

Exhibit 4–37. Water Quality Analysis for Granite Point (13.75 m water depth; 300 bpd)

Pollutant	Effluent Concentration (ug/l)		Effluent Concentration at Edge of Mixing Zone (ug/l)										Drinking Water Standards (ug/l)	Federal Water Quality Criteria (ug/l)		
			50–ft		200–ft		100–m		1,000–m		2,000–m					
	BPT	BAT[a]	BPT	BAT	BPT	BAT	BPT	BAT	BPT	BAT	BPT	BAT		Acute	Chronic	HH
Aluminum	78	50	41	26	10	6.3	6.0	3.8	0.45	0.29	0.16	0.10	200			
Anthracene	25	7.4	**13**	**3.9**	**3.2**	**0.94**	**1.9**	**0.56**	**0.15**	**0.043**	0.053	0.015				0.0311
Benzene	3,386	1,226	**1,782**	**645**	**429**	**155**	**258**	**94**	**20**	**7.1**	**7.1**	2.6	5.0	5,100	700	710
Benzo(a)pyrene	11	4.7	**5.6**	**2.4**	**1.3**	**0.59**	**0.81**	**0.35**	0.061	0.027	0.022	0.010				0.311
Chlorobenzene	8.1	7.8	4.2	4.1	1.0	0.99	0.61	0.59	0.047	0.045	0.017	0.016				21,000
Di–n–butyl–phthalate	16	6.4	8.5	3.4	2.0	0.81	1.23	0.49	0.093	0.037	0.034	0.013				12,000
Ethylbenzene	158	62	83	33	20	7.9	12	4.7	0.91	0.36	0.33	0.13	700	430		29,000
Naphthalene	934	92	491	48	118	12	71	7.0	5.4	0.53	1.9	0.19		2,350		
Phenol	431	536	227	282	55	68	33	41	2.5	3.1	0.90	1.1		5,800		
Toluene	1,507	828	793	436	191	105	115	63	8.7	4.8	3.1	1.7	1,000	6,300	5,000	424,000
Xylenes (total)	543	378	286	199	69	48	41	29	3.1	2.2	1.1	0.8	10,000			
Arsenic	114	73	**60**	**38**	**14**	**9.3**	**8.7**	**5.6**	0.66	0.42	0.24	0.15	50			1.4
Barium	55,564	35,561	**29,244**	**18,716**	**7,033**	**4,501**	**4,242**	**2,715**	321	206	116	74	2,000			
Cadmium	23	14	**12**	**7.6**	2.9	1.8	1.7	1.1	0.13	0.084	0.047	0.030	5.0	43	9.3	
Copper	445	285	**234**	**150**	**56**	**36**	**34**	**22**	2.6	1.6	0.93	0.59	1,000	2.9		
Iron	4,916	3,146	**2,587**	**1,656**	**622**	**398**	**375**	240	28	18	10	6.6	300			
Lead	195	125	**103**	**66**	**25**	**16**	**15**	**10**	1.1	0.72	0.41	0.26		220	5.6	
Manganese	116	74	**61**	39	15	9.4	8.8	5.7	0.67	0.43	0.24	0.15	50			
Nickel	1,705	1,091	**898**	**574**	**216**	**138**	**130**	**83**	**9.9**	6.3	3.6	2.3	100	75	8.3	100
Zinc	45	134	24	70	5.7	17	3.4	10	0.26	0.77	0.093	0.28	5,000	95	86	
Radium–226	1E–06	2E–04	2E–06	**2E–04**	6E–07	**6E–05**	3E–07	**3E–05**	3E–08	3E–06	9E–09	9E–07	5 pCi/l (total)			
Radium–228	3E–06	2E–04	(Totals)										(5E–6 ug/l)			
Total Water Quality Exceedances:			18	14	12	13	13	10	3	2	1	0				
Breakdown of Standards Exceeded:																
Acute			2	2	2	2	2	2	–	–	–	–				
Chronic			4	2	2	2	2	2	1	–	–	–				
Human Health			5	4	4	4	4	3	1	1	–	–				
Drinking Water			7	6	4	5	5	3	1	1	1	–				

[a] BAT Options 2 and 4.

All state standards are met by the BPT–level concentrations by 2.5 km.

Exhibit 4–38. Water Quality Analysis for Phillips NCIU (21.3 m water depth; 170 bpd)

Pollutant	Effluent Concentration (ug/l)		Effluent Concentration at Edge of Mixing Zone (ug/l)								Drinking Water Standards (ug/l)	Federal Water Quality Criteria (ug/l)		
			50–ft		200–ft		100–m		500–m					
	BPT	BAT[a]	BPT	BAT	BPT	BAT	BPT	BAT	BPT	BAT		Acute	Chronic	HH
Aluminum	78	49.9	2.0	1.3	0.50	0.32	0.30	0.19	0.06	0.04	200			
Anthracene	25	7.4	**0.65**	**0.19**	**0.16**	**0.047**	**0.10**	0.029	0.020	0.0058				0.0311
Benzene	3,386	1,226	**87**	**31**	**22**	**7.9**	**13**	4.8	2.6	0.96	5.0	5,100	700	710
Benzo(a)pyrene	11	4.7	0.27	0.12	0.068	0.030	0.041	0.018	0.0082	0.0036				0.311
Chlorobenzene	8.1	7.8	0.21	0.20	0.052	0.050	0.031	0.030	0.0063	0.0061				21,000
Di–n–butyl–phthalate	16	6.4	0.41	0.16	0.10	0.04	0.06	0.03	0.013	0.0050				12,000
Ethylbenzene	158	62	4.0	1.6	1.0	0.40	0.62	0.24	0.12	0.049	700	430		29,000
Naphthalene	934	92	24	2.4	6.0	0.59	3.6	0.36	0.73	0.072		2,350		
Phenol	431	536	11	14	2.8	3.4	1.7	2.1	0.34	0.42		5,800		
Toluene	1,507	828	39	21	9.7	5.3	5.9	3.2	1.2	0.65	1,000	6,300	5,000	424,000
Xylenes (total)	543	378	14	10	3.5	2.4	2.1	1.5	0.42	0.29	10,000			
Arsenic	114	73	**2.9**	**1.9**	0.73	0.47	0.45	0.29	0.089	0.057	50			1.4
Barium	55,564	35,561	1,425	912	356	228	217	139	43	28	2,000			
Cadmium	23	14	0.58	0.37	0.15	0.093	0.088	0.057	0.018	0.011	5.0	43	9.3	
Copper	445	285	**11**	**7.3**	**2.9**	1.8	1.7	1.1	0.35	0.22	1,000	2.9		
Iron	4,916	3,146	126	81	32	20	19	12	3.8	2.5	300			
Lead	195	125	5.0	3.2	1.3	0.80	0.76	0.49	0.15	0.10		220	5.6	
Manganese	116	74	3.0	1.9	0.74	0.48	0.45	0.29	0.090	0.058	50			
Nickel	1,705	1,091	**44**	**28**	**11**	7.0	6.7	4.3	1.3	0.85	100	75	8.3	100
Zinc	45	134	1.1	3.4	0.29	0.86	0.17	0.52	0.035	0.10	5,000	95	86	
Radium–226	1E–06	2E–04	1E–07	**1E–05**	3E–08	3E–06	2E–08	2E–06	4E–09	4E–07	5 pCi/l (total)			
Radium–228	3E–06	2E–04	(Totals)								(5E–6 ug/l)			
Total Water Quality Exceedances:			5	6	4	2	2	0	0	0				
Breakdown of Standards Exceeded:														
Acute			1	1	1	–	–	–	–	–				
Chronic			1	1	1	–	–	–	–	–				
Human Health			2	2	1	1	1	–	–	–				
Drinking Water			1	2	1	1	1	–	–	–				

[a] BAT Options 2 and 4.

Exhibit 4–39. Water Quality Analysis for Platform Bruce (19 m water depth; 160 bpd)

Pollutant	Effluent Concentration (ug/l)		Effluent Concentration at Edge of Mixing Zone (ug/l)				Drinking Water Standards (ug/l)	Federal Water Quality Criteria (ug/l)		
			50–ft		200–ft					
	BPT	BAT [a]	BPT	BAT	BPT	BAT		Acute	Chronic	HH
Aluminum	78	50	0.14	0.093	0.036	0.023	200			
Anthracene	25	7.4	0.047	0.014	0.012	0.003				0.0311
Benzene	3,386	1,226	6.3	2.3	1.6	0.57	5.0	5,100	700	710
Benzo(a)pyrene	11	4.7	0.020	0.009	0.005	0.002				0.311
Chlorobenzene	8.1	7.8	0.015	0.014	0.004	0.004				21,000
Di–n–butyl–phthalate	16	6.4	0.030	0.012	0.007	0.003				12,000
Ethylbenzene	158	62	0.29	0.12	0.073	0.029	700	430		29,000
Naphthalene	934	92	1.7	0.17	0.43	0.043		2,350		
Phenol	431	536	0.80	1.0	0.20	0.25		5,800		
Toluene	1,507	828	2.8	1.5	0.70	0.38	1,000	6,300	5,000	424,000
Xylenes (total)	543	378	1.0	0.70	0.25	0.18	10,000			
Arsenic	114	73	0.21	0.14	0.05	0.03	50			1.4
Barium	55,564	35,561	103	66	26	17	2,000			
Cadmium	23	14	0.042	0.027	0.011	0.007	5.0	43	9.3	
Copper	445	285	0.83	0.53	0.21	0.13	1,000	2.9		
Iron	4,916	3,146	9.1	5.8	2.3	1.5	300			
Lead	195	125	0.36	0.23	0.091	0.058		220	5.6	
Manganese	116	74	0.22	0.14	0.054	0.034	50			
Nickel	1,705	1,091	3.2	2.0	0.79	0.51	100	75	8.3	100
Zinc	45	134	0.08	0.25	0.021	0.062	5,000	95	86	
Radium–226	1E–06	2E–04	8.4E–09	8.4E–07	2.1E–09	2.1E–07	5 pCi/l (total)			
Radium–228	3E–06	2E–04	(Totals)				(5E–6 ug/l)			
Total Water Quality Exceedances:			2	0	0	0				
Breakdown of Standards Exceeded:										
Acute			–	–	–	–				
Chronic			–	–	–	–				
Human Health			1	–	–	–				
Drinking Water			1	–	–	–				

[a] BAT Options 2 and 4.

Exhibit 4–40. Water Quality Analysis for Platform Baker (31 m water depth; 30 bpd)

Pollutant	Effluent Concentration (ug/l) BPT	Effluent Concentration (ug/l) BAT[a]	Effluent Concentration at Edge of Mixing Zone (ug/l) 50–ft BPT	Effluent Concentration at Edge of Mixing Zone (ug/l) 50–ft BAT	Drinking Water Standards (ug/l)	Federal Water Quality Criteria (ug/l) Acute	Federal Water Quality Criteria (ug/l) Chronic	Federal Water Quality Criteria (ug/l) HH
Aluminum	78	50	0.009	0.0055	200			
Anthracene	25	7.4	0.0028	0.0008				0.0311
Benzene	3,386	1,226	0.37	0.13	5.0	5,100	700	710
Benzo(a)pyrene	11	4.7	0.0012	0.0005				0.311
Chlorobenzene	8.1	7.8	0.0009	0.0009				21,000
Di–n–butyl–phthalate	16	6.4	0.0018	0.0007				12,000
Ethylbenzene	158	62	0.017	0.0068	700	430		29,000
Naphthalene	934	92	0.10	0.010		2,350		
Phenol	431	536	0.047	0.059		5,800		
Toluene	1,507	828	0.17	0.091	1,000	6,300	5,000	424,000
Xylenes (total)	543	378	0.059	0.041	10,000			
Arsenic	114	73	0.013	0.0080	50			1.4
Barium	55,564	35,561	6.1	3.9	2,000			
Cadmium	23	14	0.0025	0.0016	5.0	43	9.3	
Copper	445	285	0.049	0.031	1,000	2.9		
Iron	4,916	3,146	0.54	0.34	300			
Lead	195	125	0.021	0.014		220	5.6	
Manganese	116	74	0.013	0.0081	50			
Nickel	1,705	1,091	0.19	0.12	100	75	8.3	100
Zinc	45	134	0.005	0.015	5,000	95	86	
Radium–226	1.4E–06	2E–04	5E–10	5E–08	5 pCi/l (total)			
Radium–228	3.1E–06	2E–04	(Totals)		(5E–6 ug/l)			
Total Water Quality Exceedances:			0	0				
Breakdown of Standards Exceeded:								
Acute			–	–				
Chronic			–	–				
Human Health			–	–				
Drinking Water			–	–				

[a] BAT Options 2 and 4.

Exhibit 4–41. Summary of Pollutant Limitations Exceeded in Texas and Louisiana
Current BPT

Discharge Scenario	State	Acute Standards	Chronic Standards	Human Health Standards	Total Exceeded
			1 Meter Water Depth		
Median by Outfall	Texas		No standards are exceeded		0
	Louisiana	Copper (Avg & Max)	Copper (Avg)	Benzene (Avg & Max)	5
Mean	Texas		Silver (Avg)		1
	Louisiana	Copper (Avg & Max)	Copper (Avg) Lead (Avg)	Benzene (Avg & Max)	6
Median by Flow	Texas	Copper (Avg) Silver (Avg)	Copper (Avg) Lead (Avg) Silver (Avg & Max)		6
	Louisiana	Copper (Avg & Max) Toluene (Avg)	Copper (Avg & Max) Lead (Avg & Max) Nickel (Avg & Max) Toluene (Avg)	Benzene (Avg & Max) Phenol (Avg)	13
			3 Meter Water Depth		
Median by Outfall	Texas		No standards are exceeded		0
	Louisiana			Benzene (Avg)	1
Mean	Texas		No standards are exceeded		0
	Louisiana	Copper (Avg)		Benzene (Avg & Max)	3
Median by Flow	Texas		Silver (Avg)		1
	Louisiana	Copper (Avg & Max)	Copper (Avg & Max) Lead (Avg) Nickel (Avg)	Benzene (Avg & Max)	8

[a] Avg = State Daily Average Limitation; Max = State Daily Maximum Limitation

health) and 1 exceedance (in Louisiana) at the 3 meter depth (daily average limitation for benzene human health).

The mean discharge rate results in 7 exceedances (1 in Texas; 6 in Louisiana) at the 1-meter depth (5 daily average limitations - copper acute, copper chronic, lead chronic, silver chronic, and benzene human health; and 2 daily maximum limitations - copper acute and benzene human health) and 3 exceedances (all in Louisiana) at the 3-meter depth (2 daily average limitations - copper acute and benzene human health; and 1 daily maximum limitation - benzene human health).

The median discharge rate by flow results in 19 exceedances (6 in Texas; 13 in Louisiana) at the 1-meter depth (13 daily average limitations - copper acute, copper chronic, lead chronic, nickel chronic, silver acute, silver chronic, benzene human health, phenol human health, toluene acute, and toluene chronic; and 5 daily maximum limitations - copper acute, copper chronic, lead chronic, nickel chronic, silver chronic, and benzene human health) and 9 exceedances (1 in Texas; 8 in Louisiana) at the 3-meter depth (6 daily average limitations - copper acute, copper chronic, lead chronic, nickel chronic, silver chronic, and benzene human health; and 3 daily maximum limitations - copper acute, copper chronic, and benzene human health).

The current BPT discharges also exceed 5 Louisiana oil and gas effluent limitations required at the point of discharge (see Exhibit 4-31). The benzene, toluene, radium, oil and grease, and TSS concentrations reported for current BPT discharges exceed the oil and gas limitations.

4.5.2 Gulf of Mexico - Gas Flotation (BAT Option 2)

The results of the water quality analyses for Texas and Louisiana BAT discharges in 1 meter and 3 meters of water are presented in Exhibit 4-42. The median discharge rate by outfall results in 8 exceedances (3 in Texas; 5 in Louisiana) at the 1-meter water depth (5 daily average limitations - copper acute, copper chronic, silver acute, silver chronic, and benzene human health; and 3 daily maximum limitations copper acute, silver chronic, and benzene human health) and no exceedances at the 3-meter depth.

The mean discharge rate results in 11 exceedances (4 in Texas; 7 in Louisiana) at the 1-meter depth (6 daily average limitations - copper acute, copper chronic, nickel chronic, silver acute, silver chronic, and benzene human health; and 5 daily maximum limitations - copper acute, copper chronic, silver acute, silver chronic, and benzene human health) and 4 exceedances (1 in Texas; 3 in Louisiana) at the 3-meter depth (4 daily average limitations - copper acute, copper chronic, silver chronic, and benzene human health).

The median discharge rate by flow results in 16 exceedances (6 in Texas; 10 in Louisiana) at the 1-meter depth (10 daily average limitations - copper acute, copper chronic, lead chronic, nickel chronic, silver acute, silver chronic, benzene human health, and phenol human health; and 6 daily maximum limitations - copper acute, copper chronic, nickel chronic, silver acute, silver chronic, and benzene human health) and 9 exceedances (2 in Texas; 7 in Louisiana) at the 3-meter depth (5 daily average limitations - copper acute,

Exhibit 4–42. Summary of Pollutant Limitations Exceeded in Texas and Louisiana
Gas Flotation (BAT Option 2)

Discharge Scenario	State	Acute Standards [a]	Chronic Standards [a]	Human Health Standards [a]	Total Exceeded
			1 Meter Water Depth		
Median by Outfall	Texas	Silver (Avg)	Silver (Avg & Max)		3
	Louisiana	Copper (Avg & Max)	Copper (Avg)	Benzene (Avg & Max)	5
Mean	Texas	Silver (Avg & Max)	Silver (Avg & Max)		4
	Louisiana	Copper (Avg & Max)	Copper (Avg & Max)	Benzene (Avg & Max)	
			Nickel (Avg)		7
Median by Flow	Texas	Copper (Avg)	Copper (Avg)		
		Silver (Avg & Max)	Silver (Avg & Max)		6
	Louisiana	Copper (Avg & Max)	Copper (Avg & Max)	Benzene (Avg & Max)	
			Lead (Avg)	Phenol (Avg)	
			Nickel (Avg & Max)		10
			3 Meter Water Depth		
Median by Outfall	Texas	No standards are exceeded			0
	Louisiana	No standards are exceeded			0
Mean	Texas		Silver (Avg)		1
	Louisiana	Copper (Avg)	Copper (Avg)	Benzene (Avg)	3
Median by Flow	Texas		Silver (Avg & Max)		2
	Louisiana	Copper (Avg & Max)	Copper (Avg & Max)	Benzene (Avg & Max)	
			Nickel (Avg)		7

[a] Avg = State Daily Average Limitation; Max = State Daily Maximum Limitation

copper chronic, nickel chronic, silver chronic, and benzene human health; and 4 daily maximum limitations - copper acute, copper chronic, silver chronic, and benzene human health).

The gas flotation (BAT Option 2) discharges also exceed 4 Louisiana oil and gas effluent limitations at the point of discharge (see Exhibit 4-31). The benzene, toluene, radium, and oil and grease concentrations reported for gas flotation (BAT Option 2) discharges exceed the oil and gas limitations.

4.5.3 Gulf of Mexico - Zero Discharge Options

There are three BAT options that require all facilities in the coastal subcategory of Gulf of Mexico states to meet zero discharge of produced water. Under these options (Options 3 through 5), all state water quality standards would be met due to cessation of discharges.

4.5.4 Cook Inlet, Alaska Water Quality Analyses

Because Alaska state standards do not specify mixing zones for enforcement of the numerical standards, results of the Alaska water quality analysis are presented in Exhibit 4-43 as the distance from each facility's discharge point where all of the standards are met. This distance for the eight facilities ranges from within 50 feet to 2.5 km for Current BPT and from within 50 feet to 2.0 km for gas flotation (BAT Options 2 and 4).

Exhibit 4–43. Mixing Zones Required for Alaska Outfalls

Facility	Mixing Zone Needed to Achieve Standards (m)	
	Current BPT	Gas Flotation (BAT Option 2)
Trading Bay	2,500	2,000
Granite Point	2,500	2,000
Anna	1,000	500
East Foreland	1,000	750
Phillips NCIU	500	100
Dillon	61	61
Bruce	61	<15
Baker	<15	<15

5. WATER QUALITY COMPLIANCE ASSESSMENTS FOR COOK INLET DRILLING WASTE

Cook Inlet, Alaska is the only coastal area in which the discharge of drilling muds are currently authorized. Under the proposed effluent guidelines, EPA has developed options for their regulation. To evaluate these options, this WQBA has included the following water quality assessment for drilling fluids discharges in Cook Inlet.

5.1 Characterization of Drilling Discharges

The pollutant concentrations for drilling fluids, the most significant waste stream from drilling operations, are provided in Exhibit 5-1. Metals data are from the offshore subcategory of the Gulf of Mexico with the exception of barium, which is calculated for average weight muds for Cook Inlet. Organic pollutant concentrations are based on the presence of 0.02% mineral oil by volume. These concentration data are presented and discussed in further detail in EPA, 1994a.

For the purposes of the water quality compliance assessments, the pollutant concentrations do not change from current BPT practices (BAT Option 1) to BAT Option 2 practices. EPA (1994a) provides pollutant concentrations based on a basic drilling fluid formulation and only the whole effluent toxicity is assumed to change from current BPT (BAT Option 1) to BAT Option 2. BAT Option 3 for Cook Inlet drilling discharges is zero discharge.

5.2 Dilution Modeling

Modeling of drilling fluid discharges was not conducted as part of this WQBA. The modeling results used for this water quality assessment of Cook Inlet discharges is from dilution modeling conducted for EPA Region 10 for the issuance of a general permit for Cook Inlet operations. The modeling was conducted as part of the Ocean Discharge Criteria Evaluation (TetraTech, 1994) using the Offshore Operator's Committee (OOC) Mud Discharge Model (version 1.0; Brandsma et al., 1983).

Because drilling fluid dispersion had been found to be dependent to a large degree on water depth, modeling was conducted for three depth ranges. These ranges are: 40 to 300 meters; 20 to 40 meters; and 10 to 20 meters. For the 40 to 300 meter water depth range, discharge rates of 1,000 bph (the maximum allowable rate under the Region 10 permit for this depth) and 500 bph were modeled for current speeds from 2 to 150 cm/sec. For the 20 to 40 meter water depth range, discharge rates of 750 bph (the maximum allowable rate under the Region 10 permit for this depth) and 500 bph were modeled for current speeds from 10 to 150 cm/sec. For the 10 to 20 meter water depth range, discharge rates of 500 bph (the maximum allowable rate under the Region 10 permit for this depth) and 250 bph were modeled for current speeds from 2 to 30 cm/sec. Discharges are prohibited in waters between the shore and the 5 meter isobath.

Although Alaska standards do not specify spatially-defined mixing zones, Region 10's approach to assessing water quality impacts for the general permit used modeling to predict the number of dilutions for

Exhibit 5–1. Pollutant Concentrations in Drilling Fluid Effluent

Pollutant	Average Concentration in Dry Drilling Waste (mg/l)	Average Concentration in Drilling Effluent (mg/l)[a]
Metals (lbs/MM lbs dry mud)		
Cadmium	1.1	0.35
Mercury	0.1	0.03
Aluminum	9,069.9	2,920
Antimony	5.7	1.84
Arsenic	7.1	2.29
Barium	120,000	38,632
Beryllium	0.7	0.23
Chromium	240	77.26
Copper	18.7	6.02
Iron	15,344.3	4,940
Lead	35.1	11.30
Nickel	13.5	4.35
Selenium	1.1	0.35
Silver	0.7	0.23
Thallium	1.2	0.39
Tin	14.6	4.70
Titanium	87.5	28.17
Zinc	200.5	64.55
Organics (lbs/bbl mud)		
Naphthalene	0.0000035	0.010
Fluorene	0.0000563	0.161
Phenanthrene	0.0000084	0.024
Alkylated benzenes	0.0021017	6.00
Alkylated naphthalenes	0.0000344	0.098
Alkylated fluorenes	0.0001218	0.348
Alkylated phenenthrenes	0.0000143	0.041
Total biphenyls	0.0001360	0.388
Total dibenzothiophenes	0.0000004	0.001

Source: EPA, 1994a.

[a] Metals calculated as: Conc./1,000,000 lb dry wgt. * 454,000 (mg/lb)*0.7091 (lb dry mud/l)
Organic pollutants calculated as: Conc. * 454,000 (mg/lb)/159 (l/bbl)

the solids and dissolved portions of drilling fluids discharges at 100 meters from the discharge point assuming a discharge of 1 hour duration. The results of the modeling are summarized in Exhibit 5-2.

5.3 Water Quality Analysis, Cook Inlet Drilling Discharges

The concentrations of pollutants in drilling fluid effluent are divided by the number of dilutions at the edge of the mixing zone to determine the pollutant concentration in the water column. For metals, the effluent concentration is first multiplied by a leachability factor (see Exhibit 5-3) that represents the portion that will exist in the effluent in a dissolved form. The number of dilutions used are those projected for the dissolved portion of the discharge plume at the edge of a 100-meter mixing zone. These calculated concentrations of effluent pollutants at the edge of the mixing zone are compared to the state water quality standards to determine if the standards are met by current BPT and BAT effluent discharges. The results of the water quality analysis are presented in Exhibit 5-3.

For current BPT and BAT Options 1 and 2, a 1,000 bph discharge at the 40 meter water depth exceeds 2 standards (drinking water standards for aluminum and iron). A 750 bph discharge at the 20 meter water depth also exceeds 2 standards (drinking water standards for aluminum and iron). A 500 bph discharge at the 10 meter water depth exceeds 3 standards (drinking water standards for aluminum, antimony, and iron). For BAT Option 3, zero discharge, no water quality standards would be exceeded in Cook Inlet.

Exhibit 5–2. Summary of OOC Model Results from Region 10 Permit Development

Current Speed (cm/sec)	Number of Dilutions at Edge of 100–m Mixing Zone					
	1,000 bph/40 m depth		750 bph/20 m depth		500 bph/10 m depth	
	Solids	Dissolved	Solids	Dissolved	Solids	Dissolved
2	2,156	1,660	--	--	--	--
10	1,039	1,012	1,329	747	3,323	420
30	3,957	886	1,252	700	2,126	269
100	3,995	6,024	4,810	7,143	--	--
150	4,025	6,061	--	--	--	--

Source: TetraTech, 1994.

Exhibit 5–3. Water Quality Analysis for Drilling Discharges to Cook Inlet

Pollutant	Whole Mud Average Concentration (ug/l)	Percent Leach[a]	Soluble Concentration (ug/l)	Effluent Concentration at 100–m Mixing Zone[b] 40 m depth[c] (1,000 bph)	20 m depth[d] (750 bph)	10 m depth[e] (500 bph)	Federal Water Quality Criteria (ug/l) Acute	Chronic	Human Health	Drinking Water Standards (ug/l)
Aluminum	2,920,000	39	1,138,800	**1,125**	**1,627**	**4,233**	–	–	–	**200**
Antimony	1,840	100	1,840	1.82	2.63	**6.84**	–	–	–	**6.0**
Arsenic	2,290	0.5	11.5	0.011	0.016	0.043	–	–	1.4	50
Barium	38,632,000	0.21	81,127	80.2	116	302	–	–	–	2,000
Beryllium	230	100	230	0.227	0.329	0.855	–	–	–	4.0
Cadmium	350	11	38.5	0.0380	0.0550	0.143	43	9.3	–	5.0
Chromium[f]	77,260	3.4	2,627	2.60	3.75	9.77	–	–	–	100
Copper	6,020	0.63	37.9	0.0375	0.0542	0.141	2.9	–	–	1,000
Iron	4,940,000	13	642,200	**634.58**	**917**	**2,387**	–	–	–	**300**
Lead	11,300	2	226	0.223	0.323	0.840	220	5.6	–	–
Mercury	30	1.8	0.540	0.000534	0.000771	0.00201	–	–	–	100
Nickel	4,350	4.3	187	0.185	0.267	0.695	75	8.3	100	100
Selenium	350	100	350	0.346	0.500	1.30	–	–	–	50
Silver	230	100	230	0.227	0.329	0.855	–	–	–	100
Thallium	390	100	390	0.385	0.557	1.45	–	–	–	2.0
Zinc	64,550	0.41	265	0.262	0.378	0.984	95	86	–	5,000
Naphthalene	10	100	10	0.00988	0.0143	0.0372	2,350	–	–	–

[a] Percentage leach assumed to be 100% for metals for which leachability data were not available.
[b] Concentration at 100 m = effluent conc.*percent leach/dissolved dilution; dilutions used for analysis are the minimum predicted at the maximum allowable discharge rate using a range of current speeds.
[c] 10 cm/sec current speed – 1,012 dissolved dilutions.
[d] 30 cm/sec current speed – 700 dissolved dilutions.
[e] 30 cm/sec current speed – 269 dissolved dilutions.
[f] Criteria are for hexavalent chromium.

6. VALUATION OF RESOURCES AT RISK IN THE GULF OF MEXICO

6.1 Review of Coastal Wetland Values

A literature review for wetland value estimates was conducted for MMS (MMS, 1991). The literature review contains many different ways to value wetlands, depending on the different uses of these wetlands. Demonstrating the difficulty in estimating the value of wetlands, MMS (1991) establishes three broad types of wetland use values. These values include on-site use values, off-site use values, and nonuse values. On-site use values of wetlands are the easily recognized and priceable benefits that come from wetlands. On-site use values include hunting, trapping, and hay and peat production. Off-site use values of wetlands are not as easily recognized because these use values do not occur at the wetlands. Rather, they are recognized as values associated with other geographic areas. For example, wetlands are breeding, nesting, and nursery grounds for many species of animals, especially fish and birds, that occur outside of wetlands. Off-site use values of wetlands include sport and commercial fisheries, waterfowl, and fur-bearing animals. Values can be assigned to such off-site uses of wetlands after the wetlands dependence of these end uses is established. Nonuse values of wetlands are benefits that are the most difficult to quantify. It is difficult, and in some cases even impossible, to put a price on the nonuse values of wetlands. Nonuse values of wetlands include:

- Biological productivity
- Biological diversity
- Ecosystem stability
- Flood control
- Climate control
- Water purification
- Pollution filtration
- Aesthetic values.

Different methods of valuing wetlands are identified by MMS (1991). The following briefly summarizes the different methods of valuing wetlands.

Market Price Method. Estimates the economic value of commercially traded products and services from wetlands (e.g., peat, hay, hunting rights) on the basis of their market prices. This method does not deduct market value of other resources used to bring wetland products to market.

Net Factor Income Method. Estimates the value of wetland resources in commercial production by estimating the profits of wetland-dependent commercial activities after payments are made to other factors of production.

Travel Cost (TC) Method. Used to estimate the value of recreational benefits generated by wetlands. Assumes that the value of a site is reflected in how much people are willing to pay to get there.

Hedonic Pricing - Property Value (PV) Analysis. Hedonic techniques assume that the price paid for a commodity is directly related to the supply of the commodity's attributes. Most common is the PV approach, which uses variations in property values to reveal implicit values and demand for environmental amenities.

Contingent Valuation (CV) Method. The only available technique for estimating most nonuse values. This method questions individuals directly about their willingness to pay (WTP) or willingness to accept payment.

Valuation (Benefit) Transfer: The Activity Day Method. Simple transfer: an activity day valued at one site is used to value the same activity at the study site. Values are usually site/location/user specific, but transfers can be useful for gross estimates of recreational values.

Replacement Cost (RC) Method. Estimates the value of a non-market service based on the cost of substitution. This involves three steps: estimate level of service provided, identify least cost alternative, and establish public demand for this alternative.

Damage Cost (DC) Method. Estimates the value of a service based on the cost of damage that may result from its loss. Steps include: assess service level, estimate potential damage, translate to dollar terms, and identify possible substitute.

Energy Analysis/Biological Productive Method. Assumes that the value of a good is reflected in the energy required to produce it. Values wetlands on the basis of their biological productivity [(kilo calories of biomass) x (energy price)].

Opportunity Cost Method. Proxy value for uncertain wetland functions/services calculated on the basis of the cost of foregone development values and appropriate least-cost substitutes.

In the literature reviewed in MMS (1991), generalized unit wetland values range from $424 to over $200,000 per acre. MMS (1991) states that the "emerging consensus" for appropriate wetland values ranges from $7,000 to $20,000 per acre. However, the value of certain specific uses and products of wetlands covers a much broader range. Exhibit 6-1 gives a complete list of wetland value estimates for the Gulf of Mexico. The following summary provides ranges of wetland value estimates for different products and uses of wetlands.

Exhibit 6-1. Summary of Literature Review of Wetlands Values

Location	Wetland Type	Basis of Estimate	Value (year)	Value Updated to 1990	Reference
Louisiana	Coastal Marsh	Consumer's surplus	$155/acre/yr (1979)	$268/acre/yr	Mumphrey et al., 1978
Louisiana	Coastal Marsh	Gross benefits (fish and fur harvests; recreational hunting and fishing)	$241/acre/yr (1979) $352/acre/yr (1979) $544/acre/yr (1979) $231/acre/yr (1979)	$416/acre/yr $608/acre/yr $939/acre/yr $399/acre/yr	Gosselink, Odum, & Pope, 1974 Vora, 1974 Mumphrey et al., 1978 Mumphrey et al., 1978
Louisiana	Coastal Marsh	Net benefits	$237/acre/yr (1979)	$409	Costanza and Farber, 1985
Louisiana	Coastal Marsh	Replacement Value	$3,120 (1979)	$5,386	Costanza and Farber, 1985
Louisiana	Coastal Marsh	Biological Productivity	$300/acre/yr (1979)	$518	Costanza and Farber, 1985
Mississippi	Beaver Pond	Survey of duck hunters; WTP for duck hunting rights on ponds	58%: $37/ha/yr 42%: $62/ha/yr	$72 $121	Lochmiller, 1979
Florida	Cypress swamp	Embodied energy analysis	$383/acre	$818/acre	Odum, H.T., 1978
Louisiana	Atchafalaya basin	Commercial fishing Recreational value - estimate	$25 million/yr $42 million	$64 million/yr $107 million	Schueler, 1975
Florida	Marsh	Value of march contribution to the blue crab industry - present value	$3.00/ marginal marsh acre	$4.60/ marginal marsh acre	Lynne, Conroy, & Prochasta, 1981
Mississippi	Delta Bottomland	Used a logit analysis for estimating hunter participation as a function of waterfowl habitat and other variables (travel costs), then considered a 10% loss in habitat. - average value for duck hunting	$82/acre	$126/acre	Gupta, 1972
Louisiana	Coastal (Terrebonne Parish)	Two Methods: willingness to pay applied to three wetland contributions 1. Commercial fishing and trapping values 5.17 lbs/acre shrimp - Marsh 2.30 lbs/acre blue crab - Saltmarsh 6.00 lbs/acre oyster - Estuary 145.00 lbs/acre menhaden - Estuary 1.86 lbs/acre trapping - Wetlands Total annual value - present value at (8%)	 $10.86 $0.67 $8.04 $5.80 $12.09 $37.46/acre $468.25/acre	 $14.19 $0.88 $10.51 $7.58 $15.80 $48.96/acre $612.01/acre	Farber & Costanza, 1987 Study was composed of 650,000 wetlands in 1970

Exhibit 6-1. Summary of Literature Review of Wetlands Values (Continued)

Location	Wetland Type	Basis of Estimate	Value (year)	Value Updated to 1990	Reference
Louisiana	(Terrebonne Parish) (Continued)	2. Recreation values estimated using travel costs and contingent valuation methods			Farber & Costanza, 1987 (Continued)
		- annual value	$6.00/acre (1983)	$7.84/acre	
		- present value (at 8%)	$111.00/acre	$145.08/acre	
		3. Storm protection values estimated expected storm wind damages from loss of one mile of wetlands along the coast-line		$0.58/acre	
		- annual value	$0.44/acre (1983)	$9.78/acre	
		- present value (at 8%)	$7.48/acre		
		4. Total			
		- present value (at 8%)	$586.73/acre	$766.86/acre	
		B. Energy analysis evaluation			
		- Estimate gross primary production, determined fossil fuel equivalent values, and converted to dollars			
		- salt marsh present value	$6,700/acre (1983)	$8,760/acre	
		- brackish marsh present value	$10,602/acre	$13,857/acre	
		- fresh marsh	$6,400/acre	$8,360/acre	
	Coastal	Follow up to the previous entry. Used WTP and energy analysis methodologies to develop a range of values for wetlands in coastal Louisiana			
		• WTP based:	8% - 3% discount	8%-3% discount	
		- commericial fishery	$317 - $846	$414 - $1,106	
		- trapping	$151 - $401	$197 - $524	
		- recreation	$46 - $181	$60 - $237	
		- storm protection (wind and flood)			
		- Total	$1,915 - $7,549	$2,503 - $9,867	
		• EA-based GPP conversion	$2,429 - $8,977	$3,175 - $11,733	
		• "Best estimate"	$6,400 - $17,000	$8,364 - $22,219	
Florida	General	Present value/acre life support (energy theory of value)	$82,000/acre	$235,000/acre	Gosselink, Odum, & Pope, 1974
		Marginal productivity theory			
		- sport fishing	$286/acre/yr	$559	
		- non-consumptive recreation	$138.24/acre/yr	$270.35	
		- trapping of fur bearers	$31.23/acre/yr	$61.08	
		- commercial fishing	$30.78/acre/yr	$60.20	
		Total	$489.69/acre/yr	$950.63	

Exhibit 6-1. Summary of Literature Review of Wetlands Values (Continued)

Location	Wetland Type	Basis of Estimate	Value (year)	Value Updated to 1990	Reference
Florida West Coast	Saltwater	Value of marginal project; capitalization 8.625% - ex-vessel for for commercial fisheries - retail value	 $413/acre $1,355/acre	 $541.02/acre $1,775.05/acre	
Florida	Unknown	Ex-vessel Value of Estuary-Dependent Commercial Landings, Florida W. Coast	$114,704,971 (1984)	$144,225,434	
Florida	Salt Marshes	Marginal value of product of salt marsh (Joint Commercial Species)	$27.48/acre (1984)	$34.55/acre	
Florida	Salt Marshes West Coast	Estimate of wetland value for fisheries production based on: a) Lyonne acreage b) NOAA acreage	 $356 $416	 $1089.92	
Florida	Salt Marshes	Present value/acre Value on ex-vessel level to commercial fishing industry	 $220	 $280	
Louisiana	Fresh, Salt Water, and Brackish Marsh	Commercial Fishing Commercial trapping Sport fishing	$94/acre/yr $3.47/acre/yr $12.13/acre/yr	$162/acre/yr $5.99/acre/yr $20.94/acre/yr	Gosselink, 1980
Gulf of Mexico	Coastal Marsh	Value of storm protection based on hurricane damage estimates 1) assumption of a 1 mile caveat of the wetland 2) assuming loss of a 207 ft. strip 3) present value of 1 acute at 8% discount in the coastal strip 4) same as #3, assuming 1.3% population growth	 $5,752,816/yr (1983) $128.20/yr (1983) $1,604 $1,915	 $7,823,829 $174.35 $2,181.44 $2,604.40	
Gulf of Mexico	Salt Marsh Salt Aquatic Brackish Marsh Brackish Aquatic Fresh Marsh Fresh Aquatic	Conversion of energy analysis to economic value	$624/acre $86/acre $914/acre $67/acre $630/acre $121/acre	$817.44 $112.66 $1,197.34 $87.77 $825.30 $158.51	

Exhibit 6-1. Summary of Literature Review of Wetlands Values (Continued)

Location	Wetland Type	Basis of Estimate	Value (year)	Value Updated to 1990	Reference
Gulf of Mexico	Salt Marsh	Economic value of the commercial fisheries production of an acre of salt marsh; products of ex-vessel price and an annual marginal product estimate for commercial fisheries production	$25.36 (1983)	$34.89	U.S.D.C.
Gulf of Mexico	Brackish, Intermediate Marshes and Freshwater	Annual value of pelt productivity Present value: 8% discount 3% discount	$12.04 (1981) $151 $401	$16.97 $212.91 $565.41	
S.E. U.S.	Tidal Marsh	Waste treatment functions (Based on estimated replacement cost)	$12,350 (1977)	$26,300	Gosselink and Turner, 1986
Florida		Based on marginal productivity - sport fishing - nonconsumptive recreation	 $286 (1978) $138 (1978)	 $6,587 $1,688	Raphael & Turner, 1978
Louisiana	Coastal Marsh	Total biological productivity	$300 (1979)	$6,350	Costanza & Farber, 1985
Florida	General Wetlands	Present value/acre Energy analysis	$82,000/acre	$209,100	Gosselink, Odum, & Pope, 1974
Florida	Salt Marsh	Marginal value of product of salt marsh to Florida fisheries (joint commercial species)	$27.48/acre	$424	Bell, 1989
Gulf of Mexico	Saltmarsh/Brackish Marsh/Fresh Marsh	Energy Analysis	$624/acre/yr $914/acre/yr $630/acre/yr	$10,000 $14,600 $10,000	Costanza, Farber, Maxwell, 1989
Coastal Louisiana		Willingness to pay/Energy Analysis 8% discount 3% discount	 $2,429-$6,400 $8,977-$17,000 (1983)	 $3,200-$8,400 $11,800-$22,270	Costanza, Farber, Maxwell, 1989
Western Gulf of Mexico		Sum of aesthetic, commercial fishery, recreation, and wildlife values	$14,720/acre	$18,700	Barry, 1990

Source: MMS, 1991.

Product or Use	Estimated Value
Commercial fishing	$34.55 - $1,775/acre
Recreational fishing	$21 - $559/acre
Fur trapping/hunting	$6 - $524/acre
Water fowl	$178 - $299/acre
Shellfish (blue crab, shrimp, or oyster)	$0.88 - $14/acre
Nonconsumptive recreation	$8 - $270/acre
Storm protection	$0.58 - $767/acre
Sum of the above products and uses	$48.96 - $18,700/acre
Various total intrinsic/extrinsic wetlands values (energy analysis, life support, biological productivity, replacement value)	$818 - $209,100/acre

Based on the information in this review for Louisiana wetlands values, a range of $57 to $940 per acre per year (1990 dollars) is identified; the median value is $410 per acre per year. The studies reviewed are Costanza and Farber, 1985; Farber and Costanza, 1987; Gosselink et al., 1974; Gosselink, 1980; Mumphrey et al., 1978; and Vora, 1974. These values are used for the monetization of ecological benefits for the Gulf-wide assessment presented in Section 9.4 of this WQBA. These values were selected because of the greater proportion of produced water discharges to Louisiana and their applicability to Louisiana resource valuations.

6.2 Recreational Fisheries, Galveston Bay

The draft document prepared for the Galveston Bay National Estuary Program (GBNEP; Whittington et al., 1994), using contingent valuation and benefit transfer, estimated the annual economic value of recreational fishing to the Houston-Galveston area using two different data sets: Texas Parks and Wildlife Department (TPWD) data, and data collected from a mail-only survey performed by the authors of the report. The mail-only survey was performed in a five-county region around Galveston Bay. This survey did not include people who travel to the bay and are not from these counties, and therefore under-represents the actual value of the recreational fishery. This survey estimated 4.5 million recreational fishing days in Galveston Bay, based on the mean number of fishing days per household. The mail survey only had a 49% response rate. Thus, the authors assumed that nonrespondents ranged from zero to half the usage rate of respondents. Using the range of $25 to $38 (1993 dollars) as the value for a fishing day (Walsh et al., 1992 as cited by Whittington et al., 1994), the value of recreational fishing in the Galveston Bay ranges from $75 million to $150 million per year.

The second data set used to estimate the value of recreational fishing in Galveston Bay was site-intercept data collected by TPWD. The authors state that this data also may underestimate the recreational fishery value because not all boats are accessible. The authors indicate that this number could be up to 25% higher (McEachron and Green, 1984 as cited in MMS, 1991). This estimate also does not take into account fishing

done from shore, which could account for an additional 33% to 36% of the recreational landings along the Texas coast (Campbell et al, 1991 as cited in MMS, 1991). Finally, this estimate does not include night fishing from private- and party-boats. Using the TPWD data, the estimated value of recreational fishing in the Galveston Bay in 1993 was $44 million to $60 million per year. The authors assume that their survey was a more accurate estimate of the number of recreational fishing days in the Galveston Bay. However, when $44 million is increased by 25% to account for boat access and 35% to account for shore fishing, the resulting range of values is $74 million to $101 million. This range is not far from the estimate by Whittington et al. (1994), especially because night fishing is not included in this calculation.

6.3 Nonconsumptive and Other Recreational Values, Galveston Bay

The draft document prepared for the GBNEP presents a survey of the value of recreational boating in the Galveston Bay, not including the economic value of recreational fishing from a boat (Whittington et al., 1994). Using benefit transfer, the value of a boating day was assumed to be $15 to $33 (1993 dollars; Walsh et al., 1992 as cited in Whittington et al., 1994). The estimate of the number of boater days is based on boat registration, commercial marina, and wet slip data for the area of Galveston Bay. Data on the frequency of boat use is based on a TPWD report entitled *1990 Comprehensive Outdoor Recreation Plan*. The resulting value of recreational boating in this Galveston Bay study was estimated to be $25 million to $50 million per year.

The same document estimates the value of other land-based recreational activities in Galveston Bay. These activities include swimming, hiking, picnicking, camping, hunting, and trail walking/jogging. A mail-only survey was used to estimate that there were 1,620,000 use days in the Houston-Galveston area in 1993. This survey assumed that the use by non-respondents was one-half that of the respondents. The value of land-based recreational activities was estimated to be $15 million to $50 million per year.

6.4 Total Recreational Value, Galveston Bay

The draft document prepared for the GBNEP presents a range of values for all recreational uses of Galveston Bay. These values were developed by adding the estimates of the values for recreational fishing, the value of boating to users of the bay, and the value of other recreational uses of the bay. These valuations are summarized in Exhibit 6-2. For all recreational uses, the estimated value of the bay ranges from $115 million to $250 million per year. Based on Galveston Bay acreage of 342,275 acres, derived from an EPA ORD document (EPA, 1994b), this represents a range of $336 to $730 per acre, with a midpoint value of $533 per acre. These range and midpoint values are used to develop estimates of monetized ecological benefits developed for the Trinity Bay case study, presented in Section 9.3 of this WQBA.

Nonconsumptive wildlife uses in Texas and Louisiana were estimated by USFWS (1993a; 1993b). These uses include observing wildlife, feeding wildlife, and photographing wildlife. In Texas, in 1991, 5.5 million participants over the age of 16, spent up to $878 million on nonconsumptive wildlife uses. In Louisiana, in 1991, 1.4 million participants over the age of 16, spent $22 million in nonconsumptive wildlife activities.

Exhibit 6-2. Summary of Galveston Bay Recreational Values

Activity	Value
Recreational Fishing	$75 - $150 million
Recreational Boating	$25 - $50 million
Other Recreation	$15 - $50 million
Total Recreational Value	$115 - $250 million
Galveston Bay Acreage	342,275 acres
Recreational Value of Galveston Bay	$336 - $730 per acre
Midpoint Value	$533 per acre

6.5 Commercial Fisheries, Texas and Louisiana

Most commercial fishery species spend a significant portion of their life cycle in bays and estuaries. Of 26 commercial species caught in Louisiana (NOAA, 1985; NMFS, 1993a), 18 species spend a significant portion of their life cycle in the estuary. These 18 species made up 98% of the total weight landed in Louisiana, in 1992. Similarly, of 18 commercial species caught in Texas (NOAA, 1985; NMFS, 1993a), 12 species spend a significant portion of their life cycle in the estuary. These 12 species made up 92% of the total commercial landings in Texas, in 1992. Therefore, the water and sediment quality of coastal subcategory waters may affect the early life stages of the important commercial species, and affect both coastal and offshore fisheries.

The commercial fisheries in Texas and Louisiana (finfish and shellfish) were together valued at $476 million (ex-vessel value) in 1992 (NMFS, 1993b). This value represents 75% of the entire value of the Gulf of Mexico fishery. Louisiana's commercial fishery was valued at $295 million, while the Texas commercial fisheries brought in $181 million (NMFS, 1993b). It is not possible to reliably quantify the benefits of these proposed coastal oil and gas regulations to these fisheries. However, the mass and toxic loadings estimated to derive from produced water discharges to the estuarine drainage systems of Texas and Louisiana are appreciable (17-67% of the current BPT point source mass load and 80-94% of the current point source toxic load). A reasonable assumption is that such reductions in these loadings, or their elimination through zero discharge, will improve water and sediment quality for commercial species, even if these improvements cannot be accurately quantified at present.

6.6 Endangered and Threatened Species

There are 51 endangered and threatened species within coastal areas of the Gulf of Mexico (Carmody, 1993; Stevens, 1993; Francesco, 1994; USFWS, 1992). Thirty-two threatened or endangered species occur in Louisiana and Texas. These 32 species include:

- 12 endangered and 1 threatened species of birds
- 3 endangered and 4 threatened species of reptiles
- 4 endangered and 1 threatened species of mammals
- 1 endangered and 1 threatened species of fish
- 1 endangered and 1 threatened species of mollusks
- 3 endangered species of plants.

Exhibit 6-3 presents a complete list of the threatened and endangered species that occur in the coastal areas of the Gulf of Mexico.

Exhibit 6-3. Threatened and Endangered Species of the Gulf of Mexico

Listed Species	Florida	Alabama	Mississippi	Louisiana	Texas
BIRDS					
Brown Pelican	--	E	--	E	E
Arctic Peregrine Falcon	T	T	T	T	E
Bald Eagle	E	E	E	E	E
Piping Plover	T	T	T	T	T
Interior Least Tern	--	--	--	E	E
Attwater's Prairie Chicken	--	--	--	--	E
Ivory-billed Woodpecker	--	--	--	E	--
Red-cockaded Woodpecker	--	--	--	E	--
Black-capped Vireo	--	--	--	E	--
Aplomado Falcon	--	--	--	E	--
Eskimo Curlew	--	--	--	E	--
Bachman's Warbler	--	--	--	E	--
Whooping Crane	--	--	--	--	E
Wood Stork	E	E	--	--	--
Roseate Tern	T	--	--	--	--
Cape Sable Sparrow	E, CH	--	--	--	--
REPTILES					
Green Sea Turtle	E	T	T	T	T
Hawksbille Sea Turtle	E	E	E	E	E
Leatherback Sea Turtle	E	E	--	E	E
Loggerhead Sea Turtle	T	T	T	T	T
Kemp's (Atlantic) Ridley Sea Turtle	E	E	E	E	E
Ringed Sawback Turtle	--	--	--	T	--
American Alligator	E, CH	--	--	T*	
MAMMALS					
Jaguarundi	--	--	--	--	E
Ocelot	--	--	--	--	E

E = Endangered T - Threatened CH = Critical Habitat
C = Candidate * Classified as "Threatened due to Similarity of Appearance"

Exhibit 6-3. Threatened and Endangered Species of the Gulf of Mexico (Continued)

Listed Species	Florida	Alabama	Mississippi	Louisiana	Texas
Louisiana Black Bear	--	--	--	T	--
Florida Panther	E	E	E	E	--
Red Wolf	--	--	--	E	--
Key Deer	E	--	--	--	--
Florida Salt Marsh Bole	E	--	--	--	--
St. Andrew Beach Mouse	C	--	--	--	--
Santa Rosa Beach Mouse	C	--	--	--	--
Choctawhatchee Beach Mouse	E, CH	--	--	--	--
Perdido Key Beach Mouse	E	E, CH	--	--	--
Alabama Beach Mouse	--	E, CH	--	--	--
Key Largo Cotton Mouse	E	--	--	--	--
Key Largo Woodrat	E	--	--	--	--
Lower Keys Rabbit	E	--	--	--	--
Florida Manatee	E, CH	E	--	--	--
FISH					
Gulf Sturgeon	T	T	T	T	--
Pallid Sturgeon	--	--	--	E	--
MOLLUSKS					
Louisiana Pearlshell Mussell	--	--	--	T	--
Pink Mucket Mussell	--	--	--	E	--
Stock Island Tree Snail	T	--	--	--	--
INSECTS					
Schaus' Swallowtail Butterfly	T	--	--	--	--
PLANTS					
Texas Prairie Dawn	--	--	--	--	E
Slender Rush-pea	--	--	--	--	E
Louisiana Quillwort	--	--	--	E	--
Key Tree Cactus	E	--	--	--	--
Garber's Spurge	T	--	--	--	--

E = Endangered T - Threatened CH = Critical Habitat
C = Candidate * Classified as "Threatened due to Similarity of Appearance"

7. POPULATIONS EXPOSED TO COASTAL PRODUCED WATER DISCHARGES

Analyses of potentially exposed populations, including various socioeconomic and ethnic groups, were performed to conduct exposure assessments for the risk assessment presented in Section 8 of this WQBA and to address environmental equity issues related to produced water discharges from coastal oil and gas facilities. Information on seafood consumption patterns is based on work performed for the Galveston Bay Estuary Program (GBNEP) and includes data on high-rate consumers, assumed to be frequent recreational fishermen and subsistence fishermen. This GBNEP study determined cumulative risk potentials at each of four Galveston Bay sampling sites, which demonstrated contamination by several metals and PAHs found in coastal oil and gas-derived produced water.

7.1 Recreational Anglers

Demographic data from the U.S. Fish and Wildlife Service (USFWS) are used to characterize the number and proportion of recreational fishermen in Texas and Louisiana (USFWS, 1993a; 1993b). This characterization includes those with low income levels (i.e., below $20,000) who may consume seafood at higher than average rates. Exhibit 7-1 presents these demographic data for recreational fishermen in Texas and Louisiana. These data indicate there is a total of 801,200 recreational anglers in the state of Louisiana. There are 246,900 "recreational" anglers in Louisiana who have annual incomes below $20,000 (31% of all recreational anglers in Louisiana; USFWS, 1993a). In the state of Texas, there are 2.65 million recreational anglers; 372,600 of these recreational anglers have annual incomes below $20,000 (14% of all recreational anglers in Texas). These low income recreational fishermen, and members of their households, are assumed to consume much of their catch. For the risk assessment in Section 8, these individuals are assumed to consume seafood products at approximately the subsistence, or high-rate consumption level.

To calculate the population of these recreational anglers and their household members (see also Exhibit 7-1), the number of recreational anglers was multiplied by the county-weighted average of persons per household for the coastal counties of Texas and Louisiana (See Section 7-2, below). In Texas and Louisiana, the total population of recreational anglers and their household members is estimated at 9,724,155 people. The population of low income recreational anglers and their households (annual incomes below $20,000) in Texas and Louisiana is estimated at 1,758,033. The estimated population of middle and high income recreational anglers and their households (i.e., with annual incomes above $20,000) is 7,966,122. These population estimates are used in the radium risk assessment and the monetization of human health benefits presented in Section 8 of this document. Low income recreational anglers and their household members constitute the estimated population of high-rate seafood consumers. Recreational anglers with annual incomes greater than $20,000 and their household members constitute the estimated population of average-rate consumers.

Exhibit 7–1. Recreational Angler Characterization for Texas and Louisiana

State	Income Range	Recreational Anglers Number by Income[a]	Recreational Anglers % of State Anglers	Average Persons per Household[b]	Estimated Exposed Population[c]
Texas	Under $20,000	372,600	14%	2.79	1,039,554
	Over $20,000	2,277,100	86%	2.79	6,353,109
	Entire State	2,649,700		2.79	7,392,663
Louisiana	Under $20,000	246,900	31%	2.91	718,479
	Over $20,000	554,300	69%	2.91	1,613,013
	Entire State	801,200		2.91	2,331,492
Total	Under $20,000	619,500	18%		1,758,033
	Over $20,000	2,831,400	82%		7,966,122
	Both States	3,450,900			9,724,155
Total Texas Population[d]		17,950,285			
Total Louisiana Population[d]		4,298,609			
Total Texas and Louisiana Population		22,248,894			

[a] Source: USFWS, 1993a; 1993b.
[b] County–weighted average (CACI, 1993); see Exhibit 7–2 for derivation.
[c] Recreational anglers and household members.
[d] Source: 1993 population from CACI, 1993.

7.2 Coastal Demographics

Census and demographic data could also be used to estimate exposed populations that may rely more heavily on subsistence fishing and consume seafood products at a higher than average level. One potential subpopulation of higher than average-rate seafood consumers are households below the poverty line ($12,674 annually for a family of four). Census and demographic data also are used to identify the number of households in coastal parishes or counties of Louisiana and Texas and the average number of individuals per household, from which estimates of total consumer populations are derived.

Exhibit 7-2 presents the demographic data for the coastal counties of Texas and Louisiana. Approximately 84,000 family and non-family households are below the poverty level ($12,674 annual income for a family of 4) in coastal Louisiana parishes (CACI, 1993). Based on the average persons per household in each Louisiana coastal parish, a population of 243,461 persons may consume contaminated seafood at a higher than average consumption rate. For all Texas coastal counties there are 587,126 households below the poverty line (CACI, 1993), which, when multiplied by the average number of persons per household for each coastal county, yields a total of 1,641,208 people below the poverty line. For coastal counties bordering Galveston Bay in Texas (Chambers, Harris, Galveston, and Liberty), the same analysis yields approximately 363,498 households and 980,373 persons below the poverty line that may consume seafood at a higher than average consumption rate. Another demographic group that has a cultural pattern of high seafood consumption is Asians. There are approximately 139,00 persons of Asian ethnicity residing in the four counties surrounding Galveston Bay.

Within the recreational fishing and demographic data sets, different income levels are used to group subpopulations (i.e., $10,000 or $20,000 for the recreational angler data vs. $12,674 for the demographic data). Also, an overlap in the subpopulation members occurs (i.e., recreational anglers with incomes below $12,674) that cannot be adjusted for, resulting in a double counting of individuals in a combined data set. Therefore, for the estimates of exposed populations used in the risk assessment, the data on recreational anglers are used as the basis for exposed population estimates. This choice was made because it was believed more compelling to assume high-rate seafood consumers to be both low income and recreational angler households than to be low income households at large.

7.3 Consumption Rates and Patterns

A basic population exposure parameter in environmental health risk assessment methodologies is exposure from ingestion of food. Thus, consumption rates of seafood potentially contaminated by produced water pollutants were identified for this WQBA and used to estimate the potential risk to exposed populations. A study for the Galveston Bay National Estuary Program is the basis for seafood consumption estimates used in this WQBA. The GBNEP study estimates that the average consumer of Galveston Bay seafood eats 15 grams per day (g/d). This is an aggregate of 12.3 g/d of finfish, 1.6 g/d of oysters, and 1.1 g/d of crabs (Brooks et al., 1992). The high rate consumer is defined as the 95th percentile of the seafood consuming population, and is assumed to be the frequent recreational fisherman or the subsistence

Exhibit 7–2. Demographics for Texas and Louisiana Coastal Counties

State	County	% Households Below Poverty Family	Nonfamily	Total	Total Households	No. Households Below Poverty Level	Average Household Size	Number Individuals Below Poverty	Total Population	Percent Asians
Texas	Aransas	20.9%	26.2%	47.1%	7,464	3,516	2.52	8,859	19,054	3.90%
	Brazoria	7.7%	19.3%	27.0%	71,346	19,263	2.84	54,708	211,171	1.20%
	Calhoun	14.9%	27.9%	42.8%	6,963	2,980	2.76	8,225	19,395	3.80%
	Cameron	33.7%	37.3%	71.0%	80,012	56,809	3.47	197,126	282,561	0.40%
	Chambers	10.5%	31.0%	41.5%	7,254	3,010	2.87	8,640	20,930	0.80%
	Galveston	12.5%	21.2%	33.7%	87,669	29,544	2.62	77,406	232,373	1.90%
	Harris	12.5%	16.3%	28.8%	1,115,304	321,208	2.70	867,260	3,044,569	4.40%
	Jackson	17.5%	37.3%	54.8%	4,709	2,581	2.65	6,838	12,613	0.10%
	Jefferson	15.5%	26.0%	41.5%	100,795	41,830	2.57	107,503	247,457	2.50%
	Kenedy	13.4%	40.9%	54.3%	134	73	3.07	223	422	0.00%
	Kleberg	22.2%	42.6%	64.8%	9,828	6,369	2.87	18,278	29,407	1.00%
	Liberty	14.7%	35.2%	49.9%	19,512	9,736	2.78	27,067	55,162	2.00%
	Matagorda	16.1%	32.1%	48.2%	13,792	6,648	2.77	18,414	38,461	2.70%
	Nueces	17.2%	25.3%	42.5%	105,153	44,690	2.85	127,367	303,979	0.90%
	Orange	12.5%	26.5%	39.0%	30,399	11,856	2.73	32,366	83,525	0.60%
	Refugio	20.5%	25.0%	45.5%	2,800	1,274	2.67	3,402	7,538	0.10%
	San Patricio	20.4%	31.7%	52.1%	19,423	10,119	3.07	31,067	60,249	0.30%
	Victoria	14.3%	26.6%	40.9%	27,535	11,262	2.79	31,420	77,494	0.40%
	Willacy	37.6%	46.5%	84.1%	5,183	4,359	3.45	15,038	18,043	0.10%
	Total					587,126	2.79 [a]	1,641,208	4,764,403	27.10%
Louisiana	Cameron	14.3%	23.2%	37.5%	3,138	1,177	2.90	3,413	9,146	0.40%
	Iberia	20.9%	37.9%	58.8%	23,794	13,991	2.93	40,993	70,503	1.70%
	LaFourche	19.0%	35.0%	54.0%	29,516	15,939	2.90	46,222	87,045	0.90%
	Plaquemines	18.7%	34.1%	52.8%	8,283	4,373	3.00	13,120	25,569	2.80%
	St. Bernard	11.9%	25.1%	37.0%	23,486	8,690	2.83	24,592	67,090	1.10%
	St. Mary	22.4%	29.2%	51.6%	19,498	10,061	2.92	29,378	57,686	2.00%
	Terrebonne	20.2%	33.7%	53.9%	33,592	18,106	3.00	54,318	101,535	0.90%
	Vermilion	23.2%	39.8%	63.0%	18,007	11,344	2.77	31,424	50,321	1.70%
	Total					83,681	2.91 [a]	243,461	468,895	11.50%

[a] County–weighted average.
Source: CACI, 1993.

fisherman. The high-rate seafood consumer is estimated to consume 147.3 g/d. This is an aggregate of 94.5 g/d of finfish, 31.3 g/d of oysters, and 21.5 g/d of crabs (Brooks et al., 1992).

The GBNEP study also determined that an individual eating Galveston Bay seafood at the high-rate consumption level would exceed an EPA benchmark risk level of 1×10^{-4} at each of four Galveston Bay study sampling sites. (This benchmark has been used by EPA Headquarters for carcinogenic risk and by EPA Region 6 for noncarcinogenic risk.) This determination is based on potential, cumulative risks from a number of carcinogenic and noncarcinogenic substances identified at these sampling sites, including several contaminants also detected in produced water effluent analyses (e.g. metals and PAHs). The average-rate consumer exceeded the benchmark risk level of 1×10^{-4} at each of the four sampling sites for noncarcinogenic substances, and at two of the four sampling sites for carcinogenic substances.

No population-specific consumption data were available for coastal Louisiana subsistence cultures (i.e., Cajun/Creole) or for those ethnic groups in coastal Texas that are believed to maintain their cultural and community-based, high-rate seafood consumption patterns (e.g., Asians; particularly Vietnamese).

8. RADIUM RISK ASSESSMENT AND MONETIZATION OF POTENTIAL HUMAN HEALTH BENEFITS

8.1 Methodology

An assessment of the potential human health impacts from ingestion of seafood contaminated with radium from discharged produced water is presented in this section. This assessment is an initial, first-order assessment, based on both field data and plume dispersion modeling approaches to estimate seafood radium contaminant levels. For the field data approach, organism radium levels are based on the average of midpoints of the ranges of values detected in studies conducted in coastal Louisiana waters near produced water outfalls. For the modeling approach, produced water dilutions are estimated from Texas and Louisiana water quality modeling, based on mean flow rates and the average of mixing zone dilutions available at 1- and 3-meter water depths (see Section 4 of this WQBA). Produced water radium concentrations are based on EPA sampling data as described in Section 2.3.1, Exhibit 2-4, above. Bioconcentration factors (BCFs) are obtained from an earlier EPA risk assessment of potential radium health effects conducted for the offshore subcategory (EPA, 1993).

These estimated seafood radium levels are then combined with high-rate (147.3 g/d) and average-rate (15 g/d) seafood consumption levels (disaggregated for fish, crab, and oyster consumption levels) that were developed for the Galveston Bay National Estuary Program (Brooks et al., 1992). As per EPA methodology (EPA, 1989; 1993), an exposure duration of 30 years for average-rate consumers, an exposure duration of 70 years for high-rate consumers, and carcinogenicity potency factors for radium 226 (1.2×10^{-10}) and radium 228 (1.0×10^{-10}) are used. Resulting individual carcinogenic risks from all seafood categories are adjusted, also as per EPA methodology (EPA, 1993), by factors of 0.20 and 0.75, to account for ingestion of seafood from various locations, some of which are not contaminated. These reductions are performed for both field data and modeling approaches.

The estimated total exposed population used for this assessment is recreational anglers and their household members in Texas and Louisiana (presented in Section 7, Exhibit 7-1). The total population of all recreational anglers and their household members is 9.7 million. The population of recreational anglers and their households in Texas and Louisiana with incomes below $20,000 is considered as a high-rate seafood consumer group. This population totals 1.8 million individuals in coastal Texas and Louisiana. The population of recreational anglers and their households with incomes above $20,000 is assumed to be average-rate seafood consumers. This population totals 8.0 million individuals in coastal Texas and Louisiana.

8.2 Results

Exhibit 8-1 presents the complete calculations and results of estimated increases of lifetime cancer risks for high-rate and average-rate consumers using the modeling approach. The range presented for

Exhibit 8–1. Estimated Increased Lifetime Cancer Risk – EPA Modeling Methodology

Organism	Average Conc. (pCi/l)	Estimated Dilutions[a]	BCF (l/kg)	Consumption (kg/yr)	Exposure Duration (years)	Radionuclide Potency Factor (lifetime risk/pCi)	Additional Lifetime Cancer Risk	Maximum Additional Cancer Risk	Reduction Factor[b] (0.2)	Reduction Factor[b] (0.75)
Ra–226		**Average–Rate Consumer (15 g seafood per day)**								
Fish	172	112.5	80	4.5	30	1.20E–10	2.0E–06			
Crab	172	112.5	200	0.4	30	1.20E–10	4.4E–07			
Oyster	172	112.5	300	0.6	30	1.20E–10	9.9E–07			
								3.4E–06	6.8E–07	2.6E–06
Ra–228										
Fish	228	112.5	80	4.5	30	1.00E–10	2.2E–06			
Crab	228	112.5	200	0.4	30	1.00E–10	4.9E–07			
Oyster	228	112.5	300	0.6	30	1.00E–10	1.1E–06			
								3.8E–06	7.5E–07	2.8E–06
Combined Ra–226 + Ra–228								7.2E–06	1.4E–06	5.4E–06
Ra–226		**High–Rate, Subsistence Consumer (147.3 g seafood per day)**								
Fish	172	112.5	80	34.5	70	1.20E–10	3.5E–05			
Crab	172	112.5	200	7.8	70	1.20E–10	2.0E–05			
Oyster	172	112.5	300	11.4	70	1.20E–10	4.4E–05			
								9.9E–05	2.0E–05	7.5E–05
Ra–228										
Fish	228	112.5	80	34.5	70	1.00E–10	3.9E–05			
Crab	228	112.5	200	7.8	70	1.00E–10	2.2E–05			
Oyster	228	112.5	300	11.4	70	1.00E–10	4.9E–05			
								1.1E–04	2.2E–05	8.2E–05
Combined Ra–226 + Ra–228								2.1E–04	4.2E–05	1.6E–04

[a] Dilutions are estimated from the calculated values for Texas and Louisiana based on the mean of average flow dilutions for 1– and 3–meter water depths at the edge of 50–foot and 200–foot mixing zones: 36.7 and 188 dilutions at 1– and 3–meter water depths, respectively.

[b] Use of the 0.2 and 0.75 reduction factors (from the maximum value) is the EPA methodology to account for the ingestion of seafood from various locations, some contaminated, some not; the resulting range is believed to be the estimated risk.

modeling estimates of risk (and also for field data estimates discussed below) result from the application of a factor of 0.2 and 0.75 to the maximum lifetime excess cancer risk. The application of these factors accounts for seafood consumption from noncontaminated sources. For the average-rate seafood consumer, the estimated increased lifetime cancer risk, based on the modeling approach, ranges from 1.4×10^{-6} to 5×10^{-6}. Estimated increased lifetime cancer risk due to $Ra^{226+228}$ for the high-rate consumer (147.3 g/d) based on the modeling approach ranges from 4.2×10^{-5} to 1.6×10^{-4}.

Exhibit 8-2 presents projected excess lifetime cancer cases in Texas and Louisiana for estimated exposed populations based on modeled data. Assuming that the population of 8.0 million middle and high income recreational anglers and their households (i.e., with incomes above $20,000) are average-rate seafood consumers, there are 11 to 43 excess lifetime cancer cases projected. Assuming that the population of Texas and Louisiana recreational anglers and their households with incomes below $20,000 (1.8 million people) are high-rate seafood consumers, there are 74 to 276 excess lifetime cancer cases projected. Thus, there is a total of 85 to 319 lifetime excess cancer cases projected for Texas and Louisiana for combined average- and high-rate seafood consumer populations using the modeling methodology.

Exhibit 8-3 presents the calculations for estimated increased lifetime cancer risks for high-rate and average-rate consumers based on the average of midpoints of the ranges of radium contamination levels in field samples of various organisms (fish, crabs, and oysters) in coastal Louisiana. Estimated increased lifetime cancer risk due to $Ra^{226+228}$ ranges from 1.2×10^{-6} to 4.3×10^{-6} for the average-rate seafood consumer (15 g/d) and from 4.0×10^{-5} to 1.5×10^{-4} for the high-rate seafood consumer (147.3 g/d). As per EPA methodology (EPA, 1993b), this range is a result of the application of the factors of 0.2 and 0.75 to account for consumption of seafood from noncontaminated sources.

Exhibit 8-4 presents the projected excess lifetime cancers for Louisiana and Texas populations of recreational anglers and their households, based on field measurements of radium contamination levels. If the population of 1.8 million recreational anglers and their households who have incomes below $20,000 are considered to be high-rate seafood consumers, there will be an increase of 70 to 264 lifetime excess cancer cases. Recreational anglers and their households in Texas and Louisiana with incomes above $20,000, who are considered to be average-rate consumers, have a projected 10 to 34 excess lifetime cancer cases. The projected increase of cancer cases for the entire population of recreational anglers and their household members in Texas and Louisiana ranges from 80 to 298 excess lifetime cases.

Table 8-5 presents a summary of estimated lifetime excess cancer cases and the projected annual lifetime cancer cases (based on a 70-year life span) for the populations of recreational anglers and their household members in the states of Texas and Louisiana. Using the modeling methodology, there will be an increase of 1.06 to 3.94 cancer cases per year for high-rate seafood consumers. Using the field sample data, there will be an increase of 1.00 to 3.80 cancer cases per year for high-rate consumers. For average-rate consumers, there will be an excess of 0.16 to 0.61 cancer cases per year using the modeling methodology. Using the field sample data, there will be 0.14 to 0.49 excess cancer cases per year for the average-rate

Exhibit 8–2. Projected Excess Cancers in Texas and Louisiana Populations – EPA Modeling Methodology

Target Population	Estimated Number of Anglers	Average Persons per Household[a]	Estimated Exposed Population	Maximum Lifetime Excess Cancer Cases[b]			
				Average Consumption[c]		High Consumption[c]	
				20%	75%	20%	75%
Recreational Anglers w/Incomes <$20K							
Texas	372,600	2.79	1,039,554			43	163
Louisiana	246,900	2.91	718,479			30	113
Total	619,500		1,758,033			74	276
Recreational Anglers w/Incomes >$20K							
Texas	2,277,100	2.79	6,353,109	9	34		
Louisiana	554,300	2.91	1,613,013	2	9		
Total	2,831,400		7,966,122	11	43		

				Maximum Lifetime Excess Cancer Cases[b]	
				20%	75%
Total (Income <$20K+>$20K) Recreational Anglers					
Texas	2,649,700	2.79	7,392,663	53	197
Louisiana	801,200	2.91	2,331,492	32	121
Total	3,450,900		9,724,155	85	319

[a] County–weighted average of persons per household (CACI, 1993).
[b] Maximum lifetime excess cancer cases (MLECC); reduction to 20% and 75% of the calculated MLECC, to account for food sources from other than contaminated sites.
[c] Average consumption based on 15 g/day ingestion for 30 years; high rate consumption based on 147 g/day ingestion for 70 years.

Exhibit 8–3. Estimated Increased Lifetime Cancer Risk – Field Sampling Methodology

Organism	Estimated Body Burden[a] (pCi/g)	Conversion from g to kg (x 1,000)	Consumption (kg/yr)	Exposure Duration (years)	Radionuclide Potency Factor (lifetime risk/pCi)	Additional Lifetime Cancer Risk	Maximum Additional Cancer Risk	Reduction Factor[b] (0.2)	Reduction Factor[b] (0.75)
Ra–226	**Average–Rate Consumer (15 g seafood per day)**								
Fish	0.07	1,000	4.5	30	1.20E–10	1.1E–06			
Crab	0.2	1,000	0.4	30	1.20E–10	2.9E–07			
Oyster	0.8	1,000	0.6	30	1.20E–10	1.7E–06			
							3.2E–06	6.3E–07	2.4E–06
Ra–228									
Fish	0.07	1,000	4.5	30	1.00E–10	9.5E–07			
Crab	0.2	1,000	0.4	30	1.00E–10	2.4E–07			
Oyster	0.8	1,000	0.6	30	1.00E–10	1.4E–06			
							2.6E–06	5.3E–07	2.0E–06
Combined Ra–226+Ra–228							5.8E–06	1.2E–06	4.3E–06
Ra–226	**High–Rate, Subsistence Consumer (147.3 g seafood per day)**								
Fish	0.07	1,000	34.5	70	1.20E–10	2.0E–05			
Crab	0.2	1,000	7.8	70	1.20E–10	1.3E–05			
Oyster	0.8	1,000	11.4	70	1.20E–10	7.7E–05			
							1.1E–04	2.2E–05	8.2E–05
Ra–228									
Fish	0.07	1,000	34.5	70	1.00E–10	1.7E–05			
Crab	0.2	1,000	7.8	70	1.00E–10	1.1E–05			
Oyster	0.8	1,000	11.4	70	1.00E–10	6.4E–05			
							9.2E–05	1.8E–05	6.9E–05
Combined Ra–226+Ra–228							2.0E–04	4.0E–05	1.5E–04

[a] Based on the average of the midpoints of ranges of radium levels in seafood collected near produced water outfalls in coastal Louisiana.
[b] Use of the 0.2 and 0.75 reduction factors (from the maximum value) is the EPA methodology to account for the ingestion of seafood from various locations, some contaminated, some not; the resulting range is believed to be the estimated risk.

Exhibit 8–4. Projected Excess Cancers in Texas and Louisiana Populations – Field Sampling Methodology

Target Population	Estimated Number of Anglers	Average Persons per Household[a]	Estimated Exposed Population	Maximum Lifetime Excess Cancer Cases[b] Average Consumption[c] 20%	75%	High Consumption[c] 20%	75%
Recreational Anglers w/Incomes <$20K							
Texas	372,600	2.79	1,039,554			42	156
Louisiana	246,900	2.91	718,479			29	108
Total	619,500		1,758,033			70	264
Recreational Anglers w/Incomes >$20K							
Texas	2,277,100	2.79	6,353,109	8	27		
Louisiana	554,300	2.91	1,613,013	2	7		
Total	2,831,400		7,966,122	10	34		

				Maximum Lifetime Excess Cancer Cases[b] 20%	75%
Total Recreational Anglers					
Texas	2,649,700	2.79	7,392,663	49	183
Louisiana	801,200	2.91	2,331,492	31	115
Total	3,450,900		9,724,155	80	298

[a] County–weighted average of persons per household (CACI, 1993).
[b] Maximum lifetime excess cancer cases (MLECC); reduction to 20% and 75% of the calculated MLECC to account for food sources from other than contaminated sites.
[c] Average consumption based on 15 g/day ingestion for 30 years; high rate consumption based on 147 g/day ingestion for 70 years.

Exhibit 8–5. Estimated Lifetime Excess Cancer for Recreational Anglers and Their Households

Target Population	Methodology	Exposed Population (TX & LA)	Consumption Rate	Maximum Lifetime Excess Cancer Cases[a] (MLECC)	Projected Lifetime Cancer Cases 20% MLECC	Projected Lifetime Cancer Cases 75% MLECC	Projected Annual Excess Cancer Cases[b] 20% MLECC	Projected Annual Excess Cancer Cases[b] 75% MLECC
Recreational Anglers & Households w/Income <$20K	Modeling	1,758,033	High	510	74	276	1.06	3.94
	Field Samples	1,758,033	High	1,283	70	264	1.00	3.77
Recreational Anglers & Households w/Income >$20K	Modeling	7,966,122	Average	79	11	43	0.16	0.61
	Field Samples	7,966,122	Average	159	10	34	0.14	0.49
Total	Modeling	9,724,155	Total	589	85	319	1.21	4.56
	Field Samples	9,724,155	Total	1,443	80	298	1.14	4.26

[a] The exposed population of recreational anglers for Texas and Louisiana is 9,835,065 and the exposed population for recreational anglers with incomes below $20,000 for Texas and Louisiana is 1,765,575.

[b] The estimated lifetime is 70 years.

consumers. For the total population of recreational anglers (low and middle/high income) and their household members, there will be an increase of 1.21 to 4.56 cancer cases per year in Texas and Louisiana due to radium contamination using the modeling methodology. There will be a total increase of 1.14 to 4.3 cancer cases per year due to radium contamination in Texas and Louisiana using the field measurements of contamination levels.

Table 8-6 presents the annual monetized benefits for cancer case avoidance assuming the lifetime cost of each cancer case ranges from $2 million to $10 million. The annual monetized benefits of cancer case avoidance for high-rate consumers in Texas and Louisiana, based on the modeling methodology, range from $2.1 million to $39 million, with a range of midpoint values from $6.4 million to $24 million. Using field sample measurements, the annual monetized benefits of cancer case avoidance for high-rate consumers in Texas and Louisiana is valued at $2.0 million per year to $38 million per year, with a range of midpoint values from $6.0 million per year to $23 million per year.

The annual monetized benefits of cancer case avoidance in Texas and Louisiana for the average-rate seafood consumers, using the modeling methodology, are valued at $0.3 million to $6.1 million, with a range of midpoint values from $1.0 million, to $3.7 million. Using field sample measurements, projected cancer case avoidance for average-rate seafood consumers is valued at $0.3 million per year to $4.9 million per year, with range of a midpoint values from $0.8 million per year to $3.0 million per year.

Using the modeling methodology, the total annual monetized benefits for cancer case avoidance in Texas and Louisiana is $2.4 million to $46 million, with a range of midpoint values from $7 million to $27 million. For field data, total annual cancer case avoidance is valued at $2.3 million to $43 million, with a range of midpoint values from $7 million to $26 million.

8.3 Evaluation of the Assessment

The assessment and monetized risk reductions projected for the selected option is a first-order analysis based on available data. The assessment is qualified both by the paradigm used in its conceptual approach and the extent and quality of the data used as input to the risk assessment. This assessment uses two approaches to estimating tissue levels of radium in seafood products consumed by humans — a modeling approach and a field sampling and analysis approach. For the field sampling approach, tissue radium levels are based on the midpoint of maximum and minimum tissues levels derived from available data. These data are adequate for the assessment. However, field data on collected organisms is not extensive.

For the modeling approach, data and analytical requirements include: effluent radium levels, surface water dispersion modeling, and aquatic biocencentration factors. Data on effluent radium levels in produced water are sufficient for this assessment. Input data and the surface water model used to estimate available dilution are adequate for this assessment. Modeling is based on operational and environmental data (e.g., discharge rate, effluent density, pipe diameter, port location, water depth, current speed, salinity, etc.) representing average or typical conditions. Thus, only a subset of the subcategory-wide variation in these

Exhibit 8–6. Annual Monetized Benefits of Cancer Case Avoidance for Recreational Anglers and Their Households[a]

Target Population	Methodology	Consumption Rate	$ Million Saved/Annual Cancer Cases Avoided 20% MLECC[b]	75% MLECC[b]
Recreational Anglers & Households w/Income <$20K	Modeling	High	$6.4 [c]($2.1 $11)	$24 ($7.9 $39)
	Field Samples	High	$6 ($2.0 $10)	$23 ($7.5 $38)
Recreational Anglers & Household w/Income >$20K	Modeling	Average	$1.0 ($0.3 $1.6)	$3.7 ($1.2 $6.1)
	Field Samples	Average	$0.8 ($0.3 $1.4)	$3 ($1.0 $4.9)
Total	Modeling	Total	$7 ($2.4 $12)	$27 ($9.1 $46)
	Field Samples	Total	$7 ($2.3 $11)	$26 ($8.5 $43)

[a] Cancer case avoidance is valued at $2 million to $10 million per case.
[b] Maximum Lifetime Excess Cancer Cases (MLECC); reduction to 20% and 75% of the calculated MLECC, to account for food sources from other than contaminated sites.
[c] Midpoint (range)

parameters are modeled. However, the parameters selected are believed to adequately represent the industry as a whole. The model selected (CORMIX Version 2.1) is considered satisfactory without any further modification for the type of discharge conditions that are thought to represent the typical case, specifically, where the discharge plume impacts the bottom of the receiving water body.

Human exposure assessments are then based on assumption patterns of these seafood product types (fish, crabs, and oysters) and projected radium levels in finfish, crustaceans, and bivalves. Field data were available and analyzed within these three categories. Tissue levels of radium in seafood from model projections are based on available BCF data specific to these three seafood groups. Average and upper 95th percentile values were used for this assessment. Limitations on these data are that field data are limited in their extent. BCFs are available for all three seafood groups, but supporting data also are not extensive. In addition, BCFs only apply to water-mediated bioaccumulation. Produced water impacts are largely sediment-related, and the BCFs used do not account for sediment routes of exposure (ingestion; higher pore water concentrations than projected by surface water dilution models) or ingestion of contaminated food by finfish, crabs, or oysters.

Consumption data are derived from consumption patterns in the Gulf of Mexico region. These data are applicable and sufficient for this assessment. The methodology for risk estimation and risk reduction monetizations are based on standard EPA methodologies. Agency specified carcinogenic potency factors, exposure durations, and valuations of life estimates are used. Discussion of these factors are found the EPA guidance that is cited previously in this section of the WQBA.

One consideration that requires more data than are currently available relates to the time-course of recovery after produced water discharges have ceased. The physical and biological response kinetics of Ra^{226} and Ra^{228} are not known in sufficient detail to assess the rate of recovery of affected ecosystems. Dispersion and decay of these pollutants; and sedimentation, capping, and complexation phenomena will reduce their availability to consumed species. Depuration in formerly exposed organisms will occur. However, the rates of these processes are largely unknown. For this rule, total impacts and recovery are calculated and averaged as a snap-shot, i.e., assumed to occur over a one year time period. This renders the ecological and human health benefits assessment comparable to the technology and economic assessments as all use annualized (i.e., average) costs. This issue is discussed further in Section 9.5 of the WQBA.

9. TRINITY BAY CASE STUDY OF ECOLOGICAL IMPACTS AND MONETIZED BENEFITS

A case study of a produced water outfall to a coastal embayment in Texas is presented in this section. This study has sufficiently developed spatial and temporal data on benthic community measures to develop estimates of ecological impact associated with this outfall. Based on estimates of produced water flow at this facility and EAD estimates of average, industry-wide unit compliance costs (i.e., costs of compliance in terms of $ per barrel of produced water disposed) for reinjection of produced water, compliance costs for the zero discharge option are estimated for this case study facility. Based on the ecological valuation developed in Section 6 of this report and estimates of ecological impacts developed in this section, monetized ecological benefits also are estimated for the zero discharge option for this case study facility. Using this case study as an estimator for the industry, linear projections of Gulf of Mexico-wide compliance costs and monetized ecological benefits for the zero discharge option are projected.

9.1 Description of the Trinity Bay Study

A study of a coastal subcategory oil and gas production facility located in Trinity Bay, Texas has been performed (Armstrong et al., 1977). This 21-month study was conducted at the C-2 separator platform located in Trinity Bay, Texas from April of 1974 to December of 1975. The separator platform was located in 8 feet of water, with a range in the bay of 6 feet to 9 feet. The authors noted that during the study, the platform discharged 4,100-10,000 bpd of produced water (midpoint = 7,050 bpd). The outfall was located 3 feet from the bottom. Sediment texture in the study area was uniform, with all stations classified as silty-clay except one that was classified as sandy-silty-clay. From November of 1974 to April of 1975, a temporary second outfall was used, located 900 feet NW of the C-2 separator outfall. This outfall was located within 400 feet of sampling station A-1.

Sediment benthic community analyses and sediment total naphthalenes (naphthalene through dimethyl naphthalenes) analyses were performed monthly (except for April and November of 1975). Benthic grab samples (0.023 m^2) were obtained at 15 stations located from 50 feet to 19,000 feet from the C-2 separator along 3 transects (Exhibit 9-1). Benthic total abundance and species richness were assessed. A 0.5 mm sieve was used to separate benthic organisms from April to November of 1974, when the sieve size was reduced to 0.25 mm for the remainder of the study. Sediment naphthalene analyses also were performed using two methods. From April to November of 1974, sediment was obtained by scooping the top layer of sediment from the grab sampler; a 5°C/24-hour, n-hexane static extraction protocol was used. Beginning in December of 1974, a core sampler was used for obtaining sediment samples, and in addition to the 5°C/24-hour static extraction, a 20°C/72-hour extraction with continuous shaking was performed. Total naphthalenes were determined by UV spectrophotometry.

The authors observed a distance-dependent decrease in total sediment naphthalenes. Exhibit 9-2 presents a scatter plot of sediment naphthalenes concentrations versus distance for 20°C/72-hour extraction data. Exhibit 9-3 presents a plot of mean sediment naphthalene concentrations versus distance for both

Exhibit 9-1. Map of Trinity Bay Showing Location of C-2 Separator Platform and Extent of Transects

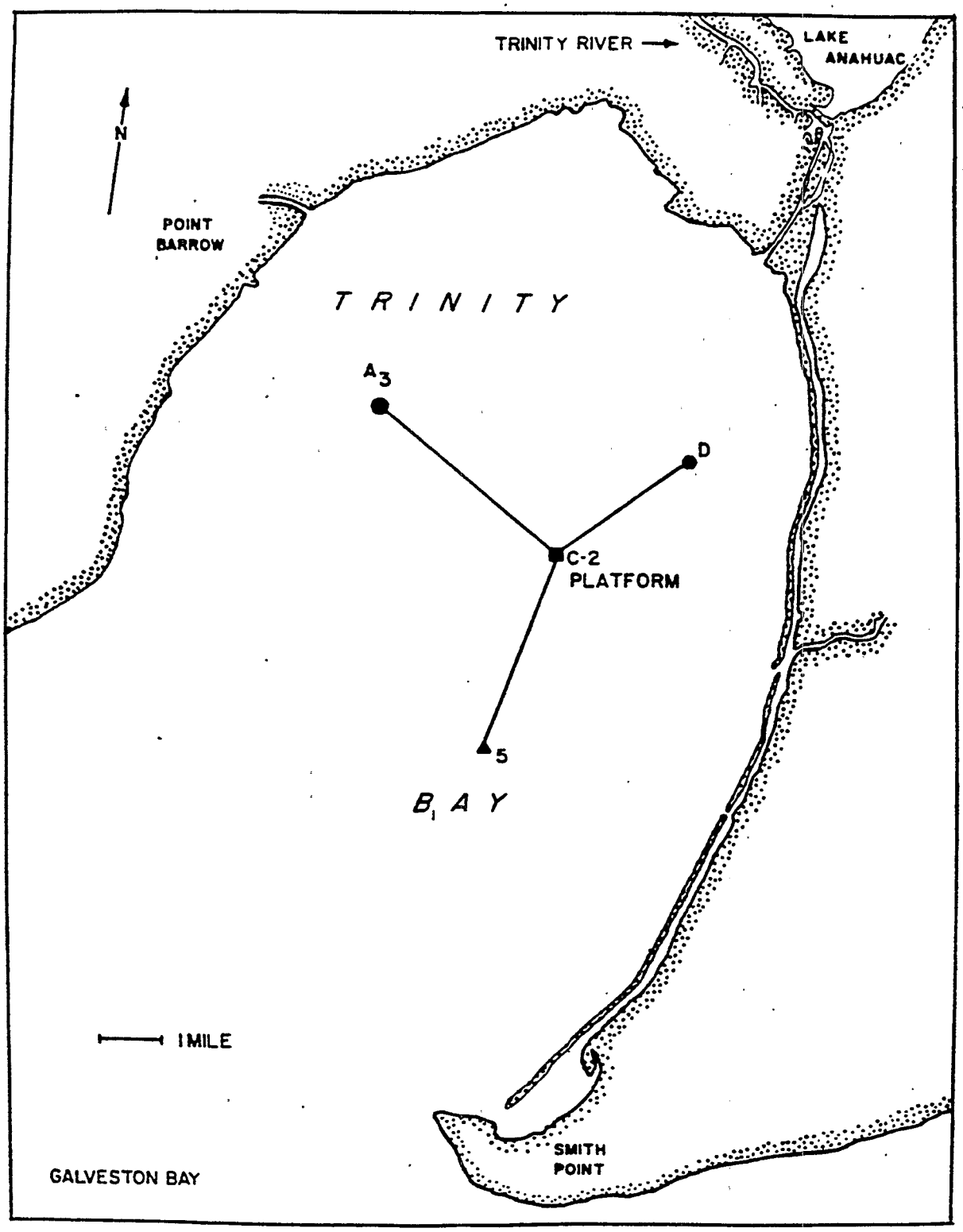


Exhibit 9-2. Scatter Plot: Sediment Naphthalene vs Distance from Outfall, All Samples, 20°C/72hr Extraction

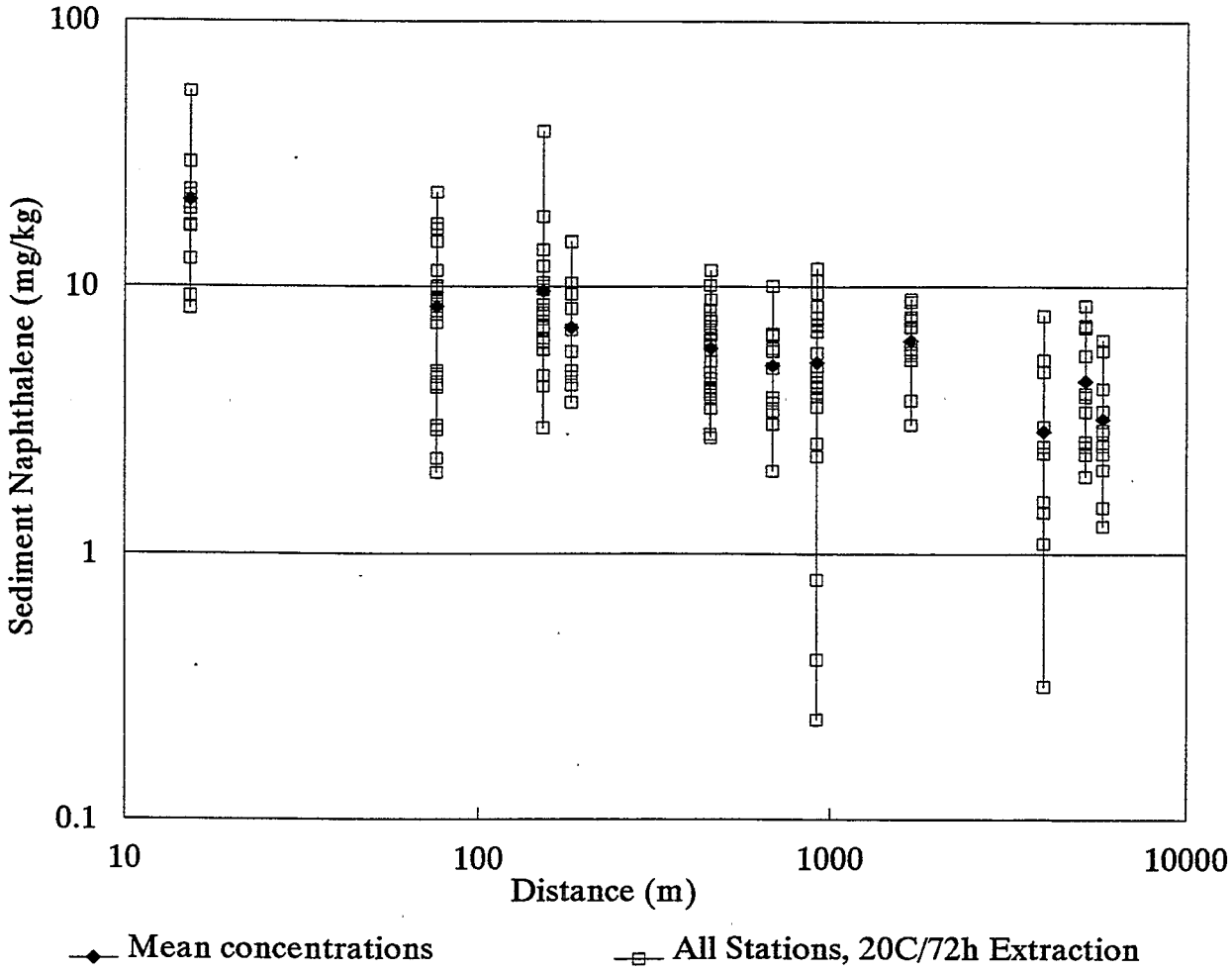
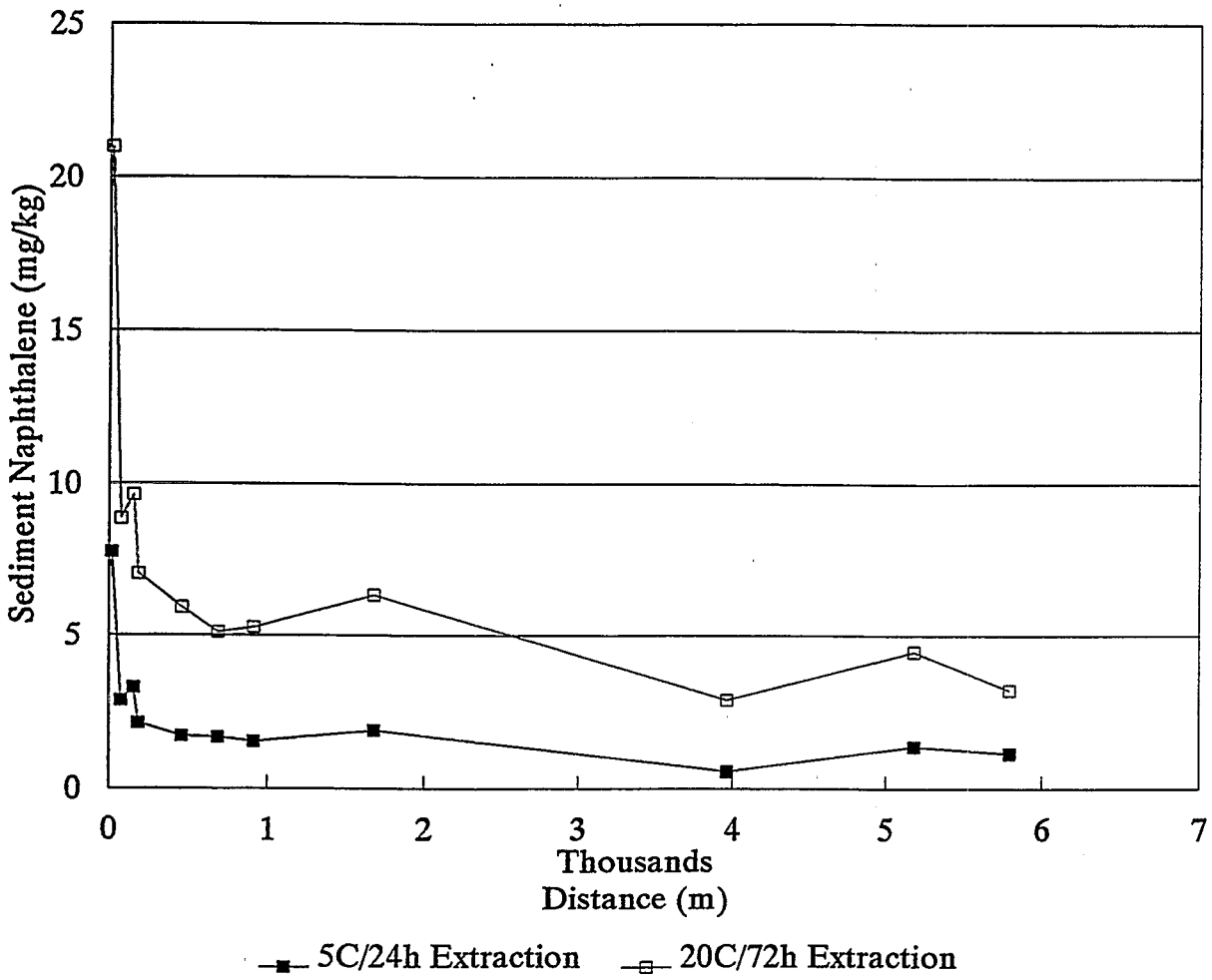


Exhibit 9-3. Mean Sediment Naphthalene vs Distance from Outfall, Distance-Averaged



5°C/24-hour and 20°C/72-hour extractions. Exhibit 9-4 presents these same data for both extraction protocols in a log:log format. The authors noted a reasonably consistent, 3- to 5-fold higher level of extracted naphthalenes in samples treated at 20°C for 72 hours. GC-MS analyses indicated the 20°C/72-hour extraction method recovered 90-95% of the total naphthalenes.

Benthic abundance and species richness were found to be correlated with total sediment naphthalenes (Exhibit 9-5). The 50-foot station was devoid of biota, and stations within 500 feet were severely depressed (< 25% peak levels for both community parameters). These observations were thought surprising because analysis of receiving water samples at the 50-foot station indicated a 2,000-fold dilution of naphthalene compared to effluent levels. However, although effluent samples showed a total naphthalenes level of 1.62 ppm while the 50-foot station water column samples showed 1.6 ppb total naphthalenes, the 50-foot station sediment samples showed total naphthalenes of 18.7 ppm.

The authors also observed that the temporary second outfall produced a rapid buildup of sediment naphthalenes at Station A-1, which remained unusually high at least 6 months after the discharge from this outfall ceased. The authors noted the use of this second outfall may have created an additional depressed area equal to that of the single platform outfall, rather than minimizing the effect of the single outfall.

9.2 Case Study Approach

This study site had sufficient temporal and spatial data, both field and operational, to assess benthic community impacts from this facility. Spatial impact assessments are developed for benthic abundance and species richness. Because the sieve size was changed during the course of the study, two sets of analyses are performed, one for the 0.25 mm mesh size sieve and one for the 0.50 mm mesh size sieve. Based on field measurements of benthic abundance and species richness at various distances from the outfall (Exhibit 9-6), linear interpolations of reductions in these community parameters are derived for the study area. Exhibits 9-7 and 9-8 present benthic abundance and species richness versus distance for the 0.50 mm sieve and the 0.25 mm sieve sizes, respectively. Exhibit 9-9 presents the results of both sieve sizes for abundance versus distance; Exhibit 9-10 presents the same data for species richness versus distance.

The reductions in benthic abundance and species richness are expressed as an aggregate, normalized, percentage reduction in benthic abundance and species richness within the observed impact radius. The impact radius is defined as the minimum distance at which stations exhibit 100% benthic abundance or species richness. This normalized percentage reduction in benthic abundance or species richness, when applied to the total area circumscribed within the impact radius, determines the reduction in areal productivity. This reduction in areal productivity is expressed as the number of equivalent acres affected (i.e., a 10% reduction over 500 acres would result in 50 equivalent acres affected). Based on the different sieve sizes used and the differences in benthic abundance and species richness as community impact measures, a range of equivalent acreage affected is developed.

Exhibit 9-4. Log Mean Sediment Naphthalene vs Log Distance from Outfall, Distance-Averaged

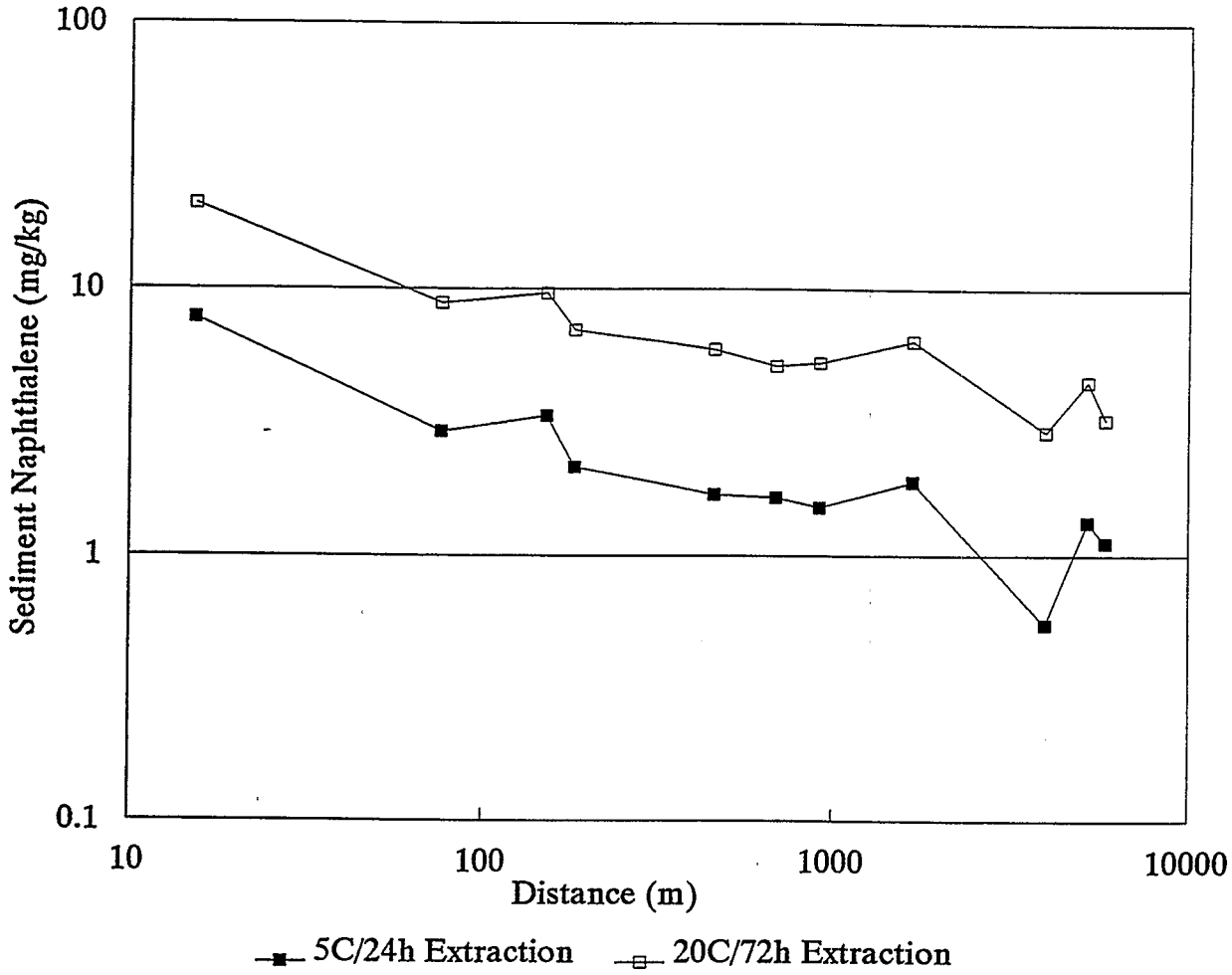
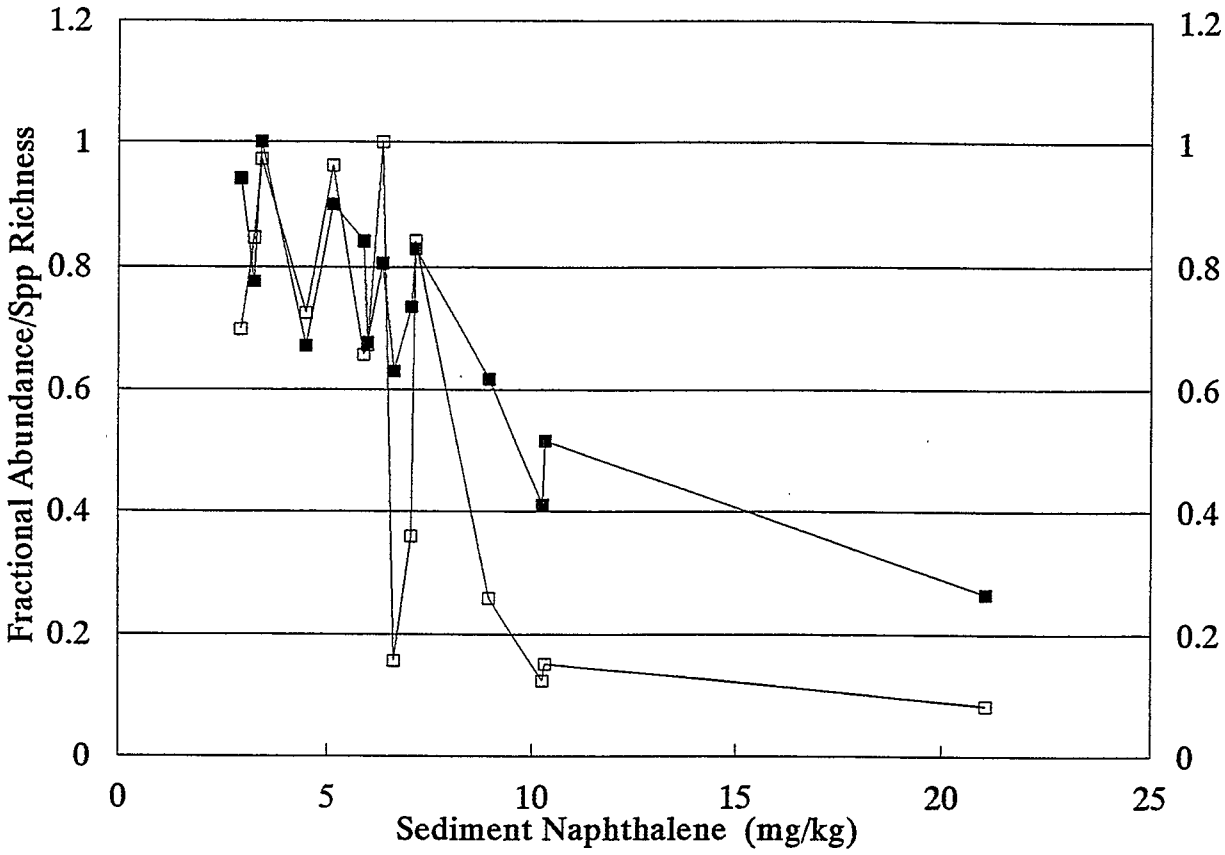


Exhibit 9-5. Fractional Benthic Abundance and Species Richness vs Sediment Naphthalenes



Fractional Species Richness Fractional Abundance

Annual averages, 1.0 = max avg annual value
All stations included

Exhibit 9-6. Trinity Bay, Texas Produced Water Outfall Fractional Abundance and Species Richness Data

Station	Distance (m)	0.50 mm Sieve Average Abundance	0.50 mm Sieve Average Spp Richness	0.25 mm Sieve Average Abundance	0.25 mm Sieve Average Spp Richness
Total Abundance and Species Richness – All Stations					
1	15.2	7	1.78	58	4.09
A0	76.2	10	1.11	110	9.27
X	76.2	1	0.56	87	6.36
A1	152	6	2.22	106	6.18
A	152	7	2.00	182	9.55
1.5	183	8	1.56	253	11.36
2	457	21	2.56	472	10.45
B	457	17	3.78	462	13.00
A2	686	18	3.00	677	13.91
C	915	39	4.11	684	15.45
3	915	26	4.00	592	12.82
4	1,677	23	3.22	703	12.45
D	3,963	43	5.33	491	14.55
5	5,183	28	3.33	510	10.36
A3	5,793	19	2.00	596	11.00
Total Abundance and Species Richness – Distance – Averaged Stations					
1	15.2	7	1.78	58	4.09
X, A0	76.2	5	0.83	98	7.82
A, A1	152	7	2.11	144	7.86
1.5	183	8	1.56	253	11.36
B, 2	457	19	3.17	467	11.73
A2	686	18	3.00	677	13.91
3, C	915	33	4.06	638	14.14
4	1,677	23	3.22	703	12.45
D	3,963	43	5.33	491	14.55
5	5,183	28	3.33	510	10.36
A3	5,793	19	2.00	596	11.00
Relative Abundance and Species Richness – Distance – Averaged Stations					
1	15.2	0.16	0.33	0.08	0.28
X, A0	76.2	0.12	0.16	0.14	0.54
A, A1	152	0.16	0.40	0.21	0.54
1.5	183	0.20	0.29	0.36	0.78
B, 2	457	0.44	0.59	0.66	0.81
A2	686	0.43	0.56	0.96	0.96
3, C	915	0.77	0.76	0.91	0.97
4	1,677	0.55	0.60	1.00	0.86
D	3,963	1.00	1.00	0.70	1.00
5	5,183	0.66	0.62	0.73	0.71
A3	5,793	0.44	0.38	0.85	0.76
Area @ unit (100%) biol. density (m^2 x 100% relative biol. density)		49,364,647	49,364,647	8,830,713	49,364,648
Area @ fractional biol. density (m^2 x 100% fractional density)		37,958,835	39,237,664	8,021,322	46,070,207
		23.1%	20.5%	9.2%	6.7%
Areally–reduced biol. density Acres within impact radius		12,192	12,192	2,181	12,192
Acre–equivalents affected		2,817	2,501	200	817

Exhibit 9-7. Fractional Abundance/Species Richness vs. Distance, 0.50 mm Mesh Sieve Size

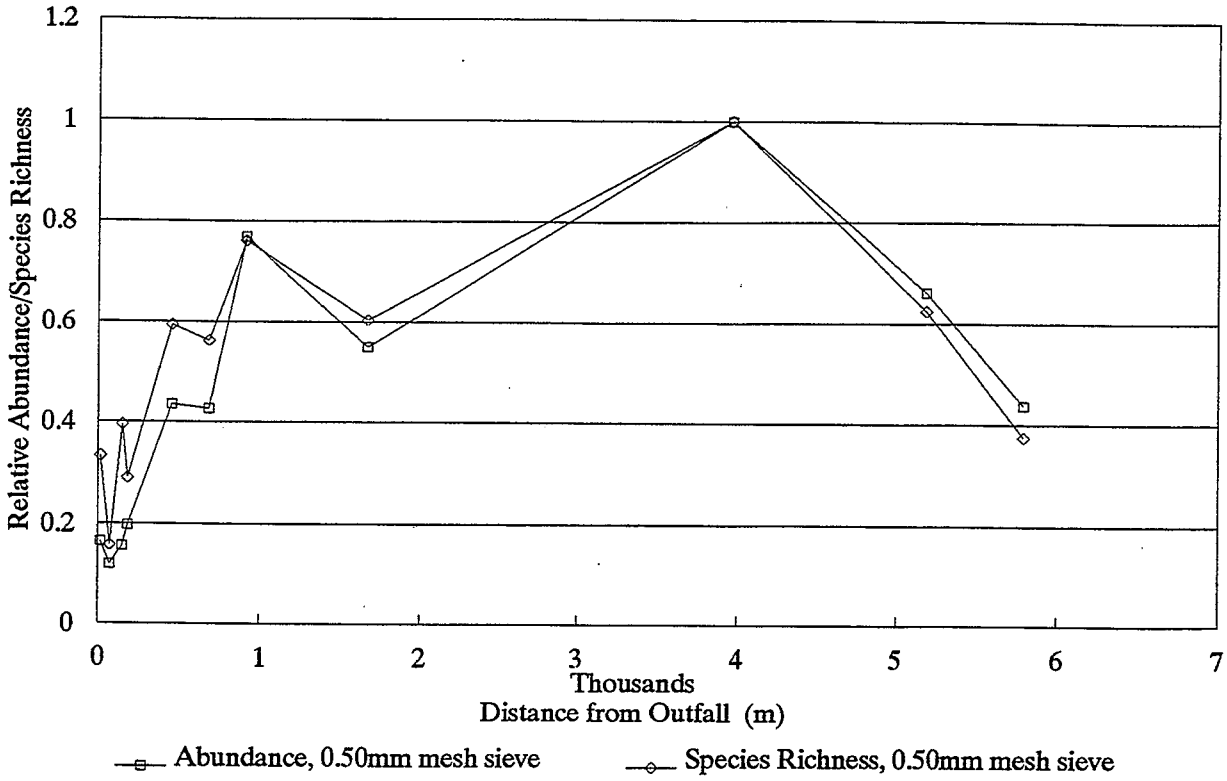


Exhibit 9-8. Fractional Abundance/Species Richness vs. Distance, 0.25 mm Mesh Sieve Size

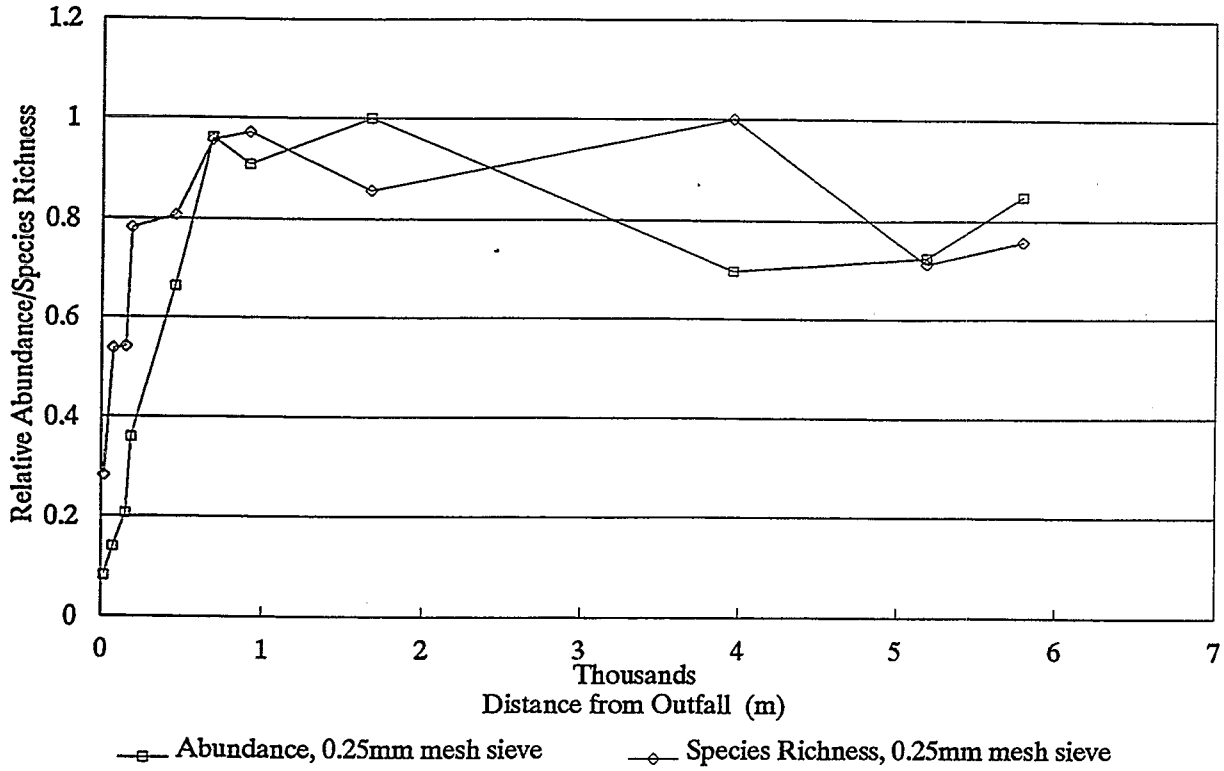


Exhibit 9-9. Fractional Abundance vs. Distance, 0.25 mm and 0.50 mm Mesh Sieve Size

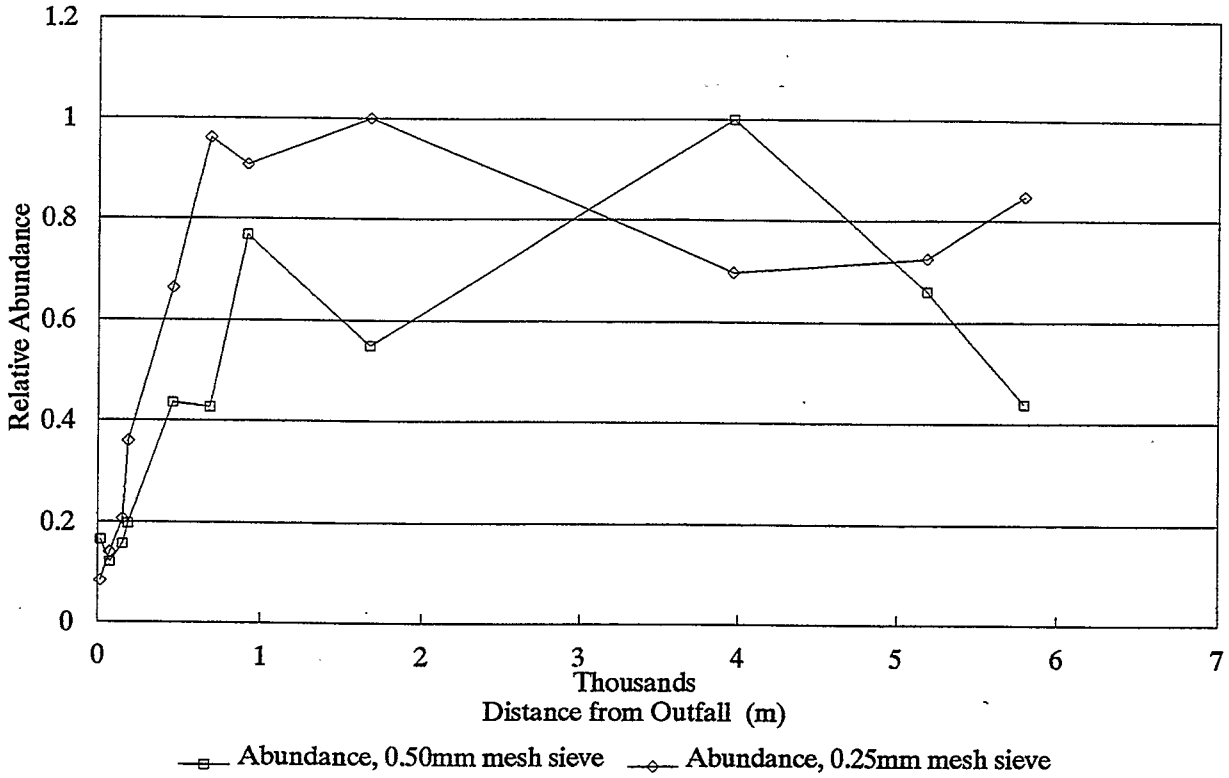
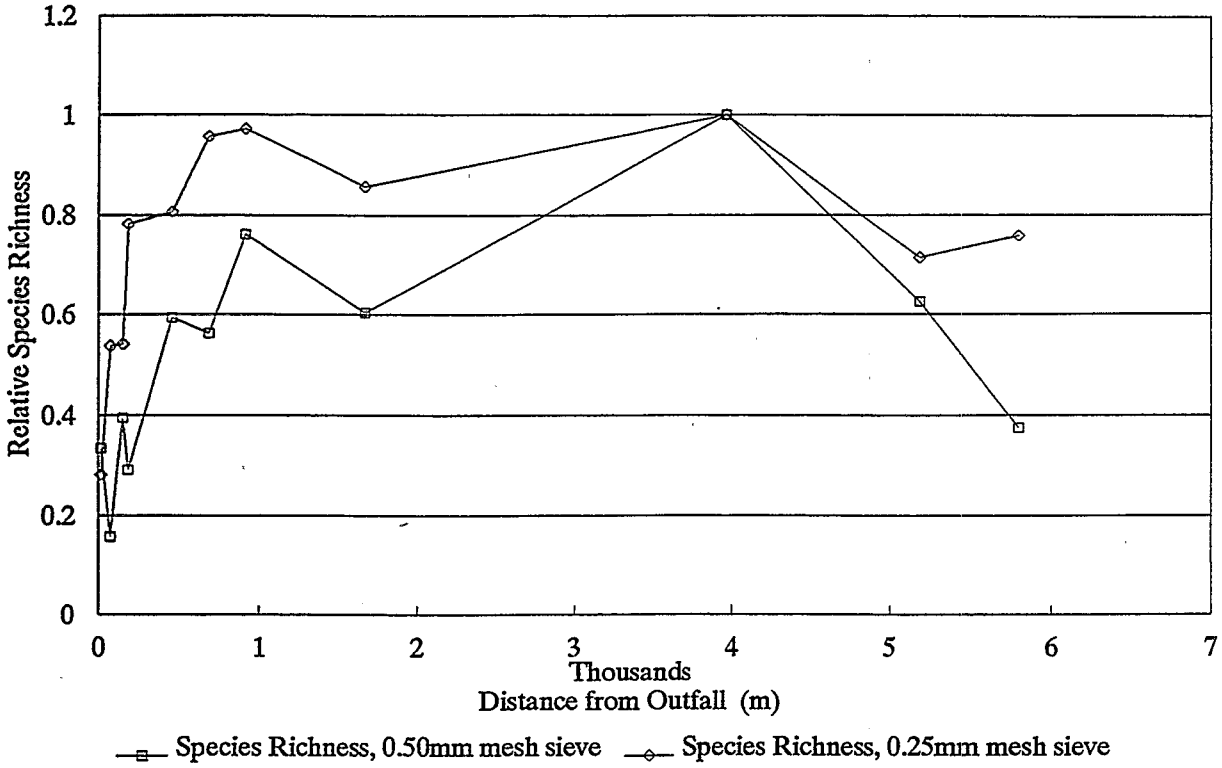


Exhibit 9-10. Fractional Species Richness vs. Distance, 0.25 mm and 0.50 mm Mesh Sieve Size



To examine the compliance costs for this case study facility, compliance costs for this facility are derived from the estimated flow at the facility and the average, industry-wide estimate of per barrel compliance costs for reinjection of produced water. The range for total recreational and commercial value derived for Galveston Bay, developed for the Galveston Bay National Estuary Program (see Section 6.4), and the estimated acreage of Galveston Bay are used to estimate the range of per-acre ecological values. These ecological values per acre are then applied to the case study's estimates of the equivalent area affected by the produced water discharge to estimate the monetized ecological benefit of reinjecting the discharge for this case study.

The results of this analysis are also scaled to an industry-wide, coastal subcategory level for the Gulf of Mexico. This projection is based on the assumption of industry-wide impacts proportional to those observed in this case study. Thus the acreage affected, as determined for this case study, is proportionated to the estimated flow for this study, and then expanded to the total flow for all operators in the coastal subcategory in the Gulf of Mexico. The Galveston Bay ecological value per acre is then applied to the estimated total acreage affected for the coastal subcategory to determine the Gulf-wide ecological cost of produced water discharges. Industry-wide costs for coastal operations in the Gulf of Mexico are provided by EAD.

9.3 Trinity Bay, Texas Case Study Assessment

Differences in distance-to-background estimates occur between two benthic sieve mesh sizes used in the study. The larger mesh size (0.50 mm) results in clear impacts to about 4,000 m for both total benthic abundance and species richness (see Exhibit 9-7). The smaller mesh size (0.25 mm, which captures smaller and earlier life stage forms) shows a faster recovery for both benthic abundance and species richness and, for abundance, suggests an impact radius of only 1,677 meters (see Exhibit 9-8). Projections of benthic impact are, therefore, run for all four scenarios (both total abundance and species richness for both 0.25 mm and 0.50 mm mesh size data) and are summarized in Exhibit 9-11. For 0.50 mm mesh size data, benthic abundance/species richness are respectively reduced 23% and 21% within a 3,963-m impact radius, amounting to 2,817 and 2,501 equivalent acres affected. For 0.25 mm mesh size data, species richness was reduced 7% within a 3,963-meter impact radius, for 814 equivalent acres affected; benthic abundance was reduced 9% within a 1,677-meter impact radius for 200 equivalent acres affected. Thus, the equivalent acreage affected at this case study facility ranges from 200 to 2,817 acres (midpoint of the extremes = 1,509 acres; mean = 1,583 acres).

The Trinity Bay facility discharged produced water at an average, estimated rate of 7,050 bpd over 21 months. Based on the coastal effluent guidelines cost analysis for Gulf of Mexico facilities of $20,291,749 and an estimated 489,237 bbl per day of produced water generated, and average cost of $0.11 per bbl disposed is derived. Based on this per bbl disposal cost and an average flow of 7,050 bpd at the Trinity Bay facility, the projected annual compliance cost for this operator is $283,058. An assessment of Galveston Bay (of which Trinity Bay is a part) suggests the annual economic value of all recreational uses of Galveston Bay ranges from $115 million - $250 million (see Section 6.4). The area of Galveston Bay is 342,275 acres, resulting in annual recreational value ranging from $336 to $730 per acre with a midpoint value of $533/acre. A study

Exhibit 9-11. Total Abundance and Species Richness for 0.25 mm and 0.50 mm Mesh Size Data

Sampling Period	4/74 - 11/74[a]		12/74 - 12/75[a]	
Sieve Size (mm)	0.50	0.50	0.25	0.25
Community Metric	Abundance	Species Richness	Abundance	Species Richness
Impact Radius (m)	3,963[b]	3,963[b]	1,677[b]	3,963[b]
Reduction in Biological Density (%)	23.1%	20.5%	9.2%	6.7%
Equivalent Acres Affected	2,817[c]	2,501[c]	200[c]	814[c]

a Samples taken monthly, except 6/75 and 11/75

b Based on the maximum, distance-averaged community metric

c Acre equivalents based on a linear proportionation of percentage affected and area of the impact radius (i.e., a 10% reduction in abundance over 2,000 acres results in 200 acre-equivalents affected)

conducted for MMS (1991) estimates the value of wetlands (NOTE: not open bays) ranging from $9,000 to $17,000 per acre.

The range of projected compliance costs and monetized ecological benefits for this case study facility are summarized in Exhibit 9-12. At the extremes (minimum ecological value/acre and equivalent acres affected; maximum ecological value/acre and maximum equivalent acres affected), the monetized ecological benefits range from $67,200 to $2,056,410 for this facility. At an estimated compliance costs of $283,058, these extremes are approximately 4.2-fold higher than the minimum ecological benefit and about 7.3-fold lower than the maximum ecological benefit. Using the midpoint of the projected impact area (1,509 equivalent acres affected) and the full range of ecological value/acre ($336-$730/acre), monetized ecological benefits of $507,024 to $1,101,570 result (midpoint = $804,297). Using this intermediate range, projected ecological benefits range from 1.2-fold to 2.7-fold greater than compliance costs (2-fold at the midpoint of this range). Using a different range of intermediate values, based on the midpoint of ecological value ($533/acre) and the full range of equivalent areas affected (200-2,817 acres), monetized ecological benefits range from $106,600 to $1,501,461 (the midpoint value = $804,297). Thus for this analysis projected ecological benefits range from 25% of projected compliance costs to 3.6-fold greater than compliance costs (also 2-fold greater at the midpoint of the range).

9.4 Gulf of Mexico-wide Assessment

One approach to scaling up the data available for the Trinity Bay case study is to assume a linear relationship among all parameters (i.e., flow, environmental impact, and costs). Although sparse data exist to assess this assumption, the few impact and cost data available indicate this to be a plausible assumption. Using this assumption of impacts proportional to the Trinity Bay study (Exhibit 9-13), the total current BPT flow for the coastal subcategory in Texas is projected at 73,318 bpd (10.4-fold greater than the Trinity Bay case study flow). The range of acreage affected, therefore is 2,080 to 29,297 acres, with a midpoint of 15,694 acres. For Louisiana, the total BPT flow is projected at 415,919 bpd (59-fold greater than the Trinity Bay case study flow). The range of acreage affected is 11,799 to 166,191 acres, with a midpoint of 89,024 acres. Total Texas and Louisiana acreage affected ranges from 14,607 acres to 195,488 acres, with a midpoint of 104,718 acres.

To estimate resource values for the Gulf-wide assessment, a different approach was used. Because the majority of produced water flows occur in Louisiana, and Galveston Bay resource values may not reflect Louisiana values, more appropriate resource values were used. A review of wetland valuations conducted for MMS (MMS, 1991) that includes Louisiana resources was used instead of the Galveston Bay study cited above. Based on this MMS study, wetland values range from $57 to $940 per acre per year (with a median value of $410 per acre per year) in 1990 dollars).

Assuming the median ecological value estimate of $410/acre and the full range of ecological impact areas affected (i.e., using the 200- to 2,817-acre estimates from the Trinity Bay study as the basis for the Gulf-wide assessment), ecological benefits of the zero discharge option range from $6.0 million to $80

Exhibit 9-12. Summary of Trinity Bay Case Study Compliance Costs and Monetized Ecological Benefits

Compliance Costs

Estimated Flow: 7,050 bbl/d; 2,573,250 bbl/yr @ $0.11/bbl reinjected

Estimated Annual Compliance Cost: $283,058

Ecological Benefits

Estimated Recreational Value, per acre[a]: minimum - $336
midpoint - $533
maximum - $730

Estimated Equivalent Acres Affected[b]: minimum - 200
midpoint - 1,509
maximum - 2,817

[a]: Based on Galveston Bay total recreational values of $115-$250 million and 342,275 acres

[b]: See Exhibit 9-11

Estimated Ecological Benefit of Zero Discharge Option	Impact Area		
	Minimum (200 acre)	Midpoint (1,509 acre)	Maximum (2,817 acre)
Minimum value/acre ($336)	$67,200	$507,024	$946,512
Midpoint value/acre ($533)	$106,600	$804,297	$1,501,461
Maximum value/acre ($730)	$146,000	$1,101,570	$2,056,410

Exhibit 9-13. Summary of Gulf-Wide Projected Monetized Ecological Benefits, Zero Discharge Option

Trinity Bay Case Study Flow, bpd:	7,050
Total Texas Flow, bpd:	73,318 = 10.4x Trinity Bay Flow
Total Louisiana Flow, bpd:	415,919 = 59.0x Trinity Bay Flow

	Minimum	Midpoint	Maximum
Trinity Bay Estimated Impacts (equivalent acres)	200	1,509	2,817
Projected Texas Impacts	2,808	15,694	29,297
Projected Louisiana Impacts	11,799	89,024	166,191
Projected Total Impacts (equivalent acres)	14,607	104,718	195,488

	Minimum Impact Area	Midpoint Impact Area	Maximum Impact Area
Projected Monetized Ecological Benefits, Zero Discharge Option, $ million (Galveston Bay Ecological Values)			
$57/acre[a]	$0.83	$6.0	$11.1
$410 acre	$6.0	$42.9	$80.2
$940/acre	$13.7	$98.4	$184

[a] in 1990 dollars

million, with a midpoint of $43 million (1990 dollars). Assuming the midpoint impact area estimate of 1,509 equivalent acres and the full range of ecological valuations per acre (i.e., the $57 to $910/acre estimates from the GBNEP study), ecological benefits of the zero discharge option range from $6.0 million to $98 million, with the same estimate of $43 million using the midpoints for both valuation and impact ranges. At the minimum and maximum resource valuations of the MMS study ($57 and $940 per acre, respectively) and impact area estimates (200 and 2,817 equivalent acres as the basis for the Gulf-wide assessment, respectively), monetized ecological benefits range from $0.8 million to $184 million (1990 dollars).

9.5 Evaluation of the Assessment

The Trinity Bay study represents an extensive and useful examination of point source impacts of a produced water discharge presenting a reasonably coherent collection of chemical and biological impact data. The study includes several methodological alterations (changes in extraction protocols and benthic sieve mesh sizes). These alterations generate uncertainty over the exact extent of potential impacts (i.e., the distance to a background or reference condition). The approach used to mitigate this uncertainty in the WQBA is to present the analysis in terms of a range of possible impacts.

An issue with respect to the subcategory-wide impact estimate is the central assumption that impacts will be linearly related to flow. This assumption cannot be readily tested with available data. However, the case study presented data that indicated when the discharge flow was separated to two outfall locations, a second focus of impact quickly developed and did not quickly attenuate. These data support the assumption that impacts are proportional to flow, although they do not unequivocally prove the validity of this assumption. This case study appears to be a reasonable basis for assuming impact from outfalls in Texas, based on the general nature of receiving waters in Texas (i.e., shallow bays). Its reasonableness for estimating impacts in certain receiving waters in Louisiana (e.g., canals and marshes) may be is less certain.

With respect to the monetization of ecological impacts, a factor not explicitly considered is benthic:water column coupling. The assumption of this WQBA is that the total recreational use value is applied to benthic acreage that is 100% affected. This probably is not the case for certain recreational values, e.g., for hiking or bird-watching values.

EPA lacks data to estimate how quickly biological resources would recover following implementation of controls, but calculates total benefits assuming they are fully realized. The temporal dynamics of both impacts and benefits assessments are an issue relevant to the human health risk assessment (and to the projected ecological benefits assessment, discussed below, as well). For the assessments of benefits in this WQBA, the methodology uses a one year "snap-shot" to be consistent with the methodology for estimating the costs of the rule. However, this approach can be interpreted to imply that all benefits are restored within a one-year time-frame. While this assumption may be true in some cases, it will not be valid in all cases. Few data on recovery times exist on produced water impacts. However, some data indicate recovery times (as measured by sediment chemistry alterations) may be as long as several years. Thus, allocating the full value of annual monetized benefits within one year following cessation of produced water discharges may

appear to overestimate the potential annual benefits in cases where incomplete recovery has occurred. This analysis does not attempt to identify or allocate benefits on a yearly basis, but merely averages total benefits so that benefits may be compared to costs that are developed using the same approach.

The temporal dynamics of produced water impacts are complicated, and data scant. For cases in which impacts are incompletely recovered within one year (and benefits commensurately reduced to the level of recovery which has occurred), a logical conclusion is that impacts are likewise extended beyond the one-year time-frame. Thus, a consideration of total impact would include impacts not only occurring during the one-year period at issue, but also include any impacts occurring that year from previous discharges, as well as impacts from discharges during this period that may be expected to occur beyond the year. Thus, the two processes of impact and recovery are coupled, move in opposite directions to each other, and have very large uncertainties associated with their understanding for produced water discharges.

10. PRODUCED WATER LITERATURE REVIEW

10.1 Summary of the Produced Water Literature Review

A review of the literature is presented to identify field studies for assessing impacts from coastal produced water discharges. Queries from electronic databases, trade associations, and personal contacts with state and federal agencies and sources were used to identify potential citations. Studies were obtained and reviewed to characterize the nature, extent, and duration of potential impacts from coastal discharges of produced water. From this review, impacts from organic and metal pollutants (Exhibit 10-1) and radiochemical pollutants (Exhibit 10-2) are summarized. Abstracts of the selected studies follow the summary tables.

A total of 25 study sites (12 sites in Louisiana and 13 sites in Texas) are summarized. Of these 25 study sites, 13 sites (3 in Texas and 10 in Louisiana) are in relatively low energy locations (marshes, canals, etc.) and 12 sites (9 in Texas and 3 in Louisiana) are in relatively high energy areas (bayous, river distributaries, open bays/lakes, etc.). Also, 12 wetlands locations are included in the 25 study sites reviewed. Of these 12 wetlands sites, 6 are saltmarsh sites and 6 are fresh or brackish marsh sites. For both groups of saltmarsh and fresh/brackish marsh sites, 5 sites are located in Louisiana and one site is located in Texas. Water depth is reported for 19 study sites; 15 are in depths less than 3 meters. Of these 15 shallow water study sites, 7 sites are in Texas, and 8 sites are in Louisiana. The remaining 4 sites, located in waters greater than 3 meters, are all in Louisiana.

Most studies that examined impacts of produced water discharges on normal estuarine salinity gradients have documented effects. Typical salinity effects were detected between 100 and 300 meters from the discharge(s). However, in one dead-end canal, a salinity effect was detected to 800 meters from the discharge.

Water column hydrocarbon and metals effects were generally apparent near the discharges, often elevated as far as 1,000 meters or more, and in one instance to 1,800 meters. Sediment hydrocarbon impacts typically were detected as far as 100 to 300 meters from the discharge, and were detected at distances over 1,000 meters from discharges at several sites. Sediment metals impacts also showed a distance-dependent relationship.

Impacts to biota usually showed a spatial correlation to the discharge (i.e., depressed community structure such as abundance or diversity). Sediments near outfalls (< 50 feet) have been shown to be virtually devoid of organisms; within 500 feet of outfalls, benthic fauna have been shown to be severely depressed (< 25% peak abundance at farther distances). Caged organism studies had highly variable results, including high control mortality. Statistically significant benthic biotic impacts were detected from 80 meters to over 1,000 meters from the discharge(s).

Radiochemical impacts on water column and sediments were variable, but generally limited to close proximity to the discharge (background levels were often unknown at the study sites). Indigenous biota were generally found to have detectable levels, but again, background levels were generally not known. Caged organisms (deployed for 14 days) showed bioaccumulation occurring as far as 350 meters from the discharge.

Exhibit 10-1. Summary of Organics and Metals Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water

Study Site Characteristics (number of facilities)	Salinity Plume (See Note A)	Toxicity Data	Water Column or Effluent Hydrocarbons (HC) and Metals	Sediment Hydrocarbons and Metals	Bioaccumulation and/or Ecological Indicators (Includes Tissue Samples of Biota if Reported)
Bayou Rigaud[1] Saltmarsh, bay; Depth 3-6 m; 146,000 bpd (2)	None	ND	PAH & Volatile HC (VHC) levels elevated only near outfall	PAH and VHC levels elevated at 1300 m; Ba,Zn,Pb elevated, but no spatial trend	Benthic biota dominated by polychaetes and bivalves; significant community-type differences found among stations.
Pass Fourchon[1] Saltmarsh, Dead-end canal; Depth 2.5-3.5 m; 48,000 bpd (3)	800m	ND	PAH levels elevated to 800m; VHC elevated to 1000m	Distance dependent PAH levels to 1km, temporal variation; Max. levels of Ba,Zn,Ni at 600m	Benthic infauna composed primarily of polychaetes; depressed benthic fauna noted within 800m of discharge; infauna reduced in deeper parts of channel where effluent density plume followed bottom contours.
East Timbalier Island[1] Saltmarsh, natural and dredged canals; Depth 1.5-2 m; 25,558 bpd (4)	<100m	ND	Petrogenic HC contamination within 250m	HC and trace metals detected <250m from discharge sites (including an abandoned site)	Benthic infaunal community characterized by marine fauna (mostly polychaetes); variety and abundance varied between the two transects; reductions correlated to some elevated sediment chemical levels.
Emeline Pass[1] Fresh water marsh; (Miss. River distributary); Depth 3-5 m; 3,693 bpd (1)	None	ND	Low levels of saturated HC in bottom waters <280m from discharge	PAH elevations detected to 300m have no clear relationship to discharge	Few species and low abundances of benthic macroinfaunal community (author believes due to the high energy, low-organic content of the sediments).
Romere Pass[1] Freshwater marsh; Depth 1-2 m 20,000 bpd (2)	None	ND	VHC and PAH elevated to 500m were positivley related	Alkylated PAH detected to 1000m; Aliphatic HC max. at 750m	Benthic infauna consisted of both fresh and brackish biota (bivalves, nemertean worms, oligochaetes, amphipods, polychaetes, and gastropods.

Exhibit 10-1. Summary of Organics and Metals Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water (Continued)

Study Site Characteristics (number of facilities)	Salinity Plume (See Note A)	Toxicity Data	Water Column or Effluent Hydrocarbons (HC) and Metals	Sediment Hydrocarbons and Metals	Bioaccumulation and/or Ecological Indicators (Includes Tissue Samples of Biota if Reported)
Empire Waterway[1] Saltmarsh, access canal; Depth 5-6 m; 10,959 bpd (and an abandoned site)	None	ND	Low levels of saturated HC (thought to be from natural sources)	Alkylated PAH levels max. at 200m from abandoned site; distance gradient of HC levels from abandoned site	Benthic infauna combination of marine and intermediate salinity organisms (primarily polychaetes); only reduction of species and individuals was near abandoned discharge; associated with elevated levels of alkylated PAH and total HC in surficial sediments.
Lake Salvador[2] Fresh-salt interface, low energy open water; Depth < 3 m; no discharge rate data	230m (See Note G)	ND	BTEX detected to 90m; Paraffinic HC detected to 1800m	PAH and BTEX detected near discharge; Paraffinic HC detected to 90m; Metals present in all samples	Benthic infauna and epifauna community distribution and abundance were negatively impacted within 90m of the discharge; salinity effects appear to be partly responsible (relative to reference sites); the community structures present are typical of oligohaline Louisiana estuaries
Lirette[3] Brackish marsh, canal; Depth 1-3 m; 462 bpd	325m	See Note B	Elevated PAH, HC, and Metals in effluent samples	Total HC Homologs = 0.6 ppm at 260m; Background at 1000m Metals (See note C)	Caged Oysters = 7% mortality Bioaccumulation (from tissue samples): Volatile HC = 372 ppb, PAH = 22 ppb
Bully Camp[3] Brackish marsh, canal; Depth 1-3 m; 4,767 bpd	300m	See Note B	Elevated PAH, HC, and Metals in effluent samples	Total HC Homologs = 2.2 ppm at 320m; background at 600m Metals (See note C)	Caged Oysters = 0% mortality Bioaccumulation (from tissue samples): Volatile HC = 17 ppb, PAH = 13 ppb
Delta Farms[3] Brackish marsh, canal; Depth 1-3 m; 13,458 bpd	300m	See Note B	Elevated PAH, HC, and Metals in effluent samples	Total HC Homologs = 7.7 ppm at 320m; background at 600m Metals (no data)	Biota not Evaluated

Exhibit 10-1. Summary of Organics and Metals Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water (Continued)

Study Site Characteristics (number of facilities)	Salinity Plume (See Note A)	Toxicity Data	Water Column or Effluent Hydrocarbons (HC) and Metals	Sediment Hydrocarbons and Metals	Bioaccumulation and/or Ecological Indicators (Includes Tissue Samples of Biota if Reported)
Lake Washington[3] Saline marsh, canal; Depth 1-2m; 1,600 bpd	350m	See Note B	Elevated PAH, HC, and Metals in effluent samples	Total HC Homologs = 0.6 ppm at 270m; background at 600m Metals (See note C)	Caged Oysters = 64% mortality Bioaccumulation (from tissue samples): Volatile HC = 3 ppb, PAH = 280 ppb
Caillou Lake[3] Oyster Reference Site Low energy	ND	ND	ND	ND	Caged Oysters = 0% mortality Bioaccumulation (from tissue samples): Volatile HC = Not detected, PAH = Trace
Trinity Bay[4] Open bay system; mean depth 2.5m; range of 4,100 - 10,000 bpd discharged during study period (1 and 2)	ND	ND	HC concentrations (conc.) in bottom waters at 15m; 3 orders of magnitude lower than effluent	Naphthalene levels at 75m 20-50% of levels at 15m; HC conc. at 15m were 4 x effluent	Bay bottom virtually devoid of benthic fauna within 15m of outfall; severely depressed benthic fauna at 150m; unaffected at 455m; both numbers of species and individuals increased with distance from outfall and dropped at control station
Copano Bay[5] Open bay system; outfall 15m from shore; Depths <3m; no discharge rate data	None	ND	ND	Distance dependent elevations of Cd and oil & grease from discharge to 100m	ND
Nueces Bay[5] Open bay system; outfall into adjacent wetland; Depths <2m; no discharge rate data	None	ND	ND	Distance dependent elevations of oil & grease from discharge to 500m	ND

Exhibit 10-1. Summary of Organics and Metals Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water (Continued)

Study Site Characteristics (number of facilities)	Salinity Plume (See Note A)	Toxicity Data	Water Column or Effluent Hydrocarbons (HC) and Metals	Sediment Hydrocarbons and Metals	Bioaccumulation and/or Ecological Indicators (Includes Tissue Samples of Biota if Reported)
Corpus Christi Bay[5] Open bay system; 3 discharge sites 15m from shore; Depths <4m; no discharge rate data	None	ND	ND	Distance dependent elevations of Hg and oil & grease from discharge to 500m	ND
Cow Bayou[6] Effluent dominated tidal creek; Depth 2m; 80,000 bpd during study period	ND	See note D	ND	Petroleum hydrocarbons and strontium levels elevated above background at all stations	Reduced abundance, species richness, and diversity of the benthic macroinvertebrate community up to 1,030m from discharge
Tabbs Bay[6] Low energy open bay system; no depth or discharge data	ND	See note D	ND	Petroleum hydrocarbons, barium, and strontium levels elevated above background at stations up to 364m from discharge	Reduced abundance, species richness, and diversity of the benthic macroinvertebrate community up to 82m from discharge
Nueces Bay[7] Open bay system; no depth or discharge data	Note E	Note D	Hydrocarbon and metals levels in effluent were elevated	ND	ND
Trinity Bay Field[8] Open bay system; range 5,500-9,400 bpd; Depth 2-3m (3)	Note E	ND	ND	ND	Benthic effects detected >100m from discharge; zone of stimulation observed

Exhibit 10-1. Summary of Organics and Metals Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water (Continued)

Study Site Characteristics (number of facilities)	Salinity Plume (See Note A)	Toxicity Data	Water Column or Effluent Hydrocarbons (HC) and Metals	Sediment Hydrocarbons and Metals	Bioaccumulation and/or Ecological Indicators (Includes Tissue Samples of Biota if Reported)
Fisher's Reef Field, Trinity Bay[8] Open bay system; 11,400 bpd; Depth 2-3m	Note E	ND	ND	ND	Benthic effects detected >100m from discharge; zone of stimulation observed
Clear Creek-Clear Lake Area (Cow Bayou)[8] Low energy, tidally-influenced areas; 36,000 bpd; Depth 2m	Gradient absent in Cow Bayou (>1000m)	ND	ND	ND	Benthic effects detected to 1,000m from discharge (effluent dominated creek)
Menefee Lake-Lavaca River[8] Low energy, tidally-influenced; 14,402 bpd; Depth <1m	Note E	ND	ND	ND	Benthic effects detected to approximately 800m from discharge in the largest Lake (Menefee 1)
Lavaca and Matagorda Bays[8] Open bay system; 2-600 bpd; no depth data (4)	Note F	ND	ND	ND	No effects detected
Baffin Bay Area[8] Open bay system; 600-14,500 bpd; Depth <2m	Atypical gradient (Hyper-saline area >50 ‰)	ND	ND	ND	No effects detected

Exhibit 10-1. Summary of Organics and Metals Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water (Continued)

Notes

A Data reported in the *Salinity Effects* column consist of (for Study #1, where reported) water column effluent dilution data; (for Study #2) interstitial water chloride values.

B Toxicity data are available for produced water effluent and sediments (not included on this table).

C Metals for all of the Study #2 sites (Ba, Hg, As, Ni, and Cd) show source-associated spatial trends or elevated values relative to the reference stations at each study site.

D Toxicity data are available for effluent and sediments.

E Salinity gradients were present but altered from the brine discharges (particularly in low energy areas) and exhibited a high seasonal variability.

F Produced water discharge consisted of a low salinity brine discharge (about 7 ‰); a natural estuarine salinity gradient was present.

G The study states that the discharged produced water "mixes readily" with lake water; however, it also acknowledges the presence of a "lens" of brine on the bottom.

References

1 Rabalais et al., 1991.
2 Knecht and Poirrier, 1988.
3 St. Pé, 1990.
4 Armstrong et al., 1977.
5 Southwest Research Institute, 1978.
6 Roach et al., 1992.
7 Caudle, 1993.
8 Mackin, 1971.

Exhibit 10-2. Summary of Radiochemical Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water

Study Site Characteristics	Radio-nuclide	Effluent (pCi/l)	Receiving Water (pCi/l)	Sediment (pCi/g)	Tissue Samples of Biota (pCi/g) Total Radium ($^{226+228}Ra$) Unless otherwise indicated
English Bay (LA)[1] Low energy < 2 meters 4,000 bpd	^{226}Ra ^{228}Ra	258.3 199.4 386.0 380.0	1.3 at 7.6m(L) 0.1 at 15.2m(C) 8.9 at 7.6m(L) 0.0 at <15.2m(X[b])	23.5 at 0.0m 0.7 at 7.6m(L) 2.6 at 0.0 m 0.0 at <7.6m(X[c])	Bivalve 0.040 at 1,200m; 0.004 at >1m[d] Crustacean 0.264 at 0m; 0.011 at 1,200m Fish 0.107 at 0m; 0.010 at 0m[e] Plants 0.402 at 0m; 0.021 at 1,200m
Golden Meadow (LA)[1] Well flushed 2-3 meters 3,775 bpd	^{226}Ra ^{228}Ra	134.3 86.8 255.1 233.6	0.8 at 7.6m(L) 0.1 at 15.2m(L) 2.8 at 7.6m(L) 0.0 at <7.6m(X[f])	0.5 at 0.0m 0.1 at 7.6m(X[g]) 0.1 at 15.2m(R) 0.0 at 0.0m(X[h])	Bivalve 0.023 at 0m; 0.000 at 3000m Crustacean 0.197 at 3000m; 0.005 at 3000m[j] Fish 0.202 at 3,000m; 0.000 at 0m[k] Plants 0.639 at 0m; 0.032 at 0m[l]
Avery Island (LA)[1] Low energy 1-3 meters 5,076 bpd	^{226}Ra ^{228}Ra	256.0 247.7 255.3 254.4	5.6 at 7.6m(L) 0.4 at 15.2m(LC) 26.9 at 7.6m(R) 0.0 at <15.2m(X[l])	3.2 at 7.6m(R) 0.7 at 7.6m(L) 1.7 at 15.2m(R) 0.0 at 0.0m(X[m])	Bivalve no data reported Crustacean 0.694 at 0m; 0.041 at 0m[m] Fish 0.082 at 2,300m; 0.037 at 0m[n] Plants 0.520 at 2,000m; 0.010 at 2,000m[o]
Bayou Rigaud (LA)[2] Low energy 3-6 meters 145,760 bpd	^{210}Pb Total Ra	12.5 <0.1 460.0 138.2	<0.1-1.4; 2-30 times natural[q] 7.7-38.8; up to 40 times natural	0.25 - 1.89; at or above natural[q]	Caged oysters had total radium concentrations of 0.63 pCi/g at the sample station 300 m from discharge, all other sample stations showed concentrations below the detection limit
Pass Fourchon (LA)[2] Low energy 2.5-3.5 meters 33,756 bpd	^{210}Pb Total Ra	11.6 <0.5 1,050.9 168.6	1.4 at 400 m <0.1 at 1000 m(N) 78.6 at 600 m(N) 19.5 at 600 m(S)	3.22 at 400 m 0.23 at 900 m(N)	Caged oysters had total radium concentrations of 1.95 pCi/g at 150 m from discharge and 0.5 pCi/g at 350 m from the discharge, all other sample stations yielded levels below detection limit

Exhibit 10-2. Summary of Radiochemical Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water (Continued)

Study Site Characteristics	Radio-nuclide	Effluent (pCi/l)	Receiving Water (pCi/l)	Sediment (pCi/g)	Tissue Samples of Biota (pCi/g) Total Radium ($^{226+228}Ra$) Unless otherwise indicated
East Timbalier Island (LA)[2] Low energy 1.5-2 meters 18,263 bpd	^{210}Pb Total Ra	4.8 <1.7 664.5 590.5	0.2-<0.1; up to 5 x natural levels[q] 40.5-14.6; 15 to 45 x natural[q]	0.37-0.08; within natural levels[q]	Biota not evaluated
Emeline Pass (LA)[2] Well flushed 3-5 meters 3,693 bpd	^{210}Pb Total Ra	2.0 0.5 300.9 188.6	0.41 at 450 m(W) <0.01 at 250 m(E) 1.05 at 100 m(E) 0.27 at 1,000 m(E)	1.22 at 450 m(W) 0.06 at 250 m(E)	Biota not evaluated
Romere Pass (LA)[2] Well flushed 1-2 meters 3,021 bpd	^{210}Pb Total Ra	0.9 0.7 394.1 105.0	0.44 at 450 m(S) 0.10 at 0 m 3.32 at 1,000 m(N) 1.41 at 550 m(N)	0.71 at 1,000 m(N) 0.25 at 0 m	Biota not evaluated
Empire Waterway (LA)[2] Low energy	^{210}Pb Total Ra	0.7 907.3	0.16-0.03; up to 3 x natural[q] 41.82-29.55; 32 to 45 x natural[q]	1.28-0.52; at upper limit of natural[q]	Biota not evaluated
Lirette (LA)[3] Low energy 1-3 m; 462 bpd	^{226}Ra	537	No data	533.0 at 0 m 33.0 at 20 m 7.9 at 500 m	Caged oysters deployed for 30 days at a distance of 110 m from the outfall had ^{226}Ra concentrations of 3.1 pCi/g
Bully Camp (LA)[3] Low energy 1-3 m; 4,767 bpd	^{226}Ra	567	No data	182.0 at 0 m 47.5 at 50 m 5.2 at 300 m	Caged oysters deployed for 30 days at a distance of 85 m from the outfall had ^{226}Ra concentrations below the lower level of detection

Exhibit 10-2. Summary of Radiochemical Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water (Continued)

Study Site Characteristics	Radio-nuclide	Effluent (pCi/l)	Receiving Water (pCi/l)	Sediment (pCi/g)	Tissue Samples of Biota (pCi/g) Total Radium ($^{226+228}Ra$) Unless otherwise indicated
Delta Farms (LA)[3] Low energy 1-3 m; 13,458 bpd	^{226}Ra	355	No data	6.1 at 0 m 9.2 at 200 m 4.0 at 300 m	Biota not evaluated
Lake Washington (LA)[3] Low energy 1-2m; 1,600 bpd	^{226}Ra	529	No data	300.0 at 0 m 158.0 at 50 m 4.1 at 300 m	Caged oysters deployed for 33 days at a distance of 70 m from the outfall had ^{226}Ra concentrations below the lower level of detection
Caillou Lake (LA)[3] Low energy 1 m; (Control Site)		——	——	——	Caged oysters deployed for 30 days at the control site had ^{226}Ra concentrations below the lower level of detection
Lirette (LA)[4] Low energy 1-3 m; no flow data	^{226}Ra ^{228}Ra	756 470	No data	307.0 at 0 m 5.0 at 100 m 165.0 at 0 m 1.6 at 20 m	Biota not evaluated

a The range of values listed is the maximum replicate concentration at the 7.6m stations and the minimum replicate concentration at the 15.2m stations. In study #1, three stations were spaced equidistantly on two semicircular arrays located at distances of 7.6 m and 15.2 m from each discharge site. Stations are labeled (L) left, (C) center, and (R) right as viewed standing at the discharge site facing out towards (C) center. An "X" indicates that the impact is applicable to more than one station (as described in the corresponding footnote). In study #2, an "N," "E," "S," or "W" the direction of the sampling station from the discharge and may discretely identify the station. Also note that some studies had multiple sampling dates, which may introduce seasonal variations.

b Zero values reported for 1 of the 2 replicate samples at the following stations 7.6m (R), 15.2m (L, R, and C).

c Four of the 6 replicates at the 15.2 m stations and 4 of the 6 replicates at the 7.6m stations reported zero values; both of the replicates at the 15.2m (L) station were above zero.

d One of the replicates at the discharge yielded the lowest value along with one of the replicates at the C2 station (1500 m distant from the discharge).

e The two replicates at the discharge yielded both the maximum and minimum values.

f Zero values were reported for both of the replicates at two of the 7.6m (R and L) stations and for 1 of the 2 replicates at the 15.2m (L) station and for both of the replicates at each of the other 15.2m (C and R) stations.

g Values of 0.1 were reported for 4 of 6 replicates at 7.6m (L, R, and C) stations and 1 replicate at the 15.2m (C) station.

h All 6 of the replicates at the three 7.6m stations reported zero values and 4 of the 6 replicates at the 15.2m stations report zero values; both of the replicates from the 15.2(R) station are >0.5 pCi/g.

Exhibit 10-2. Summary of Radiochemical Impacts Found in Studies of Coastal Subcategory Discharges of Produced Water (Continued)

i One of the replicates at the C2 station (3000 m from the discharge) yielded the maximum value and the other replicate yielded the lowest value.

j The data represent an apparent anomaly; the maximum value is reported the greatest distance from the discharge and the minimum value is nearest the discharge.

k One of the replicates at the discharge yielded the maximum value and the other replicate at this station yielded the lowest value.

l Zero values were reported for 6 replicates above the pycnocline at all three of the 7.6m stations (L, R, and C); zeros were also reported for 1 of the replicates below the pycnocline at the 7.6m(L) station and both of the replicates below the pycnocline at the 7.6(C) station.

m Both of the replicates at the 0.0 station and both of the replicates at the 7.6m station had zero values; all others are >0.01 pCi/g.

n One of the replicates at the discharge yielded the maximum value and the other replicate at this station yielded the lowest value.

o The data represent an apparent anomaly; the maximum value is reported at station C1 (2,300m from the discharge); the minimum value is nearest the discharge.

p One of the replicates at station C2 (2,000m from the discharge) yielded the maximum value and the other replicate at this station yielded the lowest value.

q The ^{210}Pb activity for natural waters, as reported in this study, is 0.05 pCi/l (range: 0.005 to 0.068); total radium activity for natural waters, as reported in this study, is 0.91 pCi/l (range: 0.023 to 2.27). For the definition of "natural levels," Rabalais cited Reid, D.F. 1983. *Radium in formation waters: How much and is it of concern?* pp. 187-191 In Proceedings, Fourth Annual Gulf of Mexico Information Transfer Meeting. OCS Report/MMS 84-0026, U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, LA, 474 pp. Also note that the values varied seasonally and from station to station, particularly where some study sites had more than one outfall and the sampling stations were located between 2 or more outfalls.

References

1 Continental Shelf Associates, 1991.

2 Rabalais et al., 1991.

3 St. Pé, 1990.

4 Steimle and Associates, 1991.

10.2 Summary of Coastal Studies Cited

Author and Title: Rabalais, N.N., B. McKee, and D. Reed. 1991. Fate and Effects of Nearshore Discharges of OCS Produced Waters. Prepared for the U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office. Three Volumes - Executive Summary, 337 p. Technical Report, and Appendices.

Study Overview: An extensive chemical and biological assessment of seven produced water discharges in coastal Louisiana was conducted. The produced water that is generated by oil and gas production activities on the outer continental shelf (OCS) was the specific target of the study. This study expanded on the initial assessment by Boesch and Rabalais (1989) by increasing the temporal and spatial studies of three areas and also studied different areas (including an abandoned site) representing a larger cross section of discharge types and configurations.

At each study area, produced water and the near bottom water of the receiving water column were examined for contaminants, including salinity, hydrocarbons, trace metals, radionuclides and sulfides. The top 10 centimeters (cm) of surficial sediments were sampled at all stations along a gradient away from the discharge for interstitial salinity, hydrocarbons, trace metals, and radionuclides (sediment cores were also taken at some of the stations). Studies of bioaccumulation of selected contaminants (including total radium activity, expressed as $^{226+228}Ra$) in oysters (*Crassostra virginica*) that had been deployed at known distances from the discharges for known periods of time were conducted for two of the study sites.

Summary of Results: The study included a data synthesis of the fates and effects of OCS produced water discharged into coastal waters based on the field assessments. The data synthesis resulted in the discussion of a variety of issues, including a comparison of effluents, receiving waters/environments, dispersion of the brine effluent, sediment contamination, and biological effects. Maximum impacts found in this study include elevated PAH and volatile hydrocarbon levels in sediments at distances up to 1,300 m from the discharge. No spatial trends in trace metal elevations were noted in sediments, but maximum levels of Ba, Zn, and Ni were found as far as 600 m from a discharge to a dead-end canal (the Pass Fourchon site). Water column volatile hydrocarbon levels were detected as far as 1,000 m from the Pass Fourchon site; and water column PAH levels were elevated as far as 800 m from the same discharge (along with a clearly recognizable density (i.e., salinity) plume).

The most severely depressed benthic macroinfaunal communities (abundance and diversity) were found within 800 m of one of the discharges to the Pass Fourchon site. Benthic infauna were essentially absent or substantially reduced at 400, 500, 600, and 800 m from the discharge point for most of the sampling periods. Bioaccumulation of produced water origin contaminants (alkylated PAH, total hydrocarbons, and total radium activity) was documented near discharges at both sites and up to 200 m from one site (the Pass Fourchon site) where oysters were deployed (the other site is the Bayou Rigaud site). Clear potential for uptake was demonstrated both in close proximity to the discharge and to great distances from the discharge.

Author and Title: St. Pé, K.M. (Editor). 1990. An Assessment of Produced Water Impacts to Low-Energy, Brackish Water Systems in Southeast Louisiana. Prepared by the Louisiana Department of Environmental Quality. 199 p.

Study Overview: The objectives of this study were to further evaluate past observations made by the Louisiana Department of Environmental Quality staff and other investigators and to add to the available data base with respect to produced water discharges to low-flow systems. Four sites were examined at which produced water was being discharged in coastal Louisiana. These sites (Lirette, Bully Camp, Delta Farms, and Lake Washington) all discharge to canals or passes and are located in the coastal subcategory.

At each study site, the hydraulic behavior of the produced water was evaluated by tracking the chloride concentrations in the receiving water and surficial sediments. A produced water effluent sample was collected as well as sediment samples and water quality data along three transects radiating from a point near each discharge. In addition, caged oysters were used to assess the potential for uptake of ^{226}Ra (among other pollutants) at three of the four sites.

Summary of Results: Results indicated that produced water influences on chloride concentrations of the receiving water body are much more apparent in the sediments than in the water column. A recognizable salinity plume was recorded at distances at least 300 m from the discharge point at all four study sites. Toxicity testing was conducted on produced water effluents and sediments and indicated that acute toxicity was attributable to produced water components other than salinity.

High levels of metals and organics were found in the produced water effluent samples as well as elevated levels of total hydrocarbon homologs in sediment samples up to 1,000 m from the discharge at one of the sites (the Lirette site - background levels were achieved at 600 m from the discharges at the other three study sites).

With respect to radionuclides, the study found that ^{226}Ra levels were elevated at all of the sites, ranging from a low of 355 pCi/l at Delta Farms to 567 pCi/l at Bully Camp. The top 10 cm of sediment from the sample stations nearest the outfalls on each transect contained ^{226}Ra concentrations of 182 pCi/g at Bully Camp to 533 pCi/g at Lirette. Levels of ^{226}Ra were noted as being above background levels as far as 500 m from the outfalls at the Lirette, Bully Camp, and Lake Washington sites. Sediment accumulation of ^{226}Ra did not follow the same pattern at the Delta Farms site. The authors attributed this to the predominantly organic nature of the sediments at that site.

Among caged oysters deployed (at all of the sites except Delta Farms), increased ^{226}Ra levels were found only at the Lirette site (3.1 pCi/g with an error of 0.3). Sediment hydrocarbon contamination resulting in decreased filtering rates was offered as a possible explanation. An additional point of particular interest in this study is the hydraulic behavior of the produced water effluent in a receiving water body and underlying sediments. The study found that the high density/salinity water did not mix with receiving waters (at some

stations) and penetrated the sediments to a depth of up to 30 cm. Interstitial chlorinity values were greatest near the discharge points and decreased with distance.

Author and Title: Stiemle and Associates. 1991. Lirette Field Sediment Radionuclide Sampling Survey February 21, 1991. Prepared for the Louisiana Division of the Mid-Continent Oil and Gas Association. 23 p. + Tables, Figures, and Appendices.

Study Overview: The Lirette site from the St. Pé (1990) study was revisited and the analytical methods used in that study were verified by comparing the ^{226}Ra content of collected sediment samples to the results from this site in the St. Pé study.

Summary of Results: The results of this study indicate that the methods used by St. Pé may have introduced a positive bias (by a factor of 2-3) to the results. The study bases this conclusion on the comparison of results using gamma spectroscopy methods (used by St. Pé) to other methods that are assessed in the report.

Author and Title: Southwest Research Institute. 1978. Effect of Oil Field Produced Water Discharge on Water and Sediment Quality at Five Selected Sites in Copano, Nueces, and Corpus Christi Bays, Texas. Prepared by the Southwest research Institute for the Corpus Christi Area Operators. 251 p. + Appendices.

Study Overview: In June and July of 1978 Southwest Research Institute, utilizing the facilities of its Ocean Science and Engineering Laboratory at Corpus Christi, Texas, conducted a water and sediment sampling program at five produced water discharges in the Corpus Christi area. At each site, *in situ* physicochemical water characterizations were determined. The parameters analyzed included dissolved oxygen content, pH, transmissivity, current speed and direction, temperature, and salinity. Grab samples of bottom sediment were obtained and analyzed for cadmium, lead, mercury, zinc, and oil and grease content.

Summary of Results: Based on the data collected during the course of this study, a discernible detrimental effect of the produced water discharge on the physiochemical water parameters studied could not be identified at any of the five discharge sites. The sediment parameters tested offer a long-term indication of the continuing effect of the produced water discharges in that the sediment has collected in it a long-term accumulation of the materials found in the discharged waters as well as materials introduced from unknown sources. Generally, no significant demonstrable adverse effect of the produced water discharges was found on the sediment chemical parameters tested. However, the sediment data indicated distance dependent elevations of: oil and grease up to 500 m from the discharge at two sampling sites (and up to 100 m at another site); Hg up to 500 m at one site; and Cd up to 100 m at one site.

Author and Title: Knecht, A.T. and M. Poirrier. 1988. A Survey to Determine the Impact of Produced Water Discharge on the Estuarine Environment of Lake Salvador. Prepared by the Department of Biological Sciences, University of New Orleans for Texaco, Inc. 29 p. + Appendices.

Study Overview: A study was conducted to determine if produced water discharged from Texaco's oil and gas operation in Lake Salvador has a measurable impact on the infauna and epifauna in the area. Chemical and biological surveys were conducted to determine the distribution of petroleum hydrocarbons and salinity, and indigenous organisms in the area around the discharge.

Summary of Results: Volatile hydrocarbons (benzene, toluene, ethylbenzene and total xylenes - BTEX) were detected in the water column to distances up to 90 m from the discharge. Paraffinic hydrocarbons were detected in the water column to distances of up to 1,800 m from the discharge.

PAH and BTEX were detected in sediments near the discharge and paraffinic hydrocarbons were detected in the sediment up to 90 m from the discharge. Metals were present in essentially all sediment samples but did not exhibit a spatial correlation to the discharge.

Benthic infauna and epifauna community distribution and abundance were negatively impacted within 90 m of the discharge. The salinity effects appear to be partly responsible, relative to reference sites. The community structures present are representative of typical oligohaline Louisiana estuaries.

Author and Title: Roach, R.W., R. Carr, C. Howard, and B. Cain. 1993. An Assessment of Produced Water Impacts in the Galveston Bay System. Prepared by the U.S. Fish and Wildlife Service and the University of Houston-Clear Lake, Biology Department. 56 p.

Study Overview: This study provides a general assessment of adverse environmental effects resulting from tidal disposal of produced water. Three parameters were used in making this assessment: (1) documenting any alteration to the benthic macroinvertebrate communities; (2) physically and chemically characterizing impacted and unimpacted sediments; and (3) assessing the sediment toxicity caused by these discharges.

Summary of Results: Petroleum hydrocarbons and strontium levels were elevated above background at all sample stations at one of the study sites (the Cow Bayou site). Petroleum hydrocarbons, strontium, and barium levels were elevated above background at all sample stations up to 364 m from the discharge at the other study site (the Tabbs Bay site).

Reduced abundance, species richness, and species diversity of the benthic macroinvertebrate community was documented up to 1,030 m from the discharge at the Cow Bayou site. Reduced abundance, species richness, and species diversity of the benthic macroinvertebrate community was documented up to 82 m from the discharge at the Tabbs Bay site.

Author and Title: Caudle, C.S. 1993. An Impact Assessment of the Waters Discharging into Nueces Bay. Prepared by the Texas Water Commission. 30 p. + Appendices.

Study Overview: The purpose of this project was to: (1) develop data concerning location, quantity, and quality of produced water discharges into Nueces Bay and the Nueces River Tidal and (2) to examine the

physical, chemical, and toxicological properties of these produced water discharges. A total of 16 produced water discharges were found to be active in Nueces Bay and the Nueces River Tidal and were responsible for discharging a total volume of 654,537.6 gallons/day of produced water to the Nueces estuary.

Summary of Results: The produced water effluents characteristically had low dissolved oxygen concentrations, high water temperatures, and elevated levels of salinity and conductivity. Additionally the effluents contained inordinate amounts of salts, ammonia, and oil and grease, as well as, varied levels of aromatic hydrocarbons and metals known to be toxic. The discharges were all found to be acutely and chronically toxic to mysid shrimp.

Advanced degradation of the aesthetic quality of the aquatic environment was observed at all outfall sites. Impacts observed included highly stained and discolored sediments, extensive oil sheens on the surface of the discharges, denuded areas within and around the discharge streams in which vegetation, organisms and birds were absent. The resultant compounding impact of these discharges is a noticeable degradation of valuable habitats and biological communities in Nueces Bay and the Nueces River Tidal, as well as a reduction in the ecological suitability of this system as a high quality estuary. These findings have implications concerning the future permitting of produced water discharges to these areas and in the future management decisions of the Nueces Estuary.

Author and Title: Continental Shelf Associates. 1991. Measurements of naturally Occurring Radioactive Materials (NORM) at Three Produced water Outfalls. Final Report. Prepared for Mid-Continent Oil and Gas Association. 41 p. + Appendices.

Study Overview: The objective of this study was to provide information concerning concentrations of radium (Ra^{226} and Ra^{228}) in water, sediment, and biological tissue in the immediate vicinity of three produced water outfalls known to contain varying levels of NORM. The receiving waters at each of the discharge sites, located in coastal Louisiana, were generally low energy, brackish water, canal environments. Discharges at each of the sites have been occurring for several years with rates that are typical of produced water outfalls (3,000 to 5,000 bbl/d).

Summary of Results: The results of the study included produced water effluent Ra^{226} values ranging from 199.4 to 258.3 pCi/l; and Ra^{228} values of 233.6 to 380.0 pCi/l at the three sites. Receiving water concentrations of Ra^{226} ranged from 0.1 pCi/l at 15.2 m from the discharge at two of the sites to 5.6 pCi/l at a distance of 7.6 m from the discharge at another site. Concentrations of Ra^{228} in the receiving water ranged from zero near the discharge at all three of the sites (but not all replicate samples were zero values) to as high as 26.9 pCi/l at a distance of 7.6 m from the discharge at on of the sites.

Sediment Ra^{226} values ranged from 0.5 pCi/l to 23.5 pCi/l near the discharge at two of the sites to 3.2 pCi/l at a distance of 7.6 m from one of the sites. Sediment Ra^{228} values ranged from zero near the discharge (for certain replicates at all three of the sites) to 2.6 pCi/l near the discharge at one of the sites; and ranged from 0.1 pCi/l to 1.7 pCi/l at distances of 15.2 m from two of the sites.

Tissue samples of total radium ($^{226+228}Ra$) in bivalves ranged from 0.004 pCi/g near the discharge at one site to 0.4 pCi/g at a distance of 1,200 m from the discharge at another site. Total radium ($^{226+228}Ra$) in crustacean tissue samples ranged from 0.041 pCi/g near the discharge at one site to 0.197 pCi/g at a distance of 3,000 m from the discharge at another site. Total radium ($^{226+228}Ra$) in fish tissue samples ranged from zero to 0.107 pCi/g near the discharge at two sites to as much as 0.202 pCi/g at a distance of 3,000 m from the discharge at another site. Tissue samples of total radium ($^{226+228}Ra$) taken from plants ranged from 0.032 to 0.639 pCi/g near the discharge at two sites to 0.520 pCi/g at a distance of 2,000 m from the discharge at another site.

Author and Title: Mackin, J.G. 1971. A Study of the Effects of Oil Field Brine Effluents on Biotic Communities in Texas Estuaries. Texas A&M Research Foundation Project 735. 73 p. + Figures and Tables.

Study Overview: The objective of this study was to measure the effect on the estuarine and marine communities of Texas bays caused by the discharge of produced water effluents. Six oil field areas were targeted for study primarily based on the differing salinity of the receiving water to test the effects of such discharges on as wide a range of natural environments as possible.

Summary of Results: The results of this study indicated that, based mostly on the evaluation of benthic macroinvertebrate communities, effects varied considerably with the nature of the receiving environment. Effects were detected up to 1,000 m from the discharge of one effluent dominated creek (the Cow Bayou site); about 800 m from the discharge in a large, shallow (<1 m) lake; less than 100 m from the discharge in two of the open bay systems studied (zones of stimulation were also observed at these sites); and no effects were detected at two other open bay study sites.

Author and Title: Armstrong, H.W., K. Fucik, J. Anderson, and J. Neff. 1979. Effects of Oilfield Brine Effluent on Sediments and Benthic Organisms in Trinity Bay, Texas. In *Marine Environmental Resources,* pp. 55-69. Prepared by the Department of Biology, Texas A&M University, College Station, TX.

Study Overview: Field studies have established the concentration of naphthalenes in bay sediments and water in the vicinity of an oil separator platform and their effects on the benthic fauna. Fifteen stations were occupied monthly, from July, 1974 to December, 1975, along three transects extending from the separator platform outward for a distance of 4.0 to 5.6 km. A lesser number of stations were occupied from April, 1974 to June, 1974. Bottom sediments at each station were analyzed for total naphthalenes content and for number of species and individuals.

Trinity Bay, Texas, the site of this investigation, has a mean depth of 2.5 m (all stations were located in 2 to 3 m of water). Bay waters are highly turbid due to the presence of a high concentration of clay-sized particulate matter. The brine outfall was located approximately 1 m above the bay bottom. These special conditions undoubtedly contributed significantly to the observed impact of the brine. Therefore

extrapolations from the results of this study to offshore oil production and brine disposal should be made with extreme caution.

Summary of Results: There was a definite correlation between sediment naphthalenes concentration and number of species and individuals. As expected, the first station, located 15 m from the outfall, had the highest concentration of naphthalenes of all stations sampled. The naphthalenes levels dropped sharply from the outfall to the stations located 75 m from the platform where levels were about 20-50% of those found 15 m from the outfall. Naphthalenes concentrations then decreased gradually to near background levels at stations farther out. Hydrocarbon concentrations in bottom water 15 m from the outfall were three orders of magnitude lower than those in the full strength effluent, but sediments 15 m from the outfall had hydrocarbon concentrations four times as great as in the full strength effluent. There were approximately four orders of magnitude more hydrocarbons in the sediment than in the overlying water.

The bay bottom was almost completely devoid of organisms within 15 m of the effluent outfall. Stations located 150 m from the outfall had severely depressed benthic faunas but not to the extent of stations nearer the outfall. Stations located 455 m from the platform were unaffected. Both numbers of species and individuals increased with distance from the platform and reached a peak at the first station medial to the control on each transect (685 to 1,675 m from the platform) and then dropped at the control station. Physical environmental factors such as temperature, salinity, water depth, and sediment type were essentially the same at all stations.

The temporary use of a second outfall located 275 m from the main platform outfall resulted in a rapid build up of naphthalenes in surrounding sediments which persisted for at least six months following the termination of use of the second outfall. The benthic fauna was also severely depressed in the vicinity of the second outfall. The use of multiple outfalls, located some distance apart, appears to be more harmful than the use of a single outfall.

11. ADDENDUM TO THE WQBA IN RESPONSE TO EPA REGION 6 FINAL NPDES PERMITS

EPA Region 6 has recently published final NPDES general permits covering oil and gas production facilities discharging to the coastal subcategory in the States of Louisiana and Texas (60 FR 2387; January 9, 1995). These permits prohibit the discharge of produced water and produced sand derived from these facilities to waters of the U.S. Much of the industry covered by these proposed effluent guidelines for the coastal subcategory are covered under these general permits. However, one difference between the coverage of the general permits and the guidelines is that the permits do not cover produced water discharges derived from offshore subcategory sources that are treated and discharged into certain coastal subcategory waters. Those receiving waters are the main deltaic passes of the Mississippi River or the Atchafalaya River below Morgan City including Wax Lake Outlet. These excluded facilities are covered under the proposed effluent guidelines.

The impacts and benefits presented in this WQBA are based on discharge volumes and locations that were projected for the proposed effluent guidelines absent these final NPDES general permits. Because of the close timing of the publication of these final permits and the proposed effluent guidelines, little opportunity for re-analysis occurred. Thus, the approach selected to respond to the publication of the final permits is to proportionate impacts and benefits based on a simple flow proportion. That is, the final permits are known to cover approximately 71% of the discharge volume projected for these guidelines. The remaining 29%, excluded from coverage under the final permits but covered by these guidelines, is derived from offshore subcategory-derived produced waters discharged into main deltaic passes in the coastal subcategory.

Due to the short timeline for revision of the WQBA for the purpose of proposed guidelines, this addendum provides only a simplistic estimate of the proportion of impacts and benefits based on this 29% share of produced water flow. A series of qualifications result from this approach. These concerns are discussed, with respect to the types of analyses included in this WQBA, in detail below. For the final guideline, a new WQBA will be conducted that is based on a revised industry profile.

The effect of these final general permits on the analyses conducted in this WQBA, the qualifications to the approach taken in order to respond to these permits, and the revised benefits are discussed below.

11.1 Produced Water Characterizations

Current flow estimates are revised downward to include only facilities excluded from the general permits. Existing data are sufficient for a reasonably accurate projection of flows for the excluded facilities. Produced water flows for Texas are revised to zero. Produced water flows in Louisiana are revised to 52 million barrels per year, representing 29% of the total Texas and Louisiana flow of 180 million barrels per year (see Section 2 of this WQBA). The flow estimates for produced water will be revised and confirmed for the final WQBA.

The chemical characterization of produced water continues to be based on the 10-facility survey conducted for this rulemaking. However, only a handful of dischargers will be covered under these guidelines if the final permits are not altered upon any potential judicial review. A more selective approach to waste stream characterization, focused on just these facilities, may be possible for the final rule.

11.2 Watershed Loadings

This portion of the WQBA (see Section 3) can be reasonably well projected to account for the effect of the final permits because flow data are reasonably accurate. Because produced water flows in Texas will be zero, watershed mass and toxic unit loading likewise will be zero. Based on a simple proportionation of flow in Louisiana, revised watershed mass loadings (see Table 3-18) are projected to range from 2.0 million pounds per year or 17% of Louisiana's mass load from industrial and municipal point sources (29% of 7.1 million pounds and 58%, respectively; includes ORD report pollutants only) to 6.0 million pounds per year or 23% of Louisiana's point source mass load (29% of 21 million pounds and 80%, respectively; all produced water pollutants included). Revised toxic unit loadings from produced water discharges from facilities excluded from coverage under the Region 6 final general permit are estimated to represent 25% of the point source toxic unit loadings in Louisiana (29% of 87.1%; see Table 3-20).

The accuracy of this proportionation depends on effluent characterization data as well as flow data, however. Thus, this projection may change if effluent characterization data are revised for the final rule.

11.3 Water Quality Compliance Assessment

Revisions to this portion of the WQBA (see Section 4) cannot be accurately determined at this time. One factor that can be projected with some confidence is that the discharge rates used for compliance assessments will increase for these facilities, based on their known flow rates. This factor would tend to increase noncompliance with state standards, compared to the analyses conducted in this WQBA, because of diminished available dilution at higher flow rates. This conclusion, however, assumes all other factors remain equal, which is possibly not the case. For example, site-specific receiving water characteristics may change in a direction that would tend to increase dilution (e.g., increased current speeds, such as one might expect in river passes) and counter the effects of increased flow. Therefore, no preliminary projections on the impact of the final permits can be made with respect to water quality compliance with any degree of confidence.

11.4 Valuation of Resources at Risk

The valuation of resources at risk (see Section 6), for these revised projections, are assumed to remain unchanged. This assumption will need further re-evaluation after proposal of the guidelines. The site specific characteristics of receiving waters for facilities excluded from coverage under the final Region 6 NPDES general permits will need to be evaluated in comparison to the basis used in this WQBA (Galveston Bay). Based on this re-evaluation, resource values may increase or decrease.

11.5 Populations Exposed to Produced Water Discharges

The estimate of exposed populations for these revised projections also are be assumed to remain unchanged because the time limitation for this analysis did not allow for reanalysis of this parameter (see Section 7). This assumption will need further re-evaluation after proposal, but will be assumed to remain the same for the purpose of the revised radium risk assessment presented below. Factors that may affect potentially

exposed populations will need to be reviewed in the context of the site- and location-specific findings for facilities excluded from coverage under the final general permits.

11.6 Radium Risk Assessment

Based on a reduced flow estimate of 29% of the pre-permit flow estimate, the number of reduced cancer cases and the monetized benefits from risk reductions due to the rule are commensurately reduced (see Section 8). Monetized benefits have been reduced to 29% of the estimate developed previously in this WQBA, resulting in a range of potential benefits due to cancer risk reductions from these proposed effluent guidelines of $0.7 to $13.3 million annually.

This assessment will need to be revised for the final rule in light of several considerations. These considerations include: whether radium tissue data on existing field-collected specimens are appropriate to the excluded facilities; whether surface water modeling analyses are appropriate; and whether exposed populations are appropriate. The combined influence of alterations in these factors is impossible to predict with any confidence at this time.

11.7 Ecological Benefits

Based on a revised flow estimate of 29% of the pre-permit flow estimate, the monetized ecological benefit estimate is reduced to 29% of the estimate developed previously in this WQBA (see Section 9). Thus, the range of potential benefits due to ecological improvement from these proposed effluent guidelines is $1.4 to $41.5 million annually.

This assessment will need to be revised for the final rule in light of several considerations. These considerations include: whether data on existing field impacts are appropriate to the excluded facilities; and whether resource valuations are appropriate to the excluded facilities. Alterations in these factors may serve to increase or decrease projected benefits.

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