

White Paper
**Proposed NPDES Permit for Oil and Gas Exploration,
Development, & Production Facilities Located Within
Territorial Seas of Louisiana (LAG260000)**

**Prepared for the
Louisiana Environmental Action Network (LEAN)**

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LEAN White Paper on NPDES Permit LAG260000*

Table of Contents

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Proposed Water Discharge Permit LAG260000

Under the proposed water discharge permit LAG260000, oil and gas companies would be allowed to discharge produced water and other waste streams into Louisiana territorial seas. The territorial seas are open seas that extend up to 3 miles from the Louisiana coast. The proposed NPDES permit would cover discharges from all existing and proposed wells that tie into a single production facility, and would encompass all discharges, including produced water. In this white paper we discuss the history of the proposed permit and critically review the properties and potential impact of the proposed discharges. We offer recommendations to the Louisiana Department of Environmental Quality (LDEQ), including strong support for an environmental impact statement to assess the impact of the proposed action. A large number of important documents requested of LDEQ in order to allow a full examination of the proposed permit have not been provided.

1. Oil and Gas Exploration and Production in Louisiana

The territorial seas of Louisiana contain vast amounts of underground oil and gas reservoirs. The oil and gas exploration and production (E&P) process in Louisiana territorial seas generates millions of gallons of hazardous waste streams each day. These waste streams are disposed of by discharge into the territorial seas. There are currently 118 oil and gas E&P facilities operating in the territorial seas of Louisiana, and it is anticipated that 150 new wells will be constructed in upcoming years (Kaspar and Wilson, 2009).

1.1 History of Regulation of Oil and Gas Discharges

The state of Louisiana has an extensive history of regulating the discharge of oil and gas E&P wastes. Louisiana began to express concern over the effects oil and gas E&P wastes have on the environment and human health as far back as the 1920s. However, the history of regulating oil and gas field wastes in Louisiana shows that as the oil industry grew, regulations against the discharge of oil field wastes became more lenient.

The Department of Conservation promulgated stringent regulations against the discharge of oil field wastes in Louisiana in the early 1920s. Through Act Number 133 of Louisiana State Legislation, the Department of Conservation established regulations against the disposal of oil field waste within the waters of Louisiana. The Act stated that it was “unlawful and a misdemeanor for any...corporation or any person acting for himself or for anyone else to knowingly and willfully empty or drain into or permit to be drained from any pumps, reservoirs, wells, or oil fields into any of the natural streams of

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Louisiana any oil, salt water, or noxious or poisonous gases or substances in quantities sufficient to destroy the fish in said streams.”

Accompanying these regulations were strict penalties to be imposed upon any person or corporation in violation of this act. Monetary fines ranged from no less than \$100 to \$2,000 in 1924 dollar values. This is equivalent to \$1,260 to \$25,210 in 2008 dollars. Violators of this act could also be subjected to a prison sentence of no less than thirty days. Each and every day this act was in violation by a particular person or corporation was treated as a separate offense.

The Louisiana Stream Control Commission (LSCC) is a state agency that was created in 1940 to better control the discharges of oil field wastes within the territorial jurisdiction of the state. The territorial jurisdiction of any state includes all land within its boundaries, all rivers, lakes, and any other body of water entirely within its boundaries, all bays or inlets on its coast whose mouth is not more than six miles across, and the seas that border the state’s coast for a distance of three miles seaward. The three mile distance was originally adopted by states because it was thought that this was the most extreme distance a cannon could travel (Putney, 1908). Therefore, the three mile distance included in this regulation and every regulation regarding territorial seas thereafter was not determined under the consideration of environmental or public health.

In 1940, under House Bill Number 994, Act Number 367 of Louisiana State Legislation, the LSCC gained control of the streams, waterways, and coastal waters of Louisiana. The LSCC acquired control of these water bodies to “prohibit the harmful pollution of any waters of the state and the coastal waters of the Gulf of Mexico within the territorial jurisdiction of the State of Louisiana.” Under this Act, LSCC regulated both public and private waste disposal into any of the lakes, rivers and streams of the state or any tributaries or drains flowing into any of the aforementioned bodies of water within the territorial jurisdiction of the State of Louisiana for “the prevention of pollution tending to destroy fish life, or to be injurious to the public health or the public welfare of other aquatic life or wild or domestic animals and fowls.”

Several other agencies played a role in regulating oil and gas field wastes discharged in the state of Louisiana. In the late 1930’s, the Department of Wildlife and Fisheries established a Water Pollution Control Division which monitored the State’s water quality. In the 1960’s the National Environmental Protection Act established the Environmental Protection Agency which oversaw state environmental regulations. In 1972, the Louisiana Governor formed the Governor’s Council on Environmental Quality, and LDEQ, the agency that still regulates oil and gas field waste discharges into public water bodies of Louisiana, was officially created in 1983 (LDEQ, 2008).

1.2 Oil and Gas Production in Louisiana

Oil and gas E&P in Louisiana peaked in the late 1960s and 1970s. By 1967, there were 31,051 operating wells in Louisiana. By 1979, the number of operating wells in

Louisiana had decreased to 20,898 wells. During the period from 1979 to 1986, the number of operating oil wells in Louisiana increased again by an annual average rate of 3.4 percent, but the number of operating wells in Louisiana has slowly declined since then. As of 2004, the number of operating wells in Louisiana was about 61 percent of the state's peak in 1967. (Dismukes *et al.*, 2004)

The trend of natural gas operating wells in Louisiana followed a slightly different path than that of oil wells. In 1960, there were about 6,000 operating wells in Louisiana, and the number of operating natural gas wells increased gradually from 1960 to 1978 at an average annual rate of 3.2 percent. In 1978, the Natural Gas Policies Act was passed, leading to an exceptional increase in the number of operating wells up to 1985. Between 1985 and 2000, the number of natural gas wells decreased by almost 10 percent. (Dismukes *et al.*, 2004)

The increase in oil and natural gas wells in Louisiana during the 1960s and 1970s directly correlated with the discoveries by major oil companies at the time. In 1946, Shell Oil Company discovered oil reservoirs in Louisiana and Texas (Shell Oil Company, 1998). In 1963, Humble Oil, a predecessor of Exxon Company, invented 3-D seismic technology that revolutionized the ability for oil companies to search for oil and gas. In 1966, Mobil Oil Corporation was formed, which directly led to the rapid expansion of Mobil oil wells throughout Louisiana. In 1975, Mobil Oil Corporation helped complete the world's first concrete offshore production platform. Exxon Corporation emerged from Jersey Standard in 1972, leading to the spread of Exxon oil wells throughout Louisiana. (ExxonMobil Corporation, 2007) Increased oil and natural gas production in Louisiana led to an increase in oil and gas E&P waste streams, thus increasing the volumes of waste discharged to the territorial seas of Louisiana.

2. NPDES Permit Program

LDEQ had issued a general permit to all facilities discharging oil and gas E&P wastes from offshore platforms to regulate the wastes discharged into Louisiana territorial seas by oil and gas facilities. This general permit expired on June 30, 1984 and a new general permit was not reissued to oil and gas facilities in the territorial seas until November 4, 1997.

Today, all existing and proposed oil and gas facilities located within the territorial seas of Louisiana are required to obtain a Nationally Pollutant Discharge Elimination System (NPDES) permit before any oil and gas E&P waste discharges to the territorial seas are permitted. The NPDES permit program was initiated by the US Environmental Protection Agency (EPA) in 1972 under the Clean Water Act to control water pollution by regulated point sources that discharge pollutants into waters of the United States. Point sources are those that are visible and discrete, such as pipes, sewers, or man-made ditches. If regulated point sources discharge effluent directly to surface waters, operators are required to first obtain a NPDES permit. The NPDES permit program is most often administered by authorized states with oversight from the EPA. Beginning August 1996,

the Department of Environmental Quality (LDEQ) was approved by the U.S. EPA to administer the NPDES program in Louisiana.

The first NPDES General Permit for Discharge From New and Existing Sources in the Offshore Subcategory of the Oil and Gas Extraction Category for the Territorial Seas of Louisiana (hereafter referred to as NPDES General Permit LAG260000) became effective on November 4, 1997, and was issued to all facilities discharging produced water and other oil and gas E&P waste into Louisiana territorial seas. NPDES General Permit LAG260000 was written to address the national effluent limitation guidelines promulgated on March 4, 1993 and to reissue the general permit for discharges in the territorial seas of Louisiana that expired on June 30, 1984.

One month after assuming authority to administer NPDES permits, in September 1996, the State of Louisiana requested that several changes be made to the NPDES General Permit LAG260000 in addition to the national effluent limitation guidelines promulgated on March 4, 1993. Changes made to NPDES General Permit LAG260000 were the following:

1. Language was added showing that new sources are covered under the general permit.
2. Critical dilution tables for toxicity limitations were recalculated and expanded to account for additional discharge rates and pipe diameters. That is, rather than specific concentration limits from each outfall, mixing criteria were employed.
3. Equations were added in place of the tables for determining the limitations for benzene, lead, phenols, and thallium.
4. A period of six months was given to come into compliance with the water quality based limits for produced water.
5. Model input parameters for diffuser modeling were updated based on site specific data.
6. Produced water discharges were prohibited in some instances in accordance with State regulations listed in LAC 33:IX.708.C.2.c.iii,iv, and v.
 - a. LAC 33:IX.708.C.2.c.iii states that the discharge of produced water directly onto any intermittently exposed sediment surface is prohibited.
 - b. LAC 33:IX.708.C.2.c.iv states that produced water shall not be discharged within the boundaries of any state or federal wildlife management area, refuge, or park or into any water body determined by the Louisiana Department of Environmental Quality to be of special ecological significance.
 - c. LAC 33:IX.708.C.2.c.v states that produced water shall not be discharged within 1,300 feet (via water) of an active oyster lease, live natural oyster or other molluscan reef, designated oyster seed bed, or sea grass bed. No produced water shall be discharged in a manner that, at any time, facilitates the incorporation of significant quantities of hydrocarbons or radionuclides into sediment or biota.

7. Biochemical oxygen demand and total suspended solids limitations and monitoring requirements were added for sanitary waste water discharges under 2,500 gallons per day, and chlorine limitations were added for sanitary waste water discharges from platforms which are manned by nine or fewer persons.
8. 24-hour requirements were changed to reflect State Regulations.
9. Operators were required to submit notification of intent to be covered and discharge monitoring reports to the State instead of the US EPA.
10. Louisiana's field designation was required to be included in notifications of intent to be covered.
11. Permittees were no longer required to apply for the reissued permit six months prior to the expiration date.

NPDES General Permit LAG260000 regulated discharges from eight different outfalls on oil and gas platforms located in Louisiana territorial seas. For each discharge point, the eight outfalls regulated by NPDES General Permit LAG260000 were discharges of deck drainage, well treatment, completion, and workover fluids, sanitary waste, domestic waste, hydrostatic test wastewater, miscellaneous discharges of wastewaters, seawater and freshwater which have been chemically treated, and produced water. Produced water discharges make up the largest volume of waste generated by the oil and gas E&P process and are by far the most harmful to the biota inhabiting the water column and sediments of the Louisiana territorial seas.

NPDES General Permit LAG260000 expired on December 3, 2002. Currently, 118 facilities are still operating under this expired permit. In 2008, the state of Louisiana proposed a revised permit, General Permit No. LAG260000 for Oil & Gas Exploration, Development, & Production Facilities Located within the Territorial Seas of Louisiana, (hereafter referred to as Draft NPDES General Permit LAG260000) in place of the expired version. This discharge permit would be reissued to the 118 operating facilities in the Louisiana territorial sea and the 150 new wells anticipated by LDEQ (Kaspar and Wilson, 2009). The discharge limitation guidelines for produced water discharges have not changed between the expired NPDES General Permit LAG260000 and its most recent proposed revision, except in one important instance that we discuss below.

3. Produced Water

Produced water is the largest volume of waste stream generated by the oil and gas E&P process. Hydrocarbon reservoirs from which oil and gas are produced also contain water, known as formation water. Formation water is found in hydrocarbon reservoirs due to underground flow above or below the hydrocarbon zone, flow from within the hydrocarbon zone, or flow that is injected into the reservoir during the oil and gas E&P process. Figure 1 depicts a typical hydrocarbon reservoir with oil, gas, and formation water present. As oil and gas is extracted from the reservoir, formation water is extracted with it; this is when formation water becomes produced water. When produced water is brought to the surface, it carries with it dissolved solids and other compounds that may be present in the hydrocarbon reservoir.

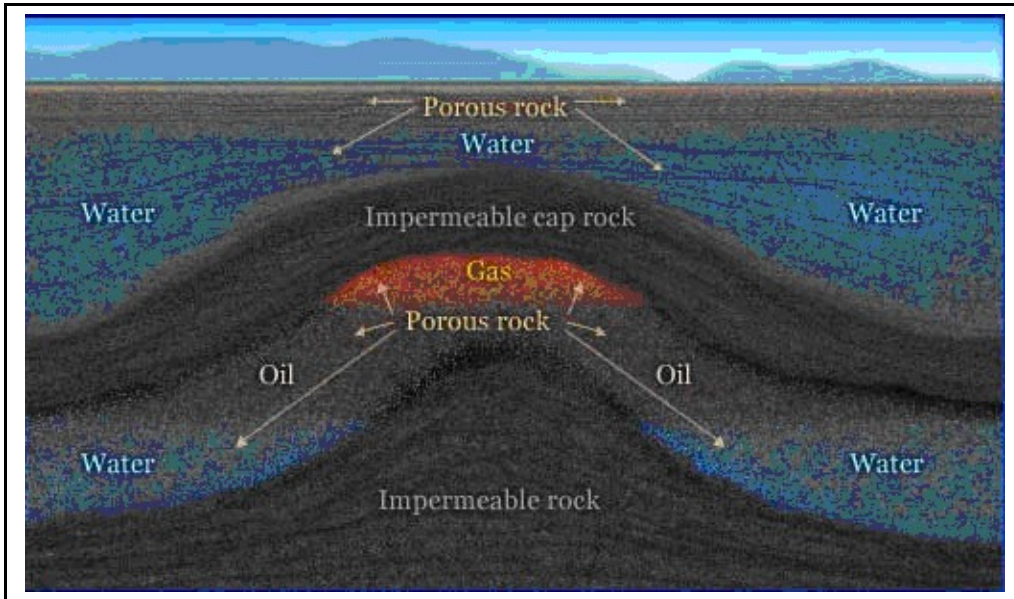


Figure 1. Typical Oil and Gas Reservoir (SEED, 2008).

To maintain the pressure when oil and gas are extracted from the hydrocarbon reservoir, water is injected back into the reservoir as oil and gas are pumped out. Injecting water back into the reservoir also serves the purpose of sweeping the reservoir by forcing the remaining underground oil towards the well. Figure 2 displays an example of how water is injected back into the underground hydrocarbon reservoir. Like formation water, injected water can also flow through the hydrocarbon reservoir and later be extracted as produced water. Injected water often contains chemical additives used in the oil and gas production process. Additives used in the production process include corrosion inhibitors, scale inhibitors, biocides, emulsion breakers and clarifiers, along with many other chemical solvents.

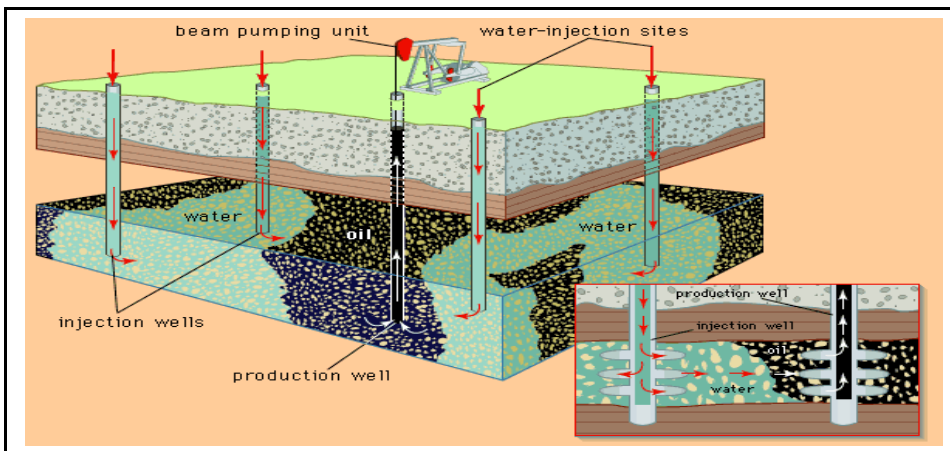


Figure 2. Injecting Water into a Hydrocarbon Reservoir (Caudle, 2009).

As produced water is pumped to the surface, it transports naturally occurring radioactive materials present in the hydrocarbon reservoir. It is well known that both uranium and thorium and their progeny are naturally present in the underground geologic formations of Louisiana from which oil and gas are produced. Uranium and thorium are not very soluble, but their daughter products, radium-226 and radium-228, are soluble in water and become mobilized by formation water (US EPA, 1993b). Thus as formation water is brought to the surface as produced water, radium-226 and radium-228 are brought to the surface as well.

3.1 Discharge Limitations on Produced Water

The US Environmental Protection Agency (EPA) estimates that 10 barrels of produced water are yielded for each barrel of oil that is produced (US EPA, 2008b). Produced waters generated by offshore oil wells in Louisiana are treated and then discharged into Louisiana’s territorial seas. Approximately 3.4 million barrels of produced water are discharged into the Gulf of Mexico each day by offshore oil and gas facilities (Boesch and Rabalais, 1985; Doyle *et al.*, 1994).

In the category of produced water, discharge limitation criteria have not changed between the expired General Permit LAG260000 and its most recent draft revision. Table 1 displays the discharge limitations placed on produced water constituents under Draft General Permit LAG260000 and how often these constituent levels must be monitored.

Table 1. Effluent Limitations and Monitoring Requirements for Discharges of Produced Water in Louisiana Territorial Seas.

Effluent	Discharge Limitation		Monitoring Frequency
	Daily Maximum	Monthly Average	
Flow	-----	-----	Once per Month
Oil and Grease	42 ppm	29 ppm	Once per Month
Toxicity	must show no observable effects for the toxicity endpoint portion of the 7-day chronic toxicity test		Dependent on Critical Dilution Value – Ranges from Once per Month to Once per Year
Benzene	(220.8 ppb / Critical Dilution) * 100	(93 ppb / Critical Dilution) * 100	Dependent on Monthly Average Discharge Value – Ranges from Once per 2 weeks to Once per Quarter
Total Lead	(36.7 ppb / Critical Dilution) * 100	(15.5 ppb / Critical Dilution) * 100	
Total Phenol	(478 ppb / Critical Dilution) * 100	(201 ppb / Critical Dilution) * 100	
Total Thallium	19.6 ppb / Critical Dilution) * 100	(8.3 ppb / Critical Dilution) * 100	
Radium-226	-----	-----	Dependent on Critical Dilution Value – Ranges from Once per Month to Once per Year
Radium-228	-----	-----	

* From Louisiana Department of Environmental Quality Draft NPDES General Permit Number LAG260000

As seen in Table 1, critical dilution is taken into account when determining the maximum allowable amounts of almost all produced water constituents discharged into territorial seas. As produced water is discharged into the open sea, chemical constituents become diluted. Critical dilution factors as defined in the draft permit are functions of the rate at which produced water is released from a discharge pipe, the size of the discharge pipe, and the distance of the discharge pipe from the seafloor. Critical dilution factors were developed for a range of discharge pipes and their distances from the seafloor, and these critical dilution factors are used to determine the allowable produced water daily maximum and monthly average discharges for each individual well operating in the territorial seas of Louisiana.

It should be noted that under Draft NPDES General Permit LAG260000, there is no discharge limitation for radium-226 and radium-228 concentrations in produced waters, or for the total radium released each year. The discharge of these constituents is important because radium-226 and radium-228 are radioactive materials that are known to concentrate in edible marine life and to cause cancer. According to the Draft NPDES General Permit LAG260000, dischargers only have to record their daily and monthly radium-226 and radium-228 discharges, regardless of how high the concentrations may be. If discharging facilities comply with their appropriate radium-226 and radium-228 monitoring schedules for one continuous year, facilities are then only required to monitor for radium-226 and radium-228 once a year, every year thereafter (LDEQ, 1997).

The use of mixing criteria rather than a specific concentration in the effluent or maximum allowable release amounts per year is an important issue. Under the proposed general permit, oil and gas companies are permitted to dispose of any quantity of radium-226 and radium-228 as long as the concentrations are lowered by sufficient mixing once discharged into seawater. Since the proposed general permit allows any number of new wells to be installed without a review of their environmental impacts, large quantities of radium-226 and radium-228 can be released into Louisiana territorial waters. The Louisiana territorial sea is relatively shallow and has a small tidal range, thus there is not much mixing energy available. It is very unlikely that total mixing and sufficient dilution of radium-226 and radium-228 discharged to the territorial sea will occur. That is, radium -226 and radium-228 will accumulate in increased amounts in the marine life consumed by humans.

3.2 Properties of Produced Water

The composition of produced water varies depending on the material with which it is being extracted, that is to say, produced water generated by gas wells differs from produced water generated by oil wells. The largest difference between these types is that produced water from gas wells contains condensed water in addition to formation water. Produced water from gas wells also contains a greater amount of aromatic hydrocarbons than those from oil operations. A study conducted in the North Sea found that produced waters from gas wells also tend to have higher pH and chloride levels than produced

waters from oil wells. Altogether, waters from gas production operations have been found to be about 10 times more toxic than that from oil production operations. (Jacobs *et al.*, 1992)

In general, treated produced water from both oil and gas operations contain hydrocarbons, other organic and inorganic chemicals, dissolved salts, metals, and radioactive materials (Neff, 2002). These compounds are in produced water because they were present in formation water or because they were used as production chemicals during the oil and gas E&P process (Jacobs, *et al.*, 1992). The constituents of produced water from offshore wells can be in a variety of physical states including solution, suspension, emulsion, adsorbed particles, and particulates (Tibbetts *et al.*, 1992). Figure 3 depicts the fate of the constituents of produced water after being discharged into seawater.

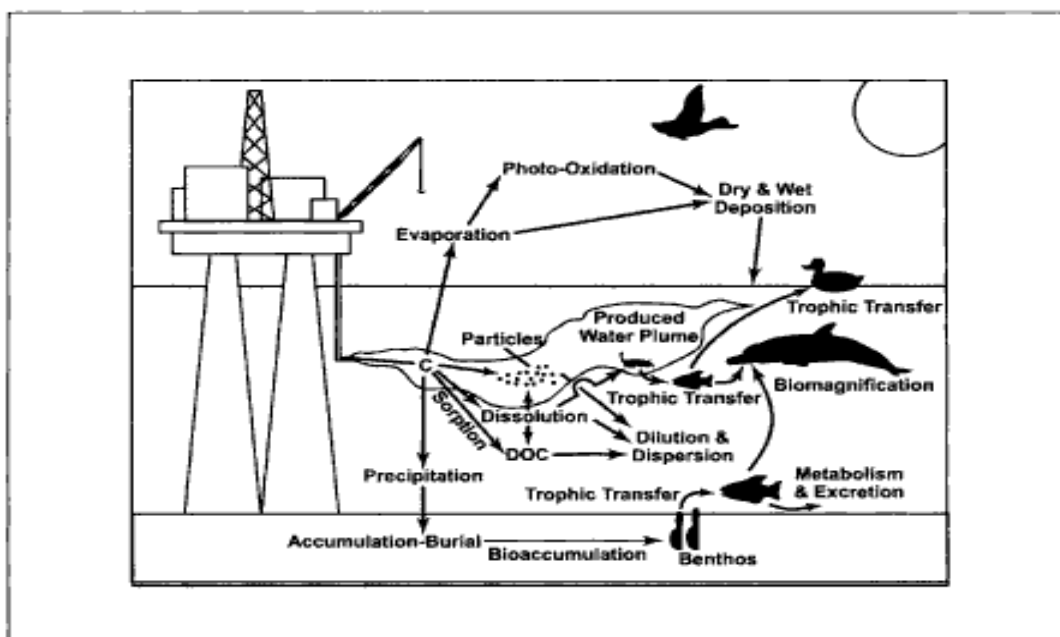


Figure 3. Fate of produced water constituents after being discharged into the sea (Neff, 2002).

3.3 Constituents of Produced Water

There are over fifty individual constituents currently found in produced waters discharged into the Gulf of Mexico. Table 2 displays these constituents and the compound class to which they belong. The following sections of this paper describe the different classes of constituents found in produced waters and the effects they can have on aquatic life in the Gulf of Mexico.

Table 2. Primary Constituents found in Produced Waters Discharged into the Gulf of Mexico.

Oil and Grease	Inorganic Compounds
Organic Compounds	Ammonia
<i>Monocyclic Aromatic Hydrocarbons</i>	Bicarbonates
Benzene	Bromides
Benzoic Acid	Sulfates
Chlorobenzene	Sulfides
Di-n-butyl phthalate	Metals
Ethylbenzene	Aluminum
Isopropylbenzene	Arsenic
n-Propylbenzene	Barium
p-chloro-m-cresol	Boron
Toluene	Cadmium
Total Xylenes	Calcium
1,3,5-Trimethylbenzene	Chloride
1,2,4-Trimethylbenzene	Chromium
2-butanone	Copper
2-4-Dimethylphenol	Iron
<i>Aliphatic Hydrocarbons</i>	Lead
n-alkanes	Manganese
<i>Polycyclic Aromatic Hydrocarbons (PAHs)</i>	Mercury
Acenaphthene	Molybdenum
Anthracene	Nickel
Benzo(a)anthracene	Potassium
Benzo(a)pyrene	Sodium
Crysene	Thallium
Dibenzothiophenes	Titanium
Fluoranthene	Vanadium
Fluorene	Zinc
Naphthalenes	Naturally Occurring Radioactive Material (NORM)
Phenanthrenes	Radium-226
Phenols	Radium-228
Pyrene	

* From Veil *et al.* (2004), Neff (2002), EPA (1993), and St. Pé (1990).

3.3.1 Oil and Grease

The release of oil and grease into the territorial sea of Louisiana can have detrimental effects on the living organisms that inhabit the sea. Oil and grease droplets in produced water are most often 4-6 microns in size, and most produced water treatment systems cannot remove droplets smaller than 10 microns in size (Bansal and Caudle, 1999).

Thus, it is inevitable that some amount of oil and grease in produced water is discharged. Oil and grease can create potentially toxic environments for the ocean's benthic community, or bottom-dwellers, which live and feed on seafloor sediments. Oysters, known to be keystone benthic species, contribute to improved water quality of the ocean and help to provide habitat for an extensive number of marine plants and animals. Oysters depend on reefs and sediment on the ocean floor to live, grow, and spawn, and oil and grease contamination among their substrate prevents oysters from carrying out their ecosystem functions. The economy of Louisiana also depends on oysters and other commercial shellfish that are affected by oil and grease contamination. A decrease in shellfish production or quality in the territorial sea could present serious economic consequences to the State of Louisiana. The Draft NPDES General Permit LAG260000 sets the daily and monthly maximum limits of oil and grease in discharged produced waters as 42 and 29 ppm, respectively, however dischargers are only required to monitor their oil and grease discharges once per month.

3.3.2 Organic Compounds

Organic compounds in produced water are usually discharged into territorial seas because they are highly soluble and cannot easily be removed. Organic compounds are those that primarily contain carbon and hydrogen. Many of the organic compounds found in produced water come from oil and gas reservoirs or from treatment chemicals such as biocides, emulsion breakers, and corrosion inhibitors. The toxicity of the hydrocarbons found in produced water is known to be additive, therefore a combination of hydrocarbons in produced water can provide a severely toxic environment for aquatic life (Glickman, 1998). Some organic compounds can be lethal to aquatic life at levels as low as 0.1 parts per million (ppm), and concentrations of the most soluble organic compounds have been measured to be greater than 5,000 ppm in some produced waters (Ali *et al.*, 1999).

3.3.2.1. *Monocyclic Aromatic Hydrocarbons*

Monocyclic aromatic hydrocarbons are organic compounds that contain a single aromatic ring. An aromatic ring is a linked ring of six carbon atoms, the simplest one being benzene. Aromatic hydrocarbons got their name because most of these compounds are associated with a distinct sweet scent. In aquatic environments, aromatic hydrocarbons are quite possibly the most important contributors to toxicity (Frost *et al.*, 1998). The most abundant group of monocyclic aromatic hydrocarbons found to be present in produced water is a group of volatile organic compounds known as BTEX (benzene, toluene, ethylbenzene, and xylenes). BTEX is acutely toxic to organisms exposed to high concentrations (NRC, 1985; Boesch and Rabalais, 1987), and the components of BTEX are known as probable carcinogens. The US EPA has designated a limitation of 0.369 ppm for BTEX in marine waters (US EPA, 2008a¹), but BTEX has been found in produced waters generated in the Gulf of Mexico at concentrations ranging as high as 600

¹ US EPA Marine Screening Benchmarks for Region 4 were used for comparison to Louisiana territorial seawater because Marine Screening Benchmarks for Region 6 were not available.

ppm (Neff, 2002). In the class of monocyclic aromatic hydrocarbons, the state of Louisiana under Draft NPDES General Permit LAG260000 only monitors produced waters for discharges of benzene. As seen in Table 2, there are thirteen other monocyclic aromatic hydrocarbons, including the remaining components of BTEX (toluene, ethylbenzene, and xylene) that are known to be present in produced waters yet are not monitored before being discharged into the Louisiana territorial sea.

3.3.2.2. *Aliphatic Hydrocarbons*

Aliphatic hydrocarbons are hydrocarbons which do not contain aromatic rings. Aliphatic hydrocarbons found in produced waters in the territorial seas of Louisiana include a group of compounds known as n-alkanes. N-alkanes are a group of single-bonded straight-chained hydrocarbons that includes compounds such as pentane, hexane, heptane, and octane, just to name a few. Most n-alkanes are volatile organic compounds and many have been classified as dangerous to the environment and toxic to aquatic organisms. Like aromatic hydrocarbons, alkanes rapidly bioaccumulate in aquatic organisms (Veil, 1992).

The solubility of n-alkanes tends to decrease as their molecular weights increase, therefore higher weight n-alkanes will not be in solution with produced water. Instead, heavier n-alkanes have been found to exist in produced water in particulate form or in a form similar to oil droplets. As previously discussed, current technology does not allow for the removal of oil droplets from water when oil droplets are smaller than 10 microns in size. Thus, n-alkane droplets smaller than 10 microns will not be removed from produced water before it is discharged to the territorial seas. A study performed on two offshore oil wells in the territorial seas of Louisiana detected 25 different n-alkanes in produced water discharges. The total discharges of all 25 n-alkanes ranged from 606 to 2,680 parts per billion (ppb) (Neff, 2002). N-alkanes, or any other aliphatic hydrocarbon in produced water discharges, are not monitored under the State of Louisiana's Draft NPDES General Permit LAG260000.

3.3.2.3. *Polycyclic Aromatic Hydrocarbons (PAHs)*

Polycyclic aromatic hydrocarbons, or PAHs, are compounds that consist of two or more fused aromatic rings. PAHs are the most toxic and environmentally stable fraction of produced water, and also the most likely constituent of produced water to adsorb to sediment on the seafloor (Rabalias *et al.*, 1991). PAHs are so hazardous because they increase biological oxygen demand², are highly toxic to aquatic organisms, and are known to be carcinogens to humans and animals. All PAHs are mutagenic, meaning that they can change the genetic information of an organism and increase the frequency at which that organism may develop mutations which may contribute to the development of cancer. All PAHs are also known to be harmful to reproduction. Heavy PAHs are not very soluble in water and are therefore very likely to bind to sediment on the seafloor.

² Biological oxygen demand (BOD) is a method of measuring decaying organic matter in a water body. High BOD indicates an abundance of decaying organic matter, which is normally present in polluted waters. Low BOD indicates water of good quality.

Their ability to strongly bind to sediment allows them to persist in the environment for very long periods of time (Danish EPA, 2003).

PAHs have been detected in produced waters at concentrations ranging as high as 3.0 ppm (Neff, 2002). Elevated levels of phenols, anthracene, and naphthalenes have been found to be as high as 0.89 ppb, 0.00056 ppb, and 0.036 ppb, respectively, in coastal Louisiana waters. The US EPA has designated a limit of 0.00018 ppm for anthracene, and a limit of 0.0014 ppm for naphthalenes in marine waters (US EPA, 2008a). It should be noted however, that concentrations in coastal waters are likely to be higher than those in territorial seas due to tidal movement and turbidity which increases mixing and dilution in territorial seas. Another PAH of concern is benzo(a)pyrene. Benzo(a)pyrene is known to readily adsorb to ocean sediment and bioconcentrate in aquatic life such as plankton, oysters, and fish (EPA, 2006). The State of Louisiana does not require that PAHs be monitored under Draft NPDES General Permit LAG260000.

Studies show that oysters have been found to release accumulated hydrocarbons when exposed to contaminant-free water after exposure to water contaminated by hydrocarbons (Somerville et al., 1987; Neff, 1988). Commercial oysters are usually harvested directly and not depurated before being sold. Therefore, oysters, and possibly other shellfish that are consumed could release accumulated hydrocarbons into human bodily fluids after consumption.

3.3.2.4. Phenols

Phenols are organic compounds of major concern because they are estrogenic endocrine disruptors. This means that they have the potential to have detrimental effects on reproduction processes (Frost *et al.*, 1998). The US EPA has designated a limit of 0.058 ppm for phenols in marine waters (US EPA, 2008a). The State of Louisiana under Draft NPDES General Permit LAG260000 requires produced water discharged into the territorial seas to be monitored for total phenols with limits based on dilution equations.

3.3.3 Inorganic Compounds

Inorganic ions control the salinity, or salt concentration, of produced waters discharged into the territorial seas of Louisiana. When positively and negatively charged inorganic ions are neutralized by other ions present in produced water they form salts, therefore increasing the salinity of the produced water. The major inorganic ions present in Gulf Coast produced waters are sodium, calcium, magnesium, chlorides, bromides, bicarbonates, and sulfates. When in ionic form, many of the metals listed in Table 2 will also react with other ions to form salts in produced water. In Gulf Coast produced waters, sodium is the most abundant positively charged inorganic ion, and chloride is the most abundant negatively charged inorganic ion (Collins, 1967). Sodium chloride accounts for seventy-three percent of all dissolved salts in produced water (Reid, 1961; Collins, 1967).

The salinity of produced water is an important factor to be considered because salinity determines how the plume of discharged produced water will disperse in the sea. If the salinity of produced water is greater than that of seawater, the produced water will be denser and sink to the seafloor. A study conducted in the Gulf of Mexico released flourocene dye at a produced water outfall of an offshore production platform and observed the plume to move to the bottom of the sea (Steimle and Associates, Inc., 1992). The dispersal of produced water among the sediment of the seafloor could poison and kill the benthic community that inhabits it. Benthic organisms are a major food source for larger aquatic life.

The salinity of seawater is normally about 35 parts per thousand (‰) (Reid, 1961). Most produced waters generated from Gulf Coast offshore oil and gas wells have salinities greater than that of seawater (St. Pé, 1990). The salinity of produced waters has been measured as high as 300 ‰ (Rittenhouse, *et al.*, 1969), and produced waters associated with Louisiana oil reserves usually range from 50 to 150 ‰ (Hanor *et al.*, 1986). The usual salinity range of Louisiana produced waters is greater than that of the average open seawater, and therefore most produced waters from offshore wells in Louisiana pose a threat to the benthic communities that inhabit the seafloors of the territorial seas adjacent to the discharge outfall.

Sulfates, inorganic salts of sulfuric acid, are commonly found in produced waters. Sulfates are important constituents of produced waters because they control the solubility, and thus the concentrations, of other constituents in produced water. Sulfides, another group of inorganic compounds, may be formed by the bacterial reduction of sulfates in produced waters that contain no oxygen (Neff, 2002). Sulfides are highly toxic, and hydrogen sulfide, one of the most toxic forms of sulfide, has been detected in produced waters at concentrations as high as 1,000 ppm (Kochelek and Stone, 1989). The EPA recommends a hydrogen sulfide limit of 0.002 ppm in marine waters (US EPA, 2008a). Ammonia, another highly toxic inorganic compound is not usually detected in produced waters, but when it was detected, concentrations were found to be as high as 650 ppm. The EPA designated a limit of 0.005 ppm for ammonia in marine water (US EPA, 2008a).

Similar to all of the other organic and inorganic compounds found in produced waters, high concentrations of salinity may contribute directly to the toxicity of the produced water. Many marine species, such as the shrimp, *Mysidopsis bahia*, only have saline tolerances of around 35‰ (Sauer *et al.*, 1997). An increase in produced water salinity due to an abundance of inorganic ions can provide a toxic, if not lethal, environment for certain marine organisms. Elevated levels of salinity have also been found to mask other potential toxicants in produced water. A study performed on produced waters sampled in Louisiana, Texas, California, and Wyoming found that the samples of produced water with higher salinities concealed other toxicants present in the samples (Sauer *et al.*, 1997). Increased salinity in produced waters may prevent scientists and researchers from detecting other hazardous toxic constituents present in produced water, thus preventing the drafting of regulations to limit these constituents in produced water discharges.

The Draft NPDES General Permit LAG260000 does not require produced water dischargers to monitor for any of the inorganic compounds discussed above. In regard to what the Draft NPDES General Permit LAG260000 does require dischargers to monitor, only seawater is considered and not seafloor sediment. Studies have shown that relying on only seawater salinity readings might result in the false conclusion that produced water quickly disperses in seawater after it is discharged (St Pé, 1990). As previously discussed, high levels of salinity cause produced waters to sink to the seafloor when discharged into the open sea. Chloride from produced water has been found in highly elevated levels in sediment while overlying water in the same location contained no detectable measures of chloride. This suggests that any dilution that might occur when produced water is discharged into the open sea may be insufficient to completely reduce the salinity difference between produced water and seawater (St. Pé, 1990). In a study conducted in Louisiana coastal waters, produced water was shown to penetrate at least 30 centimeters into seafloor sediment, and sediments were affected much further from the discharge pipe than was the overlying water (St. Pé, 1990).

3.3.4 Metals

There are about twenty different metals that have been discovered in produced waters discharged into the territorial seas of Louisiana. Metal concentrations in produced waters are often measured to be higher than metal concentrations in seawater, and elevated concentrations of metals are known to be toxic to aquatic life (Neff, 2002). When metals in anoxic produced water come in contact with oxygenated seawater, most precipitate out of produced water and rapidly settle on the seafloor. Once metals form a precipitate and are no longer dissolved in water, dilution has no effect on making metals less toxic to aquatic organisms. It has been found that metals in particulate form are generally more toxic than the metals that remain dissolved in water. Metal particles settled on the seafloor pose a direct threat to the benthic community of the Louisiana territorial seas. Tidal movement across the seafloor can also stir up sediment, therefore releasing fluxes of precipitated metals into seawater for other aquatic organisms such as fish to ingest. Metal precipitates are also known to adsorb onto oil droplets and rise to the surface of the sea. (Azetsu-Scott *et al.*, 2007)

Aquatic organisms that ingest contaminated seawater or sediment can accumulate highly toxic levels of metals within their bodies. The most frequently present metals at elevated concentrations in produced waters generated in the Gulf of Mexico are arsenic, barium, iron, lead, manganese, and zinc (Neff *et al.*, 1987). Metals that are known to accumulate in aquatic animals and/or aquatic plants are aluminum, arsenic, barium, cadmium, mercury, thallium, vanadium, and zinc (ATSDR, 2007). Concentrations of arsenic, lead, mercury, and zinc measured in produced waters generated in the Gulf of Mexico have been found to exceed marine water limitations set forth by the EPA. The EPA marine regulation limits for arsenic, lead, mercury, and zinc are 12.5, 8.1, 0.016, and 81 ppb, respectively (US EPA, 2008a). Concentrations of arsenic, lead, mercury, and zinc from produced waters generated in the Gulf of Mexico were recorded at levels as high as 31,

28, 0.2, and 3,600 ppb, respectively (Neff, 2002). Produced waters discharged into coastal waters of Louisiana contained arsenic levels as high as 87 ppb (St. Pé, 1990). Of all the known metal constituents found in produced waters, the state of Louisiana under Draft NPDES General Permit LAG260000 only requires discharging facilities to monitor their produced waters for lead and thallium.

3.3.5 Naturally Occurring Radioactive Materials (NORM)

As previously discussed, produced waters generated from oil and gas wells in Louisiana can contain a range of radium concentrations. From a health perspective, radium-226 and radium-228 are of greatest concern. Radium-226 is an alpha-emitting decay product of uranium-238 and uranium-234, and radium-228 is a beta-emitting daughter of thorium-232.

The Gulf of Mexico is an important producer of fish and shellfish, and there is a large concern that produced waters that contain radium could contaminate the fish and shellfish consumed by humans. Radium (the total of radium-226 and radium-228 combined) is known to bioaccumulate in food organisms. This means that food organisms, or organisms humans and other animals eat, take up radium at a faster rate than that at which it is lost from their bodies. Due to this uptake process, food organisms may concentrate high levels of radium within the tissues and shells or bones of their bodies. If aquatic organisms such as fish and shellfish accumulate radium in their bodies, humans that eat fish and shellfish will be exposed to elevated levels of radium. An increased uptake of radium in humans may lead to a significant increase in the risk of developing cancer, as well as other non-carcinogenic effects.

Millions of gallons of produced water carrying NORM contamination are discharged into the waters off the coast of Louisiana every year (St. Pé, 1990). The State of Louisiana currently does not have any regulation on radium concentrations in produced waters, nor does it suggest a specific discharge limitation on radium concentrations in produced water in its Draft NPDES General Permit LAG260000. Rather than establishing discharge limitation guidelines for concentrations of radium-226 and radium-228, a mixing theory was adopted based on the CORMIX Mixing Zone Model. With this model, the oil industry was able to show that radium concentrations in discharged produced waters could be reduced to nonhazardous concentrations by dilution in seawater. The CORMIX model determines allowable discharge concentrations of radium-226 and radium-228 in produced water, based on the flow rate, size, and distance from the seafloor of the discharge pipe. Studies have shown, however, that elevated concentrations of radium are still accumulating in the water column, sea floor sediment, and aquatic biota even when CORMIX critical dilution factors were taken into account.

Hazardous concentrations of radium have been specified by federal agencies. The US EPA under the Resource Conservation and Recovery Act of 1976 states that concentrations of radium greater than 50 pCi/L be considered hazardous wastes (LDEQ, 1989). The Nuclear Regulatory Commission (NRC) and the state of Louisiana under the

Louisiana Radiation Regulations prohibits the discharge of all radium-226 contaminated liquids with activities greater than 60 pCi/L from licensed nuclear facilities to unrestricted areas (LDEQ, 2005). Normal open sea activity of radium-226 has concentrations of about 0.05 pCi/L (Holt *et al.*, 1982).

Numerous studies conducted in the Gulf of Mexico have found concentrations of radium in produced waters that greatly surpass the regulatory limits set forth by the US EPA and the NRC. One study found that radium-226 concentrations in produced waters generated in Louisiana ranged from 0 to 930 pCi/L with an average concentration of 159.2 pCi/L. Radium-228 concentrations were found to vary from 0 to 928 pCi/L, with an average concentration of 164.5 pCi/L (Hamilton *et al.*, 1992). A study by the American Petroleum Institute found slightly lower Ra-228 concentrations in produced water, concentrations ranging from 255 pCi/L to 265 pCi/L (Continental Shelf Associates, Inc., 1992). Another study performed on produced waters generated by offshore wells in Louisiana found radium-226 and radium-228 concentrations to reach as high as 1,565 pCi/L and 1,509 pCi/L, respectively (Neff, 2002). A study conducted by St. Pé in Louisiana coastal waters found radium-226 concentrations in produced waters to range from 355 pCi/L to 567 pCi/L (St. Pé, 1990)³. The lowest activity level found in this study, 355 pCi/L, was 7100 times greater than the radium activity found in open seawater, and seven times greater than the radium limit regulated by the US EPA.

Another study of forty-one samples of produced water in the Gulf of Mexico region found radium-226 and radium-228 activity present in all of the forty-one produced water samples collected during the study. Of these forty-one samples, seventy-six percent contained at least 50 pCi/L of radium, and activity among these samples ranged from 19 to 2800 pCi/L (Kraemer and Reid, 1984). A study in 1991 found that the total radium activities observed in Louisiana produced waters were approximately 150 to 1150 times greater than radium activities in natural waters (Rabalais *et al.*, 1991). Several other radionuclides have been found to be present in produced waters discharged into territorial seas, but the activities of these radionuclides are much lower than those of radium. These radionuclides include but are not limited to strontium-89, strontium-90, bismuth-212, bismuth-214, actinium-228, lead-210, lead-212, and lead-214 (Van Hattum *et al.*, 1992).

Like salts, radium-226 has been found to accumulate in seafloor sediments when discharged into seawater. High levels of radium ranging from 182 pCi/g to 533 pCi/g⁴ were measured in the top ten centimeters of coastal water sediments in Louisiana (St. Pé, 1990). Although only the top ten centimeters of sediment were measured, there was evidence suggesting that radium-226 contamination in sediment near the mouth of produced water discharge pipes may increase with depth. In some locations in coastal

^{3 & 4} It should be noted that these measurements were taken in coastal waters, and not territorial sea waters. Radium concentrations in territorial sea sediments would most likely be lower than those of coastal waters because increased tidal movement will dilute some of the radium in produced waters before it settles in sediments on the seafloor of territorial seas.

Louisiana waters, radium activities from produced waters greater than 5 pCi/g were found up to 500 meters from the discharge point (St. Pé, 1990).

4. Toxicity of Produced Water on Aquatic Organisms

The discharge of produced waters to the oceans has been recognized in Canada as an emerging environmental issue, and an integrated risk assessment approach has been developed in one study based upon the Princeton Ocean Model, a Random Walk, and Monte Carlo simulation (Zhao, Chen, and Lee, 2008). Research on the effects of produced waters has primarily focused on coastal areas, and thus little information has been produced on effects in the section of the ocean closest to land, where the territorial seas occur.

The impacts from produced water discharges depend upon many factors including instantaneous and long-term precipitation, adsorption to particulate matter, physical-chemical reactions with other chemical species, dilution, volatilization, and biodegradation (Veil et al, 2004). While dilution occurs further out in the open ocean, much of the territorial seas are in more shallow near shore areas and thus do not have the degree of dilution that are present further offshore.

4.1 Bioaccumulation and Toxicity

Bioaccumulation occurs when an organism takes in a greater amount of a contaminant than it excretes. Over time the organism may build up greater and greater amounts of a contaminant as it is stored within the body. Bioaccumulation allows for contaminants to enter the food web and biomagnify as they enter higher trophic levels.

The toxicity of contaminants is dependent on many factors and varies between species. Exposure can be acute (short-term) or chronic (long-term). The bioaccumulation and toxicity of contaminants from produced waters in several types of marine organisms is discussed below.

In 1986 Harper reviewed a great deal of unpublished literature and determined that the effects from produced water were dependent on the volume and flow rates in receiving water and the quantity of produced water discharged. Elevated salinity, hydrocarbon contamination, and effected biotic communities were found kilometers downstream in coastal streams not tidally influenced. In tidally influenced environments the detrimental effects tended to be limited to 100-200 meters from the discharge (Harper, 1986).

Two studies performed in the Gulf of Mexico observed a general trend among sediment within the vicinity of offshore production platforms. The observed trend was that sediment near the discharge source consisted of high sand and gravel content, while finer-grained sediments such as silts and clays occurred at distances farther away from the platform (Middleditch, 1981 & Continental Shelf Associates, Inc., 1992). Naturally, coarser sediments, such as sand and gravel, will not be suspended in the water column.

However, finer, lighter sediments, such as silts and clays, can be carried through the water column by the movement of a discharge plume. This results in the transport of contaminated sediment to distances as far as 200 meters from a discharge source. A study conducted for the American Petroleum Institute found that concentrations of produced water constituents in sediment increased with increased distance from the discharge point (Continental Shelf Associates, Inc., 1992).

4.1.1 *Macro Invertebrates*

Various research projects have established that the contaminants from produced water discharges can harm macro invertebrates. Since there are many factors in the areas around produced water discharges it has been difficult to establish in field or laboratory studies that capture the precise effect of produced waters on the environment and marine life.

Research associated with the GOOMEX project found a reduction of genetic diversity in meiobenthic copepods in close proximity to production platforms (Fleeger et al, 2001). Negative impacts to benthic communities have been observed at distances up to 800 meters from produced water discharge locations. The benthic community at an abandoned discharge site demonstrated continued detrimental effects three years. Various research projects have established that the contaminants from produced water discharge can harm macro invertebrates. Since there are many factors in the areas around produced water discharges it has been difficult to establish in field or laboratory studies the precise effect of produced waters on the environment and marine life.

following the cessation of discharge (Rabalais et al, 1992). Depressed densities of infauna, aquatic benthic organisms living in the bottom strata, have been observed as far as one kilometer from a platform discharge in the Galveston Bay (Osenberg et al, 1992). This area was shallow and turbid; in most territorial waters a greater degree of dilution would occur, although contaminants would still accumulate in the sediment.

The study by Osenberg et al evaluated the biological impacts from discharge of produced waters in the high energy coastal environment of Southern California. In this case, discharge comes from onshore, travels through a pipe several hundred meters, and is released into the water. This scenario is similar to the territorial seas because it is a high energy open coast environment, although it somewhat sheltered by the northern Channel Islands. The surf is 1-2 meters, with seasonal variation. The calculated minimal dilution for this pipe is 125:1. The results from this study found that impacts to the infauna appeared to be primarily limited to the 50-100 meters closest to the outfall. Nematodes were more abundant near the outfall (Osenberg et al, 1992). This is indicative of effects from the discharge of produced water as nematodes respond well to organic enrichment in sediments from oil and sewage contamination.

The St. Pe study evaluated the effects of produced water on *hyalella azteca*, an amphipod. One of the samples with the amphipods demonstrated high mortality in a 10 day study. This sample had the highest salinity and chloride levels and thus the toxicity may have been due to that (St. Pe, 1990).

4.1.2 Mollusks

Mollusks are invertebrates with soft un-segmented bodies fully enclosed in a shell. Examples of mollusks within this section include abalone (edible sea snails), mussels, and oysters.

An early study on oil pollution and oysters in 1935 found that oil pollution and "bleed water" pollution are detrimental to oysters because they decrease the feeding activity of oysters and by inhibiting the production of diatoms which make up a large portion of the oyster diet (Montgomery, 1946).

One study was conducted in Southern California by an outfall in a mostly open high-energy coastal area found a decrease in the performance of abalone larvae associated with exposure to the produced water. The abalone larvae demonstrated reductions in survival, settlement, and metamorphosis with increased proximity to the outfall. This study also found that when the outfall was not active for 10 days and no produced water was discharged that these effects disappeared (Ray and Engelhardt, 1992). This study did not include information about the bioaccumulation of contaminants in the abalone.

A study by Osenberg et al. found that mussels near the same outfall discussed in the preceding paragraph grew more slowly and had lower tissue weights than mussels further from the outfall (Osenberg et al., 1992). Another study on California mussel larvae found that exposure to barium (as barium acetate) led to consistent abnormal shell development and larvae morphology. This result suggests that calcification during the larval stage is sensitive to the presence of elevated levels of barium (Spangenberg and Cherr, 1996).

In the Somerville et al study mussels were placed 0, 6, 10, 25, and 60 meters from a produced water outfall in the open sea for a 10 to 16 week period. Hydrocarbon concentrations which accumulated in the mussels at the outfall were 60 to 100 times higher than in the unexposed controls, 6 to 10 times higher than the controls at 6 meters, and were consistent with the control levels at 10 meters (Somerville et al., 1987).

In the Jeffree and Simpson study on uranium mill tailings freshwater mussels were found to accumulate a dry weight tissue mean concentration of 679 pCi/g Ra-226 when exposed to a water concentration of 50 pCi/L of Ra-226 for 56 days. This study also found that freshwater mussels retained the Ra-226 when placed in radium free water for 286 days (Jeffree and Simpson, 1986).

Oysters are an important commercial product in Louisiana as well as being a useful indicator of water quality. Several studies have assessed the effects to oysters from produced waters in the Gulf region.

The 1990 St. Pe study evaluated the accumulation of VOCs, PAHs, and Ra-226 in caged oysters near three produced water discharges and one reference site in coastal Louisiana. The oysters were left in cages for 30 days with exposure to both the water column and sediment. The amount of oyster tissue available for analysis was dependent on the number of oysters still alive in the cages at the end of 30 days. In one of the locations no oysters died, one location had 64% mortality with only 27 of 75 surviving, while the fourth had 7% mortality with 70 of 75 surviving. At the reference location all of the oysters survived. Benzene was detected in the oysters at two of the locations and toluene and ethyl benzene were detected at all three locations, and no volatiles were detected at the reference location. The total volatile concentrations ranged from 0.003-0.372 µg/g. Only trace amounts of PAHs were detected at the reference location, while the other three locations had total PAH concentrations of 0.022-0.28 µg/g. Radium-226 was detected in one location at 3.1 pCi/g wet weight (distance of 110 meters from the outfall). The other two locations and the reference location had Ra-226 concentrations below the detection limit. The site with the highest mortality was also the site with the highest levels of PAHs accumulated in the oysters, although it did not have the highest levels of VOCs or Ra-226. This study demonstrates that oysters can accumulate VOCs, PAHs, and Ra-226 in a relatively short time near produced water discharge locations. It was not clear to the researchers whether the Ra-226 that accumulated in the oysters were from the water column or sediments.

In a study by Rabalais et al. American oysters were deployed in cages at various distances from produced water discharges in the coastal area of Louisiana. The oysters were deployed in water depths of 1-2 meters approximately 0.1 meters above the sediment. Oysters in two of the locations accumulated significant levels of PAHs and total hydrocarbons above background levels. A second deployment of oysters was conducted which found lower uptake. The lowered uptake is thought to be due to seasonal variation and reproductive conditions of the oysters. Radium activity above the detection limit was observed in four of 14 samples analyzed; the four detections, ranging from below the detection limit to 4.3 dpm/g (1.94 pCi/g), were found adjacent to a discharge and 200 meters from a discharge location (Rabalais et al., 1992). It is not stated within the study whether the measured concentration pertained to whole body or just the soft tissue of the oysters. It is assumed that only the tissue was tested, although the shells of oysters would likely accumulate more radium than the soft edible parts.

One study in coastal Louisiana found that a whole bicolor purse oyster had a concentration of 0.1 pCi/g of Ra-226 and <0.8 pCi/g of Ra-228, while one whole scissor datemussel had a concentration of 0.2 pCi/g of Ra-226 and <0.8 pCi/g of Ra-228, and one whole transverse ark clam had a concentration of 0.1 pCi/g of Ra-226 and 1.9 pCi/g of Ra-228. (Milino and Rayle, 1992)

American oysters are bottom dwelling filter feeders which burrow into the sediment in the benthic zone. Hydrocarbons sorb to sediment and are bioavailable to bottom feeders leading to their introduction into the aquatic food web. Oysters in one study were exposed to four dilutions of contaminated estuarine sediment from Pass Fourchon in Louisiana, containing 0%, 12.5%, 25%, and 50% contaminated sediment. The contaminated sediment had a concentration of 52 mg/kg total petroleum aromatic hydrocarbons. This study found that the sediment bound contaminants associated with produced water discharges are bioavailable to filter feeders such as oysters. Accumulation occurred as quickly as within three days and petroleum aromatic hydrocarbons increased with a dose and time dependent relationship. Significant mortality was noted at the two highest dose rates; these mortalities occurred at the higher dose levels and appeared to be due to the compromised physiological state of the oysters from contaminant exposure (Winston and Means, 1995). This study found that hydrocarbons can rapidly enter the aquatic food web and cause adverse impacts.

In the Boesch and Rabalais study, in areas in close proximity to produced water discharge in coastal Louisiana, PAHs have been detected at concentrations of 0.24-3.4 $\mu\text{g/g}$ in oysters and 0.015-0.88 $\mu\text{g/g}$ in ribbed mussels. Total saturated hydrocarbons were detected in the tissue of oysters at concentrations of 68-550 $\mu\text{g/g}$ and in ribbed mussels at concentrations of 33-180 $\mu\text{g/g}$ (Boesch and Rabalais, 1989).

Several factors can affect the uptake of radium in aquatic organisms. Calcium ions in water can reduce radium uptake. Small increases in temperature led to increased biological activity and thus the uptake and excretion of radionuclides. In a study on shellfish, one study found that the primary factors affecting concentration factors were salinity and temperature (Meinhold and Hamilton, 1992). Radium accumulates in marine organisms. It concentrates in bone, shell, and exoskeletons due to its similarity to calcium. It has been determined that oysters can accumulate radium-226 in a linear manner from produced water containing radium at levels which were much lower than those measured in the coastal waters of Louisiana (Jeffrey and Simpson, 1986).

4.1.3 Crustaceans

Crustaceans are primarily aquatic organisms including animals such as barnacles, crabs, lobsters, and shrimp. One study has looked at the concentrations of contaminants detected in barnacles and crabs in coastal Louisiana.

The St. Pe study evaluated the effects of produced water on opossum shrimp. The opossum shrimp experienced acute toxicity in the four samples tested. The salinity levels and the effects did not follow a pattern, and so salinity did not appear to be the primary cause of toxicity (St. Pe, 1990).

This study found that whole barnacles had concentrations of 0.2-0.8 pCi/g of Ra-226 and <0.9-1.3 pCi/g of Ra-228. The hard parts of barnacles had concentrations of non-detect - 0.7 pCi/g of Ra-226 and non-detect-3.7 pCi/g of Ra-228. The soft parts of barnacles had

concentrations of non-detect-0.4 pCi/g for Ra-226 and non-detect-1.3 pCi/g for Ra-228. Whole stone crabs had concentrations of non-detect-1.3 pCi/g of Ra-226 and non-detect-2.0 of Ra-228. This study demonstrates that radium does concentrate in the hard calcified parts of aquatic life. These data also found that the concentrations of Ra-226 in sediment are highest in closer proximity to discharges, particularly within 20 meters (Milino and Rayle, 1992).

An American Petroleum Institute study detected concentrations of Ra-226 and Ra-228 in samples of spider crab shells collected at distances of 0, 50, and 100 meters from the discharge point of an offshore production platform (Continental Shelf Associates, Inc., 1992). In another American Petroleum Institute study, the maximum tissue concentration of Ra-226 in crabs located on one of the platform legs at a depth of 9 meters was 1.3 ± 0.3 pCi/g. The maximum Ra-228 tissue concentration was 3.7 ± 1.2 pCi/g (Steimle and Associates, Inc., 1992).

4.1.4 Fish

In one study in the coastal waters of Louisiana, whole crested blennys, a type of fish, did not have detections of Ra-226 and had concentrations of non-detect-2.7 pCi/g of Ra-228 (Milino and Rayle, 1992).

A study performed at two offshore production platforms in the Northern Gulf of Mexico detected measurable levels of Ra-228 in two species of mid-water fish in the vicinity of the platforms: the red snapper, *Lutjanus campechanus* and the bluefish, *Pomatomus saltatrix*. Ra-228 was detectable in all three tissue types, the skin, fillet, and bone, of the red snapper. Ra-228 was detected in the skin tissue of the blue fish. In the same study, Ra-228 was also detected in two specimens of catfish collected 100 and 300 meters from the discharge point of an offshore platform. (Continental Shelf Associates, Inc., 1992)

The St. Pe study evaluated the effects of produced water on sheepshead minnows. The minnows also experienced acute toxicity in the four samples tested. Salinity did not appear to be the cause of toxicity in the minnows either (St. Pe, 1990).

4.1.5 Other Marine Life

Sea urchins were found to have decreased reproductively in areas closest to produced water discharge sites in an area sampled along 1 kilometer from an active produced water outfall (Krause, 1995). Migrant shorebirds have been found to have accumulated high levels of heavy metals and PAHs while wintering in the area of produced water discharges (Roach et al, 1993).

4.2 Human Consumption

We briefly evaluated the potential risk to humans consuming seafood contaminated by produced water. This analysis is presented below.

$$Dose \left(\frac{mrem}{yr} \right) = Shellfish \text{ Ingestion Rate} \left(\frac{g}{day} \right) \times Time \left(\frac{days}{yr} \right) \times Shellfish \text{ Concentration}_{Ra-226} \left(\frac{pCi}{g} \right) \times DCF_{Ra-226} \left(\frac{mrem}{pCi} \right)$$

Where:

Shellfish Ingestion Rate = 2.00-74.2 g/day⁵

Time = 365 days/year

Shellfish Concentration_{Ra-226} = 3.1 pCi/g⁶

DCF_{Ra-226} = 1.32E-03 mrem/pCi (3.58E-07 Sv/Bq)⁷

The results of this calculation result in a dose to a human from shellfish consumption are 3 to 111 mrem/yr. If we assume the 5,900 g/yr used in Meinhold and Hamilton for the maximum consumption of mollusks by adults in the West South Central Region of the US (Arkansas, Louisiana, Oklahoma, and Texas) than the resulting dose is 24 mrem/yr. By means of comparison, the EPA recommends that radiation exposure not exceed 10 mrem/yr while the NRC requires that radiation exposure from a closed facility not exceed 25 mrem/yr. It should be noted that the EPA recommendation does not pertain specifically to this case as the exposure limit of 10 mrem/yr is put forth by the Clean Water Act which is not pertinent to territorial seas. Nonetheless, an exposure to 10 mrem/yr or greater could very well be hazardous to human health. There is some potential for exposure to seafood contaminated by produced waters to exceed these values. Without studies on marine life specifically in the territorial seas we do not have precise data to use on the activity in oysters in that region. We use an activity from the coastal area as it was taken in one of the most thorough studies to date on produced waters.

5. Discharges Other than Produced Water

Although produced water discharges are the largest contributors of toxicants to the territorial seas, they are not the only toxic wastes generated by the oil and gas E&P process. Discharges of deck drainage contain remnants of oil and grease and toxic contaminants spilled or leaked on oil and gas well platforms. Well treatment, completion, and workover fluids contain oil and grease, radium-226 and radium-228, and trace amounts of the 126 priority pollutants. Sanitary waste discharges contains fecal coliform and floating solids and can change the pH of seawater. Domestic waste, such as materials discharged from galleys, sinks, showers, eye wash stations, and laundries, can contain chemical compounds toxic to aquatic life. Hydrostatic test water is known to contain BTEX, lead, and oil and grease. Draft NPDES General Permit LAG260000 set the daily maximum limitation of total BTEX concentrations in hydrostatic test water at 250 ppb. As previously discussed, BTEX concentrations have been found in produced waters as high as 600,000 ppb. Miscellaneous discharges of wastewaters and seawater and freshwater that have been chemically treated contain treatment chemicals and oil and grease.

⁵ ATSDR, 2004

⁶ St. Pe, 1990

⁷ ICRP-30

6. Changes from Original NPDES General Permit LAG260000

Several changes have been made between the proposed NPDES General Permit LAG260000 and its original version that expired in 2002. Draft NPDES General Permit LAG260000 incorporates a revised Notice of Intent (NOI) that streamlines the permitting process by issuing a new general permit to specific sites instead of individual operators. Each specific site can then institute a number of new wells without having to obtain a new permit through a simple NOI to the LDEQ.

Allowing specific sites to establish an unregulated number of new wells without having to first obtain the approval of LDEQ have the potential to result in harmful environmental impacts. The implementation of a NOI does not require that an environmental review of a new well and its associated discharges be conducted before it is put into operation. Environmental impacts are driven by the total quantities of waste discharged; an unspecified number of wells in a general area will lead to an unknown total quantity of discharges. Discharges from a number of wells within close proximity to each other will have hazardous cumulative effects on aquatic biota.

The proposed NPDES General Permit LAG260000 incorporates a conditional Stormwater Pollution Prevent Plan requirement to those facilities that have had a reportable quantity release of oil or a hazardous substance in stormwater⁸. Draft NPDES General Permit LAG260000 also incorporates washing prohibitions and best management practices (BMPs) for washdown wastewaters for the outfall category of deck drainage, and additional BMPs for spill prevention and control measurement plans have been added to the permit as well.

Other changes to the proposed NPDES General Permit LAG260000 include adding a flow parameter to be measured in millions of gallons per day (MGD) to all discharge types. This parameter was not required in the original NPDES General Permit LAG260000. The monthly average limitation on every effluent parameter for sanitary waste discharges has been changed to a weekly average and the daily maximum limitation has been removed.

The discharge of hydrostatic test water has been added to the permit as Outfall Category 6. This discharge type was not included in the original NPDES General Permit LAG260000, but it has since been recognized that hydrostatic test water is a commonly discharged byproduct of well installation and repair processes and therefore should be regulated under this permit. The limitations and monitoring frequencies assigned to hydrostatic test waters are based on limits issued by LDEQ on September 19, 2007. A reporting requirements for hydrostatic test water has been incorporated into the proposed NPDES General Permit LAG260000 as well.

⁸ See 40 CFR 110.6 and 40 CFR 302.6 for definition of reportable quantity release in stormwater.

Language not included in the original NPDES General Permit LAG260000 has been added to the proposed General Permit to address specific conditions of the permit. Such conditions include coverage under subsequent permits, termination of authorization to discharge, state water quality standards, and combined outfalls. A permit reopener clause has also been added to the general permit.

Discharge monitoring report (DMR) submittal schedule has been changed from an annual submittal to a quarterly submittal, designed to identify habitual non-compliant facilities. With the change in DMR submittal, operators will be allowed to submit a list of outfalls that had no discharge in lieu of submitting DMRs for those outfalls whose discharges do not occur at a certain time of the oil and gas E&P process.

7. Criticisms of NPDES General Permit LAG 260000

The State of Louisiana and the US EPA failed to produce an Environmental Impact Statement before revising expired NPDES General Permit LAG260000. LDEQ anticipates that 150 new wells will be constructed in the territorial seas of Louisiana under the revised general permit, in addition to the existing 118. Effects of produced water discharges on marine life and endangered species were not reevaluated, nor were the cumulative environmental effects of 150 additional new produced water discharges prior to revising NPDES General Permit LAG260000. A draft EIS was produced by the EPA in 1996, but it has so far not been released to the general public.

Cumulative affects of produced water discharges are not accounted for when preparing the Draft NPDES General Permit LAG260000. Organisms can accumulate elevated levels of toxicants, such as PAHs, radium, and metals in their body tissues and exoskeletons. Toxicant concentrations in produced waters discharged from each well, accounting for mixing, could comply with the discharge limitations put forth by NPDES General Permit LAG 260000, but the total quantity of toxicants discharged into the water column and seafloor sediments will be much larger, and the concentrations accumulated in aquatic organisms such as oysters or other shellfish will likely increase over time. Edible marine sea life, such as oysters have shown to accumulate PAHs, VOCs, and radium. Discharging produced waters in the vicinity of marine life directly increases human uptake of PAHs, VOCs, and radium accumulating in the territorial seas. The cumulative effects have simply not been evaluated.

The produced water discharge limitation of 1,300 feet from any active oyster lease, live natural oyster or other molluscan reef, designated oyster seed bed, or sea grass bed may not be a sufficient distance depending on the number of facilities which surround the oyster bed. If facilities surround a molluscan habitat so that a ring of facilities with a radius of 1,300 feet around the habitat results, the cumulative effects from all of those produced water discharges will be detrimental to that population of mollusks. There is no regulation in Draft NPDES General Permit LAG260000 that limits the number of facilities that are allowed to operate around oyster or other ecologically sensitive habitats.

Draft NPDES General Permit LAG260000 does not require that each individual well operate under its own NPDES permit, but only that each operating facility obtains one permit for all of its wells. Therefore, permittees can add a number of wells to its facility without having to apply for an additional NPDES General Permit for each well constructed. This means that any number of wells can be added to an area without assessing the cumulative harm presented to the surrounding environment. As previously discussed, while an individual well must be located 1300 feet from an oyster bed, under the proposed general permit there could be a large number of wells at 1300 feet from the oyster bed, creating a hazardous condition. Hazardous environmental impacts are not driven by just one source of discharge, or how well the discharge is mixed, but by the cumulative quantity of waste discharged from many sources.

There are over fifty individual constituents found in produced waters discharged into the Gulf of Mexico, yet only a small fraction of these constituents are monitored under Draft NPDES General Permit LAG260000. Compounds such as BTEX, PAHs, chloride, and arsenic are known to be highly toxic to aquatic plants and organisms, some accumulate in sediments, and some may bioaccumulate in marine organisms. Draft NPDES General Permit LAG260000 does not require covered facilities to monitor their produced waters for toxic compounds such as these before discharging produced water into the territorial seas of Louisiana.

The frequency at which produced water discharges are monitored is unacceptable. Millions of barrels of produced water are discharged by offshore platforms into the Gulf of Mexico each day, and some facilities are required to only monitor the toxicity of produced water discharges once every three months. This could lead to the discharge of highly elevated levels of undetected contaminants to the territorial seas. The combination of only monthly reporting of quantities of only 7 produced water constituents and the requirement of only a notice of intent for all new wells does not allow LDEQ to exercise effective oversight of produced water discharges to territorial seas. Monthly reporting does not allow LDEQ to fully assess the impacts produced water discharges are having on the territorial seas.

The produced water discharge limitation guidelines in Draft NPDES General Permit LAG260000 do not comply with Louisiana Administrative Code 33:IX.708.C.2.c.v, and therefore do not comply with the Draft NPDES General Permit LAG260000 itself. LAC33:IX.708.C.2.c.v. and Draft NPDES General Permit LAG260000 Section A, Part 1, Page 6, state that “no produced water shall be discharged in a manner that, at any time, facilitates the incorporation of significant quantities of hydrocarbons or radionuclides into sediment or biota.” Studies show that both hydrocarbons and radionuclides have accumulated in sediment directly beneath and several kilometers away from produced water discharge pipes, and that hydrocarbons and radionuclides from produced water discharges have accumulated in edible aquatic organisms.

A reduction in monitoring frequency should not be awarded to those facilities that comply with monitoring requirements for one full consecutive year. Allowing facilities

to monitor for hazardous contaminants in produced water only once a year would lead to the discharge of highly elevated levels of undetected contaminants to the territorial seas. This highly elevated levels of contaminants would create a toxic environment for aquatic organisms and potentially harm the humans who consume them.

There is no established limit for radium-226 and radium-228 concentration or total radioactivity released in produced water discharges under Draft NPDES General Permit LAG260000. The US EPA has designated radium activity greater than 50 pCi/L as hazardous waste, and the Nuclear Regulatory Commission (NRC) and the State of Louisiana prohibit discharges of any liquid containing 60 pCi/L or more of radium from nuclear power plants to unrestricted areas. The concentrations of radium-226 and radium-228 measured in produced waters in the territorial seas of Louisiana greatly exceed the limits set forth both by the US EPA and the NRC.

Only the water column, and not sediment, is considered when monitoring discharges of produced water in territorial seas. Continued research has shown, in near shore areas and in territorial sea areas, that sediment can become quite contaminated and remain so even following the cessation of discharge. Sediments have also been found to contain elevated concentrations of salts, metals, PAHs, and radium while the overlying water column does not contain any measurable levels of these same toxics. As of now, it has not been determined if benthic organisms are exposed to toxicity of produced water mainly through water or sediment, therefore, the monitoring of sediments cannot be excluded from Draft NPDES General Permit LAG260000.

Critical dilution factors are not sufficient for diluting all constituents in produced water discharged into the territorial seas of Louisiana. Chloride from produced water has been found in highly elevated levels in sediment while overlying water in the same location contained no detectable measures of chloride. This shows that any dilution that might occur when produced water is discharged into the open sea may be insufficient to completely reduce the concentration difference between produced water and seawater (St. Pé, 1990).

8. Incomplete Record/Missing Documents

Our analysis suffers from the fact that LDEQ and the EPA have failed to produce numerous requested documents. We have attempted to obtain these documents through personal communications with LDEQ and with a FOIA request to the EPA. Without these documents, LEAN and its experts have not been able to supply detailed comments regarding the proposed action and the record is incomplete. The primary documents we are missing are a draft EIS prepared by the EPA, and a final EIS. As far as we are aware, the final EIS may or may not have been issued, but it referred to in a November 1997 Federal Register notice for this NPDES permit. In addition to these EIS documents, we lack the basic calculations that support replacing concentration limits with mixing parameters, with use of the software CORMIX2. We need the inputs/outputs to CORMIX2 that form the basis for replacing concentration limits. If the agencies evaluate

more than one discharge point for production water, we need the input/output for this analysis as well.

Specific documents we requested include the following:

Characterization of Data Collected from the Louisiana Department of Environmental Quality Permit Files for Development of Texas and Louisiana Coastal Subcategory NPDES General Permits. Submitted to EPA Region 6, Water Management Division, 1992. Avanti Corporation

Ocean Discharge Criteria Evaluation for the NPDES General Permit for the Eastern Gulf of Mexico. Submitted to EPA Region 4, Water Management Division, 1993. Avanti Corporation

Biological Assessment for the NPDES General Permit for Oil and Gas Exploration, Development and Production Activities on the Eastern Gulf of Mexico OCS. Submitted to EPA Region 4, Water Management Division, 1993. Avanti Corporation

Draft Supplemental Environmental Impact Statement for National Pollutant Discharge Elimination System Permitting for Gulf of Mexico Offshore Oil and Gas Extraction, EPA 904/9-95-001A. Gannett Fleming, Inc.

9. Recommended Changes to Final NPDES General Permit LAG260000

With the recent suspension and review of all federal agency actions by the new administration, we recommend that the State similarly hold up the issuance of any new permits until it can be determined whether new federal regulations will be considered or issued. The EPA will have a new administrator and directives. It makes little sense to issue new NPDES permits now that may later be revised or undone.

An Environmental Impact Statement (EIS) should be completed before accepting the conditions of the Draft NPDES General Permit LAG260000. This EIS should assess the hazardous effects existing permittees under expired NPDES General Permit LAG260000 may have on the environment of the territorial seas, as well as the potential effects an additional 150 wells may have. Discharge limitation guidelines set in the original version of the NPDES General Permit LAG260000 should be reevaluated, and effects on sediment should be assessed as well. The LDEQ should first require a scoping process, and allow the public to review all supporting references for the draft and final EIS.

The Draft NPDES General Permit LAG260000 should require that produced water be re-injected into subsurface strata as is done in most cases in the coastal zone and in upland areas in Louisiana. Re-injection is a proven and cost effective method of disposing of produced waters, as well as other wastes.

The requirement of the 1300 ft distance of all discharges from oyster beds should be reevaluated, and a limit should be placed on the number of wells allowed to operate within an established distance from oyster and other molluscan reefs and sea beds. Cumulative discharges from numerous wells in one area could create hazardous conditions for oysters and other mollusks that live in territorial seas. Rather than issuing a blank check to oil and gas permittees under the proposed NPDES permit, the State should carefully assess the cumulative impact of additional wells near oysters beds.

The Draft NPDES General Permit LAG260000 should set discharge limitation guidelines for more of the hazardous constituents of produced water and incorporate a greater variety of aquatic species in toxicity testing. We recommend that in addition to oil and grease, benzene, lead, thallium, total phenol, radium-226, and radium-228, water and sediment samples should also be analyzed for arsenic, BTEX, and total PAHs. The State of Louisiana should also include a greater amount of toxicity testing on organisms such as bivalves, crustaceans, and fish in order to establish the extent of disturbance to the local environment in territorial waters from the discharge of produced waters. An example of a state that has incorporated these changes is California. The State of California requires additional guidelines for the discharge of produced waters. These include sampling for 26 chemicals, setting discharge volume limits for each platform, quarterly toxicity testing with red abalone, annual chronic toxicity testing with giant kelp and topsmelt, and studying the impacts of produced water discharges on fish (Veil et al., 2004). Interestingly, EPA-issued NPDES permits for discharges from oil and gas production platforms in federal water on the outer continental shelf required several platforms to meet effluent standards at the platform (California Coastal Commission, 2004).

The Draft NPDES General Permit LAG260000 should require ongoing studies by the permit holders to assess the environmental impacts of their produced water discharges. Such impacts of produced water discharges were found by LDEQ studies in the coastal areas of Louisiana, and these studies led to further regulation of produced water.

Biological monitoring provides a method to assess the impact from contaminants, including those involving synergistic interactions from multiple compounds. Biomonitoring should be a component of any permit as the many contaminants in produced water can act synergistically and can bioaccumulate overtime. It is important that biomonitoring evaluate non-lethal endpoints as well as mortality. As suggested by Carney, 1987 and Osenberg et al, 1992 more sensitive bioindicators such as growth or reproduction may provide a better method of assessment due to the spatial and temporal variability in population density of aquatic organisms. These parameters have rarely been utilized when evaluating produced waters in field studies.

Sediment samples from the area of the discharge should be taken in order to determine if contaminants are accumulating in areas other than the water column. Continued discharge has shown, in near shore areas, that sediment can become quite contaminated and remain so even following the cessation of discharge. In addition, the cumulative impacts from

multiple discharges may lead to unacceptable levels of contamination. Since contaminants such as PAHs and radium do accumulate in the sediments, sediments from the discharge area should be used along with water in the toxicity testing. This would provide more complete insight into how the discharge of produced waters is impacting the local environment.

Discharge limitation guidelines for radium-226 and radium-228 should be established and specified in the general permit as 50 pCi/L, the level recognized as hazardous waste by the US EPA.

The frequency at which produced water discharges are monitored should be increased, and permittees should not be allowed to decrease monitoring frequency after one year of compliance. We recommend that monitoring frequency be shortened and all facilities report produced water discharge concentrations once per month. Facilities monitoring frequency should not be reduced to once per year after they have been compliant for one full consecutive year. The monitoring frequency of all wells should remain at once per month for the entirety of that wells operation.

Input factors used to determine critical dilution factors should be reevaluated and results from sediment toxicity tests should be considered when determining critical dilution factors. Many studies indicated that although it appeared that contaminants in produced water were diluted when introduced to seawater, sediment layers underlying produced water discharges contained elevated concentrations of PAHs, radium, and salts particles. Concentrations of produced water constituents have also been measured in sediments several kilometers from discharge pipes. Therefore, dilution factors currently used are insufficient and need to be reevaluated.

Lastly, we recommend that the state develop better technology to remove smaller sized oil droplets from produced water. Current technology cannot remove oil droplets smaller in size than 10 microns. Many toxic constituents of produced water adsorb to oil droplets and are therefore unable to be removed from produced water before being discharged into territorial seas.

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