Assessment of Potential Technical and Regulatory Issues Relating to Naturally Occurring Radioactive Materials (NORM) in Class II Wells

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Chapter 1

Introduction

Radioactive compounds exist naturally at low levels in soils and rocks. Naturally occurring radionuclides include potassium-40 (K-40), rubidium-87 (Rb-87), and radionuclides in the uranium-238 (U-238) and thorium-232 (Th-232) decay series (see Exhibit 1), including radium-226 (Ra-226) and radium-228 (Ra-228). As a result of human activities, naturally occurring radioactive material (NORM) may be concentrated at levels that present significant human health hazards. In particular, certain mineral extracting and refining activities can concentrate radionuclides in soils and rocks to levels that are many times greater than those that occur naturally.

For example, the operation of oil and gas production wells yields large quantities of "produced" water, which can contain many radioactive daughter products (i.e., Ra-226 and Ra-228) that are derived from the natural decay of uranium isotopes (U-235 and U-238) and thorium (Th-232). As produced water is extracted from the earth and as physical conditions change (e.g., water pressure and temperature), the solubility of these constituents is reduced. Therefore, radionuclides precipitate out of solution and deposit as sludge on the walls of tubing, casing, and surface processing equipment. The concentrations of Ra-226 and Ra-228 in these deposited formations vary widely, from just over background levels ($\approx$ 1 pCi/g) to 400,000 pCi/g.[1]

Currently, the management and disposal of NORM wastes associated with the production of oil and gas are not federally regulated. Six states have regulations that apply to NORM at oil and gas facilities. Some of these regulations restrict land use depending on NORM concentrations, and others address the disposal of NORM wastes.

EPA's Underground Injection Control Branch (UICB) of the Office of Ground Water and Drinking Water (OGWDW) is often asked by other EPA program offices (e.g., the Office of Radiation and Indoor Air (ORIA) and the Office of Solid Waste (OSW)), EPA regional offices, and state agencies to provide technical opinions about managing and disposing of NORM wastes. Therefore, UICB personnel need up-to-date, comprehensive information on NORM-related environmental issues and their influence on current and future EPA program activities.

This document provides comprehensive information on existing and developing state regulatory programs and alternative management and disposal techniques applicable to NORM wastes. It also provides a bibliography of documents pertaining to scientific, engineering, and regulatory information related to NORM wastes derived from oil and gas wells. In addition, this document provides recommendations for guidance language relating to the disposal of NORM wastes in Class II wells.

Chapter 2 of this document presents an overview of NORM waste generated at oil and gas production facilities, and discusses current research being conducted by the American Petroleum Institute (API) and the Department of Energy (DOE) related to NORM management and disposal alternatives.

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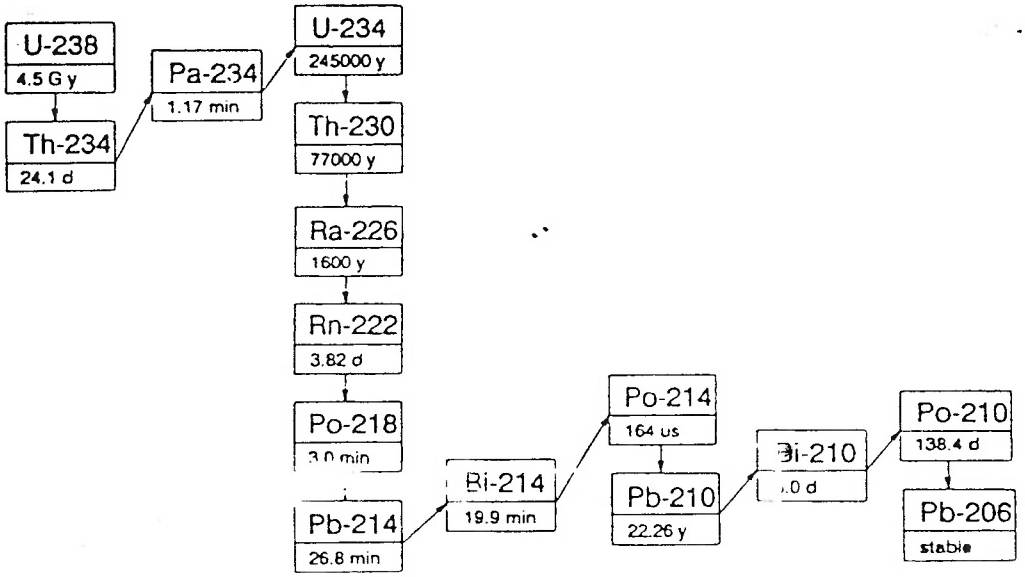
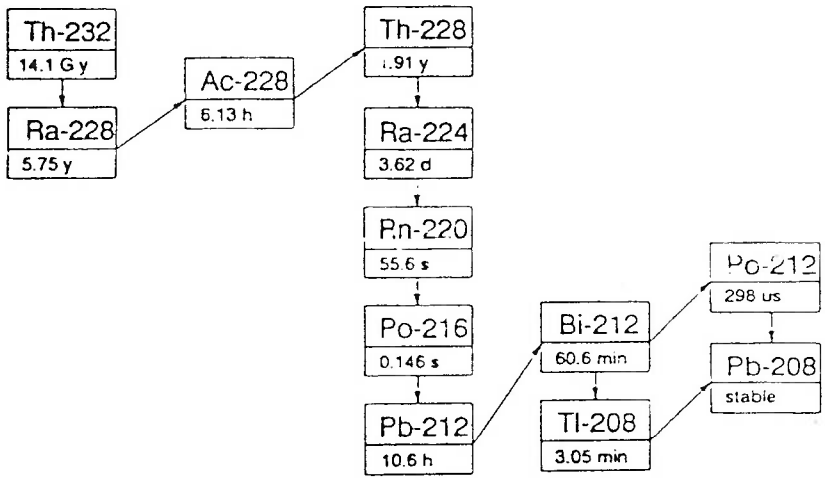
[1] *Diffuse NORM Wastes: Waste Characterization and Preliminary Risk Assessment.* EPA-9232/1-2, Volume I. U.S. Environmental Protection Agency. May 1993.

Exhibit 1: Uranium-238 and Thorium-232 Decay Series

Uranium-238 Decay Series



Thorium-232 Decay Series



KEY

Isotope
Half-Life

Adapted from Gregory J. White, *Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Industry Equipment and Wastes: A Literature Review*, Idaho National Engineering Laboratory, DOE/ID/01570-T158, June 1992.

The chapter also describes and summarizes NORM disposal alternatives. Chapter 3 discusses state NORM regulations and presents a table, *Regulatory Summary for State NORM Requirements*, which identifies current and projected state NORM regulations, alternative state-regulated NORM management and disposal technologies, and state NORM licensing requirements. Also included in this chapter is a summary of the regulatory status of states that do not have NORM requirements. Chapter 4 describes and presents a bibliography of literature related to NORM waste associated with oil and gas production. Finally, Chapter 5 presents the conclusions and recommendations related to disposal of NORM wastes in Class II wells. Acronyms used in this document and an accompanying glossary of technical terms is in Appendix A, "Definitions."

Chapter 2

Disposal Alternatives for NORM Wastes Generated at Oil and Gas Production Facilities

2.1 Introduction

This chapter discusses naturally occurring radioactive material (NORM) wastes generated by the oil and gas production industry and potential disposal alternatives for these wastes. It first describes common waste forms generated at these facilities, and the volume and typical radionuclide concentrations of each waste form. The cleaning of NORM scale and sludge from contaminated equipment and tubing is discussed because it is a necessary preliminary step for some disposal alternatives and, therefore, may influence the selection of alternatives. Next, the chapter outlines current and proposed research to evaluate NORM waste disposal alternatives. A discussion of NORM disposal alternatives which involve wells and do not involve wells is then presented. Finally, a summary table presents details of all of the disposal alternatives discussed in the text.

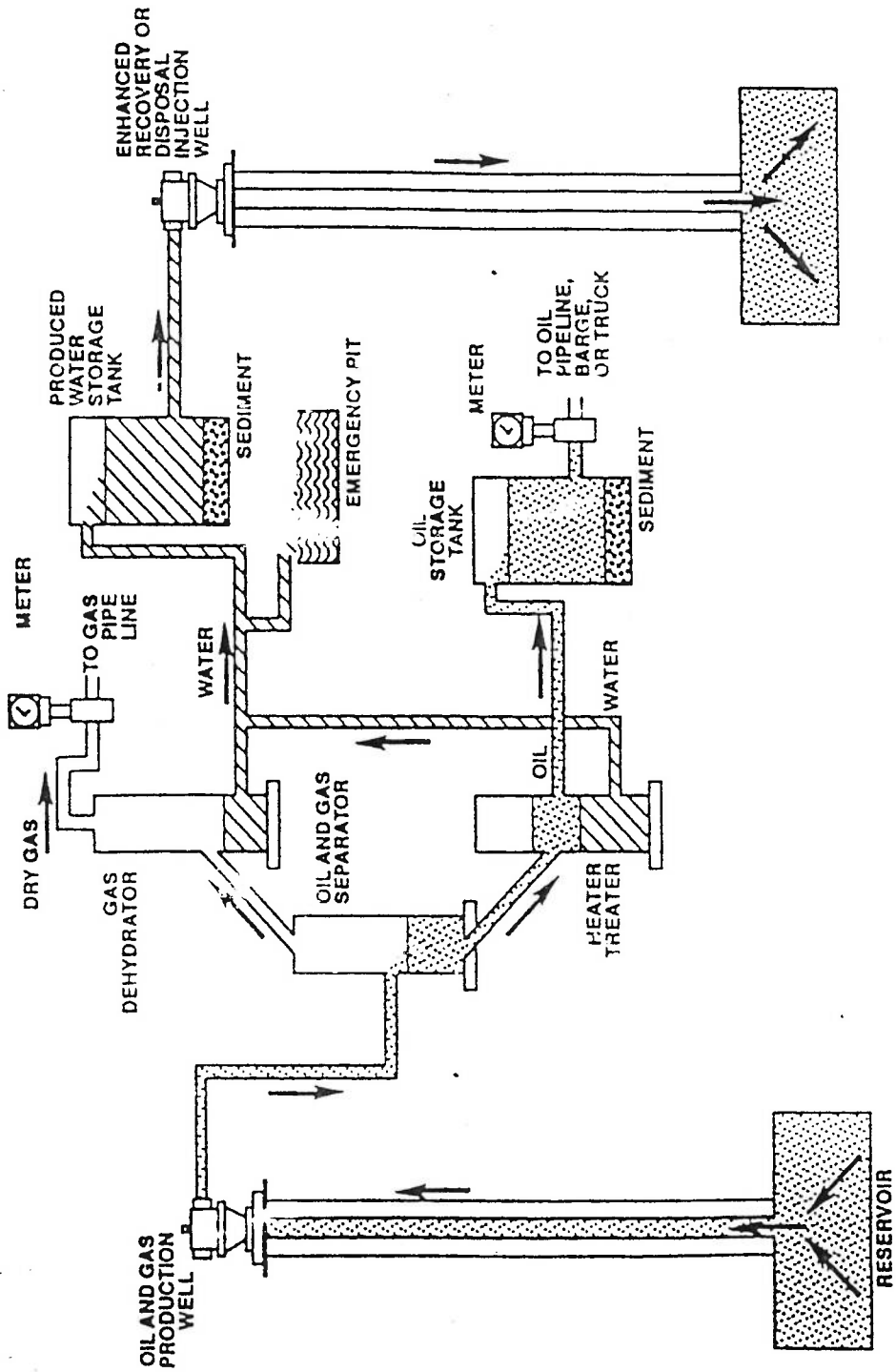
2.2 NORM Waste Generation and Characteristics at Oil and Gas Production Facilities

NORM is present in geologic formations from which oil and gas are produced. The material generally consists of the radionuclides uranium and thorium and their daughter products, including radium. Oil and gas production processes often mobilize NORM in formations into the produced fluids (oil, gas, and water). However, NORM is usually associated with the water phase of produced fluids, and it may be precipitated as scale or into sludges.

Exhibit 2 is a basic flow diagram for a typical oil and gas production operation showing extraction, processing, and disposal steps. The oil and gas production stream passes through separators where the oil, gas, and water are divided into separate streams. The produced water flows from these separators into storage tanks from which it may be injected into disposal or recovery wells. Scales are found in piping and tubing throughout the operation, with the largest volumes of scale typically found in water lines associated with separators, heater treaters, and gas dehydrators. The highest concentrations of NORM are usually found in and around the wellhead piping.[2]

[2] *Diffuse NORM Wastes: Waste Characterization and Preliminary Risk Assessment*, Volume 1. U.S. Environmental Protection Agency. May 1993.

Exhibit 2: Typical Production Operation, Showing Separation of Oil, Gas, and Water



Adapted from *Diffuse NORM Wastes: Waste Characterization and Preliminary Risk Assessment*, U.S. EPA, Office of Radiation and Indoor Air, May 1993.

Scale, which is deposited on the inside of piping and equipment, generally consists of radium coprecipitated with barium sulfate.[3] EPA estimates that the average activity of scale is 360 pCi/g, and concentrations as high as 400,000 pCi/g have been found.[4] The American Petroleum Institute (API) estimates that scale activities range from background to thousands of pCi/g.[5] Therefore, some scale falls in the category of discrete NORM waste (>2 nCi/g). The majority of scale deposits are found in piping.[6]

Sludge results from solids in oil and produced water settling out in production equipment, such as heater treaters, separators, tanks, and valves. However, the greatest amount of sludge is found in oil and water storage tanks. EPA estimates the average activity of sludge to be about 75 pCi/g.[7] The API estimates that the activity of sludge ranges from background levels to several hundred pCi/g.[8] EPA estimates that 10 million metric tons of sludge were generated between 1949 and 1989.[9] Further, it is estimated that 260,000 tons of scale and sludge are generated annually, and most of the material is being stored on site at oil and gas production facilities.[10]

Contaminated soil results from spills, well workovers, and the cleaning of sludge and scale from contaminated equipment. The activity of contaminated soil can range from background levels to the elevated levels sometimes found in NORM scale. Little information is available on the volume of contaminated soils at oil and gas production facilities.

Contaminated piping and tubing from the build-up of NORM scale typically exhibits radium activities on the order of several hundred pCi/g.[11] Equipment containing scale and sludge exhibits activities ranging from background levels to over 100,000 pCi/g and background to over 10,000 pCi/g, respectively.[12] In production facilities, water handling equipment typically exhibits the greatest NORM

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[3] *A Preliminary Risk Assessment of Management and Disposal Options for Oil Field Wastes and Piping Contaminated with NORM in the State of Louisiana*. Peer Review Draft. Prepared for U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. March 1993.

[4] *Draft Issue Paper: NORM Wastes at Potential Radiation Cleanup Sites*. Prepared for U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. January 13, 1994.

[5] *Bulletin on Management of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Production*. API Bulletin E2 (BUL E2) First Edition. April 1, 1992

[6] *A Preliminary Risk Assessment of Management and Disposal Options for Oil Field Wastes and Piping Contaminated with NORM in the State of Louisiana*.

[7] *Draft Issue Paper: NORM Wastes at Potential Radiation Cleanup Sites*.

[8] *API Bulletin E2*.

[9] *Diffuse NORM Wastes: Waste Characterization and Preliminary Risk Assessment*, Volume 1. U.S. Environmental Protection Agency. May 1993.

[10] *Draft Issue Paper: NORM Wastes at Potential Radiation Cleanup Sites*.

[11] *A Preliminary Risk Assessment of Management and Disposal Options for Oil Field Wastes and Piping Contaminated with NORM in the State of Louisiana*.

[12] *A Preliminary Risk Assessment of Management and Disposal Options for Oil Field Wastes and Piping Contaminated with NORM in the State of Louisiana*. (Calculated from statistical distribution of radiation exposure measurements.)

activity levels.[13] The actual volume of contaminated tubing and equipment generated by oil and gas production facilities is difficult to quantify. However, in an assessment of the risks of various disposal alternatives for NORM in Louisiana, the authors estimated that a ten-well production facility generates about 6,000 cubic feet of contaminated tubing and equipment over a 30-year period.[14]

Produced water (brine) is a by-product of the oil and gas production industry and is brought to the surface in increasing quantities as the oil in the formation is depleted. Particularly in coastal wells, a large amount of water is produced.[15] The average well in Louisiana generates 155,000 cubic feet per year of produced water.[16] Radium in brines typically range from 100 to 500 pCi/L or 0.1 to 0.5 pCi/g.[17] Therefore, produced water is a high volume, low concentration (diffuse) NORM waste.

2.3 NORM Waste Disposal

In the past, oil and gas production wastes were disposed of in pits, in piles, in coastal waters, or by well injection into geologic formations. However, in the mid-to-late-1980s, the industry was becoming aware that some oil and gas production wastes contain elevated levels of NORM. At present, most solid NORM waste generated at oil and gas production facilities, as well as solid wastes generated in the past, is being stored on-site (e.g., in drums) pending the development of regulations governing disposal. Some states prohibit disposal of NORM until regulations are promulgated. Liquid NORM waste (i.e., produced water) continues to be injected into formations for disposal or for enhanced oil recovery.

Although the cleaning of NORM scale and sludge from contaminated tubing and equipment is not in itself a disposal alternative, it deserves mention here because it is a necessary preliminary step for several disposal alternatives and because the economics and risks involved may influence the selection of alternatives. If the tubing or equipment is valuable, it may be economically worthwhile to clean it of accumulated scale or sludge rather than dispose of it. This is common practice in the oil and gas production industry, particularly for tubulars containing scale. However, cleaning tubulars and equipment containing NORM scale increases worker exposure to NORM through increased handling. Scale may be removed from tubulars and equipment by mechanical means such as boring machines, brush machines, or hydroblasting (high-pressure water spray). Or, scale can be removed by chemical means such as dissolving the scale in a solvent bath. In addition, these methods can be used in combination. Methods that involve liquids tend to keep NORM-contaminated dust to a minimum, but result in liquid wastes

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[13] *Bulletin on Management of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Production*. API Bulletin E2 (BUL E2). First Edition. April 1, 1992.

[14] *A Preliminary Risk Assessment of Management and Disposal Options for Oil Field Wastes and Piping Contaminated with NORM in the State of Louisiana*. Peer Review Draft. Prepared for U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. March 1993.

[15] Personal communication with personnel at the American Petroleum Institute, Dallas Office, on July 19, 1994.

[16] *A Preliminary Risk Assessment of Management and Disposal Options for Oil Field Wastes and Piping Contaminated with NORM in the State of Louisiana*.

[17] *Draft Issue Paper: NORM Wastes at Potential Radiation Cleanup Sites*. Prepared for U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. January 13, 1994.

which themselves require disposal. Sludge is generally easier to remove from equipment and may involve shoveling the sludge from equipment and hand-washing, or pumping the sludge from equipment.[18]

There are many potentially applicable alternatives for the disposal of NORM wastes generated at oil and gas production facilities. Some alternatives involve disposal in wells, either production wells or Class II injection/disposal wells, while others involve other means, such as land surface disposal. The various disposal alternatives are described in the next section. Exhibit 3 presents a summary of the disposal alternatives, including the types of NORM wastes to which each alternative applies, the stage of development, advantages and disadvantages, performance, and cost.

A report prepared by Rogers and Associates Engineering Corporation for API[19] uses a risk assessment approach to evaluate the theoretical performance of NORM waste disposal alternatives. It considers 4 waste forms (sludges, scales, production equipment, and gas plant equipment) and 12 disposal options. Based on radiation exposure limits at receptor locations and migration in 7 different environmental pathways, the API report estimates the concentration of NORM waste that can be disposed of using each of the 12 disposal alternatives. The radiation exposure limits considered in the report are:

- Indoor radon inhalation: 2 pCi/L
- Groundwater ingestion (Ra-226, 228): 5 pCi/L
- General public exposure, all other pathways: 25 mrem/yr
- Inadvertent intruders, all other pathways: 100 mrem/yr

Exhibit 3 refers to these performance estimates for NORM waste disposal alternatives evaluated by Rogers and Associates.

2.4 Disposal Alternatives Involving Wells

2.4.1 Overview of Class II Well Construction

Class II injection wells are used for disposal of fluids (such as produced water) that are brought to the surface in connection with conventional oil or natural gas production. Additionally, some Class II wells are used to store hydrocarbon products. Typically, a Class II injection well is a bored, drilled, or driven shaft serving to deliver a fluid from the surface into a designated underground injection zone. As shown in Exhibit 4, conventional construction of a Class II well features several layers of protection to prevent endangerment to underground sources of drinking water (USDWs). These layers of protection include surface casing set and cemented into place, long string casing that extends from the surface to the injection zone, which is also cemented into place, and injection tubing set on a packer to seal the borehole/casing annulus. Some components of the design, such as well depth and diameter, or types and dimensions of casing and tubing may vary depending on site-specific conditions.

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[18] *Bulletin on Management of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Production*. API Bulletin E2 (BUL E2). First Edition. April 1, 1992.

[19] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*. RAE-8837/2-2. Rogers & Associates Engineering Corp. Prepared for API. May 1990.

Exhibit 3: Disposal Alternatives for Oil & Gas NORM Waste

Oil and Gas Production NORM Disposal Alternatives (Applicable NORM waste types - see bottom of page)	Stage of Development	Advantages	Disadvantages	Performance	Cost
DISPOSAL ALTERNATIVES INVOLVING WELLS					
Plugging and abandonment of wells with contaminated tubulars left in place. (f)	• The Louisiana Dept of Natural Resources has established specific plugging and abandonment procedures for closing wells after emplacement of NORM materials, but doesn't specifically mention this practice.	• Provides potentially lower doses and risks to humans than near-surface disposal. • No waste transport or resultant exposure due to handling.	• Performance dependent on the long-term viability of the casing and plug. • Results in many small disposal sites, rather than a centralized site. • Percentage of total NORM waste suitable for this disposal method is small.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), NORM materials or contaminated equipment with radium concentrations over 100,000 pCi/g could be disposed of using this alternative (9).	• Saves the cost of cleaning out wells or removing well tubing and casing and disposing by other means.
Plugging and abandonment of Class II wells after emplacement of containerized tubular goods, equipment, and solids below potable aquifers. (a,b,d,e,f)	• Louisiana state regulations allow this practice by permit with specific criteria for the method of plugging and abandonment (1). This is a common practice in Louisiana (15). • Considered viable by the oil & gas production industry (3). • BP has state approval in Alaska to dispose of NORM scale by mixing it into cement slurries and using the slurries in well abandonment procedures (13). • Some facilities are considering the option of breaking up NORM-contaminated equipment and encapsulating it in well bores (3).	• Provides potentially lower doses and risks to humans than near surface disposal. • May not require off-site transport (and resultant human exposure).	• Performance dependent on the long-term viability of the casing and plug. • Results in many small disposal sites, rather than a centralized site. • Not applicable for medium-sized to large equipment. • Requires short-term storage of NORM wastes. • Calcium-containing scales and sludges incorporated into the wellbore cement plugs can cause the cement to set prematurely (8).	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), NORM materials or contaminated equipment with radium concentrations over 100,000 pCi/g could be disposed of using this alternative (9).	• Saves the cost of cleaning scale from tubular goods and equipment. • Breaking up NORM-contaminated equipment and encapsulating it in well bores would likely be expensive according to API personnel (3).

Note: (a) Scale, (b) Sludge, (c) Produced Water, (d), Contaminated Equipment, (e) Contaminated Soil, (f) Contaminated Pipe & Tubing. Numbered references are provided in a list of sources on page 17.

Exhibit 3: Disposal Alternatives for Oil & Gas NORM Waste (Continued)

Oil and Gas Production NORM Disposal Alternatives (Applicable NORM waste types - see bottom of page)	Stage of Development	Advantages	Disadvantages	Performance	Cost
Plugging and abandonment of orphan wells (wells with no viable owner or operator but that have not been plugged) after emplacement of containerized tubular goods, equipment, and solids below potable aquifers. (a,b,d,e,f)	• Allowed in Louisiana with permit (same criteria as above for plugging and abandonment) (1).	• Provides a relatively high degree of isolation of wastes compared with the other alternatives (9). • Provides potentially lower doses and risks to humans than near surface disposal. • May not require off-site transport (and resultant human exposure).	• Performance dependent on the long-term viability of the casing and plug. • Results in many small disposal sites, rather than a centralized site. • Not applicable for large equipment. • Requires short-term storage of NORM wastes. • Calcium-containing scales and sludges incorporated into the wellbore cement plugs can cause the cement to set prematurely (8). • Potential liability due to uncertainty regarding well integrity.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), NORM materials or contaminated equipment with radium concentrations over 100,000 pCi/g (actually 30 μCi/g) could be disposed of using this alternative (9).	• Saves the cost of cleaning scale from tubular goods and equipment.
Injecting into formations through dedicated Class II wells. (a,b,c)	• Considered viable by the oil & gas production industry, esp. for higher level NORM (3). • Louisiana DEQ allows this practice by permit for captive facilities only (not commercial). Very few facilities have requested permits to inject solids (7), but injecting produced water is common (15). • DOE soliciting competitive bids for field, pilot scale demonstration of NORM treatment & disposal technologies involving Class II injection. • Occasionally practiced in the Gulf of Mexico (14).	• Based on an EPA risk assessment of NORM waste injection, it was concluded that no significant human health risks would result if disposal is conducted in deep formations and isolated from sources of drinking water (5). • Would provide a relatively high degree of isolation of wastes compared with other alternatives (9).	• May not be economical to remove scale and sludge from equipment. • Requires short-term storage of NORM wastes. • Long-term integrity of Class II wells and associated ability to effectively seal boreholes and prevent contaminant migration to USDWs is a concern. • Lack of clear regulatory applicability of underground injection requirements.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), NORM materials or contaminated equipment with radium concentrations over 100,000 pCi/g could be disposed of using this alternative. If injection is within a useable aquifer, the limit for sludge becomes 30,000 pCi/g (9).	• Considered less expensive than near surface disposal in licensed NORM facilities (6).

Note: (a) Scale, (b) Sludge, (c) Produced Water, (d), Contaminated Equipment, (e) Contaminated Soil, (f) Contaminated Pipe & Tubing. Numbered references are provided in a list of sources on page 17.

Exhibit 3: Disposal Alternatives fo. ,il & Gas NORM Waste (Continued)

Oil and Gas Production NORM Disposal Alternatives (Applicable NORM waste types - see bottom of page)	Stage of Development	Advantages	Disadvantages	Performance	Cost
Injecting into formations through dedicated Class II wells with hydraulic fracturing. (a,b,c)	• Considered viable by the oil & gas production industry esp. for higher level NORM (3). • Louisiana DEQ is considering allowing this practice by permit for captive facilities if permittee can show that formation will not accept waste below fracture pressure. However, very few facilities have requested permits (7), and industry appears to be backing off from requesting this method as a disposal alternative in Louisiana (15). • Hydraulic fracturing has been used to dispose of intermediate level ($3x10^6$ pCi/g) radioactive wastes (10). • BP Alaska has state approval to inject NORM-containing slurries. BP began NORM injection in 1992 (13).	• Would provide a relatively high degree of isolation of wastes compared with other alternatives due to tendency for hydraulic fracturing occurring in deep formations (9).	• May not be economical to remove scale and sludge from equipment. • Requires short-term storage of NORM wastes. • Difficult to predict fracture characteristics and behavior. • Long-term integrity of Class II wells and associated ability to effectively seal boreholes and prevent contaminant migration to underground sources of drinking water (USDWs) is a concern. • May involve greater potential for contaminating (USDWs). • Lack of clear regulatory applicability of underground injection requirements.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), NORM materials can be disposed using this alternative with no limit on radium concentrations because migration time to an aquifer is likely to be long. Even if more rapid flow occurred along a fault, concentration limit would far exceed 100,000 pCi/g (9).	• Considered less expensive than near surface disposal in licensed NORM facilities (6).
Emplacement into salt dome cavities. (a,b,c,e,f)		• Provides greatest degree of isolation compared with other alternatives.	• Requires short-term storage of NORM wastes. • Expensive to create and maintain "dry space" in salt mines.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), NORM materials or contaminated equipment with radium concentrations over 100,000 pCi/g could be disposed of using this alternative (9).	• Likely to be expensive due to value of salt domes for petroleum storage and expensive to create and maintain.

Note: (a) Scale, (b) Sludge, (c) Produced Water, (d), Contaminated Equipment, (e) Contaminated Soil, (f) Contaminated Pipe & Tubing. Numbered references are provided in a list of sources on page 17.

Exhibit 3: Disposal Alternatives for Oil & Gas NORM Waste (Continued)

Oil and Gas Production NORM Disposal Alternatives (Applicable NORM waste types - see bottom of page)	Stage of Development	Advantages	Disadvantages	Performance	Cost
DISPOSAL ALTERNATIVES NOT INVOLVING WELLS					
Discharge off-shore. (c)	• Water produced on off-shore production rigs has commonly been discharged directly into the ocean. • This method of disposal may be regulated by the Minerals Management Service in federal waters. • Many studies are on-going (API, DOE, Continental Shelf Associates, EPA Office of Water and Office of Radiation) related to the fate and effects of NORM-contaminated produced water discharged off-shore (6). • Disposal of NORM well solids into the waters of the Gulf of Mexico is not a widespread practice (14).	• A 1991 study of the effects of radium on aquatic biota found no detectable impacts from off-shore discharges of radium. The overall ecological risk associated with the discharge of produced water to coastal Louisiana was found to be small (6). • Economical method of disposal.	• Possible impacts to marine life and human health via the food chain. • Uncontrolled patterns of migration.	• Large capacity for dilution of contaminated produced water.	• Inexpensive because produced water does not have to be treated, stored, or transported.
Discharging into non-potable coastal waters. (c)	• Louisiana is requiring that discharges of produced water to brackish and saline coastal waters be phased out by Jan. 1, 1995. Texas has prohibited produced water discharges to fresh water areas (4).	• Economical method of disposal for O&G facilities.	• Potential for impacts on marine life. • Potential human health risks from consumption of contaminated shellfish.	• Less capacity for dilution than discharge off-shore.	• Likely to be an inexpensive method of disposal.
Landspreading (surface disposal without cover). (a,b,e)	• Considered viable for low-level NORM by the oil & gas production industry (3).	• Does not require the development of detailed technical criteria for disposal. • Not likely to contaminate groundwater because infiltration rate of radium in soils is very low and radium is not mobile in aquifers because of its high adsorption capacity to rock in fresh waters (6).	• May not be economical to remove scale and sludge from equipment. • Allows potentially higher doses and risks to humans than disposal in plugged and abandoned wells. • Potential threat to wildlife. • Lack of clear regulatory applicability of land disposal requirements	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), scale and sludge with radium concentrations up to 120 pCi/g can be disposed of in this manner. The scenario assumes a NORM thickness of 1/4 inch, the limit decreases with increasing thickness (9).	• $87/m³ based on evaluation of Texas NORM waste (11).

Note: (a) Scale, (b) Sludge, (c) Produced Water, (d), Contaminated Equipment, (e) Contaminated Soil, (f) Contaminated Pipe & Tubing. Numbered references are provided in a list of sources on page 17.

Exhibit 3: Disposal Alternatives for Oil & Gas NORM Waste (Continued)

Oil and Gas Production NORM Disposal Alternatives (Applicable NORM waste types - see bottom of page)	Stage of Development	Advantages	Disadvantages	Performance	Cost
Disposing in pits (lined or unlined). (a,b,c)	• This was common practice for scale and sludge wastes until the NORM issue was realized. Since then, most pits have been dug up and the contents are being stored in drums pending NORM disposal regulations. • Nearly all produced water disposal pits have been prohibited in coastal areas of Louisiana (4).	• Does not require the development of detailed technical criteria for disposal. • Not likely to contaminate groundwater because infiltration rate of radium in soils is very low and radium is not mobile in aquifers because of its high adsorption capacity to rock in fresh waters (6).	• Potential threat to wildlife. • May not be economical to remove scale and sludge from equipment. • Depending on location, potential exposure to radon and gamma radiation.		
Landfarming (mixing with top 8 inches soil). (a,b,e)	• Considered viable for low-level NORM by the oil & gas production industry (3).	• Does not require the development of detailed technical criteria for disposal. • Not likely to contaminate groundwater because infiltration rate of radium in soils is very low and radium is not mobile in aquifers because of its high adsorption capacity to rock in fresh waters (6).	• May not be economical to remove scale and sludge from equipment. • Allows potentially higher doses and risks to humans than disposal in plugged and abandoned wells. • Lack of clear regulatory applicability of land disposal requirements.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), scale and sludge with radium concentrations up to 260 pCi/g can be safely disposed of in this manner (assuming a waste loading of 4 barrels per 100 m^2 area diluted with top 8 inches of soil) (9).	• \$90/m^3 based on evaluation of Texas NORM waste (11).
Land burial (soil excavation, waste disposal, covering with fill 1-20 ft). (a,b,d,e,f)	• Considered viable for low-level NORM by the oil & gas production industry (3).	• Not likely to contaminate groundwater because infiltration rate of radium in soils is very low and radium is not mobile in aquifers because of its high adsorption capacity to rock in fresh waters (6).	• Lack of clear regulatory applicability of land disposal requirements. • May not be economical to remove sludge and scale from equipment. • Potential exposures due to off-site transport of wastes.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), sludge, scale, and equipment with radium concentrations up to 29, 130, and 440 pCi/g, respectively could be buried with unrestricted site use below 15 feet of cover (9).	• \$132/m^3 based on evaluation of Texas NORM waste buried on-site (11).

Note: (a) Scale, (b) Sludge, (c) Produced Water, (d), Contaminated Equipment, (e) Contaminated Soil, (f) Contaminated Pipe & Tubing. Numbered references are provided in a list of sources on page 17.

Exhibit 3: Disposal Alternatives for Oil & Gas NORM Waste (Continued)

Oil and Gas Production NORM Disposal Alternatives (Applicable NORM waste types - see bottom of page)	Stage of Development	Advantages	Disadvantages	Performance	Cost
Disposing in commercial nonhazardous oilfield waste (NOW) facility. (a,b,e)	• In Louisiana, permitted commercial nonhazardous oilfield waste (NOW) facilities may receive and treat NORM with Ra-226 or Ra-228 concentrations of up to 200 pCi/g. (NORM cannot be mixed with non-NORM NOW.) (12).	• Provides a centralized disposal site.	• Requires detailed regulatory guidelines and procedures, such as confirmatory surveys, protective measures, sampling, and record keeping (1).	• Louisiana allows Ra-226 and Ra-228 concentrations up to 200 pCi/g in these facilities (12).	
Disposing in sanitary landfill. (a,b,d,e,f)		• Not likely to contaminate groundwater because infiltration rate of radium in soils is very low and radium is not mobile in aquifers because of its high adsorption capacity to rock in fresh waters (6).	• Potential exposures due to transport of wastes to facility. • Lack of clear regulatory applicability of land disposal requirements.	• Depending on design, may protect against radon exposure and groundwater contamination.	• $107/m^3$ based on evaluation of Texas NORM waste (11).
Byproduct material impoundment (uranium tailings disposal facility per 40 CFR 192) [licensed NORM waste disposal site]. (a,b,e)	• As of 1992, only one site in U.S. (Enviro-Care of Utah) accepted diffuse radium waste (<2 nCi/g average over shipment) (6). • One commercial facility (Campbell Wells) is permitted in Louisiana solely for NORM oilfield waste (defined as <200 pCi/g) (2)(15).	• May not require the development of detailed technical criteria for disposal if current criteria are deemed appropriate. • Not likely to contaminate groundwater because infiltration rate of radium in soils is very low and radium is not mobile in aquifers because of its high adsorption capacity to rock in fresh waters (6).	• May not be economical to remove scale and sludge from equipment. • Allows potentially higher doses and risks to humans than disposal in plugged and abandoned wells. • Potential exposures due to transport of wastes to facility. • Lack of clear regulatory applicability of land disposal requirements. • Some NORM wastes have higher activities than are allowed in these facilities.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), sludge, scale, and equipment with radium concentrations up to 1,000, 4,500, and 68,000 pCi/L, respectively could be disposed of using this alternative. It is assumed that after closure the site is deeded to the state for permanent monitoring and restricted future use (9).	• $529/m^3$ based on evaluation of Texas NORM waste (11).

Note: (a) Scale, (b) Sludge, (c) Produced Water, (d), Contaminated Equipment, (e) Contaminated Soil, (f) Contaminated Pipe & Tubing. Numbered references are provided in a list of references on page 17.

Exhibit 3: Disposal Alternatives for Oil & Gas NORM Waste (Continued)

Oil and Gas Production NORM Disposal Alternatives (Applicable NORM waste types - see bottom of page)	Stage of Development	Advantages	Disadvantages	Performance	Cost
Disposing in LLW disposal facility. (Licensed under NRC regulations 10 CFR 61). (a,b,d,e,f)	• As of 1990, 3 such facilities were operating.	• Not likely to contaminate groundwater because infiltration rate of radium in soils is very low and radium is not mobile in aquifers because of its high adsorption capacity to rock in fresh waters (6).	• Potential exposures due to transport of wastes to facility. • Lack of clear regulatory applicability of land disposal requirements. • May not accept diffuse NORM waste, but if they do it could be very expensive.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), sludge and scale with radium concentrations up to 50,000 pCi/g and equipment with concentrations up to 100,000 pCi/g could be disposed of using this alternative (9).	• $1,780/m³ based on evaluation of Texas NORM waste (11).
Steel resmelting. (d,f)	• The Petroleum Environmental Research Forum (PERF) published a report in 1992 dealing with smelting NORM-contaminated petroleum equipment. The study was limited to proving the concept and evaluating the potential risks. API and DOE are considering performing another study to test the economics of a dedicated smelter (3).	• Reduces the volume of NORM waste requiring disposal.	• Potential exposures due to transport of wastes to facility. • The smelting process may produce airborne dust that is respirable by on-site workers and off-site residents (9). • The NORM-containing slag from the process can expose workers to gamma radiation and can produce respirable dust (9). • A small amount of the radionuclides is generally retained in the iron (9).	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), contaminated metal equipment with radium concentrations up to 40,000 pCi/g could be disposed of using this alternative. The scenario assumes most NORM accumulates in the slag and the metal is reused as water pipes and frying pans for public use (9).	
Nonretrieval of surface pipe. (f)	• Louisiana DEQ allows this practice if a survey of the soil surface shows no reading exceeding 25 μR/hr, pipeline is flushed to remove hydrocarbons and produced water, and lease agreement allows lines to remain in place (1). • In Louisiana, this is more common than removing and disposing of surface pipe (15).	• No additional exposures related to transport or handling of wastes.	• Requires radiation survey and indefinitely maintained documentation (LA DEQ) (1). • Long-term potential for exposure from inadvertent perforation of pipe (such as from construction of the basement of a dwelling) (9).	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), pipes contaminated with sludge and scale with radium concentrations up to 2,700 and 6,700 pCi/g, respectively could be disposed of using this alternative (9).	• Relatively inexpensive because there is no transport or handling of waste, or design of the disposal site.

Note: (a) Scale, (b) Sludge, (c) Produced Water, (d), Contaminated Equipment, (e) Contaminated Soil, (f) Contaminated Pipe & Tubing. Numbered references are provided in a list of sources on page 17.

Exhibit 3: Disposal Alternatives for Oil & Gas NORM Waste (Continued)

Oil and Gas Production NORM Disposal Alternatives (Applicable NORM waste types - see bottom of page)	Stage of Development	Advantages	Disadvantages	Performance	Cost
Burial in surface mines. (a,b,d,e,f)		• Disposal areas are generally sufficient to accommodate large quantities of waste (8). • Erosion or other disturbances of waste materials would be minimized because of the depth of the wastes. • Allows for disposal of most waste forms. • Provides a centralized disposal site.	• May require long-term controls to limit access to the site.	• Based on a risk-based assessment of disposal alternatives prepared by Rogers and Associates Engineering Corp. for API (detailed in the text), sludge, scale, and equipment with radium concentrations over 100,000 pCi/g could be disposed of using this alternative. Typical burial depth is 50 feet or greater (9).	

Note: (a) Scale, (b) Sludge, (c) Produced Water, (d), Contaminated Equipment, (e) Contaminated Soil, (f) Contaminated Pipe & Tubing. Numbered references are provided in a list of sources on page 17.

Sources for Exhibit 3

(1) *Implementation Manual for Management of NORM in Louisiana*, Louisiana Department of Environmental Quality, Radiation Protection Division, June 1992.

(2) Personal communication with Darryl Westmoreland, Louisiana Department of Environmental Quality, Office of Water Resources, July 21, 1994.

(3) Personal communication with personnel at API, Dallas, Texas, July 19, 1994.

(4) G.E. Smith, et al., *Recent Improvements in State Regulatory Programs and Compliance Practices*, Presented at SPE/EPA Exploration & Production Environmental Conference in San Antonio, Texas, March 1993.

(5) *A Preliminary Risk Assessment of Management and Disposal Options for Oil Field Wastes and Piping Contaminated with NORM in the State of Louisiana*, Peer Review Draft, March 1993.

(6) White, Gregory, *Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Industry Equipment and Wastes (A Literature Review)*, Idaho National Engineering Laboratory, DOE/ID/01570-T158, June 1992.

(7) Personal communication with personnel at Louisiana Department of Environmental Quality, Radiation Protection Division, July 28, 1994.

(8) *Bulletin on Management of Naturally Occurring Radioactive Materials (NORM) in Oil & Gas Production*, API Bulletin E2 (BUL E2), First Edition, April 1, 1992.

(9) *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*, RAE-8837/2-2, Rogers & Associates Engineering Corporation, Prepared for API, May 1990. [This study considers all of the pathways of exposure to NORM radiation for several disposal alternatives and calculates the maximum radionuclide concentration that could be disposed of by each option without exceeding established radiation exposure limits. The exposure limits used in the study include 2 pCi/L for indoor radon inhalation, 2 pCi/m2/s for radon flux into a dwelling, 5 pCi/L for groundwater ingestion, 25 mrem/yr for general public exposure from all other pathways, and 100 mrem/yr to inadvertent intruders from all other pathways. The study considers 2 geohydrological settings that affect exposure pathways: a humid permeable site and an arid permeable site.]

(10) *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*, RAE-8837/2-2, p. 3-7: refers to another source: *The Management of Radioactive Waste at the Oak Ridge National Laboratory: A Technical Review*. U.S. Department of Energy, DOE/DP/48010-T1, 1985.

(11) Nielson, K.K., V.C. Rogers, C.S. Pollard, *BRC Disposal Alternatives for NORM Wastes in Texas*. [Examines disposal of Texas NORM wastes from three sources: Texas oilfield production, rare earth processing, and water treatment operations].

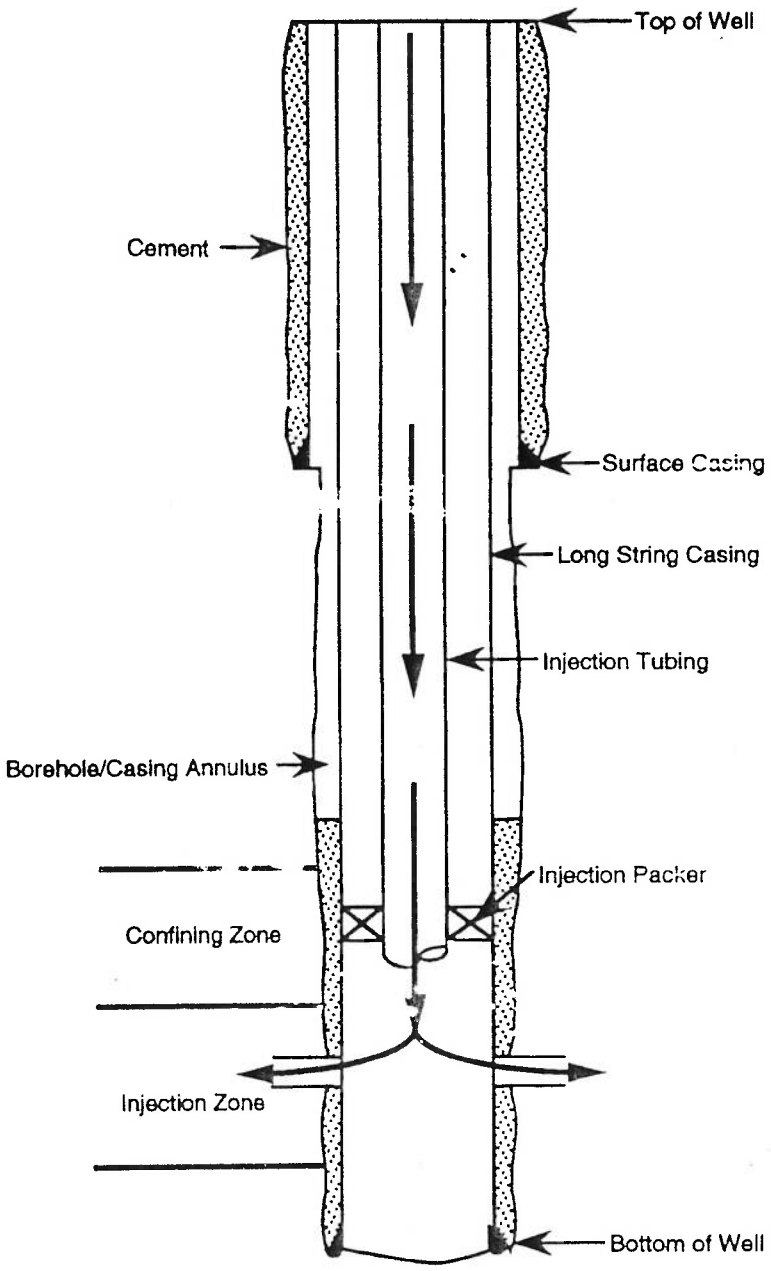
(12) Wascom, Carroll, *Regulating Naturally Occurring Radioactive Materials (NORM). State of Louisiana Dept of Natural Resources*, Presented at the Ground Water Protection Council, Feb. 1994.

(13) Lowe, D.J., *NORM Cleaning and Disposal Using Closed-Loop Hydroblasting or Solvent Bath and Underground Injection System*, Prepared for the SPE/EPA Exploration & Production Environmental Conference, March 1993.

(14) Shannon, B.E., *An Operational Perspective on the Handling and Disposal of NORM in the Gulf of Mexico*, Presented at the SPE/EPA Exploration & Production Environmental Conference, March 1993.

(15) Personal communication with personnel at Louisiana Department of Natural Resources, Office of Conservation, Injection and Mining Division.

Exhibit 4: Schematic Diagram of Class II Well



2.4.2 Plugging and Abandonment of Wells With Contaminated Tubulars Left in Place

This disposal alternative involves leaving NORM-contaminated tubulars in place in production or injection wells after the wells are no longer productive or useable. The wells are then plugged and abandoned according to standard procedures, or according to plugging and abandonment procedures specific to NORM-contaminated wells. Leaving the NORM-contaminated tubulars in place would save the cost of removing and disposing of them, or removing them, cleaning them of NORM wastes, and disposing of the waste material. This disposal alternative could be used in conjunction with several other disposal alternatives such as emplacement of NORM-contaminated materials, injection of NORM wastes, and injection with fracturing. One main advantage to this method of disposal is that waste handling is minimized.

2.4.3 Plugging and Abandonment of Class II Wells After Emplacement of Containerized Tubular Goods, Equipment, and Solids Below Potable Aquifers

Well plugging and abandonment operations provide an opportunity to dispose of NORM-contaminated wastes, including scale, sludge, soil, pipe, tubulars, and small equipment. Emplacement of NORM-contaminated equipment and NORM material is allowed with a permit in Louisiana. As stated in the *Implementation Manual for Management of NORM in Louisiana*, the Louisiana Department of Environmental Quality "will consider proposals for downhole disposal of NORM solids and NORM contaminated tubular goods and equipment in wells which are to be plugged and abandoned, if such procedures are performed in accordance with approved practices of the LOC and the Department of Environmental Quality."[20] The state allows NORM disposal in producing, formerly producing, and Class II injection/disposal wells, and the manual details specific plugging and abandonment criteria that must be met for this method of disposal. The criteria include 100-foot long cement plugs above and below the waste, proof of mechanical integrity of plugs and casing to 1,000 psig, and specified depth of NORM material placement. This method of disposal is specifically prohibited in open holes or in wells where the production casing has been removed. In addition, NORM solids cannot be mixed with any cement slurry that is to be used as a plug. Rogers and Associates[21] suggests that NORM wastes could be blended with the well control fluids and circulated in the wellbore below the lowermost USDW. The oil producer British Petroleum (BP) has approval to dispose of NORM materials in Alaska by mixing it with cement slurries to be used in well abandonment procedures.[22]

2.4.4 Injecting Into Formations Through Dedicated Class II Wells

NORM-contaminated produced water, scale, and sludge in the form of slurries could be injected into underground formations which are isolated geologically and mechanically from USDWs. Currently, this is the required method of disposing of produced water from on-shore operations. Approximately 80

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[20] *Implementation Manual for Management of NORM in Louisiana.* Department of Environmental Quality, Radiation Protection Division. February 1995 Draft. p. 12.

[21] *Safety Analysis for the Disposal of Naturally-Occurring Radioactive Materials in Texas.* RAE-8818-1. Prepared by Rogers and Associates Engineering Corporation for Texas Low-Level Radioactive Waste Disposal Authority. October 1988.

[22] Lowe, D.J. *NORM Cleaning and Disposal Using Closed-Loop Hydroblasting or Solvent Bath and Underground Injection System.* Prepared for the SPE/EPA Exploration & Production Environmental Conference. March 1993.

percent of all on-shore produced water is disposed of in injection wells.[23] There is no requirement to test the produced water for NORM contamination before disposal. Since the discovery of the NORM contamination problem is relatively new, it is likely that much NORM-contaminated produced water has been disposed of in this manner. Potential groundwater contamination problems could result from this practice if there is inadequate surface casing to protect all potential USDWs. In the past, each state set its own standard for the depth of surface casing required on Class II wells. BP Alaska has state approval to dispose of NORM solids (scale) by injection into Class II wells and began injecting NORM in 1992. In unconsolidated formations, the existing rock matrix is displaced to allow for the injected solids. In consolidated formations, disposal is accomplished by fracturing the formation (see next section).[24]

2.4.5 Injecting Into Formations Through Dedicated Class II Wells With Hydraulic Fracturing

Injection with hydraulic fracturing involves pumping of a mixture of sludges, scales, and slurry (typically produced saline water) into a well at elevated pressure. This results in fracturing of the formation and allows for emplacement of the waste slurry. Rogers and Associates report that use of this process normally creates a vertical fracture that may extend several hundred feet from the injection well.[25] Pressure is reduced to normal after slurry injection, thus closing the fracture and isolating the waste. The process can be repeated, but when the well is ultimately abandoned, it is plugged with cement to minimize or prevent any additional migration of fluids. Rogers and Associates report that intermediate level ($3x10^8$ pCi/g) radioactive wastes have been disposed of using this method.[26] While this method of disposal would provide a relatively high degree of waste isolation, concern exists regarding the ability to predict fracture behavior and the potential for fracturing to damage the mechanical integrity of the injection well or other wells located in the surrounding area. A demonstration of the technology in a Louisiana off-shore well was recently completed by Halliburton Energy Services.[27] In the demonstration, 2,300 drums of NORM-contaminated waste were processed into a bentonite-based gel to form a slurry and injected (by fracturing) about 1 mile below the sea floor. The study indicated that the same well site can be used for future disposal.

2.4.6 Emplacement Into Salt Dome Cavities

Rogers and Associates[28] report that salt dome cavities have been used to store petroleum products and that their use has been proposed for disposal of intermediate- and high-level radioactive wastes. It is believed that a salt formation would provide an impermeable containment zone for these wastes. They reportedly have plastic properties and would tend to self-anneal if any defects occurred in the containment

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[23] *A Preliminary Risk Assessment of Management and Disposal Options for Oil Field Wastes and Piping Contaminated with NORM in the State of Louisiana*. Peer Review Draft. Prepared for U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. March 1993.

[24] Lowe, D.J. *NORM Cleaning and Disposal Using Closed-Loop Hydroblasting or Solvent Bath and Underground Injection System*. Prepared for the SPE/EPA Exploration & Production Environmental Conference. March 1983.

[25] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*. RAE-8837/2-2. Rogers & Associates Engineering Corp. Prepared for API. May 1990.

[26] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*.

[27] Gardiner, Nicholas H. "NORM Scale Safely Disposed of by Fracturing Well." *Oil & Gas Journal*. May 23, 1994.

[28] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*.

structure.[29] Sludges, scales, and contaminated soils, equipment, and tubing potentially could be disposed of in this manner. While this alternative would potentially provide the greatest degree of isolation of wastes, it is unlikely that this will be an economically feasible alternative due to the high value of "wet space" in salt domes for storing petroleum products and the high expense to create and maintain "dry space" in salt mines.

2.5 Disposal Alternatives Not Involving Wells

2.5.1 Discharging Off-Shore

Discharge of produced water generated at off-shore locations has commonly been practiced. Many studies are under way to evaluate the impacts of NORM-contaminated produced water on marine life. At least one study has found that the off-shore discharge of radium results in no detectable impacts and that the overall ecological impacts are small.[30] The advantage of this method of disposal is that it is an economical alternative for oil and gas facilities to use. It is also likely to be inexpensive because it does not require treatment, storage, or transportation of the produced water.

2.5.2 Discharging Into Non-Potable Coastal Waters

Louisiana is requiring that discharges of produced water to brackish and saline coastal waters be phased out by January 1, 1995. Texas has prohibited produced water discharges to fresh water areas. There are potential impacts to marine life and potential human health effects associated with consumption of contaminated shellfish. This method of disposal is economical for oil and gas facilities to use, as it is relatively inexpensive compared with other methods.

2.5.3 Landspreading (Surface Disposal Without Cover)

In the landspreading option, sludges, scales, and soils are disposed of on the surface of open land. Rogers and Associates report[31] that the waste layer may range in thickness from 0.25 inches to 8 inches. A 0.25 inch layer is the minimum waste thickness that can be spread, and 8 inches is the maximum practical layer thickness. Rogers and Associates indicate that record-keeping is required to prevent repeated applications in a single area, thus limiting radiation buildup at the surface. More important, heavy reliance on this technique would require substantial use of surficial land area. In addition, radiation surveys are probably necessary to quantify radiation levels before and after waste is spread onto the surface.

2.5.4 Disposing in Pits (Lined or Unlined)

Disposing of scale, sludge, and produced water in lined or unlined pits was common practice until the presence of elevated levels of NORM in these materials became known. Since then, the material in most disposal pits has been excavated and is being stored in drums pending the promulgation of NORM

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[29] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment.* RAE-8837/2-2. Rogers & Associates Engineering Corp. Prepared for API. May 1990.

[30] White, Gregory. *Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Industry Equipment and Wastes. A Literature Review.* Idaho National Engineering Laboratory. DOE/ID/01570-T158. June 1992.

[31] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment.*

regulations. Wastes were removed from the pits due to concern about groundwater contamination. However, a literature review by Gregory White[32] quotes an API-funded literature review concluding that NORM radionuclides are not likely to contaminate groundwater because of their slow infiltration rate in soils and low mobility in fresh water aquifers due to their high adsorption capacity to soils and rock.

2.5.5 Landfarming (Mixing With Top 8 Inches Soil)

Landfarming is defined as mixing scale, sludge, and contaminated soil within the top 8 inches of soil on open land. Eight inches (depth of waste plus soil) is assumed because this corresponds to the tillage depth of standard agricultural equipment.[33] Like landspreading, one-time application is assumed, and therefore, significant surficial land is required and record-keeping would be necessary to prevent repeated application in the same area. Radiation surveys would also be necessary.

The state of Louisiana recently licensed one facility to landfarm NORM wastes. However unlike the scenario presented by Rogers[34] in which NORM waste is mixed with soil and left permanently in place, the Louisiana facility mixes NORM wastes with sufficient quantities of clean soil to dilute the radioactivity. The mixture is then placed in a landfill-type cell and treated as non-hazardous oilfield waste (NOW). The NOW remains in the cell until the NOW characteristics (e.g., oils and grease and chloride) have attenuated to the point where it is no longer considered a waste and can be excavated and placed in reuse piles. The state plans to reuse the material for such purposes as on-site levees and off-site roadbeds.[35] It is estimated that 3 to 5 percent of the NOW generated in Louisiana is contaminated to varying degrees with NORM.[36]

2.5.6 Land Burial (Soil Excavation, Waste Disposal, Covering With Fill 1-20 ft)

NORM wastes may be buried at commercial oil field waste sites, and may or may not be mixed with non-NORM oil field wastes before burial. If the wastes are mixed, it would serve to dilute the NORM wastes. Either way, this alternative involves soil excavation, waste disposal, and covering with fill that is level with the surrounding soil to minimize erosion. NORM-contaminated scale, sludge, soil, equipment, and tubing could be disposed of in this way. In Louisiana, specifically licensed nonhazardous oilfield waste (NOW) facilities may receive and treat NORM with Ra-226 or Ra-228 concentrations of up to 200 pCi/g; however, NORM and non-NORM wastes cannot be mixed.[37]

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[32] White, Gregory. *Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Industry Equipment and Wastes. A Literature Review*. Idaho National Engineering Laboratory. DOE/ID/01570-T158. June 1992. and Snavely, E.S. *Radionuclides in Produced Water — A Literature Review*. API Publication No. 4504. 1989.

[33] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*. RAE-8837/2-2. Rogers & Associates Engineering Corp. Prepared for API. May 1990.

[34] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*. RAE-8837/2-2; and *Safety Analysis for the Disposal of Naturally-Occurring Radioactive Materials in Texas*. RAE-8818-1. Prepared by Rogers & Associates Engineering Corporation for Texas Low-Level Radioactive Waste Disposal Authority. October 1988.

[35] Personal communication with Darryl Westmoreland of the Louisiana Department of Environmental Quality, Radiation Protection Division, on July 21, 1994.

[36] Wascom, Carroll D. "Regulating Naturally Occurring Radioactive Materials (NORM)." Presented at the Ground Water Protection Council Semi-Annual Meeting, Boston, Massachusetts. February 1994.

[37] Wascom, Carroll D. "Regulating Naturally Occurring Radioactive Materials (NORM)."

2.5.7 Disposing in Commercial Nonhazardous Oilfield Waste (NOW) Facility

There are facilities that accept nonhazardous oilfield waste and process it by landfarming the material to allow for biological reduction in the contaminants such as oil and grease. Such facilities might be used to dispose of NORM-contaminated NOW (scale, sludge, and soil). However, additional protective measures may be required because there is no way to accelerate the natural decay process of radioactive materials. Currently NORM and non-NORM oilfield wastes are not being disposed of in the same facility.[38] This method would provide a centralized disposal site, but detailed regulatory guidelines and procedures would likely be necessary.

2.5.8 Disposing in Sanitary Landfill

Sanitary landfills provide an opportunity for disposing of solid NORM wastes such as scale, sludge, soil, equipment, and tubing. For instance, Type I municipal landfills in Texas that comply with Texas municipal solid waste management regulations might be utilized for NORM disposal. At these facilities, the waste is compacted as it is emplaced and is covered with a layer of soil at the end of each day. Once full, the landfill is covered with at least 2 feet of soil. Infiltration and runoff are minimized to prevent groundwater contamination and to protect the integrity of the waste from a 100-year flood. Criteria for site location and access are specified.[39] These facilities can be designed to minimize radon exposure and groundwater contamination.

2.5.9 Byproduct Material Impoundment (Uranium Tailings Disposal Facility per 40 CFR 192)

NORM wastes generated at oil and gas production facilities could be disposed of in licensed NORM disposal facilities defined by EPA in 40 CFR 192. These facilities are designed to be effective for 1,000 years "to the extent reasonably achievable, or in any event, for at least 200 years." They are designed to limit radon flux to the atmosphere to 20 $pCi/m^2/s$.[40] Radon control is achieved with an earthen cover, and leaching and migration are minimized by exercising judgement in facility location and using engineering controls such as liners. Controls are maintained at the site to limit access or other activities. Scale, sludge, and contaminated soil and equipment could be disposed of in this manner. While this disposal alternative has been proposed for NORM wastes from oil and gas production operations, concern exists about the applicability of 40 CFR 192 technical criteria to these wastes. As of 1992, only one site in the United States accepted diffuse radium wastes, defined as having less than 2 nCi/g radium averaged over the shipment.[41]

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[38] Personal communications with personnel at the Louisiana DEQ and DNR.

[39] *Safety Analysis for the Disposal of Naturally-Occurring Radioactive Materials in Texas*. RAE-8818-1. Prepared by Rogers and Associates Engineering Corporation for Texas Low-Level Radioactive Waste Disposal Authority. October 1988.

[40] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*. RAE-8837/2-2. Rogers & Associates Engineering Corp. Prepared for API. May 1990.

[41] White, Gregory. *Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Industry Equipment and Wastes. A Literature Review*. Idaho National Engineering Laboratory. DOE/ID/01570-T158. June 1992.

2.5.10 Disposing in LLW Disposal Facility (Licensed Under NRC Regulations 10 CFR 61)

Oil and gas production NORM wastes could also be disposed of in low-level radioactive waste disposal sites licensed by the Nuclear Regulatory Commission (NRC). NORM-contaminated scale, sludge, soil, equipment, and tubing could be disposed of in this way. NRC regulations specify siting and other protective criteria to limit the number of feasible sites. Controls are implemented at the sites to limit future access. As of 1990, only three such facilities existed: Hanford, Washington; Beatty, Nevada; and Barnwell, South Carolina.[42] While NORM could potentially be disposed of in LLW facilities, the criteria for LLW disposal are not necessarily applicable to NORM disposal, partly because of the potential for radon generation from NORM containing Ra-226, as reported by Bernhardt and Rogers.[43]

2.5.11 Steel Resmelting

NORM-contaminated steel piping and equipment could be smelted. Most of the NORM would be separated from the metal and would accumulate in the slag; however, some residual NORM may remain.[44] Several companies, members of the Petroleum Environmental Research Forum (PERF), are sponsoring an on-going study of the viability of this process. However, there are many drawbacks to the process. There is a high potential for exposure to NORM due to transport, handling, and the process itself, and the NORM slag that results must be disposed of. The advantages of this process is that it reduces the volume of NORM waste, and it may be more economical than cleaning scale and sludge from contaminated equipment or disposing of the contaminated equipment.

2.5.12 Non-Retrieval of Surface Pipe

Transmission pipe contaminated with NORM could be left in the ground just below the surface as a means of disposal. This alternative would reduce the short-term exposure to NORM from alternatives that require cleaning the NORM scale from the piping, but it would increase the long-term potential exposure over alternatives involving injection or deeper land burial. In addition, this alternative carries the risk that, in the absence of effective institutional controls, humans may be exposed to the NORM by inadvertently cutting into the pipeline at some time in the future.[45]

2.5.13 Burial in Surface Mines

NORM scales, sludges, soil, and equipment could be disposed of by emplacing them in existing mine excavations and covering them with soil. Rogers and Associates[46] report that typical burial depths would be 50 feet or greater, and existing excavations could accommodate large quantities of waste. These large depths of burial make erosion of the wastes or intrusion into the disposal area unlikely, but it is

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[42] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment.* RAE-8837/2-2. Rogers & Associates Engineering Corp. Prepared for API. May 1990.

[43] Bernhardt, D.E., and V.C. Rogers. *Characteristics of NORM Waste Disposal.* Spectrum '92 International Topical Meeting on Nuclear and Hazardous Waste Management. Vol 1, p. 432-437. 1992.

[44] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment.*

[45] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment.*

[46] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment.*

possible.[47] This method of disposal would provide a centralized disposal site, rather than small scattered sites such as what would be found in a well field.

2.6 Current and Proposed Research Related to NORM Waste Management and Disposal

Several current and proposed studies relate to the generation, management, and disposal of NORM waste. The purpose and status of these studies are described below.

2.6.1 NORM Waste Characterization

The American Petroleum Institute (API) is conducting a nation-wide study of NORM waste generation. The study, funded by the Gas Research Institute (GRI) and the Department of Energy (DOE), will include testing of production facilities, pipe yards, and waste storage areas. The purpose of the study is to determine the volumes and types of NORM waste being generated in the petroleum industry. The current study is designed to expand on the results of a previous API-funded study conducted in the mid-1980s to identify the geographic areas within the United States where petroleum processing facilities have the highest incidence of NORM contamination, and to identify the types of equipment with the highest NORM concentrations.[48]

API has designed the sampling protocol for the nation-wide study of NORM waste generation and is supplying the sampling bottles to the facilities included in the survey. At these facilities, health and safety staff or sampling technicians conduct the sampling; alpha, beta, gamma, and radon readings are taken. Analytical services are provided by Idaho National Engineering Laboratory, but the University of Texas at Austin may be involved in testing for chemical composition. The ultimate goal of the study is to investigate 300 to 400 facilities (as in the previous study); to date, API has completed investigation for approximately 20 facilities. API plans to continue contacting industry representatives to increase the involvement of more facilities. It is likely that the study will not be completed for several more years.[49]

A joint study is being conducted in California by the state's Department of Health Services and the Department of Oil, Gas, and Geothermal Resources (DOGGR), with the cooperation of the oil and gas producing industry. The study includes 100 oil and gas sites, selected based on input from industry and the DOGGR. The sites are located in oil-producing areas, gas-producing parts of the Sacramento Valley, and geothermal sites. Samples from wells, tanks, separators, pipe-yards, gas plants, tank batteries, and sumps are being tested for radioactive pipe scale, sediment, and produced water. Sampling was completed in October of 1994 and results may be available in a report written by the Department of Health Services by spring of 1995.[50]

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[47] *Management and Disposal Alternatives for NORM Wastes in Oil Production and Gas Plant Equipment*. RAE-8837/2-2. Rogers & Associates Engineering Corp. Prepared for API. May 1990.

[48] Otto, G. H. *A National Survey on Naturally Occurring Radioactive Materials (NORM) in Petroleum Producing and Gas Processing Facilities*. Prepared for API. Dallas, Texas. 1989.

[49] Personal communication with Mike Laudermilk, API, Dallas, Texas, on February 17, 1995.

[50] Personal communication with Jim Campion, Acting Director, California Department of Oil, Gas, and Geothermal Resources (DOGGR) on November 11, 1994 and February 17, 1995.

2.6.2 NORM Management Costs

API also has conducted a study which provides a "snapshot" of how much current NORM management and disposal practices are costing industry. The report is in draft form and should be final by June of 1995.[51]

2.6.3 NORM Disposal

DOE is initiating a program to evaluate treatment and disposal alternatives for NORM waste, culminating in development of a full-scale commercial facility. The program has solicited competitive bids from contractors to demonstrate, on a field pilot scale, NORM treatment and disposal technologies. DOE is in the process of reviewing the bids and will select and evaluate one or two technologies that involve underground disposal of NORM sludge related to natural gas production. A contractor will be chosen by April, 1995. Contaminated equipment, piping, and scale are not being considered in the program. After the demonstrations and evaluations are complete, DOE plans to build a full-scale commercial facility in Louisiana using the selected technology. The program is funded through DOE's Natural Gas Environmental Research Regulatory Impact Analysis Program.[52]

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[51] Personal communication with Mike Laudermilk, API, Dallas, Texas, on February 17, 1995.

[52] Personal communication with personnel from API's Dallas office and DOE personnel from the Baton Rouge office on July 19, 1994 and February 17, 1995.

CHAPTER 3

State NORM Regulations

3.1 State NORM Regulations - Information Gathering

Currently, the management and disposal of NORM wastes associated with the production of oil and gas are not federally regulated. To determine the regulatory actions which states have taken, Exhibit 5 was compiled to identify current and projected state NORM regulations, alternative state-regulated NORM management and disposal technologies, and state NORM licensing requirements. To prepare the table, numerous sources were contacted including, but not limited to: state agencies, the Interstate Oil and Gas Compact Commission (IOGCC), the Council of Radiation Control Program Directors (CRCPD), and Peter Gray & Associates, which publishes *The NORM Report*.[53] Copies of final, proposed, and/or draft NORM regulations were obtained from 11 of the 36 states with active oil and gas producing wells. The State of Wyoming could not provide us with copies of their draft regulations. Wyoming's proposed NORM regulations for the oil and gas industry are in internal draft form.

The following issues were discussed with each state representative contacted:

- the scope of current and/or proposed NORM regulations;
- the estimated number of facilities within the oil and gas industry that would be affected by NORM regulations;
- the time table for the state's regulatory action; and
- the names, addresses, and phone numbers of state personnel involved in NORM related activities.

Relevant data from *The NORM Report* was incorporated into the exhibit. The IOGCC also provided extensive information. According to discussions with the states, five states (Indiana, Kansas, Nebraska, New York, and North Dakota) plan to wait for the IOGCC to draft a proposal for regulating NORM, which they can use to draft their own state NORM regulations. However, the IOGCC indicated that it has no plans to draft such a proposal in the near future, and referred these five states to CRCPD's *Part N Regulation and Licensing of Naturally Occurring Radioactive Material (NORM)*. A copy of the "Part N" report was received from the CRCPD. The data from this report was incorporated into the exhibit for each of the five states. Each state representative was contacted to verify the NORM regulatory data compiled in the exhibit.

[53] Published quarterly by Peter Gray & Associates, P.O. Box 470932, Tulsa, OK 74147, (Tel. 918-492-5250).

Exhibit 5: Regulatory Summary for State NORM Requirements

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Arkansas[1] Status of NORM Regulations: Final State Contact: Bernard Bevill, Arkansas Department of Health, Division of Radiation Control & Emergency Management 4815 W. Markham Mail Slot #30 Little Rock, AR 72205-3867 (501) 661-2000	General license required for materials exceeding: - 5 pCi/g Radium; - 0.05% by weight of Uranium or Thorium; or - 150 pCi/g of any other NORM radionuclide below the surface. General license does not authorize the manufacturing or distribution of NORM.	No person shall transfer land for unrestricted use where the concentration of Radium-226 or Radium-228 in soil averaged over any 100 square meters exceeds the background level by more than: - 5 pCi/g averaged over the first 15 cm of soil below the surface; and - 15 pCi/g averaged over 15 cm thick layers of soil more than 15 cm below the surface NORM contaminated equipment in excess of the levels set forth in Appendix C, Section 7, of the General License Section (see Appendix C of this document) may be released for maintenance and/or overhaul provided that the recipient is specifically licensed to perform the activity on contaminated equipment.	The possession and use of natural gas, natural gas products, crude oil and crude oil products are exempt from the requirements of these regulations. The distribution of natural gas and crude oil and the manufacturing and distribution of natural gas and crude oil products are exempt from specific licensing requirements in the Exemptions Section but are subject to general licensing requirements in the General License Section.	Each person subject to the general license in the General License Section or a specific license shall manage and dispose of NORM contaminated wastes: - in accordance with the applicable U.S. EPA requirements; - by transferring the wastes for disposal to a land disposal facility licensed by U.S. NRC, an Agreement State, or a Licensing State; or - in accordance with alternate methods authorized by the Arkansas Department of Health (ADOH) upon application or upon ADOH's initiative. Transfers of NORM contaminated wastes for disposal shall be made to a person specifically authorized to receive such waste.	Arkansas expects to address the issue of contaminated scale from equipment and pipes sometime in the future.

[1] Unless otherwise specified, data are based on Arkansas' *Rules and Regulations for Control of Sources of Ionizing Radiation, Section 7. NORM; The NORM Report* published by Peter Gray & Associates; *Summary of IOGCC Member States' Regulation of Naturally Occurring Radioactive Material (NORM)*; and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Colorado[2] Status of NORM Regulations: Under Consideration State Contact: Don Simpson Radiation Control, Department of Public Health and Environment 4300 Cherry Creek Dr. S. Denver, CO 80222-1530 (303) 692-3066	Although, the Colorado Department of Health drafted NORM regulations, Colorado's legislature has decided to wait until U.S. EPA takes action on regulating NORM waste. The draft regulations specify: A specific license is required to perform the commercial handling for transfer and disposal of NORM for materials exceeding: - 5 pCi/g of any NORM radionuclide; and - 5 pCi/g of radium. A specific license is required to produce any product containing a concentration of radium exceeding 5 pCi/g.	Nonexistent.	Although, the Colorado Department of Health drafted NORM regulations, Colorado's legislature has decided to wait until U.S. EPA takes action on regulating NORM waste. The draft regulations specify: Any person is exempt from the regulatory requirements to the extent that the person handles for disposal or disposes of NORM-contaminated natural gas, a natural gas product, crude oil or a crude oil product for disposal. Any person is exempt from the regulatory requirements who handles or disposes of NORM contaminated production water on-site, which is derived from the recovery, production, or processing of crude oil or natural gas provided such person's activities are in compliance with the regulations of the Oil and Gas Conservation Committee of the Colorado Department of Natural Resources.	Although, the Colorado Department of Health drafted NORM regulations, Colorado's legislature has decided to wait until U.S. EPA takes action on regulating NORM waste. The draft regulations specify: No person shall dispose of NORM contaminated material (including soil) exceeding: - 5 pCi/g of radium; and - 5 pCi/g of any other NORM radionuclide at any off-site location, except at a solid waste facility possessing applicable permits and authorizations to receive and dispose of solid waste material. No person shall dispose of NORM contaminated material (including soil) exceeding: - 30 pCi/g of radium; or - 150 pCi/g of any other NORM radionuclide, at an off-site location, except at a facility specifically licensed under Part 19, NORM Regulations, to receive and dispose of such material, or licensed by another state to dispose of NORM.	In April 1994, the Governor of Colorado signed into law Senate Bill 94-186 which defers the adoption of Colorado NORM regulations until any time after U.S. EPA adopts rules for the disposal of NORM. As a result of SB 94-186, on May 18, 1994 the Colorado Board of Health "vacated" the rule-making concerning NORM regulations. This means that no new NORM rules are now before the board.

[2] Unless otherwise specified, data are based on Draft of *Part 19: Naturally Occurring Radioactive Material (NORM)*, Colorado Department of Health, January 1, 1994; *Summary of IOGCC Member States' Regulation of Naturally Occurring Radioactive Material (NORM)*; and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Georgia[3] Status of NORM Regulations: Final State Contact: Lauren McGauhey, Air Protection-Radiation Division 4244 International Parkway Atlanta, GA 30354 (404) 363-7000	A general license is required for materials in media other than soil, or in soil averaged over any 100 square meters for the first 15 cm of soil below the surface: - With radon emanation rate less than 20 pCi/g per square meter per second, concentrations exceeding 30 pCi/g of technologically enhanced radium-226 or radium-228; - With radon emanation rate greater than 20 pCi/g per square meter per second, concentrations exceeding 5 pCi/g of technologically enhanced radium-226 or radium-228; or - Concentrations exceeding 150 pCi/g of any other NORM radionuclide.	No person shall transfer land for unrestricted use where the concentration of radium-226 or radium-228 in soil averaged over any 100 sq meters exceeds the background level by more than: - 5 pCi/g, averaged over the first 15 cm of soil below the surface; and - 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface. NORM-contaminated facilities and equipment in excess of the level set forth in the licensing requirements shall not be released for unrestricted use.	The possession, storage, transportation, commercial distribution, and use of natural gas and natural gas products and crude oil and crude oil products as fuel are exempt from the requirements of this section. The distribution of natural gas and crude oil and the manufacturing and distribution of natural gas and crude oil products are exempt from the specific license requirements of this rule but are subject to the general license requirements in (7) (General License), (8) (Protection of Workers and the General Population During Operations), and (9) (Disposal and Transfer of Waste for Disposal). Possession of produced waters from crude oil and natural gas production is exempt from these requirements if the produced waters are reinjected in a well approved by the Dept. of Natural Resources (DNR) or if the produced waters are discharged under the authority of the DNR.	Each person subject to the general license or a specific license shall manage and dispose of wastes containing NORM: - in accordance with the U.S. EPA's applicable requirements; - in a manner equivalent to the requirements for uranium and thorium byproduct materials in 40 CFR 192; - by transferring the wastes for disposal to a land disposal facility licensed by the U.S. NRC, an Agreement State, or a Licensing State; or - in accordance with alternate methods authorized by the Department of Natural Resources (DNR) upon application of upon the DNR's initiative. Transfers of NORM-contaminated waste for disposal shall be made only to a person specifically authorized to receive such waste.	None.

[3] Unless otherwise specified, data are based on *Rules and Regulations for Radioactive Materials Chapter 391-3-17, Part 8-Regulation and Licensing of Naturally-Occurring Radioactive Materials (NORM)*, Georgia Department of Natural Resources, March 16, 1994 and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Illinois[4] Status of NORM Regulations: Under Consideration State Contact: Larry Bengal, Department of Mines & Mills, Oil & Gas Division 300 West Jefferson St. Suite 300 Springfield, IL 62706 (217) 782-7756	Undecided	Undecided	Undecided	Pits shall be restored as follows: - produced waster shall be disposed of in accordance with Section 240.940(b); - crude oil bottom sediments shall be disposed of in accordance with Section 240.940(a); and - Pit residue for oil and gas residual shall be either: - removed from site and disposed of at an IL EPA-approved nonhazardous landfill provided that it does not have NORM waste; or - consolidated from the sides to bottom of the pit and covered with a clay or synthetic liner sufficient to impede the infiltration of surface water.	Illinois Department of Nuclear Safety is working on a draft of NORM regulations specific to worker safety and dust residue. The draft is not expected to be completed until sometime in 1995.

[4] Unless otherwise specified, data are based on *62 Illinois Administrative Code, Chapter 1, Section 240.860 Pits*: Emergency Amendment at 18 Illinois Regulation 10380 effective June 21, 1994, for a maximum of 150 days and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Indiana[5] Status of NORM Regulations: Under Consideration State Contact: James Slutz, Division of Oil & Gas, Department of Natural Resources 402 West Washington St. Room 293 Indianopolis, IN 46204 (317) 232-4055	A general license is required for materials exceeding: - 5 pCi/g above background of any combination of radium-226 or 228. The general license does not authorize the manufacturing or distribution of products containing NORM in concentrations greater than those specified above nor does it authorize the receipt and disposal of wastes from other persons.	No person shall transfer land for unrestricted use where the concentration of radium-226 or radium-228 in soil averaged over any 100 square meters exceeds the background level by more than: - 5 pCi/g, averaged over any 15 cm layer of soil below the surface. NORM contaminated facilities and equipment in excess of the level set forth in the Draft SSRCR, Part N of Appendix A (see Appendix C of this document) shall not be released for unrestricted use.	The possession and use of natural gas and natural gas products and crude oil and crude oil products as a fuel are exempt from these regulatory requirements. The distribution of natural gas and crude oil and the manufacturing and distribution of natural gas and crude oil products are exempt from the specific license requirements of Part N but are subject to the general license requirements in N.10 (General License), N.11 (Protection of Workers During Operations), N.12 (Protection of the General Population from Releases of Radioactivity), and N.13 (Disposal and Transfer of Waste for Disposal). Contaminated pipe and plumbing from oil and gas operations shall be disposed of: - so as to prevent any reintroduction into commerce or unrestricted use; and - within disposal areas specifically designed to meet disposal criteria.	Each person subject to the general license in N.10 (General License) or a specific license shall manage and dispose of wastes containing NORM: - in accordance with the applicable requirements of U.S. EPA for disposal of such wastes; - by transferring the wastes for disposal to a facility licensed under requirements equivalent to those for uranium and thorium byproduct materials in 40 CFR 192; - by transferring the wastes for disposal to a land disposal facility licensed by U.S. NRC, an Agreement State, or a Licensing State; or - in accordance with alternate methods authorized by the Agency upon application or upon the Agency's initiative.	State: Indiana has not specified when they will draft NORM regulations. Currently, Indiana is waiting for the Interstate Oil and Gas Compact Commission's (IOGCC) proposal on NORM regulations. IOGCC: The IOGCC does not have proposed NORM regulations. They are referring the states to the Council of Radiation Control Program Director's (CRCPD) proposed Part N.

[5] Unless otherwise specified, data are based on the Council of Radiation Control Program Director's proposed *Part N Regulations and Licensing of Naturally Occurring Radioactive Materials (NORM)* and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Kansas[6] Status of NORM Regulations: Under Consideration Contact: William Bryson, Kansas Corporation Commission 1500 SW Arrowhead Rd Topeka, KS 66604-4027 (913) 271-3100	A general license is required for materials exceeding: - 5 pCi/g above background of any combination of radium-226 or 228. The general license does not authorize the manufacturing or distribution of products containing NORM in concentrations greater than those specified above nor does it authorize the receipt and disposal of wastes from other persons.	No person shall transfer land for unrestricted use where the concentration of radium-226 or radium-228 in soil averaged over any 100 square meters exceeds the background level by more than: - 5 pCi/g, averaged over any 15 cm layer of soil below the surf NORM-contaminated facilities and equipment in excess of the level set forth in the Draft SSRCR, Part N of Appendix A (see Appendix A of this document) shall not be released for unrestricted use.	The possession and use of natural gas and natural gas products and crude oil and crude oil products as a fuel are exempt from these regulatory requirements. The distribution of natural gas and crude oil and the manufacturing and distribution of natural gas and crude oil products are exempt from the specific license requirements of Part N but are subject to the general license requirements in N.10 (General License), N.11 (Protection of Workers During Operations), N.12 (Protection of the General Population from Releases of Radioactivity), and N.13 (Disposal and Transfer of Waste for Disposal). Contaminated pipe and plumbing from oil and gas operations shall be disposed of: - so as to prevent any reintroduction into commerce or unrestricted use; and - within disposal areas specifically designed to meet disposal criteria.	Each person subject to the general license in N.10 (General License) or a specific license shall manage and dispose of wastes containing NORM: - in accordance with the applicable requirements of U.S. EPA for disposal of such wastes; - by transferring the wastes for disposal to a facility licensed under requirements equivalent to those for uranium and thorium byproduct materials in 40 CFR 192; - by transferring the wastes for disposal to a land disposal facility licensed by U.S. NRC, an Agreement State, or a Licensing State; or - in accordance with alternate methods authorized by the Agency upon application or upon the Agency's initiative.	State: Kansas has not specified when they will draft NORM regulations. Currently, Kansas is waiting for the Interstate Oil and Gas Compact Commission's (IOGCC) proposal on NORM regulations. IOGCC: The IOGCC does not have proposed NORM regulations. They are referring the states to the Council of Radiation Control Program Director's (CRCPD) proposed Part N.

[6] Unless otherwise specified, data are based on Council of Radiation Control Program Director's proposed *Part N Regulation and Licensing of Naturally Occurring Radioactive Materials (NORM)* and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Kentucky[7] Status of NORM Regulations: Proposed State Contact: John Volpe, Radiation Control Board 275 E. Main St. Frankfort, KY 40621 (502) 564-3700	Kentucky has not established numerical action levels above which NORM is regulated. Licensing criteria will be based on: - the concentration of radium in pCi/g; - % by weight of uranium or thorium; or - the concentration of other NORM radionuclides in pCi/g. This general license shall not authorize the manufacturing or distribution of products or excavation of land containing NORM in concentrations greater than those specified above nor the disposal of wastes from other persons.	Kentucky has not established numerical action levels above which NORM is regulated. It is anticipated that limits will be placed on transfer of land for unrestricted use if it is contaminated with Ra-226 or Ra-228 in soil in excess of specific concentration limits. Limits will apply to the concentration of radium: - averaged over the first 15 cm of soil below the surface; - averaged over 15 cm thick layers of soil more than 15 cm below the surface; or - the gamma exposure at 1 meter above the ground surface. NORM-contaminated facilities and equipment in excess of the levels set forth in Section 21 of Kentucky's proposed administrative regulation, 902 KAR 100:042, "Licensing of NORM" (see Appendix C of this document), shall not be released for unrestricted use.	The possession and use of natural gas and natural gas products and crude oil and crude oil products as a fuel are exempt from these regulatory requirements. The distribution of natural gas and crude oil and the manufacturing and distribution of natural gas and crude oil products are exempt from the specific license requirements of this administrative regulation, but shall be subject to the general license requirements of Sections 4 (General License), 5 (Protection of Workers During Operations), 6 (Protection of the General Population), and 7 (Disposal and Transfer of Waste for Disposal). Produced waters from crude oil and natural gas production are exempt from these regulatory requirements, if reinjected into a well approved by the U.S. EPA as a Class II injection/disposal well.	A person subject to the general license or a specific license shall manage and dispose of NORM wastes: - as specified by U.S. EPA's applicable requirement; - in a manner equivalent to the requirements for uranium or thorium byproduct materials in 40 CFR 192; - by transferring wastes for disposal to a land disposal facility licensed by the U.S. NRC, an Agreement State, or a Licensing State; or - as specified by alternate methods authorized by the Kentucky Cabinet for Human Resources (KCHR) upon application or upon the KCHR's initiative. Transfers of NORM contaminated waste for disposal shall be made only to a person specifically licensed to receive the waste.	The proposed regulations are currently in the public comment phase. It will be 6 to 9 months before the regulations are promulgated (as of September 1994).

[7] Unless otherwise specified, data are based on proposed administrative regulation: *902 KAR 100:042 Licensing of Naturally Occurring Radioactive Materials (NORM)*, Kentucky Cabinet for Human Resources, Department for Health Services, July 5, 1994 and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Louisiana[8] Status of NORM Regulations: Final State Contact: Karen Fisher-Brasher, Program Manager of NORM Section Department of Environmental Quality, Division of Radiation Protection 7220 Blue Bonnet Rd. Baton Rouge, LA 70810 (504) 765-0160	Facilities, equipment, and sites contaminated to levels exceeding those set forth below shall not be released for unrestricted use: - 5 pCi/g of radium-226 or radium-228, above background; or - 150 pCi/g of any other NORM radionuclide, provided that these concentrations are not exceeded at any time. - Equipment which contains NORM if the maximum radiation exposure level exceeds 50 microroentgens per hour at any accessible point (including background levels). The general license does not authorize the manufacturing or distribution of products containing NORM, or the landfarming of NORM, or the transfer from one general licensee to another general licensee of NORM with levels or concentrations greater than those specified in LAC 33:XV.1404 for purposes of decontamination or disposal. The general license does not authorize the cleaning of tubular goods and equipment in connection with a pipe yard, storage yard, or equipment yard. Pipeyards which currently have contamination in	Contaminant levels below 5 pCi/g are exempt; between 5 and 30 pCi/g may be treated/diluted at nonhazardous oilfield waste facilities (with some restrictions); between 30 and 200 pCi/g may be treated/diluted for reuse at specifically licensed nonhazardous oilfield waste facilities. If decontamination is required, then decontamination shall be to 5 pCi/g (of radium).	The wholesale and retail distribution (including custom blending), possession, use and transportation of the following products/materials are exempt from the requirements of these regulations: - natural gas and natural gas products; and - crude oil and crude oil products. Produced waters from crude oil and natural gas production are exempt from the requirements of these regulations. Tanks, vessels, containers, storage facilities, and distribution lines in refineries and petrochemical and gas plants contaminated with regulated NORM are not exempt from the requirements of these regulations.	Treatment or disposal of NORM waste shall be by transfer of the wastes to a licensed land disposal facility, or by authorized alternate methods. For nonhazardous oilfield waste containing NORM at concentrations not exceeding 30 pCi/g of radium-226 or radium-228 by transfer to a nonhazardous oilfield waste commercial facility regulated by DNR for treatment if the following are met: a. dilution in the end product after treatment does not exceed 5 pCi/g above background; b. the nonhazardous oilfield commercial facility has a program for screening incoming shipments to ensure that the 30 pCi/g limit is not exceeded; and c. The DNR approves; or for nonhazardous oilfield waste containing concentrations between 30 and 200 pCi/g wastes may be treated at facilities specifically licensed by the DNR for such purposes. Intrastate transfers of waste containing NORM for disposal shall be made only to persons authorized by the DNR to receive such waste. The melting of scrap metal may be authorized by a specific license if	

[8] Unless otherwise specified, data are based on *Environmental Regulatory Code Part XV. Radiation Protection*, Louisiana Department of Environmental Quality, 3rd Edition, 1994; *Summary of IOGCC Member States' Regulation of Naturally Occurring Radioactive Material (NORM)*, *The NORM Report* published by Peter Gray & Associates; and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Louisiana (Continued)	their facilities are allowed to clean them on a one-time basis. On-site maintenance is allowed only if radiation levels are below 2 millirem per hour.			the dilution of NORM in the end products or melt by-products is sufficient to reduce the concentrations of radium-226 and radium-228 to less than 5 pCi/g.	
Michigan[9] Status of NORM Regulations: Under Consideration State Contact: Ray Vugrinovich, Department of Natural Resources 735 E. Hazel St. Lansing, MI 48912 (517) 334-6923	The following interim standards intended for the oil & gas industry are not regulations, but are advisory in nature: Radiological protection standards: - NORM containing radium-226 at concentrations exceeding 5 pCi/g; and - NORM in the form of contaminated brines, sludges, scales, soils, equipment, or other waste byproducts associated with the extraction of oil, gas, or mineral resources.	The following interim standards intended for the oil & gas industry are not regulations, but are advisory in nature: Before release for unrestricted use, facilities or equipment contaminated by NORM should not exceed the following contamination limits for the listed materials: - alpha emitting nuclides—300 dpm/100 cm^2 (max) and 100 dpm/100 cm^2 (avg); and - beta-gamma emitting nuclides—15,000 dpm/100 cm^2 (max) and 5,000 dpm/100 cm^2 (avg). Before release of land for unrestricted use, the NORM contamination average over 100 square meters of land surface should not exceed: - 5 pCi/g for radium-226 averaged over the first 15 cm thick layer of soil; and - 15 pCi/g for radium-226 averaged over any succeeding 15 cm thick layer of soil.	The following interim standards intended for the oil & gas industry are not regulations, but are advisory in nature: The possession, use, and transport of NORM in natural gas, natural gas products, crude oil, or crude oil products should be exempt from these standards.	The following interim standards intended for the oil & gas industry are not regulations, but are advisory in nature: Non-exempt NORM should not be disposed of, except: - by transfer to: - a low-level radioactive waste disposal facility; - to a NORM waste disposal facility; or - to another recipient specifically authorized to receive NORM waste and licensed by NRC, NRC Agreement State, or a Licensing State as designated by the CRCPD; - by transfer to a Type II landfill, if the radium-226 concentration in the shipment does not exceed an average of 50 pCi/g; or - by downhole disposal based upon a disposal plan approved by Michigan Dept. of Natural Resources or U.S. EPA prior to actual disposal.	Michigan's Guidance Documents and Standards are proposed and under review by the Michigan Department of Health. No plans exist to promulgate these guidance documents.

[9] Unless otherwise specified, data are based on Michigan Department of Health's *Interim Standards for the Control of NORM Associated with the Oil & Gas Industry in Michigan*; *Summary of IOGCC Member States' Regulation of Naturally Occurring Radioactive Material (NORM)*; and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Mississippi[10] Status of NORM Regulations: Final State Contact: Fred Hille, Mississippi State Oil & Gas Board 500 Greymont Ave. Suite E Jackson, MS 39202 (601) 354-7142	A general license is required for materials exceeding: - 5 pCi/g of radium-226 or 228 above background; - With a radon emanation rate that does not exceed 20 pCi per square meter per second, concentration of 30 pCi/g of technologically enhanced radium-226 or 228, averaged over any 100 square meters; - 150 pCi/g of any other NORM radionuclide, provided that these concentrations are not exceeded at any time; or - equipment exceeding 25 microentgens per hour above background radiation at any accessible point. A general license does not authorize the manufacture of products containing NORM in concentrations greater than those specified above.	Unrestricted use is not permitted for facilities and equipment with NORM concentrations exceeding those in Part 801, Section N, Part 4, of *Regulations for Control of Radiation in Mississippi* (see Appendix C of this document) or for land where levels of radium-226 or 228 in soil averaged over any 100 square meters in which the radon emanation rate is less than 20 pCi per square meter per second, and in which the concentrations of technologically enhanced radium-226 or 228 are in excess of 30 pCi/g. No person shall transfer land contaminated with technologically enhanced radium-226 or 228, averaged over any 100 square meter, in which the radon emanation rate is 20 pCi per square meter per second or more; and concentrations of radium exceed: - 5 pCi/g, averaged over the first 15 cm of soil below the surface; and 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface.	The possession, use, and transportation of natural gas and natural gas products, and crude oil and crude oil products as a fuel are exempt from these regulatory requirements. The manufacturing and distribution of natural gas, crude oil, and natural gas and crude oil products are exempt from specific license requirements, but are subject to the general license requirements in Sections 801.N.10 (General License), N.11 (Protection of Workers and the General Population), N.12 (Disposal and Transfer of Waste for Disposal). Produced waters from crude oil and natural gas are exempt from these regulations if the produced waters are reinjected in a well approved by the Mississippi State Oil and Gas Board and the Mississippi Department of Environmental Quality and is a Class II injection/disposal well.	General and specific licensees shall manage and dispose of wastes containing NORM: - in accordance with the requirements of U.S. EPA for the disposal of such wastes; - in a manner equivalent to the requirements for uranium and thorium by product material in 40 CFR 192; - by transferring the wastes for disposal to a land disposal facility licensed by the U.S. NRC, an Agreement State, or a Licensing State; or - in accordance with alternate methods authorized by the Agency. Transfers of NORM contaminated waste for disposal shall be made only to a person authorized to receive such waste.	The Mississippi State Oil & Gas Board has developed NORM regulations related to extraction and production wastes. The board approved the regulations on August 17, 1994 (Rule 68), and they were approved on September 21, 1994.

[10] Unless otherwise specified, data are based on *Summary of IOGCC Member States' Regulation of Naturally Occurring Radioactive Material (NORM)* (which is based on *Regulations for Control of Radiation in Mississippi, Part 801, Section N*); *Rule 68 - Disposal of Naturally Occurring Radioactive Materials (NORM) Associated with the exploration and production of oil and gas*; The NORM Report published by Peter Gray & Associates; and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions

Mississippi
 	
(Continued)
			The following is a summary of *Rule 68 - Disposal of Naturally Occurring Radioactive Material (NORM) Associated with the exploration and production of oil and gas*:[11]
			
			In order to qualify for disposal pursuant to this rule, the NORM must have been derived from the exploration and production of oil and gas within the territorial area of Mississippi.
			
			Acceptable methods of disposal of NORM shall be limited to the following:
			- NORM material can be:
			  - placed between cement plugs; or
			  - encapsulated in pipe then placed between cement plugs;
			- NORM slurry can be:
			  - mixed with gel or mud and placed between cement plugs; or
			  - placed into a formation; or
			- NORM material can be disposed of offsite at a licensed low level radioactive waste or NORM disposal facility.		

[11] Mississippi promulgated this rule in September, 1994.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Nebraska[12] Status of NORM Regulations: Under Consideration State Contact: Paul Roberts, Nebraska Oil & Gas Commission P.O. Box 399 Sidney, NE 69162 (308) 254-4595	A general license is required for materials exceeding: - 5 pCi/g above background of any combination of radium-226 or 228. The general license does not authorize the manufacturing or distribution of products containing NORM in concentrations greater than those specified above nor does it authorize the receipt and disposal of wastes from other persons.	No person shall transfer land for unrestricted use where the concentration of radium-226 or radium-228 in soil averaged over any 100 square meters exceeds the background level by more than: - 5 pCi/g, averaged over any 15 cm layer of soil below the surface. NORM-contaminated facilities and equipment in excess of the level set forth in the Draft SSRCR, Part N of Appendix A (see Appendix C of this document) shall not be released for unrestricted use.	The possession and use of natural gas and natural gas products and crude oil and crude oil products as a fuel are exempt from these regulatory requirements. The distribution of natural gas and crude oil and the manufacturing and distribution of natural gas and crude oil products are exempt from the specific license requirements of Part N but are subject to the general license requirements in N.10 (General License), N.11 (Protection of Workers During Operations), N.12 (Protection of the General Population from Releases of Radioactivity), and N.13 (Disposal and Transfer of Waste for Disposal). Contaminated pipe and plumbing from oil and gas operations shall be disposed of: - so as to prevent any reintroduction into commerce or unrestricted use; and - within disposal areas specifically designed to meet disposal criteria.	Each person subject to the general license in N.10 (General License) or a specific license shall manage and dispose of wastes containing NORM: - in accordance with the applicable requirements of U.S. EPA for disposal of such wastes; - by transferring the wastes for disposal to a facility licensed under requirements equivalent to those for uranium and thorium byproduct materials in 40 CFR 192; - by transferring the wastes for disposal to a land disposal facility licensed by U.S. NRC, an Agreement State, or a Licensing State; or - in accordance with alternate methods authorized by the Agency upon application or upon the Agency's initiative.	State: Nebraska has not specified when they will draft NORM regulations. Currently, Nebraska is waiting for the Interstate Oil and Gas Compact Commission's (IOGCC) proposal on NORM regulations. IOGCC: The IOGCC does not have proposed NORM regulations. They are referring the states to the Council of Radiation Control Program Director's (CRCPD) proposed Part N.

[12] Unless otherwise specified, data are based on Council of Radiation Control Program Director's proposed *Part N Regulations and Licensing of Naturally Occurring Radioactive Materials (NORM)* and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
New Jersey[13] Status of NORM Regulations: Final State Contact: Fred Sickles N.J. Department of Environmental Protection, Radiation Protection Programs, Bureau of Environmental Radiation CN 415 Trenton, NJ 08625-0415 (609) 987-6367	A general license is required for materials exceeding: - 0.02 μCi/cc of Beryllium (Be 7); - 0.002 μCi/cc of Cadmium (Cd 109); - 0.008 μCi/cc of Carbon (C 14); - 0.02 μCi/cc of Chromium (Cr 51); - 0.005 μCi/cc of Cobalt (Co 57); - 0.03 μCi/cc of Hydrogen (H 3); - 0.008 μCi/cc of Iron (Fe 55); - 0.0003 μCi/cc of Manganese (Mn 52); - 0.001 μCi/cc of Manganese (Mn 54); - 0.004 μCi/cc of Tungsten (W 181); - 0.0003 μCi/cc of Vanadium (V 48); - 0.001 μCi/cc of Zinc (Zn 65); or - 1 x 10^{-6} μCi/cc of beta and/or gamma emitting radioactive material not listed above with half life less than 3 years.	Nonexistent.	Nonexistent.	Nonexistent.	Currently, New Jersey is revising its NORM regulations. Under consideration are waste disposal and soil cleanup standards.

[13] Unless otherwise specified, data are based on *New Jersey Administrative Code, Chapter 28 Bureau of Radiation Protection, Subchapter 4 Licensing of Naturally Occurring and Accelerator Produced Radioactive Materials* and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
New Mexico[14] Status of NORM Regulations: Proposed State Contact: Debra McElroy, State of New Mexico Environment Department Radiation Licensing Department Harold Runnels Building 1190 St. Francis Drive P.O. Box 26110 Santa Fe, NM 87502 (505) 824-4308	The following licensing requirements are specific to the oil and gas industry: A general license is required for materials exceeding: - 5 pCi/g of radium-226, above background, or 150 pCi/g of any other NORM radionuclide, above background, in soil averaged over 100 square meters; - 5 pCi/g of radium-226 above background, averaged over the first 5 cm of soil below the surface unless the soil has been disturbed; - 5 pCi/g of radium-226 above background, averaged over 15 cm thick layers of soil from the surface of the soil when the soil has been disturbed or prior to transfer of a facility for unrestricted use; or - equipment which contains a maximum radiation exposure level exceeding 50 microentgens/hour.	The following regulatory restrictions are specific to the oil and gas industry: Facilities and equipment containing regulated NORM shall not be released for unrestricted use. No generally licensed facility, including plugged and abandoned wells used for NORM disposal, shall be transferred for unrestricted use where the concentration of radium-226 in soil averaged over 100 square meters exceeds: - 5 pCi/g above background, averaged over the first 5 cm of soil below the surface; and - 5 pCi/g above background, averaged over 15 cm thick layers of soil 15 cm below the surface.	The possession and use of natural gas and natural gas products, and crude oil and crude oil products as a fuel are exempt from regulatory requirements. Produced water is exempt from these regulatory requirements if it is reinjected into a Class I or Class II underground injection control (UIC) well permitted by the New Mexico Oil Conservation Division (NMOCD) and/or stored or disposed of in a double, synthetically lined surface impoundment permitted by NMOCD.	The following disposal/transfer requirements are specific to the oil and gas industry: Regulated NORM shall only be disposed of by the methods listed below: - nonretrieved flowlines and pipelines; - commercial and centralized facilities; - plugged and abandoned wells; - injection; or - other methods currently accepted by NORM authorities. (See Part 14 of New Mexico's *Regulation of NORM in the Oil and Gas Industry*, Draft Version, for a detailed description of the methods See Appendix C of this document.)	The draft regulations have been approved by the New Mexico Radiation Technical Advisory Council. They are currently under review by the New Mexico Environmental Improvement Board.

[14] Unless otherwise specified, data are based on Revised NORM Regulation Task Force Draft of *Part 14 Regulation and Licensing of Naturally Occurring Radioactive Materials (NORM) In The Oil And Gas Industry*, New Mexico Environment Department, June 28, 1994; *Summary of IOGCC Member States' Regulation of Naturally Occurring Radioactive Material (NORM)*; and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
New Mexico (Continued)	A general license does not authorize the manufacture or distribution of products containing regulated NORM,[15] nor does it allow the transfer for disposal of regulated NORM between general licensees, and does not authorize the storage of regulated NORM for compensation or other commercial purposes.				

[15] Regulated NORM means NORM contained in any oil-field soils, equipment, or sludges or any other materials related to oil-field operations or processes exceeding the radiation levels specified in Part 14-104 (NORM Licensing Requirements).

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
New York[16] Status of NORM Regulations: Under Consideration Contact: Tom Noll, Mineral Resources Division, Department of Environmental Conservation Room 202 50 Wolf Rd. Albany, NY 12233-6500 (518) 457-7480	A general license is required for materials exceeding: - 5 pCi/g above background of any combination of radium-226 or 228. The general license does not authorize the manufacturing or distribution of products containing NORM in concentrations greater than those specified above nor does it authorize the receipt and disposal of wastes from other persons.	No person shall transfer land for unrestricted use where the concentration of radium-226 or radium-228 in soil averaged over any 100 square meters exceeds the background level by more than: - 5 pCi/g, averaged over any 15 cm layer of soil below the surface. NORM-contaminated facilities and equipment in excess of the level set forth in the Draft SSRCR, Part N of Appendix A (see Appendix C of this document) shall not be released for unrestricted use.	The possession and use of natural gas and natural gas products and crude oil and crude oil products as a fuel are exempt from these regulatory requirements. The distribution of natural gas and crude oil and the manufacturing and distribution of natural gas and crude oil products are exempt from the specific license requirements of Part N but are subject to the general license requirements in N.10 (General License), N.11 (Protection of Workers During Operations), N.12 (Protection of the General Population from Releases of Radioactivity), and N.13 (Disposal and Transfer of Waste for Disposal). Contaminated pipe and plumbing from oil and gas operations shall be disposed of: - so as to prevent any reintroduction into commerce or unrestricted use; and - within disposal areas specifically designed to meet disposal criteria.	Each person subject to the general license in N.10 (General License) or a specific license shall manage and dispose of wastes containing NORM: - in accordance with the applicable requirements of U.S. EPA for disposal of such wastes; - by transferring the wastes for disposal to a facility licensed under requirements equivalent to those for uranium and thorium byproduct materials in 40 CFR 192; - by transferring the wastes for disposal to a land disposal facility licensed by U.S. NRC, an Agreement State, or a Licensing State; or - in accordance with alternate methods authorized by the Agency upon application or upon the Agency's initiative.	State: New York has not specified when they will draft NORM regulations. Currently, New York is waiting for the Interstate Oil and Gas Compact Commission's (IOGCC) proposal on NORM regulations. IOGCC: The IOGCC does not have proposed NORM regulations. They are referring the states to the Council of Radiation Control Program Director's (CRCPD) proposed Part N.

[16] Unless otherwise specified, data are based on Council of Radiation Control Program Director's proposed *Part N Regulation and Licensing of Naturally Occurring Radioactive Materials (NORM)* and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
North Dakota[17] Status of NORM Regulations: Under Consideration Contact: Charles Koch, North Dakota Industrial Commission 600 E. Boulevard Ave. Bismarck, ND 58505 (701) 224-2969	A general license is required for materials exceeding: - 5 pCi/g above background of any combination of radium-226 or 228. The general license does not authorize the manufacturing or distribution of products containing NORM in concentrations greater than those specified above nor does it authorize the receipt and disposal of wastes from other persons.	No person shall transfer land for unrestricted use where the concentration of radium-226 or radium-228 in soil averaged over any 100 square meters exceeds the background level by more than: - 5 pCi/g averaged over any 15 cm layer of soil below the surface. NORM-contaminated facilities and equipment in excess of the level set forth in the Draft SSRCR, Part N of Appendix A (see Appendix C of this document) shall not be released for unrestricted use.	The possession and use of natural gas and natural gas products and crude oil and crude oil products as a fuel are exempt from these regulatory requirements. The distribution of natural gas and crude oil and the manufacturing and distribution of natural gas and crude oil products are exempt from the specific license requirements of Part N but are subject to the general license requirements in N.10 (General License), N.11 (Protection of Workers During Operations), N.12 (Protection of the General Population from Releases of Radioactivity), and N.13 (Disposal and Transfer of Waste for Disposal). Contaminated pipe and plumbing from oil and gas operations shall be disposed of: - so as to prevent any reintroduction into commerce or unrestricted use; and - within disposal areas specifically designed to meet disposal criteria.	Each person subject to the general license in N.10 (General License) or a specific license shall manage and dispose of wastes containing NORM: - in accordance with the applicable requirements of U.S. EPA for disposal of such wastes; - by transferring the wastes for disposal to a facility licensed under requirements equivalent to those for uranium and thorium byproduct materials in 40 CFR 192; - by transferring the wastes for disposal to a land disposal facility licensed by U.S. NRC, an Agreement State, or a Licensing State; or - in accordance with alternate methods authorized by the Agency upon application or upon the Agency's initiative.	State: North Dakota has not specified when they will draft NORM regulations. Currently, North Dakota is waiting for the Interstate Oil and Gas Compact Commission's (IOGCC) proposal on NORM regulations. IOGCC: The IOGCC does not have proposed NORM regulations. They are referring the states to the Council of Radiation Control Program Director's (CRCPD) proposed Part N.

[17] Unless otherwise specified, data are based on Council of Radiation Control Program Director's proposed *Part N Regulation and Licensing of Naturally Occurring Radioactive Materials (NORM)* and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Oklahoma[18] Status of NORM Regulations: Proposed State Contact: Bruce Langhus, Oklahoma Corporation Commission Jim Thorpe Office Building Oklahoma City, OK 73105-4993 (405) 521-2500	A general license is required for materials exceeding: - 30 pCi/g of technologically enhanced radium-226 or 228, averaged over 100 square meters and over the first 15 cm of soil below the surface; - 30 pCi/g of technologically enhanced radium-226 or 228 in media other than soil; - 0.05% by dry weight of uranium or thorium; or - 150 pCi/g of other NORM radionuclides. A general license does not authorize the manufacture or distribution of NORM contaminated products in excess of the above limits.	The transfer of land for unrestricted use is not permitted for land with technologically enhanced radium-226 or radium-228, concentrations, averaged over 100 square meters, in excess of: - 30 pCi/g, averaged over a maximum depth of 15 cm of soil below the surface. NORM-contaminated facilities and equipment in excess of the levels set forth in OAC 310:281-19-21 shall not be released for unrestricted use.	The possession, storage, use, transportation, and commercial distribution of natural gas and natural gas products and of crude oil and crude oil products are exempt from these regulatory requirements. The processing of natural gas and crude oil and the manufacture of natural gas products and crude oil products containing NORM are subject to the general license requirements in OAC 310:281-19 subsections 9 (General License Requirements), 5 (Protection of Workers and the General Population) and 8 (Waste Disposal Requirements).	Wastes containing NORM shall be managed and disposed of: - by transfer of the wastes for disposal to a land disposal facility licensed by the NRC, an Agreement State, or a Licensing State; - in accordance with alternate methods authorized by the Department of Environmental Quality; or - by injection of fluids containing NORM from oil and gas production activities in a Class II Injection and Disposal well, upon approval by the Corporation Commission of Oklahoma, provided that slurry can be pumped and the entrained solids are so fine-grained that they will not plug the injection formation. The transfer of NORM-contaminated waste for disposal shall be made only to a person specifically authorized to receive such waste.	According to the IOGCC, this draft is currently being reviewed and changes will probably be made soon.

[18] Unless otherwise specified, data are based on *Summary of IOGCC Member States' Regulation of Naturally Occurring Radioactive Material (NORM)* (which is based on *Oklahoma Administrative Code 310:281* - May 7, 1993 Draft); and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Oregon[19] Status of NORM Regulations: Final State Contact: Martha Dibblee Department of Health, Radioactive Material Licensing Department 800 NE Oregon, Suite 705 Portland, OR 97232 (503) 731-4014	A general license is required for materials exceeding: - 5 pCi/g of radium; - 0.05 % by weight of uranium or thorium; or - 150 pCi/g of any other NORM radionuclide, provided that these concentrations are not exceeded at any time. This general license does not authorize the manufacturing or distribution of NORM contaminated products in concentrations greater than those specified above.	No person shall transfer land for unrestricted use where the concentration of radium-226 or radium-228 in soil averaged over any 100 sq meters exceeds the background level by more than: - 5 pCi/g, averaged over the 15 cm soil below the surface, and - 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface. NORM-contaminated facilities and equipment in excess of the levels set forth in the licensing requirements shall not be released for unrestricted use.	The possession and use of natural gas and natural gas products as a fuel are exempt from these regulatory requirements. The distribution of natural gas and manufacturing and distribution of natural gas products are exempt from the specific license requirements but are subject to the general license requirements in OAR 333-117-100 (General License) and 333-117-130 (Disposal and Transfer of Waste for Disposal).	Each person subject to the general license shall manage and dispose of wastes containing NORM: - in accordance with the applicable requirements of the U.S. EPA; - in a manner equivalent to the requirements for uranium and thorium byproduct materials in 40 CFR 192; or - shall transfer wastes for disposal to a land disposal facility licensed by the U.S. NRC, an Agreement State, or Licensing state. Transfers of NORM-contaminated waste for disposal shall be made only to a person specifically licensed to receive such waste.	Oregon has plans to revise their existing NORM regulations in 1995.

[19] Unless otherwise specified, data are based on *Oregon Rules for the Control of Radiation, Division 117 Regulation and Licensing of Naturally Occurring Radioactive Material (NORM)*, State Health Division, Radiation Control Section, October 1991; and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Texas[20] Status of NORM Regulations: Final State Contact: Richard Ginn Railroad Commission of Texas 1701 N. Congress St. Capitol Station P.O. Box Drawer 12967 Austin, TX 78711 (512) 463-6796	A general license is required for materials exceeding: - A concentration of 30 pCi/g of technologically enhanced radium-226 or 228 in media other than soil and in soil (for samples with a radon emanation rate less than 20 pCi per square meter per second), averaged over any 100 square meters and averaged over the first 15 cm of soil below the surface; - A concentration of 5 pCi/g of technologically enhanced radium-226 or 228 in media other than soil and in soil (for samples with a radon emanation rate equal to or greater than 20 pCi per square meter per second), averaged over any 100 square meters and averaged over the first 15 cm of soil below the surface; or - 150 pCi/g of any other NORM radionuclide in media other than soil and in soil, averaged over any 100 square meters and averaged over the first 15 cm of soil below the surface, provided that these concentrations are not exceeded at any time.	Unrestricted use is not permitted for facilities with NORM concentrations exceeding those in Appendix 46-A of the *Texas Regulations for Control of Radiation* (see Appendix C of this document) and equipment with maximum radiation exposure levels above [illegible] microroentgen[illegible]ur.	The possession, storage, use, transportation, and commercial distribution of natural gas and natural gas products and of crude oil and crude oil products containing NORM are exempt from these regulatory requirements. The processing of natural gas and crude oil and the manufacture of natural gas products and crude oil products containing NORM are subject to the general license requirements in 46.10 (General License), 46.11 (Protection of Workers and the General Population), and 46.12 (Transfer of Waste for Disposal). Under Rule 94 (§3.94) roadspreading [illegible]il and gas NORM waste[illegible] surface water discharges of [illegible]l and gas NORM wastes other than produced waters are prohibited. Permitted disposal of produced water by injection or surface discharge is exempt. Disposal in a well that is being plugged and abandoned is authorized without a permit. Disposal through burial or land surface application may be authorized if concentrations do not exceed background by more than 5 pCi/g (this is intended	Each person subject to the general license in the General License Section shall manage and dispose of wastes containing NORM: - in accordance with U.S. EPA's applicable requirements for disposal of such wastes; - by transfer of the wastes for disposal to a facility specifically licensed to receive waste containing NORM and which is licensed under rules equivalent to those for uranium and thorium byproduct materials in Part 43 (Licensing of Uranium Recovery Facilities) of these rules; - by transfer of the wastes for disposal to a land disposal facility licensed by the U.S. NRC, an Agreement State, or a Licensing State; or - in accordance with alternate methods authorized by the authorized regulatory agency.	

[20] Unless otherwise specified, data are based on *Texas Regulations for Control of Radiation, Part 46 Licensing of Naturally Occurring Radioactive Material (NORM)*, Effective July 1, 1993, Texas Department of Health; *Statewide Rule 94 (16 TAC §3.94, Disposal of Oil and Gas NORM Waste)*, Railroad Commission of Texas, December 12, 1994; *Summary of IOGCC Member States' Regulations of Naturally Occurring Radioactive Material (NORM); The NORM Report* published by Peter Gray & Associates; and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Texas (Continued)	A general license is also required for materials in the recycling process contaminated with scale or residue, or other equipment with maximum radiation exposure levels above 50 microentgens/hour including the background radiation level at any accessible point. The general license does not authorize the manufacture of products containing NORM in concentrations greater than those specified above.		as an interim measure). §3.94 was adopted pending further study on the availability of appropriate field survey devices and/or methods, the relationship between TDH exemption criteria and exposures associated with surface disposal, and regulatory restrictions appropriate for disposal of buried pipes.		

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions
Washington[21] Status of NORM Regulations: Proposed State Contact: Gary Robertson, Department of Health Division of Radiation Protection Airdustrial Center, Bldg. 5 P.O. Box 47827 Olympia, WA 98504-7827 (206) 753-3468	Licensing requirements are not included in the proposed NORM regulations.	Regulatory restrictions are not included in the proposed NORM regulations. Current standards used for transfer of land for unrestricted use are based on the "5/15" rule (from 40 CFR 192). The standard for uranium is 10 pCi/g.	Regulatory restrictions specific to oil and gas are not included in the proposed NORM regulations.	The following is a proposed set of limits for the amount of NARM being disposed at the commercial low-level radioactive waste disposal site in the state of Washington: Naturally occurring radioactive material, excluding source material, shall be limited to a total site volume of no more than 2,500 cubic feet per calendar year, and individual generators to an annual limit of 200 cubic feet per calendar year.	The proposed regulatory revision for NARM at commercial low-level radioactive waste sites is in the public comment phase.

[21] Unless otherwise specified, data are based on Proposed New *WAC 246-250-630 Naturally Occurring or Accelerator-Produced Radioactive Material (NARM) Limits*; and personal communication with the state.

Exhibit 5: Regulatory Summary for State NORM Requirements (Continued)

State	NORM Licensing Requirements	NORM Regulatory Restrictions	NORM Regulatory Restrictions Specific to Oil and Gas	NORM Disposal/Transfer Requirements	Anticipated Regulatory Actions

Wyoming[22]
 	
Status of NORM Regulations: Under Consideration
 	
State Contact:
Tim Link
Department of Environmental Quality Solid & Hazardous Waste Division
122 W. 25th St.
Herschler Bldg.
4 West
Cheyenne, WY 82002
 	
(307) 777-7164
	Undecided	Undecided	Undecided	In August 1989, Wyoming's Department of Environmental Quality (WDEQ) requested that all produced water dischargers test for radium-226. Results of the survey of 373 dischargers of produced water are:
				- 206 had values less than 5 pCi/l; and
				- 167 had values greater than 5 pCi/l;
				  - 15 had values greater than 60 pCi/l;
				  - 6 had values greater than 100 pCi/l; and
				  - 2 had values greater than 1,000 pCi/l.
				
				WDEQ proposed the following in-stream standards:
				- Class 1 and 2 waters: 5 pCi/l of radium-226 plus 228. (U.S. EPA drinking water standard)
				
				- Class 3 and 4 waters: 60 pCi/l of radium 226 (this is based on NRC's standard for unrestricted waters).
					Wyoming has no plans for drafting universal NORM regulations, but they have an internal draft of NORM requirements for oil & gas extraction and production waste. They are not sure if the current internal draft under consideration will go final.

[22] Unless otherwise specified, data are based on *Toxicity and Radium 226 in Produced Water - Wyoming's Regulatory Approach*, Water Quality Division, Wyoming Department of Environmental Quality; and personal communication with the state.

3.2 State Regulatory Summary Table Structure

The NORM regulatory summary table (Exhibit 5) is divided into six columns as follows:

STATE identifies the state, the current NORM regulatory status, and the name, address, and phone number of the state contact.

NORM LICENSING REQUIREMENTS describes the state's basic NORM licensing requirements, and identifies the contaminant concentration levels for which a general license is required.

NORM REGULATORY RESTRICTIONS describes the land use, equipment, and facility NORM restrictions.

NORM REGULATORY RESTRICTIONS SPECIFIC TO OIL & GAS identifies NORM regulatory exemptions and restrictions specific to oil and gas producing facilities.

NORM DISPOSAL/TRANSFER REQUIREMENTS describes the disposal and transfer requirements for NORM wastes.

ANTICIPATED REGULATORY ACTIONS details the status of proposed or draft NORM regulations, and, where available, provides regulatory timing data (i.e., promulgation dates, revision dates, and/or public comment periods).

Appendix D of this document contains the state NORM regulations which pertain to the table.

3.3 Conclusions

The NORM standards in state regulations are based on several different sources. Many states have revised their general radiation regulations to include the revised 10 CFR 20 regulations (*Standards for Protection Against Radiation*). These regulations incorporate modern perspectives on radiation protection for the establishment of new dose limits.[54] They have served to set the precedent for development of Part N of the CRCPD's *Suggested State Regulations for Control of Radiation*. Another precedent is the "5/15" rule,[55] derived from 40 CFR 192.12, which has been recommended by the CRCPD and generally adopted by states with or preparing NORM regulations.[56] Other precedents for standards have been set by IOGCC member states' regulation of NORM. One of the set purposes of the IOGCC is to provide assistance to states in developing their oil and gas regulatory programs. Other sources for standards include state health department regulations, state environmental department regulations, and EPA guidelines. Michigan, for example, has standards based on alternatives from the *SSRCR*, proposed rules of the Texas Department of Health, EPA guidelines, and rules established by the Michigan Department of Public Health and the Department of Natural Resources.

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[54] *The NORM Report*. Peter Gray & Associates. Fall 1993.

[55] The "5/15" rule says that land where radium concentration averaged over 100 square meters exceeds background by more than 5 pCi/gr averaged over the top 15 cm of soil, cannot be transferred for unrestricted use.

[56] *Regulation for the Control of NORM*. Peter Gray & Associates. SPE 26212. 1993.

As listed in the table, seven states (Arkansas, Georgia, Louisiana, Mississippi, New Jersey, Oregon, and Texas) have final NORM regulations. With the exception of New Jersey, the NORM regulatory requirements for these states are similar. New Jersey regulates only discrete NORM.

Of these seven, five states plan to revise their current NORM regulations, as follows:

- **Arkansas** plans to address the issue of contaminated scale.
- **Mississippi** developed revised NORM regulations specific to oil and gas extraction and production waste which were promulgated in September 1994.
- **New Jersey** plans to address waste disposal and soil cleanup standards.
- **Oregon** plans to draft revisions to its NORM regulations in early 1995, but did not specify the nature of these revisions.
- **Texas** plans further study on several outstanding issues outlined in Rule 94, and may further revise the rule.

Four states (Kentucky, New Mexico, Oklahoma, and Washington) have proposed or draft NORM regulations. With the exception of Washington's draft, the NORM regulations of these four states are very similar to the requirements listed for the seven states with final NORM regulations. Washington centered its draft NORM regulations around the amount of Naturally Occurring and Accelerator Produced Radioactive Material (NARM) disposed of at commercial low-level radioactive waste disposal sites.

Nine states are considering enacting NORM regulations (see *Regulatory Summary for States without NORM Requirements*). They are:

- Colorado
- Illinois
- Indiana
- Kansas
- Michigan
- Nebraska
- New York
- North Dakota
- Wyoming

Based on available information, Indiana, Kansas, Nebraska, New York, and North Dakota are waiting for the IOGCC's proposal on regulating NORM. Colorado's Department of Health had drafted NORM regulations, which are similar to those for states with promulgated NORM regulations. However, Colorado's legislature signed a bill deferring the adoption of this draft rule until after EPA adopts NORM regulations. Illinois has implemented an emergency regulation on pit residue and is working on drafting NORM regulations specific to worker safety and dust residue. Currently, Michigan has established interim standards for the oil and gas industry concerning NORM waste. However, these standards are advisory in nature and are not regulations. Michigan indicated that these standards are similar to other states' NORM regulations. Wyoming has an internal draft of NORM requirements for the oil and gas industry.

3.4 States That Do Not Have NORM Requirements

This section describes the current regulatory status of states that do not have NORM requirements in place. It also notes the name of the state contact who may be able to provide further information.

ALABAMA

- Considering drafting NORM regulations.
- Currently, Alabama is researching comparable states' proposed and existing NORM regulations.

State Contact: *Mike Cash*
Alabama Department of Public Health, Division of Radiation Control
(205) 613-5391

ALASKA

- Not considering drafting NORM regulations.
- Currently, the Alaska Oil and Gas Commission supervises the disposal of NORM waste.

State Contact: *Tuckerman Babcock*
Alaska Oil and Gas Commission
(907) 279-1433

ARIZONA

- Not considering drafting NORM regulations.
- NORM waste specific to oil and gas is not a problem in Arizona. The state of Arizona has no oil and gas facilities under their jurisdiction. The Native American reservation may have some oil and gas facilities.

State Contact: *Dan Kuhl*
Arizona Radiation Regulatory Agency
(602) 255-4845

CALIFORNIA

- Considering drafting NORM regulations.
- During the early 1980s, California conducted a study of resident oil fields and concluded that NORM was not an issue. Recently, it has begun a new study to verify the results of the previous study (see section 2.6.1).

State Contact: *Mike Stettner*
California Department of Natural Resources, Division of Oil and Gas
1416 9th Street, Room 1310
Sacramento, CA 95814
(916) 323-1777

FLORIDA

- Not considering drafting NORM regulations.
- Florida had several industries sample their waste for NORM contamination; the waste containing NORM did not exceed background levels.

State Contact: *Walt Schmidt*
Florida Department of Environmental Protection
(904) 488-4191

MARYLAND

- Not considering drafting NORM regulations.
- Maryland has no licensees in the oil and gas industry, and therefore, NORM waste in the oil and gas industry is nonexistent.

State Contact: *Charles Flynn*
Department of Environment, Radioactive Material Licensing
2500 Borening Highway
Baltimore, MD 21224
(410) 631-3300

MISSOURI

- Not considering drafting NORM regulations.
- In 1989, Missouri investigated the extent of NORM-contaminated waste. Although it found low levels of NORM, Missouri concluded that NORM waste is not a problem.

State Contact: *Even Kifer*
Department of Natural Resources
111 Fairgrounds Road, Box 250
Rolla, MO 65401
(314) 364-1752

MONTANA

- Not considering drafting NORM regulations.
- Montana has been monitoring oil and gas wells for NORM contamination. Low concentrations of NORM have been reported in northeast Montana. However, Montana does not have the budget necessary to draft NORM regulations. The current state radiation regulations do not apply to NORM.

State Contact: *Tom Richmond*
Montana Board of Oil and Gas Conservation
2535 St. James Avenue
Billings, MT 89710
(406) 656-0040

NEVADA

- Not considering drafting NORM regulations.
- Nevada's existing radiation regulations apply to all radioactive material including NORM. However, the state is not concerned about NORM waste specific to the oil and gas industry, because of the low number of oil and gas wells in Nevada.

State Contact: *Stan Marshall*
Department of Health, Radiological Health Division
(702) 687-5394

OHIO

- Not considering drafting NORM regulations.
- Although Ohio wants to investigate the need for NORM regulations, it has no immediate plans to begin drafting NORM-specific regulations.

State Contact: *Dennis Christ*
Ohio Department of Natural Resources, Division of Oil and Gas
Fountain Square, Building A
Columbus, OH 43224
(614) 265-6893

PENNSYLVANIA

- Not considering drafting NORM regulations.
- Pennsylvania recently completed a study of NORM contamination. From this study, Pennsylvania concluded that NORM does not pose a significant threat. However, Pennsylvania believes that it should continue investigating NORM-related issues and, therefore, has initiated workgroups and discussions on NORM. In instances where NORM contamination is a problem, Pennsylvania defers to the Council of Radiation Control Program Director's Part N report.

State Contact: *Ron Gilius*
Bureau of Oil and Gas
(717) 787-4817

TENNESSEE

- Not considering drafting NORM regulations.
- Tennessee does not have a problem with NORM contamination, and therefore, it has no specific regulations controlling NORM. However, Tennessee's general radiation regulations do cover NORM. Tennessee indicated that it has only seven oil wells, and NORM is not an issue at any of them.

State Contact: *Tom Hansen*
U.S. EPA Region 4
345 Courtland Street, N.E.
Atlanta, GA 30365
(404) 347-3379

UTAH

- Not considering drafting NORM regulations.
- NORM is included in Utah's comprehensive radiation control regulations.

State Contact: *Dane Finerfrock*
Department of Radiation
(801) 536-4250

VIRGINIA

- Not considering drafting NORM regulations.
- According to Tom Folmer, NORM is not a problem in Virginia.

State Contact: *Tom Folmer*
Department of Mines, Minerals, and Energy
(703) 676-5423

WEST VIRGINIA

- Not considering drafting NORM regulations.
- According to Mike Lewis, NORM waste is not a problem in West Virginia, and therefore, the state has never drafted NORM-specific regulations. However, West Virginia believes that NORM is adequately covered under other state regulations, detailing registration requirements for facilities possessing, transferring, and/or disposing of radioactive material.

State Contact: *Mike Lewis*
West Virginia Department of Energy, Division of Environmental Protection
#10 McJunkin Boulevard
Nitro, WV 25304
(304) 548-3092

CHAPTER 4

Bibliography

4.1 Sources Used in Literature Search

This chapter presents a bibliography of relevant documents related to NORM in oil and gas production. The bibliography is based on searches of several data bases, including:

- Bibliographic Retrieval System (BRS)
- Boston University Library Catalog
- Boston Library Consortium (which provides access to card catalogs at several university libraries in Massachusetts and the Boston Public Library)
- EPA's Alternative Treatment Technology Information Center (ATTIC)
- The Clean-up Information Bulletin Board System (CLU-IN)
- The EPA National Catalog
- The EPA Region 1 and Region 5 Libraries
- The EPA Hazardous Waste Collection
- The EPA ORD Bulletin Board System (ORDBBS)
- Pollution Prevention Bulletin Board System (PIES)
- Remedial Action Product Information Center (RAPIC) Literature Retrieval Service (operated by Martin Marietta, Inc. for DOE)

In addition to these sources, lists of pertinent documents and copies of certain documents were obtained from EPA's Office of Water and API.

4.2 Bibliography

Exhibit 6 presents the bibliography, including full citations and annotations to describe the document. Annotations are included for documents having an abstract retrieved through a literature search. In cases where a document was unable to be obtained, or did not have an abstract, an annotation is not included in the table. Major subject categories used in the table are:

- Characteristics of NORM wastes associated with oil and gas production
- Characteristics of NORM as a function of location
- NORM Regulations
- Techniques for management and disposal of NORM wastes
- Health and environmental affects

Although each document is listed only once under a major subject heading, some of the documents address more than one subject. If a document is also applicable to another category, this is noted after the document title.

Exhibit 6
Bibliography: NORM Associated With Oil & Gas Production

CITATION	ANNOTATIONS
Characteristics of NORM wastes associated with oil & gas production	
American Petroleum Institute. *A National Survey on Naturally Occurring Radioactive Materials (NORM) in Petroleum Producing and Gas Processing Facilities*. Dallas, Texas, 1989.	Also listed under "Otto, G. H." API-funded study conducted in the mid-1980s to identify the geographic areas within the United States where petroleum processing facilities have the highest incidence of NORM contamination, and to identify the types of equipment with the highest NORM concentrations.
Barsukov, O.A. *Radioactive Investigations of Oil and Gas Wells, a Textbook*. Oxford and New York: Pergamon Press, 1965.	
Bell, K.G. *Uranium and Other Trace Elements in Petroleums and Rock Asphalts*. U.S. Geological Survey, 1960. Professional Paper 356-B.	
Bunce, L.A. and F. W. Sattler. *Radon-222 in Natural Gas*. Farmington, NM: U.S. Public Health Service, 1986. Radiological Health Data Report: 441-444.	
Cadmus Group, Inc. *Draft Issue Paper: NORM Wastes at Potential Radiation Cleanup Sites*. Prepared for the Office of Radiation and Indoor Air, 1994.	Overview of NORM waste problems in the U.S. Includes an oil and gas production scale and sludge summary.
Conference of Radiation Control Program, Inc. *Natural Radioactivity Contamination Problems*. Washington, D. C: USEPA, Office of Radiation Programs, 1978. Report No. PHS-223-76-6018 & EPA/520/4-77/15. NTIS PB 281-041.	Prepared in cooperation with Nuclear Regulatory Commission, Washington, DC and Department of Energy.
Conference of Radiation Control Program, Inc. *Natural Radioactivity Contamination Problems*. Washington, D. C: Office of Radiation Programs, 1981. NCRCPD-1, Report No. 2. NTIS PB 82-140443.	Updates first report, contains a NORM inventory and Radiation pathways table, provides soil contamination limit guidance, suggested State NORM language.
Continental Shelf Associates. "Measurements of NORM at Three Produced Water Outfalls." In *Continental Shelf Associates NORM Study*. 1989.	One in a list of references received from Marta E. Jordan, U.S. EPA Office of Water, Office of Science and Technology, Engineering and Analysis Division, on 7/15/94.
Cox, James R. "Naturally Occurring Radioactive Materials in the Oilfield: Changing the NORM." *Tulane Law Review*, 67 (March 1993): 1198-1199.	
Daniels, W.R. and K. Wolfsberg. *Laboratory Studies of Radionuclide Distributions between Selected Groundwaters and Geologic Media*. Los Alamos: Los Alamos National Laboratory, 1981. Progress Report LA-8952-PR.	

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CITATION	ANNOTATIONS
Gray, Peter. *Introduction to NORM in the Oilfield.* 1993.	Computer interactive training module for instruction on NORM in the petroleum industry.
Gray, Peter. "NORM Contamination in the Petroleum Industry." *Journal of Petroleum Technology*, January 1993.	Overview of NORM contamination of oil and gas facilities, radium isotopes and radon, disposal of NORM wastes, and regulations.
Nancollas, G.H. *Oilfield Scale, Physical Chemical Studies of its Formation and Prevention.* Buffalo: State University of New York, Chemistry Department. 1984.	
Oddo, John E. and Mason B. Tomson. "Algorithms can predict; inhibitors can control NORM scale." *Oil & Gas Journal*, Volume 92 No. 1 (January 1994): 33.	Discusses several relatively simple equations that can be used to predict scale formation.
Otto, G. H. *A National Survey on Naturally Occurring Radioactive Materials (NORM) in Petroleum Producing and Gas Processing Facilities.* Prepared for API. Dallas, Texas. 1989.	Also listed under "American Petroleum Institute." API-funded study conducted in the mid-1980s to identify the geographic areas within the United States where petroleum processing facilities have the highest incidence of NORM contamination, and to identify the types of equipment with the highest NORM concentrations.
Rintoul, Bill. "NORM." *PetroEnvironment*, Spring 1994: 33-34.	Discusses a proposed survey for NORM in oil and gas fields in California.
Smith, A.L. *Radioactive-Scale Formation.* 1987: 697-706.	
Snavely, Earl S., Jr. *Radionuclides in Produced Water - A Literature Review.* Prepared for the API Guideline Steering Committee. August 1989.	Introductory discussion on origin and distribution of radioactive elements (U and Th) and Ra isotopes in subsurface formations and water. Describes modes of accumulation and the types of accumulation in oil field producing and processing equipment. Includes 2 appendices that review numerous technical articles on the subject.
White, Gregory J. *Natural Occurring Radioactive Materials (NORM) in Oil and Gas Industry Equipment and Wastes: A Literature Review.* U.S. Department of Energy, 1992. US DOE Report No. DOE/ID/01570-T158.	
Wylie, A.W. *Nuclear Assaying of Mining Boreholes: An Introduction.* Amsterdam and New York: Elsevier Science Publishing Company, 1984.	Radiation well logging

Exhibit 6 (Continued)
Bibliography: NORM Associated With Oil & Gas Production

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Characteristics of NORM as a function of location	
Anderson, Bob. "Dealing with Radioactive Scale in Offshore Oil . roduction." *Ocean Industry*, Volume 25 No. 9 (November 1990): 33.	Guidelines for worker protection which can impact plant maintenance operations and refurbishment or disposal of production equipment.
Geofizika, Iadernaia and Fedor Alekseev. *Soviet Advances in Nuc ar Geophysics*. New York: Consultants Bureau, 1965.	Discusses oil well logging, radiation, and radioactive prospecting.
Johnson, T. S. and R.O. Hoffland. "NORM in Produced Water fshore." Presented at the Produced Water Seminar of the American Filtrat . Society, League City, Texas, January 1993.	Discusses federal and state guidelines and regulations and the operation of the ACS Production Water Treatment System for NORM wastewater.
Pierce, A.P., J.W. Mytton, and G.B. Gott. "Radioactive Elements and Their Daughter Products in the Texas Panhandle and Other Oil and Gas Fields in the United States." Presented at the International Conference, Geology of Uranium and Thorium, 1955.	
Taylor, Windle (Railroad Commission of Texas). *NORM in Produced Water Discharges in the Coastal Waters of Texas*. 1993.	One in a list of references received from Marta E. Jordan, U.S. EPA Office of Water, Office of Science and Technology, Engineering and Analysis Division, on 7/15/94.
Texas Railroad Commission. *NORM in Produced Water Discharges in the Coastal Waters of Texas*. 1992.	One in a list f references received from Marta E. Jordan, U.S. EPA Office of Water, Offic o Science and Technology, Engineering and Analysis Division, on 7/15/94.
U.S. Environmental Protection Agency. "Analysis of Radioactivity Associated with Produced Water from Offshore Oil and Gas Platforms." 1991.	One in a list of eferences received from Marta E. Jordan, U.S. EPA Office of Water, Office of Science and Technology, Engineering and Analysis Division, on 7/15/94.
U.S. Environmental Protection Agency. "EPA Coastal Oil and Gas Production Sampling." In *EPA Production Data*. 1992.	One in a list of references received from Marta E. Jordan, U.S. EPA Office of Water, Office of Science and Technology, Engineering and Analysis Division, on 7/15/94.
U.S. Environmental Protection Agency. *Review of the Idaho Radionuclide Study*. U.S. Environmental Protection Agency, Science Advisory Board, January 1992. EPA Report: EPA-SAB-RAC-LTR-92-004.	
Western Canadian NORM Committee. *Guidelines for the Handling of NORM in Western Canada*. April 1994.	Outlines procedures for handling NORM wastes in general; one section deals with the oil and gas industry.

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NORM Regulations	
_____. "Hazardous Label Looming Again for U.S. E&P Wastes." *Oil & Gas Journal*, Volume 88 No. 51 (December 1990): 18.	Issues requiring immediate attention include the management of naturally occurring radioactive material brought to the surface by oil drilling and oil field site remediation.
American Petroleum Institute Task Force on Regulatory Analysis. *NORM Regulatory Analysis Report*. April 1988.	The report identifies the various federal and State statutes and regulations that apply to NORM issues. It provides a comprehensive discussion of regulations promulgated under OSHA, CERCLA, SARA, RCRA and by the DOT, MMS, Coast Guard, and 15 oil and gas producing states.
Bohlinger, L.H. *Regulation of Naturally-Occurring Radioactive Material in Louisiana*. Louisiana Department of Environmental Quality, LA September 10-13, 1990: 833.	Report on regulations promulgated by the Louisiana Department of Environmental Quality for the management of oil field produced waters. The state regulation covers worker protection, naturally occurring radioactive material storage options, and handling and disposal of scale or soil contaminated by the cleaning of oil field equipment.
Bohlinger, L.B. "Regulation of Oil and Gas NORM in Louisiana." In Proceedings of the *Spectrum '92 International Topical Meeting on Nuclear and Hazardous Waste Management*. Volume 1: 425-428.	Abstract from RAPIC database: Rationale for NORM regulations in Louisiana.
Cadmus Group, Inc. *State NORM Requirements (AR, LA, MS, TX)*. Prepared for the Office of Radiation and Indoor Air. March 1994.	Two-page table that summarizes state licensing requirements, restrictions, and disposal and transfer stipulations for NORM wastes.
Cadmus Group Inc. *Status of State Programs for Control of NARM*. September 1993.	Draft report on state NARM regulatory programs prepared under subcontract by Energetics, Inc. Has sections on NORM.
Conference of Radiation Control Program Directors. *Model State Regulations for the Control of Radiation, Proposed Rules for Part N Regulation and Licensing of Naturally Occurring Radioactive Materials (NORM)*. June 1994.	CRCPD's model regulations that are being used by states in developing regulations for control of NORM in the oil and gas industry.
Gray, Peter. "Radioactive Materials Could Pose Problems for the Gas Industry." *Oil & Gas Journal*, Volume 88 No. 26 (June 1990): 45-48.	Describes the three types of NORM contamination that exist in the oil and gas industry: scale, films, and sludges. Also describes radon and NORM contamination in natural gas liquids systems.
Gray, Peter. *The NORM Report*. Fall 1993, Winter 1994.	A newsletter that provides a status report on regulatory activities in the oil and gas producing states.
Interstate Oil and Gas Compact Commission. *Summary of IOGCC Member States' Regulation of Naturally Occurring Radioactive Material (NORM)*. June 1994.	Reviews and summarizes existing state laws and regulations.

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Interstate Oil and Gas Compact Commission. *Alaska State Review: IOGCC/EPA State Review of Oil and Gas Exploration and Production Waste Management Regulatory Programs*. December 1992.	Review team evaluated state E&P regulatory programs against the IOGCC guidelines. Provides recommendations, critique of state programs.
Interstate Oil and Gas Compact Commission. *Arkansas State Review: IOGCC/EPA State Review of Oil and Gas Exploration and Production Waste Management Regulatory Programs*. October 1993.	Review team evaluated state E&P regulatory programs against the IOGCC guidelines. Provides recommendations, critique of state programs.
Interstate Oil and Gas Compact Commission. *California State Review: IOGCC/EPA State Review of Oil and Gas Exploration and Production Waste Management Regulatory Programs*. May 1993.	Review team evaluated state E&P regulatory programs against the IOGCC guidelines. Provides recommendations, critique of state programs.
Interstate Oil and Gas Compact Commission. *Kansas State Review: IOGCC/EPA State Review of Oil and Gas Exploration and Production Waste Management Regulatory Programs*. August 1993.	Review team evaluated state E&P regulatory programs against the IOGCC guidelines. Provides recommendations, critique of state programs.
Interstate Oil and Gas Compact Commission. *Louisiana State Review: IOGCC/EPA State Review of Oil and Gas Exploration and Production Waste Management Regulatory Programs*. July 1994.	Review team evaluated state E&P regulatory programs against the IOGCC guidelines. Provides recommendations, critique of state programs.
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Interstate Oil and Gas Compact Commission. *Pennsylvania State Review: IOGCC/EPA State Review of Oil and Gas Exploration and Production Waste Management Regulatory Programs*. March 1992.	Review team evaluated state E&P regulatory programs against the IOGCC guidelines. Provides recommendations, critique of state programs.
Interstate Oil and Gas Compact Commission. *Texas State Review: IOGCC/EPA State Review of Oil and Gas Exploration and Production Waste Management Regulatory Programs*. April 1993.	Review team evaluated state E&P regulatory programs against the IOGCC guidelines. Provides recommendations, critique of state programs.

Exhibit 6 (Continued)
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Gray, Peter. "Regulations for the Control of NORM." *The NORM Report* (March 1993): 1-7.	Discusses regulatory issues, the CRCPD model for state regulations, the status of state rule ing activities, studies being undertaken by EPA and NRC, and the approach rulemaking in Canada.
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Radiation Technical Services, Inc. *Training Manual for Management of NORM in Louisiana*. June 1992.	Includes Title 33, Part XV, Chapter 4 of Louisiana State NORM Regulations, Standards for Protection Against Radiation.
Raloff, Janet. "NORM: The New Hot Wastes. States Mobilize to Fill a Gap in Federal Radwaste Management." (Also applicable to "Techniques for Management and Disposal of NORM Wastes" category). *Science News*, (ISSN 0036-8423) Volume 140 (October 1991): 264-267.	State activities associated with NORM waste management and regulation.
Russo, William E., James M. Gruhike, and Floyd L. Galpin. "U.S. EPA Activities in Diffuse NORM."	Reports on EPA activities related to diffuse NORM. Paper received from Bill Russo on 7/19/94, SPE #25938.
Siddiqi, Toufiq and John Gilbert. *A Summary of Current and Planned Activities in the Program: Environmental Dimensions of Energy Policies*. East-West Environment & Policy Institute. October 1982, p. 27.	The major goals of the East-West Center's Environmental Dimensions of Energy Policies Program are summarized.
Smith, G.E., W.R. Smith, and Jerry Simmons. "Recent Improvements in State Regulatory Programs and Compliance Practices." Presented at the Society of Petroleum Engineers/EPA Exploration and Production Conference, San Antonio, Texas, March 1993.	Documents results of a DOE/IOGCC study to examine changes in state regulatory programs and waste management practices for exploration and production wastes.
State of Arkansas. *Arkansas Section 7 NORM Regulations*.	Text of NORM-related regulations.
State of Arkansas. *Arkansas State NORM Regulations - Summary*.	Three page summary of state regulations.
State of Georgia. *Rules and Regulations for Radioactive Materials. Chapter 391-3-17, Part 8 - Regulation and Licensing of NORM*.	Text of NORM-related regulations.

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State of Louisiana. *Louisiana State NORM Regulations - Chapter 4 Standards for Protection against Radiation (Training Manual).* Radiation Technical Services, Inc.	Text of NORM-related regulations.
State of Louisiana. Louisiana Department of Environmental Quality. *Regulatory Guide: Guidelines for Conducting NORM Confirmatory Surveys of Suspected Contamination of Land and Equipment, and Disposal of NORM Waste.* 1990.	
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State of Michigan. *Michigan Department of Health's Interim Standards for the Control of NORM Associated with the Oil and Gas Industry in Michigan.* (Marked "Draft").	Text of NORM-related regulations.
State of Mississippi. *Mississippi Part 801 Section N: Licensing of NORM.*	Text of NORM-related regulations.
State of Mississippi. *Rule 68 - Disposal of NORM Associated with the Exploration and Production of Oil and Gas.*	Text of NORM-related regulations.
State of New Jersey. *New Jersey Administrative Code, Chapter 28, Bureau of Radiation Protection, subchapter 4 - Licensing of Naturally Occurring and Accelerator Produced Radioactive Materials.*	Text of NORM-related regulations.
State of New Mexico. *Part 14 - Regulation and Licensing of NORM in the Oil and Gas Industry - Revised NORM Regulations Task Force Draft.* New Mexico Environment Department.	Text of NORM-related regulations.
State of Oregon. *Rules for the Control of Radiation, Chapter 333. Division 117. Regulation and Licensing of NORM.* State Health Division, Radiation Control Section.	Text of NORM-related regulations.
State of Texas. *Texas Regulations for Control of Radiation - General Regs Parts 11, 12, 13, 21, 22 & License Regs Parts 31, 33, 35, 36, 40, 41, 43, 44, 46.* September 1993.	Text of NORM-related regulations.

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Steingraber, Buck. "Industry Perspective on Naturally Occurring Radioactive Material (NORM)." *The Interstate Oil & Gas Compact & Committee Bulletin* Volume 5 No. 2 (1991): 26.	
Thompson, Anthony J. and Michael L. Goo. "NORM: Regulations Should Look Before They Leap." *Environmental Law Reporter*, 22 (January 1992): 10052-10061.	Paper argues that more understanding of the true extent and hazard of NORM is required before establishing state regulations on the basis of CRCPD's Model State NORM Regulations.
U.S. Environmental Protection Agency. *An SAB Report. Review of Diffuse NORM Draft Scoping Document.* Final Review Draft (marked "Do Not Cite or Quote"). March 1994. EPA Report: EPA-SAB-RAC-94-XXX.	A review of the *Diffuse NORM Wastes Draft Report.*
U.S. Environmental Protection Agency. *Low-Level and NARM Radioactive Wastes, Draft Environmental Impact Statement for Proposed Rules, Volume I, Background Information Document.* June 1988. EPA Report: EPA/520/1-87-012-1.	
Von Flatern, Rick. "NORM Contamination, Regulations Threaten Industry Economy." *Petroleum Engineer International*, Volume 65 No. 5. (May 1993): 36.	Discusses standards and procedures for NORM wastes in oil and gas producing nations and impact on the industry.
Wagner, John F. *Toxicity and Radium 226 in Produced Water - Wyoming's Regulatory Approach.* Wyoming Department of Environmental Quality, Water Quality Division.	Describes Wyoming's history of regulating produced water, toxicity tests conducted for effluents, resulting changes to NPDES permits, and use of federal and NRC standards.
Wennerberg, L. "Regulatory Controls for NORM Contamination: Emerging Issues and Strategies." In *Proceedings of a Symposium: Waste Management '92: Working Towards a Cleaner Environment, Tucson, AZ March 1-5, 1992.* Volume 1: 489-492.	Abstract from RAPIC database: Details emerging technical issues, federal and state regulatory strategies under consideration, and evaluates efficacy of selected regulatory approaches to NORM.
Wascom, Carroll D. "Regulating Naturally Occurring Radioactive Materials (NORM)." Presented at the Ground Water Protection Council Semi-Annual Meeting, Boston, MA, February 1994.	Overview of Louisiana regulatory programs for NORM, summarizes contents of NORM implementation manual, and current developments.
Techniques for management and disposal of NORM wastes	
_____. "Disposal of NORM subject of meeting (naturally occurring radioactive material)." *Geotimes* (ISSN 0016-8556) Volume 38 (January 1993): 11.	
American Petroleum Institute. *Bulletin on Management of Naturally Occurring Radioactive Materials (NORM) in Oil & Gas Production.* April, 1992. API Bulletin E2 7-8.	General document related to NORM management in oil and gas production.

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Bernhardt, D.E. and V.C. Rogers. "Characterization of NORM Waste Disposal." In *Proceedings of the Spectrum '92 International Topical Meeting on Nuclear and Hazardous Waste Management* 992. Volume 1: 432-437.	
Boothe, Joan Norris. *Cleaning Up: The Cost of Refinery Pollution Control*. New York: Council on Economic Priorities, 1975.	Petroleum was lisposal options
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Egan, J.R. and J.F. Seymour. "Disposing of NORM: A Legal Strategy." *Environmental Law Reporter*, 22 (July 1992): 10433-10439.	Argues for disposal of most NORM wastes in facilities used for disposal of uranium and thorium mill tailings.
Fellier, H.D. and D.W. Harnall. *Remediation of Groundwater Containing Radionuclides and Heavy Metals Using Ion Exchange and the AlgaSORB (reg. sign) Biosorbent System - Final Report*. U.S. Department of Energy. 1991.	Performance characteristics of the AlgaSORB process used for removal of radionuclides from ground water.
Fontenot, Sherwin T. "Dealing with NORM in the Oil and Gas Industry" In *Proceedings of the Underground Injection Practices Council*. Morgan City, LA: Oilfield Testers, Inc., January 1992.	Describes the risks associated with NORM in the oil and gas industry, precautions to protect health and safety, site surveys, and disposition of contaminated equipment and sites.
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Hong, Lee. *Potential Radioactive Pollutants Resulting from Expanded Energy Programs*. Menlo Park, CA: Stanford Research Institute, Menlo Park, CA., August 1977. EPA Report: EPA/600/7-77/082,	Discusses coal mining, coal gasification and liquefaction, oil shale mining, geothermal operations, uranium mining, nuclear reactor operations, and fuel reprocessing and waste disposal.
Lowe, D.J. *Disposal of NORM in UIC Wells in Alaska*. Presented at Ground Water Protection Council 1993 Winter Meeting held in Denver, CO, February 1993.	
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Exhibit 6 (Continued)
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Mattia, Michael. "Getting to know NORM." *Scrap Processing and Recycling*, Volume 49 No. 2, March 1992: 183.	Overview of problems related to NORM in the oil and gas industry.
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Chapter 5

Conclusions and Recommendations

To provide specific recommendations for guidance language related to NORM disposal in Class II wells, final and proposed state NORM regulations were reviewed. In addition, reports from the CRCPD and the IOGCC were examined which provide guidance and model language related to NORM waste disposal options. The most useful information was found in the state regulations, particularly, those of Louisiana, Texas, and Mississippi. Information from these sources is summarized below regarding record keeping, well configuration, hardware requirements, plugging procedures, and implications for long-term ownership issues related to managing waste sites. Recommendations are then presented based on review of this information, as well as from review of testimony given in a hearing held by the Michigan Department of Natural Resources to determine their standards for NORM waste disposal in UIC wells.

5.1 CRCPD and IOGCC Guidelines

The "Part N" model regulations from the CRCPD have no detailed technical information related to disposal of NORM waste in Class II wells. The only pertinent language relating to oil and gas NORM disposal specifies that "contaminated pipe and plumbing from oil and gas operations shall be disposed of (i.) So as to prevent any reintroduction into commerce or unrestricted use; and (ii.) Within disposal areas specifically designed to meet the criteria of N.13b." Section N.13b refers to choosing options for disposal of NORM so as to limit radon emanations, establishing an exposure limit in millirems per year (mrem/yr) for the general public, and "maintaining releases of NORM via groundwater pathways within limits as specified in the Clean Water Act and applicable regulations or standards."

The *IOGCC Environmental Guidelines for State Oil and Gas Regulatory Programs* (May 1994) also do not provide any detailed criteria for NORM waste disposal in Class II wells, but rather recommend that state regulatory programs authorize disposal alternatives and provide regulatory requirements for NORM disposal that are protective of human health and the environment.

5.2 State Procedures Related to Well Configuration, Hardware Requirements, and Plugging Procedures

Several states explicitly address disposal of NORM wastes in wells which are to be plugged or abandoned. Either the NORM regulations or implementation manuals written by the regulatory state agency stipulate procedures that apply to downhole disposal. They may refer to placing tubing in wells to be plugged and abandoned, and to injecting slurries. Louisiana, Texas, and Mississippi have guidelines specified in proposed regulations or implementation manuals which give detailed procedures for NORM disposal, while New Mexico, Oklahoma, and Michigan refer to these disposal techniques in more general terms. The specified procedures and regulatory language are included in Appendix B and summarized below.

5.2.1 State Procedures for NORM Waste Disposal in UIC Wells

State regulatory criteria specified by Louisiana, Texas, and Mississippi were reviewed. The specific criteria vary from state to state. The following discussion summarizes the criteria. It should be noted that the definition of "lowermost USDW" may vary between states. Similarly, the position of the "surface casing shoe" may be at the lowermost USDW, or it may be higher, depending on a particular state's definition. Other criteria are summarized below.

The states generally require that NORM waste be placed between cement well plugs or cast iron plugs with cement on top. Louisiana and Mississippi require that cement plugs should be a minimum of 100 feet in length and cast iron bridge plugs should have 10 (Louisiana) or 20 (Mississippi) feet of cement on top. Pressure testing should be conducted of the bottom cement plug and casing, or of the well casing above the packer where the NORM is to be injected. The states require that NORM wastes be placed in the well inside the production casing at depths ranging from a minimum of 100 (Louisiana and Mississippi) to 250 (Texas) feet below the base of the lowermost USDW. Further, Mississippi requires that two sand sections exist behind the casing below the USDW.

Texas and Mississippi require that the cement used for the surface plug should be dyed red with iron oxide, and all wells should be marked with an identifying steel plate at the top of the casing. Louisiana and Mississippi require that NORM-contaminated solids should not be mixed with cement that is to be used as a plug. Texas and Mississippi require that if NORM waste is encased in a tubing string, the tubing should be left with a top coupling on the top joint, if the string is not secured in cement. Finally, Louisiana suggests that mud-laden fluid injected in the well should have a minimum density of 9 pounds per gallon.

Exhibit 7 summarizes these state requirements for disposal of NORM waste in Class II wells.

5.3. State Procedures for Record Keeping

Texas and Mississippi specify that certain information regarding NORM waste that is disposed downhole be reported on the co-dispose applications which are submitted to the appropriate state agency. This information includes the physical nature and volume of the NORM waste; radioactivity levels; identity of the operators of the facility or tract where the NORM waste was generated; sources of the NORM waste by commission district, field, well name, lease or facility, and producing formation. Texas specifies that if the NORM waste is encased in tubing, the following must be indicated: the general characteristics of the tubing, including size, grade, weight per foot, and outside diameter; the subsurface depth to the top and bottom of the tubing; the diameter of the tubing coupling; and whether the tubing is free in the hole or secured by cement, a bridge plug, or a cement retainer.

Texas also requires that the operator of the tract or facility where the NORM waste was generated and the person responsible for disposal maintain records for three years after the date of disposal. These records must include the identity of the property where the NORM waste was generated, the disposal location, the physical nature and volume of the waste, and radioactivity levels. These records must be made available to the Texas Railroad Commission or its designee for examination upon request.

Exhibit 7
Procedures for NORM Disposal in UIC Wells

Disposal Procedure Element	Louisiana	Mississippi	Texas
Cement plugs	1. A 100-foot cement plug above uppermost perforated interval in well. 2. A 100-foot cement plug must be placed across the surface casing shoe. 3. A top cement plug of at least 100 feet must be placed at the top of the well. None of the cement used should be mixed with NORM waste.	Cement plugs at least 100 feet in length must be placed above and below the NORM waste. The top cement plug should be dyed with red iron oxide. None of the cement used should be mixed with NORM waste.	A cement plug must be set immediately above the NORM waste and the plug must be either above a cement retainer, above a cast iron bridge, or tagged to locate its position. The top cement plug should be dyed with red iron oxide.
Cast iron bridge plugs	1. A cast iron bridge plug with 10 feet of cement on top can be substituted for the bottom cement plug. 2. A cast iron bridge plug must be placed 50 feet below the casing shoe, above the NORM waste.	A cast iron bridge plug with 20 feet of cement on top may be substituted for the cement plug, top or bottom.	A top cement plug may be above a cast iron bridge.
Pressure testing	Bottom cement plug and casing should be pressure tested at 1,000 psi for 30 minutes. More than 10 psi pressure loss constitutes loss of integrity.	Well casing above the packer where the NORM is to be injected should be pressure tested at 500 psi for 30 minutes. More than a 3 percent loss constitutes a loss of integrity. Injected tubing string should be tested to 150 percent of the intended surface pressure.	
Location of NORM waste in well	NORM waste should be placed inside the production casing at a depth at least 100 feet below the surface casing shoe, which should be 100 feet below the base of the lowermost USDW	NORM should be located 100 feet below an USDW, and should be properly cemented to protect the USDW and have at least two sections of sand behind the casing below the USDW.	NORM waste should be located 250 feet below the base of usable quality water.
Identifying steel plate at top of well		All wells should be marked with a steel plate at the top of the casing indicating the well name, API number, date of plugging and the fact that NORM is in the well.	A permanent marker that shows the three-bladed radiation symbol must be welded to the steel plate at the top of the well casing.

Exhibit 7 (Continued)
Procedures for NORM Disposal in UIC Wells

Disposal Procedure Element	Louisiana	Mississippi	Texas
State of tubing		If tubing is placed between plugs but not secured in cement, the top joint of the tubing string should be left with a top coupling.	If NORM waste is encased in a tubing string, the tubing should be placed, not dropped, in the well and left with an assembly that allows ready retrieval, if the string is not secured in cement.
Fluid density	Mud-laden fluid should have a minimum density of 9 pounds per gallon. (New Mexico also has a criterion for media-laden fluid of a minimum density of 9 pounds per gallon.)		

5.4 Long-Term Ownership Implications

5.4.1 Proposed Part N Regulations

The CRCPD's proposed Part N regulations state that the transfer of NORM waste which is not exempt from the regulations from one general licensee to another may be authorized if the transfer of control or ownership of land contaminated with NORM includes an annotation of the deed records to indicate the presence of NORM. Transfers do not relieve the party making the transfer from assessing the extent of the contamination, evaluating the hazards of the NORM, informing the general licensee receiving the NORM of these assessments and evaluations, or maintaining records.

5.4.2 State Regulations

Arkansas, Mississippi and New Mexico call for the annotation of deed records when transferring land. Most of the states with final or proposed NORM regulations—including Arkansas, Louisiana, Michigan, Mississippi, New Mexico and Oklahoma—set limits on radon emanations and radium soil concentrations for the transfer of land for unrestricted use, implying restrictions on future land uses.

The issue of orphan wells is acknowledged in the *Implementation Manual for the Management of NORM in Louisiana*, which states that the process of obtaining a well from the inventory of over 1,600 orphan wells in Louisiana is being developed by the Office of Conservation. Since these wells do not have identifiable owners, it is unclear how ownership would be transferred. Where ownership of a UIC well is clear, the language pertaining to land transfers presumably would also apply to wells.

5.5 Recommendations

Recommendations are based on a review of the state and federal language, the IOGCC model regulatory language, as well as a review of expert testimony which was provided at a technical hearing held before the Supervisor of Wells and Mineral Wells in the Michigan Department of Natural Resources to receive evidence pertaining to plugging wells where NORM is present. This testimony is included as Appendix C.

5.5.1 Procedures related to Well Configuration, Hardware Requirements, and Plugging Procedures

1. Plugs

Based on the required size specified by the states, and a range of sizes suggested by expert testimony,[57] a 50-to-100-foot plug is adequate. It should be formulated to resist sulfate solutions and should be placed immediately above the highest point at which the reinserted NORM material is placed. The integrity of the plugs should be tested, either with pressure testing or through tagging. The top cement plug should be dyed with red iron oxide. No NORM waste should be mixed with the cement used for the plugs. Cast iron bridge plugs may be used in conjunction with cement plugs and should be tested with weight or pressure as well.

2. Location of NORM waste in well

NORM waste should not be placed in a well at a depth less than 100 feet below the surface shoe or 100 feet below the lowest known or suspected USDW if that aquifer is below the surface casing shoe. In general, all reinserted material should be placed as deep in the well as possible.[58]

3. State of Tubing

If tubing is not encased in cement, a coupling should be left on the top joint of the tubing string. When feasible, tubular material should be encased in cement.

4. Identification of Well

Wells should be clearly identified with a steel plate that provides the well name, API number, and date of plugging, and that notes the presence of NORM in the well.

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[57] State of Michigan, Department of Natural Resources, Supervisor of Wells and Supervisor of Mineral Wells. *Opinion and Order of the Supervisor of Wells and Supervisor of Mineral Wells in the Matter of The Need and Desirability to Issue an Order Establishing Particular Requirements for Plugging of Wells Where Naturally Occurring Radioactive Material (NORM) May be Present.* November 1992.

[58] State of Michigan, Department of Natural Resources, Supervisor of Wells and Supervisor of Mineral Wells. *Opinion and Order of the Supervisor of Wells and Supervisor of Mineral Wells in the Matter of The Need and Desirability to Issue an Order Establishing Particular Requirements for Plugging of Wells Where Naturally Occurring Radioactive Material (NORM) May be Present.* November 1992.

5. Fluid density

The density of media-laden fluid injected into a well should be a minimum of 9 pounds per gallon.

5.5.2 Procedures for Record Keeping

As Texas requires, records should be maintained for three years by the operator of the tract or facility where the NORM waste was generated and the person responsible for disposal. These records should include the identity of the property where the NORM waste was generated, the disposal location, the physical nature and volume of the waste, and its radioactivity levels. The records should be available for review by the appropriate regulatory agencies and should reflect any changes in ownership.

5.5.3 Long-Term Ownership Implications

Current language regarding deed restrictions and standards related to land transfers for unrestricted uses is contained in the CRCPD model regulations, as well as most of the state NORM regulations. Other states, such as Washington, do not have final NORM regulations in place but are using standards similar to other states for contamination limits related to unrestricted land transfers. Some states are in the process of revising these standards but have not yet determined new standards.[59]

5.6. Conclusions

Because there are currently no federal regulations for the management or disposal of NORM wastes associated with oil and gas production activities, the conclusions and recommendations of this report are largely based on state NORM regulations, regulatory language in the IOGCC model, and a review of expert testimony. These recommendations pertain specifically to procedures related to well configuration, hardware requirements, well plugging, and record keeping. The issue of NORM disposal will continue to be of regulatory interest to state and federal agencies. Because of this, it is advisable that EPA's UIC Branch staff remain fully informed of all NORM-related environmental issues because of their potential impact on future EPA program activities. This document, with its overview of NORM management and disposal alternatives, its summary of state regulations, its comprehensive bibliography, and its recommendations, has been designed to assist the UIC program in strategizing and developing its NORM policy.

[59] Personal communication with staff of Environmental Standards Group, Washington Department of Health. December 1994.