ASSOCIATED WASTE REPORT:

CRUDE OIL TANK BOTTOMS AND OILY DEBRIS

January 2000

U.S. Environmental Protection Agency
Office of Solid Waste
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DISCLAIMER

The mention of company or product names is not to be considered an endorsement by the U.S. Government or the U.S. Environmental Protection Agency (EPA).

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1.0 INTRODUCTION

In Section 3001(b)(2)(A) of the 1980 Amendments to the Resource Conservation and Recovery Act (RCRA), Congress conditionally exempted several types of solid wastes from regulation as hazardous wastes. Among the categories of wastes exempted were "drilling fluids, produced waters, and other wastes associated with the exploration, development, and production of crude oil or natural gas…" Section 8002(m) of the 1980 Amendments required the Administrator of the U.S. Environmental Protection Agency (EPA) to study these wastes and submit a report to Congress evaluating the status of their management. The Amendments also required the Administrator to determine whether to promulgate regulations under RCRA Subtitle C if these wastes were determined to be hazardous and to pose a threat to human health and the environment. In July of 1988, the Agency completed these activities and reached a determination that regulation under RCRA Subtitle C was not warranted and that the wastes would be better controlled through existing State and Federal regulatory programs (53 FR 25446). Among those exploration and production (E&P) wastes exempted are "basic sediment and water (BS&W) and other tank bottoms from production storage facilities that hold product and exempt waste." These wastes are also called crude oil tank bottoms and oily debris.

EPA has prepared reports on various wastes that are associated with the exploration, development, and production of crude oil or natural gas that are exempt from regulation as hazardous wastes under Subtitle C of RCRA. Initially, EPA has focused on evaluating three groups of associated wastes: crude oil tank bottoms and oily debris, dehydration and sweetening wastes, and completion and workover wastes. The purpose of these papers is to provide a better understanding of the wastes and their management. This report addresses tank bottoms and oily debris. Chapter 2 describes the generation of tank bottoms and oily debris and discusses the quantities and characteristics of the wastes. Chapter 3 describes waste management practices used for tank bottoms and oily debris and the potential environmental impacts that can result from such management, while Chapter 4 provides an overview of the types of waste minimization and pollution prevention techniques that may reduce the quantity of wastes generated. Finally, Chapter 5 presents a brief summary and conclusions.

Appendices A and B present confidence levels associated with estimates by the American Petroleum Institute (API) of the quantities of tank bottoms and oily debris generated in 1985 and the results of a survey of crude oil reclaimers, respectively. Appendices C, D, and E present analytical data from tank bottoms and oily debris samples collected by EPA and other parties.

2.0 WASTE GENERATION

2.1 WASTE GENERATION

In 1991, there were approximately 614,000 active oil wells (on- and offshore) in the United States producing 7,373,000 barrels of oil per day (*Annual Energy Review 1991*). The universe of generators of crude oil tank bottoms is estimated to be in the hundreds of thousands. For example, in 1988, Entropy Limited estimated the number of aboveground storage tanks associated with U.S. crude oil production to be 572,620 (Entropy Ltd., 1989). Gruy Associates estimate the number of tank batteries (assuming one tank battery for each oil lease in the U.S.) to be 232,169 based on figures current through 1989 (Gruy Engineering Corporation, 1993). Crude oil reclaimers, gas plants, and other off-lease generators would increase the number by a few hundred or perhaps thousands. Although estimates for the number of generators of oily debris were not available, this number would be at least as large as for tank bottoms.

Crude oil, as pumped from a well, is actually an emulsified mixture of oil, gas, gas liquids, water, and basic sediment. In addition, dilute concentrations of completion or workover fluids, stimulation fluids, or other chemicals (biocides, fungicides) that have been introduced into the well may periodically be present. Material pumped from the well is often called produced fluid to distinguish it from product crude oil, which is sold after treatment. Three basic elements of a produced fluid treatment program (used separately or in various combinations) include residence/holding time, heat, and in some cases, chemicals (*e.g.*, emulsion breakers). Produced fluid is sent through one or more process units to separate the waste fractions (e.g., produced water, emulsions, scale, and produced sand) from the salable hydrocarbon. These process units can include:

- Separators: used to separate free produced liquids (hydrocarbons and water) from the produced gas stream.

- Free-water knockouts: used to separate free water (water that is not linked to oil in an emulsion) from other produced fluids when there is a high water cut (water to oil ratio).

- Heater treaters: used to raise the temperature of the fluids (typically downstream of a free-water knockout) to break up emulsions that will not readily separate into gas, crude oil, and water components.

The produced liquids are then stored in one or more tanks where, depending on residence time, additional density separation is achieved as remaining solids and entrained water not removed by separators, free-water knockouts, or heater treaters separate from the crude oil. This density separation results in layering of the contents of the tank from least dense to most dense. Typically, the layers consist of a produced gas blanket above the liquid surface, the crude oil, an oil/water emulsion, produced water, possibly heavy hydrocarbon emulsions, and the bottom layer of accumulated heavy hydrocarbons, paraffins, solids, sand,

and heavy emulsions. The crude oil is typically flowed off the top of this tank to a shipping/stock tank from which it is transferred to a refinery. Similar density separation occurs in produced water storage tanks. The bottom layer from the tanks and treatment vessels is referred to as tank bottoms and is the subject of this report.

Throughout the oil or gas production processes, oily debris, such as oil contaminated soil, rags, and absorbent materials, may be generated due to minor leaks and spills. Additional oily debris is generated during well completions and workovers, gas conditioning, and water treatment (*e.g.*, spent filters and filter media). The filter media traps any remaining hydrocarbon-coated silt and sand from the produced water prior to re-injection for secondary recovery operations or disposal, or prior to other use or discharge of the water. The filter media will also trap sludges and other solids in the fluids being filtered.

According to the API Environmental Guidance Document, tank bottoms are generally defined as the liquids and residue, such as heavy hydrocarbons, solids, sands and emulsions, which collect in the bottom of treating vessels (separators, knockouts, heater treaters), or remain in the bottom of storage tanks (and presumably other production impoundments such as pits) after a period of service (API, 1989). Oily debris is typically defined as spent filters, filter media, and filter backwash. Solid filter media include gravel, coal, carbon sand, and diatomaceous earth.

Saleable crude oil is generally defined by pipeline companies as crude oil containing less than one percent BS&W. In cases where crude oil contains more than one percent BS&W, it is typically classified either as tank bottoms or off-spec crude oil by the producer and may be sold at a reduced market rate to a crude oil reclaimer for recovery. Heavy crude oils (less than 20° API), typical in California, may contain a higher percentage of water. According to one commenter on this report, crude oil in California may contain up to three percent water when sold, primarily to help facilitate the transport of the oil (Falkenhagen 1995).

2.2 WASTE QUANTITIES

The only systematic source of information on the quantities of crude oil tank bottoms and oily debris generated was a survey conducted by the American Petroleum Institute (API 1988). API surveyed member companies on their generation and management of drilling, production, and associated wastes in 1985. To extrapolate from survey respondents to all operators in selected States and the United States as a whole, API assumed that within each of those States and for the U.S., the volumes of wastes that were generated (and managed by specific methods) by survey respondents were proportional to the amount of oil produced by the responding companies in the State and the nation, respectively. This assumption allowed API to estimate the total quantities of wastes generated (and managed) by all operators in those States and the U.S. According to API, at the conclusion of the survey, 53 percent of crude oil operators had responded. API was careful to note that the statistical estimation of waste volumes assumed that respondents reported accurately and fully.

In the survey, tank bottoms and other heavy hydrocarbons were defined by API as tank bottoms (wash tanks, heater treaters, and stock tanks), pig trap paraffin and paraffin cuttings from flow lines, and cellar (sump) oil. Oily debris and filter media were defined as rags, paper towels, sorbent material, diatomaceous earth, sand, anthracite coal, sock material, and strainers (API, 1988). EPA has defined tank bottoms as basic sediment and water, accumulated heavy hydrocarbons, solids, sand, and emulsion and oily debris as rags and sorbent material; filter media are classified separately (EPA, 1990). Except as noted, API definitions are used in this report in discussing quantities of wastes.

Appendix A presents API's estimates of the total volumes of associated wastes in general, and tank bottom wastes (Table A-1) and oily debris wastes (Table A-2), specifically, that were generated in 1985. Also presented are the lower and upper 95 percent confidence intervals for the associated waste estimates (see the table notes for additional notes and qualifications). As can be seen, the confidence levels range from two percent (i.e., generally speaking, the actual volume is 95 percent likely to be within two percent of the estimated volume) in Alaska to 201 percent (i.e., the actual volume could range from 0 to three times the estimated volume) in West Virginia. In general, the narrower confidence intervals are for States where a higher percentage of the States' total oil was produced by respondent companies.

Nationally, API's estimates of tank bottom waste and oily debris waste volumes were said to have a 95 percent probability of falling within twenty percent of the reported volumes of 1,232,000 barrels and 1,261,000 barrels respectively; clearly, the estimated volume and the confidence limits rely on the assumptions behind the survey and the extrapolation. (It is not clear if the confidence levels would apply equally to tank bottoms and oily debris wastes, even were all assumptions valid; the estimation method would in no case allow the tank bottoms and oily debris estimates to be more precise than the total associated waste estimates). Figure 2-1 illustrates tank bottoms and oily debris generation in relationship to the other associated wastes (not including used oils).

Figure 2-2 illustrates the geographic distribution of the 1985 quantity of tank bottoms generated by State. The diagram graphically emphasizes the large contribution of tank bottoms from California. Comparing on-shore crude oil production with tank bottoms generated by State, Table 2-1 points out some trends and possible survey discrepancies. Notable observations from the table include:

- California, which accounted for 13 percent of the U.S. on-shore production, generated a disproportionate amount of the U.S. tank bottom wastes. (In general, it should be noted the proportion of National totals of tank bottoms or other specific associated wastes that was generated in a single State is not a statistically valid calculation since State and National totals were calculated independently. Comparisons of very large differences, however, may have some value.) This may be due partially to the heavy nature of much of California's crude oil production. Further, it may be due to the regulation of tank

bottoms as a California "designated waste,"[1] with resulting restrictions on land discharges (*e.g.*, landspreading).

- Texas accounted for 31 percent of U.S. oil production and generated a relatively low proportion of the tank bottoms.

(text continues on page 9)

[1] A "designated waste" is generally a nonhazardous waste that contains pollutants which could be released in concentrations exceeding California water quality objectives or could cause degradation of waters of the State (IOGCC May 1993).

Figure 2-1. Tank Bottoms and Oily Debris as a Proportion of All Associated Wastes, 1985
(Source: API, 1988a)

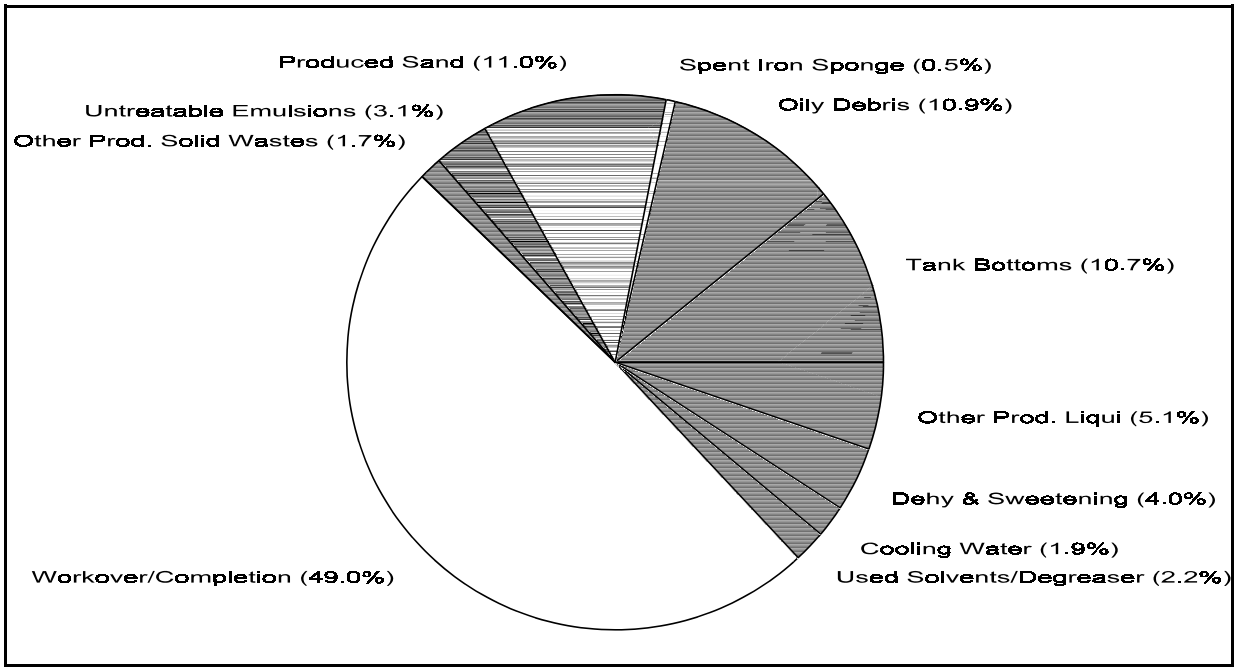
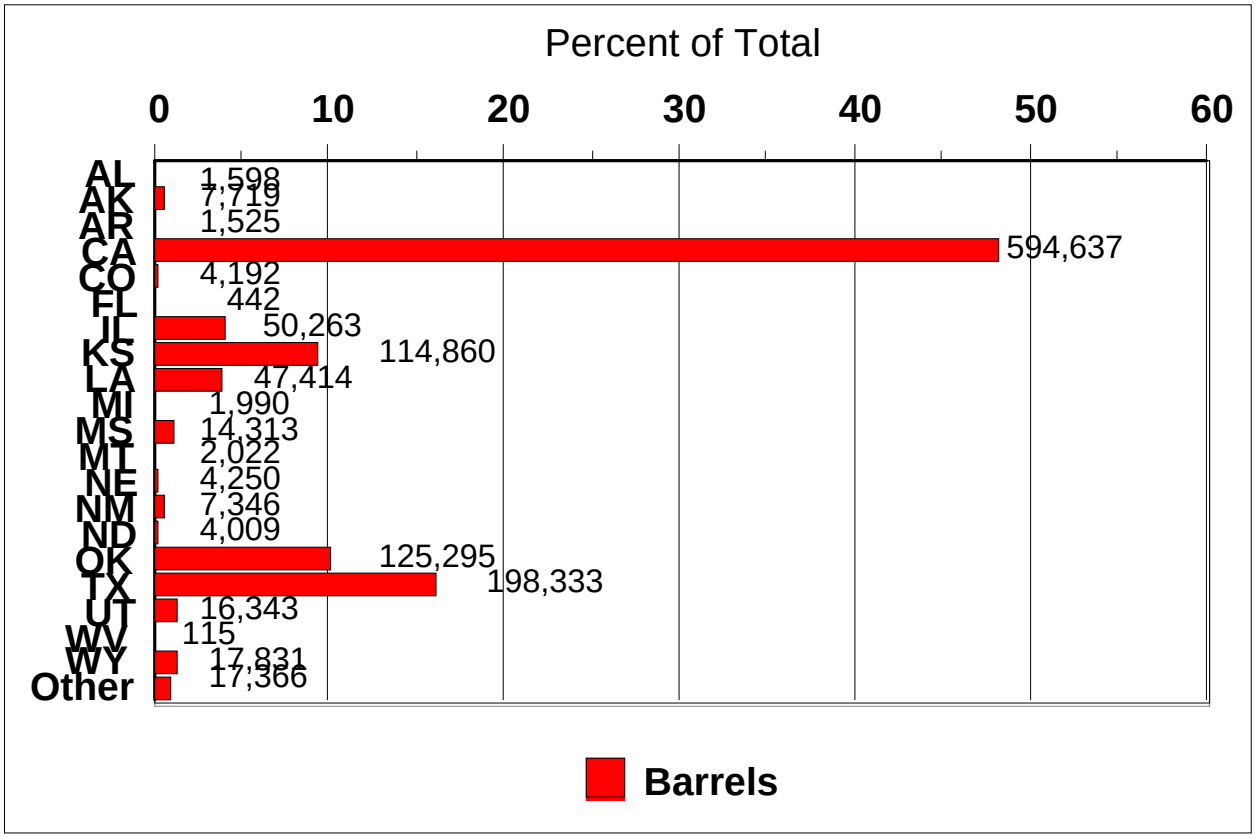


Figure 2-2. Generation of Tank Bottoms by State, 1985
(Source: API, 1988a)



Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-1. Total Oil Produced and Tank Bottoms Generated per State, 1985

State	Oil Production (Thousand Barrels)		Associated Wastes (Barrels)		Tank Bottoms (Barrels)		Tank Bottoms as Percentage of all Associated Wastes
	Total	% U.S.	Total	% U.S.	Total	% U.S. (See Note A)	
Alabama	21,581	0.8	8,000	0.1	1,598	< 5	19.32
Alaska	651,599	23.1	55,000	0.5	7,719	< 5	13.96
Arkansas	19,044	0.7	19,000	0.2	1,525	< 5	8.06
California	353,550	12.5	2,379,000	20.2	594,637	> 10	25.21
Colorado	30,246	1.1	806,000	6.9	4,192	< 5	0.52
Florida	11,458	0.4	163,000	1.4	442	< 5	0.03
Illinois	30,265	1.1	205,000	1.7	50,263	< 5	24.47
Kansas	75,407	2.7	290,000	2.5	114,860	5 - 10	39.69
Louisiana	158,806	5.6	235,000	2.0	47,414	< 5	20.67
Michigan	27,300	1.0	161,000	1.4	1,990	< 5	1.24
Mississippi	30,641	1.1	50,000	0.4	14,313	< 5	28.7
Montana	29,768	1.1	337,000	2.9	2,022	< 5	0.6
Nebraska	6,943	0.2	9,000	0.1	4,250	< 5	21.36
New Mexico	78,530	2.8	355,000	3.0	7,346	< 5	2.06
North Dakota	50,857	1.8	330,000	2.8	4,009	< 5	1.21
Oklahoma	162,739	5.8	2,491,000	21.2	125,295	> 10	5.4
Texas	867,122	30.8	3,080,000	26.2	198,333	> 10	6.57
Utah	40,792	1.4	47,000	0.4	16,343	< 5	36.0

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-1. Total Oil Produced and Tank Bottoms Generated per State, 1985
(continued)

State	Oil Production (Thousand Barrels)		Associated Wastes (Barrels)		Tank Bottoms (Barrels)		Tank Bottoms as Percentage of all Associated Wastes
	Total	% U.S.	Total	% U.S.	Total	% U.S. (See Note A)	
West Virginia	3,555	0.1	422,000	3.6	115	< 5	0.03
Wyoming	128,514	4.6	150,000	1.3	17,831	< 5	12.07
Total U.S.	2,818,450	100.0	11,759,000	100.0	1,231,863	100	10.73

Sources: API, June 1988a

Notes:

(A) The percentage of the total U.S. tank bottoms generated in specific States can be calculated but would not be statistically valid because of the statistical procedures used to calculate State and National totals (see discussion in Chapter 3). Presented here are broad ranges (< 5, 5 - 10, > 10%), which may have some value for gross comparisons.

- Tank bottoms made up 40 percent of Kansas' and 36 percent of Utah's total associated waste production.

- Alaska contributed 23 percent of U.S. oil production while only generating very little of the tank bottoms wastes. This may be due to the gravity of the crude or the decreased time spent in storage tanks prior to entry into the pipeline or being loaded onto a barge.

Table 2-2 compares the tank bottoms generated versus producing oil wells and oil production by State in 1985. Notable observations include:

- California, with eight percent of the producing wells, generated almost 12 barrels of tank bottoms for each producing well and 1.7 barrels of tank bottoms for every 1000 barrels of oil produced.

- Utah, with 0.3 percent of the U.S. producing wells, generated 8.4 barrels of tank bottoms per producing well. Tank bottoms comprised 36 percent of its total associated waste production.

- Illinois was second to California with 1.66 barrels of tank bottoms generated per 1000 barrels of oil produced.

- Texas had 33 percent of the producing oil wells and generated less than one barrel of tank bottoms per well, only 0.23 barrels of tank bottoms for every 1000 barrels of oil produced.

- Alaska, which had 23 percent of U.S. oil production and 0.15 percent of the producing wells, generated nearly eight barrels of tank bottoms per well and 0.01 barrels of bottoms per 1000 barrels of oil production. This is accounted for by the large volumes of crude oil from relatively few wells and the factors noted previously.

Figure 2-3 exhibits the geographic distribution of the oily debris generated by state. Table 2-3 compares on-shore crude oil production with oily debris generation by state in 1985. Some trends and possible survey discrepancies are summarized in the following:

- California, with 13 percent of U.S. crude oil production, generated a large percent of the U.S. total of oily debris generated.

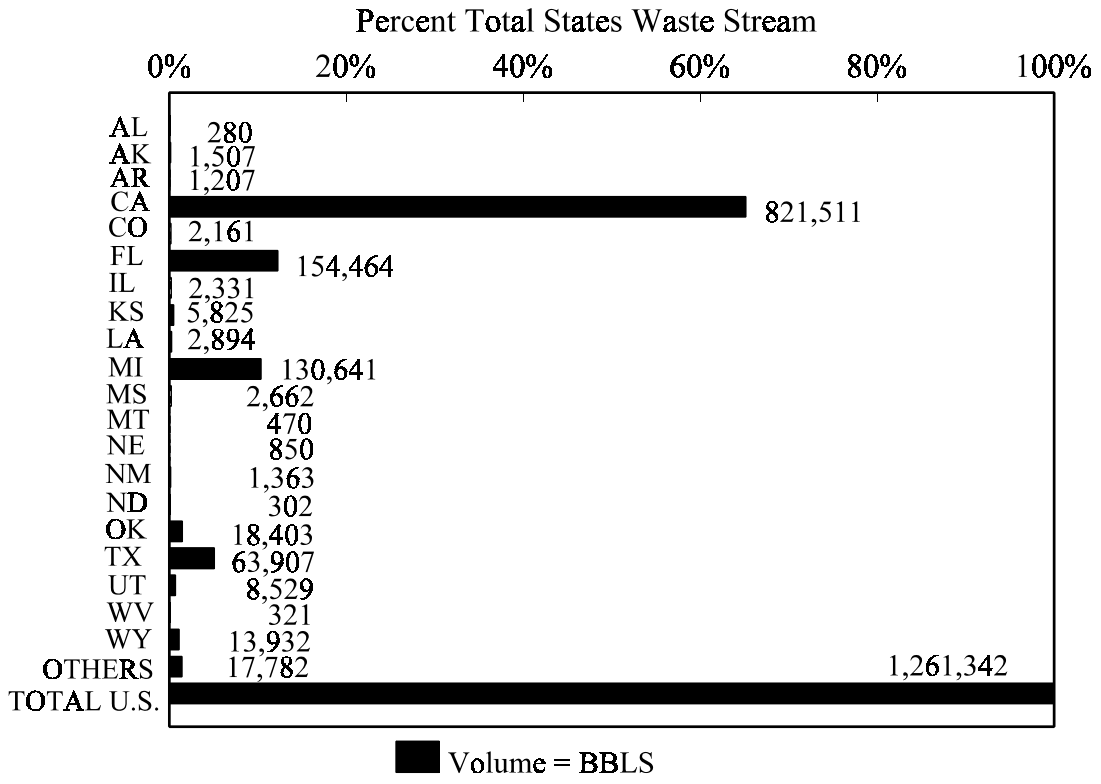
- Florida produced 0.4 percent of the U.S. oil and generated a much higher proportion of the oily debris. This made up 95 percent of Florida's total associated waste production. This may be a survey discrepancy which may have come from the survey's definition of oily debris.

- Michigan, with less than one percent of the U.S. oil production, generated a much higher proportion of the U.S. total of oily debris. Oily debris comprised 82 percent of the State's associated waste production. This may be a survey discrepancy resulting from how oily debris was defined by API.

- Texas accounted for 31 percent of the total U.S. oil production but a much lower proportion of the oily debris.

- Alaska generated a very small proportion of the total U.S. oily debris while producing 23 percent of the U.S. crude oil. This is most likely due to the large volumes of crude oil from relatively few wells.

Figure 2-3. Generation of Oily Debris by State, 1985
(Source: API 1988a)



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Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-2. Tank Bottoms Generated per Producing Well and Amount of Oil Produced, 1985

State	Number of Oil Producing Wells		Oil Production (Thousand Barrels)		Total Tank Bottom Wastes (Barrels)	Estimated Tank Bottoms per Producing Oil Well (Barrels)	Estimated Tank Bottom Wastes per 1000 Barrels of Oil Produced (Barrels)
	Total	% U.S.	Total	% U.S.			
Alabama	810	??	21,581	0.8	1,598	2.0	0.1
Alaska	977	0.2	651,599	23.1	7,719	7.9	0.0
Arkansas	9,700	1.5	19,044	0.7	1,525	0.2	0.1
California	49,874	7.8	353,550	12.5	594,637	11.9	1.7
Colorado	5,457	0.9	30,246	1.1	4,192	0.8	0.1
Florida	149	0.0	11,458	0.4	442	3.0	0.0
Illinois	31,100	4.8	30,265	1.1	50,263	1.6	1.7
Kansas	51,888	8.1	75,407	2.7	114,860	2.2	1.5
Louisiana	28,354	4.4	158,806	5.6	47,414	1.7	0.3
Michigan	5,143	0.8	27,300	1.0	1,990	0.4	0.1
Mississippi	3,468	0.5	30,641	1.1	14,313	4.1	0.5
Montana	4,196	0.7	29,768	1.1	2,022	0.5	0.1
Nebraska	2,091	0.3	6,943	0.2	4,250	2.0	0.6
New Mexico	18,697	2.9	78,530	2.8	7,346	0.4	0.1
North Dakota	3,697	0.6	50,857	1.8	4,009	1.1	0.1
Oklahoma	102,342	15.9	162,739	5.8	125,295	1.2	0.8
Texas	209,040	32.5	867,122	30.8	198,333	0.9	0.2
Utah	1,944	0.3	40,792	1.4	16,343	8.4	0.4

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-2. Tank Bottoms Generated per Producing Well and Amount of Oil Produced, 1985
(continued)

State	Number of Oil Producing Wells		Oil Production (Thousand Barrels)		Total Tank Bottom Wastes (Barrels)	Estimated Tank Bottoms per Producing Oil Well (Barrels)	Estimated Tank Bottom Wastes per 1000 Barrels of Oil Produced (Barrels)
	Total	% U.S.	Total	% U.S.			
West Virginia	15,895	2.5	3,555	0.1	115	0.0	0.0
Wyoming	12,038	1.9	128,514	4.6	17,831	1.5	0.1
Total U.S.	642,299	100.0	2,818,450	100.0	1,231,863	1.9	0.4

Source: API 1988a

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-3. Total Oil Produced and Oily Debris Waste Generated per State, 1985

State	Oil Production (Thousand Barrels)		Associated Wastes (Barrels)		Oily Debris (Barrels)		Oily Debris as Percentage of all Associated Wastes
	Total	% U.S.	Total	% U.S.	Total	% U.S. (See Note A)	
Alabama	21,581	0.2	8,000	0.1	280	< 5	3.38
Alaska	651,599	23.1	55,000	0.5	1,507	< 5	2.73
Arkansas	19,044	0.7	19,000	0.2	1,207	< 5	6.4
California	353,550	12.5	2,379,000	20.2	831,511	> 10	35.26
Colorado	30,246	1.1	806,000	6.9	2,161	< 5	0.27
Florida	11,458	0.4	163,000	1.4	154,464	> 10	95.0
Illinois	30,265	1.1	205,000	1.7	2,331	< 5	1.13
Kansas	75,407	2.7	290,000	2.5	5,825	< 5	2.0
Louisiana	158,806	5.6	235,000	2.0	2,894	< 5	1.26
Michigan	27,300	1.0	161,000	1.4	130,641	> 10	81.62
Mississippi	30,641	1.1	50,000	0.4	2,662	< 5	5.34
Montana	29,768	1.1	337,000	2.9	470	< 5	0.14
Nebraska	6,943	0.2	9,000	0.1	850	< 5	8.98
New Mexico	78,530	2.8	355,000	3.0	1,363	< 5	0.38
North Dakota	50,857	1.8	330,000	2.8	302	< 5	0.09
Oklahoma	162,739	5.8	2,491,000	21.2	18,403	< 5	0.8
Texas	867,122	30.8	3,080,000	26.2	63,907	5 - 10	2.12
Utah	40,792	1.4	47,000	0.4	8,529	< 5	18.79

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-3. Total Oil Produced and Oily Debris Generated per State, 1985
(continued)

State	Oil Production (Thousand Barrels)		Associated Wastes (Barrels)		Oily Debris (Barrels)		Oily Debris as Percentage of all Associated Wastes
	Total	% U.S.	Total	% U.S.	Total	% U.S. (See Note A)	
West Virginia	3,555	0.1	422,000	3.6	321	< 5	0.08
Wyoming	128,514	4.6	150,000	1.3	13,932	< 5	9.43
Total U.S.	2,818,450	100.0	11,759,000	100.0	1,261,342	100	11.0

Source: API 1988a

Notes:

(A) The percentages of the total tank bottoms generated in specific states can be calculated but would not be statistically valid because of the statistical procedures used to calculate State and National totals (see discussion in Chapter 3). Presented here are broad ranges (< 5, 5 - 10, > 10%), which may have some value for gross comparison.

Table 2-4 compares the oily debris generated versus producing oil wells and oil production by state in 1985. Some of the more interesting results are as follows:

- Florida generated 1,037 barrels of oily debris per well and 13.5 barrels of oily debris per 1000 barrels of produced oil. Florida produced less than 0.5 percent of the total U.S. crude oil. Oily debris comprised 95 percent of their associated waste.

- Michigan, with less than one percent of the producing wells, generated 25.4 barrels of oily debris for each producing well and almost five barrels of oily debris for every 1000 barrels of oil produced.

- California generated 17 barrels of oily debris for each producing well and 2.35 barrels of oily debris for every 1000 barrels of oil produced.

- Texas, which has 33 percent of the producing oil wells producing 31 percent of the U.S. oil, generated 0.31 barrels of oily debris per well and less than 0.1 barrels of oily debris for every 1000 barrels of oil produced.

A number of factors would account for the apparent consistencies, and inconsistencies, between waste generation and oil production. Some would be attributed to the physical characteristics of the producing formations (*e.g.*, unconsolidated sands) or to the nature of the oil and fluids from which tank bottoms are derived; for example, the differences between heavy California crude and Texas crude would account for at least some of the differences between data for those States. Other factors would include respondent interpretation of waste categories, respondent accuracy, and regulatory attention by States (which could affect the respondents' awareness of wastes and the quantity/quality of available data).

Table 2-5 presents the 1985 API tank bottoms and oily debris waste volumes and crude oil production for 1985 and 1993, along with the percent change in oil production. If crude oil production and tank bottoms and oily debris generation were directly correlated, a linear extrapolation could be applied to the 1985 data to estimate 1993 waste quantities. The resulting 1993 U.S. quantities for tank bottoms would be 799,479 barrels and for oily debris 818,611 barrels. The relationship between crude oil production and tank bottoms and oily debris generated is complicated, however, by all the factors noted above.

(text continues on page 19)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-4. Oily Debris Generated per Producing Well and Amount of Oil Produced, 1985

State	Number of Oil Producing Wells		Oil Production (Thousand Barrels)		Total Oily Debris Wastes (Barrels)	Estimated Oily Debris per Producing Oil Well (Barrels)	Barrels of Oily Debris Wastes per 1000 Barrels of Oil Produced
	Total	% U.S.	Total	% U.S.			
Alabama	810	??	21,581	0.8	280	0.3	0.0
Alaska	977	0.2	651,599	23.1	1,507	1.5	0.0
Arkansas	9,700	1.5	19,044	0.7	1,207	0.1	0.1
California	49,874	7.8	353,550	12.5	831,511	16.7	2.4
Colorado	5,457	0.9	30,246	1.1	2,161	0.4	0.1
Florida	149	0.0	11,458	0.4	154,464	1,036.7	13.5
Illinois	31,100	4.8	30,265	1.1	2,331	0.1	0.1
Kansas	51,888	8.1	75,407	2.7	5,825	0.1	0.1
Louisiana	28,354	4.4	158,806	5.6	2,894	0.1	0.0
Michigan	5,143	0.8	27,300	1.0	130,641	25.4	4.8
Mississippi	3,468	0.5	30,641	1.1	2,662	0.8	0.1
Montana	4,196	0.7	29,768	1.1	470	0.1	0.0
Nebraska	2,091	0.3	6,943	0.2	850	0.4	0.1
New Mexico	18,697	2.9	78,530	2.8	1,363	0.1	0.0
North Dakota	3,697	0.6	50,857	1.8	302	0.1	0.0
Oklahoma	102,342	15.9	162,739	5.8	18,403	0.2	0.1
Texas	209,040	32.5	867,122	30.8	63,907	0.3	0.1

(continued)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-4. Oily Debris Generated per Producing Well and Amount of Oil Produced, 1985
(continued)

State	Number of Oil Producing Wells		Oil Production (Thousand Barrels)		Total Oily Debris Wastes (Barrels)	Estimated Oily Debris per Producing Oil Well (Barrels)	Barrrels of Oily Debris Wastes per 1000 Barrels of Oil Produced
	Total	% U.S.	Total	% U.S.			
Utah	1,944	0.3	40,792	1.4	8,529	4.4	0.2
West Virginia	15,895	2.5	3,555	0.1	321	0.0	0.1
Wyoming	12,038	1.9	128,514	4.6	13,932	1.2	0.1
Total U.S.	642,299	100.0	2,818,450	100.0	1,261,342	2.0	0.4

Source: API 1988a

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-5. Volumes of Tank Bottoms and Oily Debris and Changes in Oil Production by State from 1985 - 1993

State	Tank Bottom Wastes 1985 (Barrels)	Oily Debris 1985 (Barrels)	Oil Production 1985 * (Thousand Bbls)	Oil Production 1993 * (Thousand Bbls)	Percent Difference in Oil Production 1985 to 1990
Alabama	1,598	280	21,581	18,677	-13.46
Alaska	7,719	1,507	666,233	577,494	-13.32
Arkansas	1,525	1,207	19,044	9,974	-47.63
California	594,637	831,511	423,811	293,089	-30.84
Colorado	4,192	2,161	30,246	29,398	-2.80
Florida	442	154,464	11,458	5,604	-51.09
Illinois	50,263	2,331	30,265	17,406	-42.49
Kansas	114,860	5,825	75,407	49,625	-34.19
Louisiana	47,414	2,894	508,239	138,679	-72.71
Michigan	1,990	130,641	27,300	13,799	-49.45
Mississippi	14,313	2,664	30,641	22,615	-26.19
Montana	2,022	470	29,768	17,446	-41.39
Nebraska	4,250	850	6,943	4,868	-29.89
New Mexico	7,346	1,363	78,530	68,422	-12.87
North Dakota	4,009	302	50,857	30,917	-39.21
Oklahoma	125,295	18,403	162,739	96,624	-40.63
Texas	198,333	63,907	888,831	619,088	-30.35
Utah	16,343	8,529	40,792	21,819	-46.51
West Virginia	115	321	3,555	2,048	-42.39
Wyoming	17,831	13,932	128,514	87,667	-31.78
Total U.S.	1,231,863	1,261,342	3,274,600	2,125,259	-35.10

Sources: API, June 1988.
API, January 1995

* Includes on and off-shore production volumes

2.3 WASTE COMPOSITION

Crude oil consists of complex combinations of hydrocarbon and non-hydrocarbon organic compounds with traces of inorganic compounds. Hydrocarbon organic compounds include alkanes, alkenes, alkynes, cyclic aliphatic hydrocarbons, and aromatic compounds (*e.g.*, benzene, xylene, toluene, and ethylbenzene). Non-hydrocarbon organic compounds are present only to a limited extent. Inorganic compounds include sulfur compounds (*e.g.*, H_2S, mercaptans, and alkyl sulfides) as well as trace metals. Most, if not all, of these constituents would be present in different crude oils. Besides differences in crude composition, the concentrations of constituents in tank bottoms could be expected to vary due to reasons discussed previously.

In preparing this report, EPA examined readily available tank bottoms analytical data from a variety of sources including some refineries and crude oil reclaimers. Even though the RCRA Subtitle C exemption does not apply to refining wastes, the Agency included these data in this report because the bottoms are generally derived from the same crude oil. In general, EPA has no reason to believe there are major differences in crude oil tank bottoms from E&P operations and from refineries, except that refineries may generate smaller quantities of tank bottoms per barrel of crude oil stored. (There could be some differences due to non-domestic crude stored at refineries, but these should be minor.) In addition, two samples of tank sludges/bottoms from gas processing operations have also been included. These samples were collected and analyzed from mainline compressor stations (one from a knockout tank and one from a produced water holding tank). While wastes from these types of operations have generally not been considered exempt, their composition should be consistent with similar tank bottom wastes produced at field production operations.

Analytical data from a number of other samples (*e.g.*, active and inactive production pits) were also included; although, the sources of constituents could have been from sources other than tank bottoms. Nevertheless, it can be assumed that samples from active production pits would be similar to bottom sediments that would be found in tanks storing produced water. Although details on the period of inactivity are not available, samples from inactive production pits may or may not provide interesting information on the fate of constituents of pit contents. To supplement pre-existing information, EPA also sampled a number of tank bottoms in 1992. Table 2-6 summarizes the sources of and numbers of samples examined for this report.

The samples for which analytical data were available included the following: fifty-four crude oil tank bottom samples that had been identified in mid-1992 (see Appendix C); an additional nineteen samples that were obtained during EPA's 1992 solid waste sampling effort (see Appendix D); eight samples from EPA's 1992 waste water sampling effort (see Appendix E); two samples of gas facility tank bottoms collected by the Gas Research Institute (GRI) (see Appendix F); ten raw materials tank bottoms, ten finished road mix materials tank bottoms samples and ten crude oil-containing materials samples collected at road mix production facilities by the Western States Petroleum Association (WSPA) (see Appendix G); and 51 samples collected from 38 active and 13 inactive production pits by the Pennsylvania Department of

Environmental Resources (see Appendix H). Two of the 38 active pits and four of 13 inactive pits were associated with secondary recovery operations (waterfloods). Samples represented tank bottoms from oil and gas production facilities and from crude oil reclamation facilities. Samples were taken from storage tanks (crude oil and brine produced water) and process vessels (heater treaters, freewater knockouts, and a centrifuge). In addition, two samples of oily debris and one sample of disposed tank bottoms were also available.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-6. Summary of Tank Bottom and Oily Debris Analytical Data Sources

Data Source	Number of Samples				Description of Program / Data
	Crude Oil Tank Bottoms		Oily Debris	Other	
	Producers	Reclaimers			
EPA OSW 1986	2				EPA sampling effort in 1986 to support the *1987 Report to Congress*. See Table C-1 in Appendix C. 2 samples (TCLP).
Petroleum Refining Waste Profiles, 1992					Summarizes survey response information in the Petroleum Refining Database (PRDB). See Table C-2 in Appendix C. No analytical data. "Suspected" constituents only.
EPA Refinery Sampling and Analysis, 1987	1				Submitted by industry as part of EPA's initial waste characterization data. See Table C-3 in Appendix C for data. 1 sample (TCA).
Star Enterprises' Delaware City Refinery	4				Submitted by industry as part of an on-going listing determination effort. See Table C-4 in Appendix C for data. 4 samples (TCLP).
Kansas' Crude Oil Reclaimer Data		8			Submitted to EPA by Kansas in response to 1990 request for information for crude oil reclaimer study. See Table C-5 in Appendix C. 8 samples (1 TCLP, 7 TCA).
New Mexico Crude Oil Reclaimer Data		3			Submitted to EPA by New Mexico in response to 1990 request for information for crude oil reclaimer study. See Table C-6 in Appendix C. 3 samples (TCLP).
API Crude Oil Reclaimer Data		13			Submitted to EPA by API in response to 1990 request for information for crude oil reclaimer study. See Table C-7 in Appendix C. 13 samples (TCLP, Ignitability).
API Process Vessel Bottoms Data	2				Submitted to EPA by API in response to 1990 request for information for crude oil reclaimer study. See Table C-8 in Appendix C. 2 samples (TCLP, Ignitability).
API Tank Bottoms Compositional Data	12				API data from *Exploration and Production Industry Associated Waste Report, 1988.* See Table C-9 in Appendix C. 12 samples (California STLC concentration ranges).
Canadian Petroleum Association	6		2		CPA / Environment Canada Joint Study. See Table C-10 in Appendix C. 3 Vessel Bottom, 3 Tank Bottom, 2 Oily Debris samples (CGSB Leachate Extraction Procedure)
EPA OSW 1992	11 (3)	4	1		Special Waste Branch effort to supplement existing information. See Tables D-4 through D-18 in Appendix D for the description of sampling effort. Of 16 samples plus 3 duplicates, 4 (TCLP), 15 plus 3 duplicates (TCA), 11 plus 1 duplicate (radionuclides)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-6. Summary of Tank Bottom and Oily Debris Analytical Data Sources

Data Source	Number of Samples				Description of Program / Data
	Crude Oil Tank Bottoms		Oily Debris	Other	
	Producers	Reclaimers			
EPA OW 1992	6 (2)				Office of Water effort to support study of coastal facilities. See Tables E-3 through E-7 in Appendix E for the description of sampling effort. Of 6 samples plus 2 duplicates, 5 plus 2 duplicates (TCA), 6 plus 2 duplicates (radionuclides)
GRI 1993	2				Gas Research Institute Study focussing on wastes generated from gas processing/conditioning, underground storage, and mainline compression operations; includes single tank bottom/sludge samples taken from two facilities (mainline compressor stations, see note in text)
WSPA 1993		20	10	12[1]	Western States Petroleum Association study of constituents and emissions from the production of road mix material from crude oil tank bottoms and other crude oil-containing materials at three facilities in the San Joaquin Valley in California.
PDER 1994				51[2]	Pennsylvania Department of Environmental Resources study of constituents in samples from 38 active and 13 inactive production pits in Pennsylvania oilfields.

[1] Air emission samples.
[2] Active and inactive pit samples.

Notes: TCA = Total constituent analysis
TCLP = Toxicity Characteristic Leachate Procedure
STLC = Soluble Threshold Limit Concentration (California Assessment Manual)
CGSB = Canadian General Standards Board (Class 9, Miscellaneous Substances)

Overall, analytical data from 162 samples were obtained. These results cannot be portrayed as representative of tank bottoms in general simply because of the number of samples compared to the number of generators and the volumes generated. However, the results can serve as an indicator of potential constituents of concern, those warranting further review, and to guide future efforts. If all samples, for example, showed very low concentrations of most or all constituents, EPA could use this in making decisions about the need, or the lack of need, to further examine the wastes and management methods. Alternatively, if specific constituents in specific wastes appeared in consistently high concentrations, EPA could focus attention on these wastes and constituents. The following sections briefly describe the analytical data. Additional discussions appear in Appendices C, D, E, F and G.

2.3.1 Toxicity Characteristic Leaching Procedure (TCLP) Analyses

EPA used the Toxicity Characteristic Leaching Procedure (TCLP) to evaluate the toxicity of samples. As stated in the 1987 Report to Congress, "The TCLP was designed to model a reasonable worst-case mismanagement scenario, that of co-disposal of industrial waste with municipal refuse or other types of biodegradable organic waste in a sanitary landfill." Typically, oil and gas exploration and production (E&P) wastes are not disposed in municipal landfills. Additionally, sludge and oily samples can create

operational and equipment difficulties leading to unreliable analytical results. This was a problem with a number of EPA's 1992 tank bottom TCLP samples. Therefore, "[t]his test may not reflect the true hazard of the waste when it is managed by other methods."

Ninety-two full or partial TCLP analyses were conducted on the samples summarized above: 18 production facility samples, including 12 tank bottom samples and six process vessel bottom samples[2]; 18 crude oil reclamation facility samples, including 17 tank bottom samples and one sample of centrifuged tank bottoms; three tank bottoms from road mix production facilities; two oily debris samples[2]; and 51 production pit samples. Results are compared to concentrations established under RCRA Subtitle C to identify wastes that exhibit the hazardous characteristic of toxicity. The wastes sampled are exempt from Subtitle C, so the characterization of wastes below is for illustration purposes only.

Benzene was detected in 27 of 31 production and reclaimer tank bottom TCLP samples analyzed for that constituent. Benzene was also detected in 25 of 46 production pit TCLP samples with detects in only two of 12 samples from inactive production pits and 23 of 34 active production pit samples. There does not appear to be a correlation between the active or inactive status of the production pits and the concentration of benzene or other TCLP organics detected. Twenty of the 27 tank bottom samples exhibited the hazardous characteristic of toxicity while none of the 25 production pit samples exhibited the hazardous characteristic of toxicity for benzene. Five production facility samples (of thirteen analyzed) exceeded the regulatory level for benzene, with concentrations ranging from almost twice to more than 26 times the regulatory level of 0.5 mg/L. Fifteen of 18 crude oil reclamation facility samples exhibited the hazardous characteristic for benzene, with concentrations that ranged from approximately double to 2,800 times the regulatory level. None of the three tank bottom samples from road mix production facilities exhibited detectable levels of benzene or other TCLP organics included in the analyses. (The data are so limited and variable that mean or median values would have little meaning, so these are not presented or discussed.)

Lead was detected in 12 of 30 production and reclaimer tank bottom TCLP samples analyzed for that constituent. Two samples (one crude oil reclamation facility sample and one production facility process vessel sample) exhibited the hazardous characteristic of toxicity for lead, each with concentrations almost twice the regulatory level of 5.0 mg/L. No other constituent was detected at a concentration that exceeded the toxicity characteristic threshold. Lead was not detected in the three finished road mix tank bottom TCLP samples. Of the TCLP metals included in the analyses, only barium and chromium. Both metals were detected in each of the three samples in concentrations below regulatory levels.

Lead was detected in 4 of 51 TCLP production pit samples at concentrations well below regulatory levels. All of the 4 production pit samples with detectable lead were from active pits. Similarly, selenium was

[2] Data from the 1991 Canadian Petroleum Association (CPA) study are included in these totals. However, it appeared that some leachate data reported from the CPA study may actually be minimum detection limits rather than detection levels so the CPA data are not included in the discussion or in Table 2-7. Refer to Table C-10 in Appendix C for the CPA data.

detected below regulatory levels in 5 of 38 active production pit samples and 1 of 13 inactive pit samples. Arsenic detections were evenly distributed among the TCLP production pit samples with detects in 14 of 38 active pit samples and 5 of 13 inactive pit samples, again all below regulatory levels. Barium was detected, below regulatory levels, in all 51 production pit samples. No other TCLP metals were detected in the production pit samples and none of these samples exhibited metals concentrations exceeding regulatory levels. There does not appear to be a correlation between the active or inactive status of the production pits and the concentration of detected TCLP metals.

Table 2-7 summarizes the TCLP analyses for tank bottoms for benzene, lead, and other selected constituents. Concentrations were extremely variable; as this table shows, the range of concentrations for many analytes covered several orders of magnitude. For example, TCLP concentrations for benzene from nine samples taken at production facilities ranged from 0.027 mg/L to 13 mg/L, a range of more than two orders of magnitude. Benzene results from eighteen samples taken at crude oil reclamation facilities demonstrated an even wider spread, from a minimum of 0.092 mg/L to a maximum of 1,400 mg/L, over four orders of magnitude. Another example of this extreme variability is the range of concentrations observed for lead. Production facility samples ranged from a minimum of 0.05 mg/L to a maximum of 9.6 mg/L.

Table 2-8 summarizes the TCLP analyses for finished road mix tank bottoms and production pit samples for benzene, lead, and other selected constituents. Concentrations for these samples were much less variable. As this table shows, the range of concentrations for those few analytes detected are well below regulatory levels. Benzene was not detected in the roadmix or production pit samples.

(text continues on page 26)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-7. Summary of Ignitability Characteristic and TCLP Analyses for Tank Bottoms (Select Constituents)

Constituent	Characteristic Regulatory Level	Number of Samples Detected[1]/ Samples Analyzed	Production Facility Tank and Vessel Bottoms Concentration Range (mg/L)	Number of Samples Exceeding Characteristic Reg. Level	Number of Samples Detected[1]/ Samples Analyzed	Reclamation Facility Tank Bottoms Concentration Range (mg/L)	Number of Samples Exceeding Characteristic Reg. Level
Benzene	0.5 mg/L	9/13	0.027 - 13	5	18/18	0.092 - 1,400	15
Arsenic	5.0 mg/L	5/13	0.0023 - 0.02	0	2/17	0.15 - 1.1	0
Barium	100 mg/L	11/13	0.60 - 5.80	0	14/17	0.33 - 45.6	0
Cadmium	1.0 mg/L	1/13	0.007	0	6/17	0.0061 - 0.32	0
Chromium	5.0 mg/L	4/13	0.0105 - 0.14	0	6/17	0.07 - 0.47	0
Lead	5.0 mg/L	7/13	0.05 - 9.6	1	5/17	0.8 - 9.2	1
Mercury	0.2 mg/L	0/13	0	0	2/17	0.004 - 0.033	0
Selenium	1.0 mg/L	2/13	0.01 - 0.0333	0	0/0	0	0
Silver	5.0 mg/L	0/0	0	0	1/17	0.21	0
Ignitability	< 140°F	9/13	41°F - 210°F	3 [2]	16/17	55°F - > 210°F	13

Notes:

TCLP results from the 1991 Canadian Petroleum Association study are not included in this table; however, ignitability results for two CPA sample are included. See Appendix C, Table C-10.

[1]Detections at less than the minimum detection limit were not counted as a detection.

[2]One additional sample had a Flash Point reported as > 75°F and another was reported as < 160°F. Thus, the total exceeding the characteristic level could be 5.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-8. Summary of Ignitability Characteristic and TCLP Analyses for Road Mix Tank Bottoms and Production Pit Samples (Select Constituents)

Constituent	Characteristic Regulatory Level	Number of Samples Detected/ Samples Analyzed	Finished Road Mix Tank and Vessel Bottoms Concentration Range (mg/L)	Number of Samples Exceeding Characteristic Reg. Level	Number of Samples Detected/ Samples Analyzed	Pennsylvania Production Pit Samples Concentration Range (mg/L)	Number of Samples Exceeding Characteristic Reg. Level
Benzene	0.5 mg/L	0/3	0	0	25/46	0.0011 - 0.25	0
Arsenic	5.0 mg/L	0/3	0	0	19/51	0.011 - 0.031	0
Barium	100 mg/L	3/3	0.44 - 0.51	0	51/51	0.07 - 19.1	0
Cadmium	1.0 mg/L	0/3	0	0	0/51	0	0
Chromium	5.0 mg/L	3/3	0.77 - 1.69	0	0/51	0	0
Lead	5.0 mg/L	0/3	0	0	4/51	0.102 - 0.016	0
Mercury	0.2 mg/L	0/3	0	0	0/51	0	0
Selenium	1.0 mg/L	0/3	0	0	8/51	0.01 - 0.016	0
Silver	5.0 mg/L	0/3	0	0	0/51	0	0
Ignitability	< 140°F	9/9	340°F - 465°F[3]	0	0/0	0	NA

Notes:
NA = Not Analyzed
[1]Detections at less than the minimum detection limit were not counted as a detection.
[3]ASTM Method D-92.

2.3.2 Other Hazardous Characteristic Analyses

Thirty production and reclaimer tank bottom and process vessel samples (plus two duplicates) collected by EPA for the 1992 study were analyzed for ignitability. Of these, sixteen samples (plus one duplicate) exhibited the hazardous characteristic of ignitability (flash point less than 140°F). (An additional sample had a Flash Point reported as > 75°F and another was reported as <160°F. Thus, the total could have been eighteen.) The sixteen that were ignitable included thirteen (of seventeen) reclamation facility tank bottom samples and three samples (plus one duplicate) from production facilities (out of a total of thirteen samples plus three duplicates). The road mix tank bottom samples did not exhibit the hazardous characteristic of ignitability as indicated by flash point (Cleveland open cup) results by ASTM Method D-92. The production pit samples were not tested for ignitability.

GRI's two samples of gas plant tank bottoms were analyzed for the characteristic of reactivity by determining the potential for release of hydrogen sulfide. One of the two samples exhibited the ability to release sulfide gas at a concentration of 1,458 mg H_2S/kg; higher than EPA's threshold level for reactivity of 500 mg H_2S/Kg. The reactive sulfide level in the other sample was 1 mg H_2S/kg (and the sample did not exhibit the characteristic of reactivity). The GRI Study attributes the elevated levels of reactive sulfide in the brine treatment tank sample to a "site-specific microbially-induced corrosion problem."

2.3.3 Total Constituent Analyses

Twenty-four samples (plus five duplicates) collected by EPA for the 1992 solid waste study were analyzed for total metals; of these, five samples (plus one duplicate) were analyzed as liquid samples. For purposes of comparison, the concentrations of metals were compared to Primary Maximum Contaminant Levels (MCLs). This was only for illustrative purposes since the samples analyzed were "waste" samples, rather than environmental samples, and substantial attenuation would occur before exposure, if any, resulted.

All five of the samples and the duplicate analyzed as liquids exceeded the Primary MCL for chromium (0.1 mg/L) and cadmium (0.005 mg/L). Four samples (plus one duplicate) exceeded the drinking water standard action level for lead of 0.015 mg/L; of these, one had a concentration greater than 4,000 times higher (62.8 mg/L) than the action level. Three samples (plus one duplicate) exceeded the Primary MCL for mercury (0.002 mg/L); of these, one had a concentration 24 times higher (0.0485 mg/L) than the MCL.

Several constituents were detected in all or most of the samples analyzed, as shown below (numbers shown in parentheses are duplicate samples):

- Benzene was detected in 100 percent of the samples analyzed for this constituent (20 (5) samples analyzed).

- Arsenic was detected in 86.2 percent of the samples analyzed for this constituent (20 (5) out of 24 (5)).

- Cadmium was detected in 82.8 percent of the samples analyzed for this constituent (19 (5) out of 24 (5)).

- Chromium was detected in 96.6 percent of the samples analyzed for this constituent (23 (5) out of 24 (5)).

- Lead was detected in 93.1 percent of the samples analyzed for this constituent (23 (5) out of 24 (5)).

- Mercury was detected in 65.2 percent of the samples analyzed for this constituent (12 (3) out of 23 (5)).

- Selenium was detected in 56.5 percent of the samples analyzed for this constituent (10 (3) out of 23 (5)).

- Radium was detected in 89.5 percent of the samples analyzed for this constituent (15 (2) out of 16 (3)).

Table 2-9 summarizes the total constituent analyses. These data further confirm the wide variation noted above in the ranges of concentrations for detected analytes. For example, benzene concentrations from eleven (plus three duplicate) production facility samples ranged from a minimum of 0.175 mg/Kg to a maximum of 2,685.8 mg/Kg, over fifteen thousand times higher than the minimum concentration. Cadmium ranged from less than 0.32 mg/Kg to 6,500 mg/Kg. Other constituents demonstrated similar results. The maximum concentrations of metals in the reclamation facility samples were not consistently higher than the maximums observed in production facility samples. While maximum concentrations of lead and mercury were higher, arsenic, cadmium, and chromium were lower. The maximum concentration of radium-226 in reclamation facility samples also was lower. (See section 2.3.5 for a more detailed discussion of NORM.) Apparently metals do not necessarily partition to the tank bottoms. The maximum concentration of benzene observed in reclamation facility samples was much higher than in production facility samples, however. The reason for this is unclear. Benzene is a naturally occurring constituent in crude oil: it could be, and likely is, due to differences in the sources of crude oil streams that happened to be sampled.

All of the 51 Pennsylvania production pit samples were analyzed for total metals and 23 of 51 samples were analyzed for NORM (nine of these were also tested for uranium). None of the 51 samples were analyzed for total organics. Chromium was detected in all of the samples at concentrations rangng from 3.7 mg/kg to 31.3 mg/kg. Lead was detected in 49 of 51 samples at concentrations ranging from 15 mg/kg to 59

mg/kg. Only 5 of 51 samples had detectable levels of mercury at concentrations ranging from 0.11 mg/kg to 0.197 mg/kg. Radium 226, radium-228, and thorium were detected in each of the 23 samples analyzed for NORM. In separate comments, the Pennsylvania DER stated that the levels of NORM detected in production pit samples were no different than what occurs in natural soils. This implies that NORM levels in Pennsylvania production pit samples did not exceed background levels. (See section 2.3.5 for a more detailed discussion of NORM.) Total constituent analyses and NORM results are summarized in Tables H-4 and H-5 respectively.

(text continues on page 30)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-9. Summary of Total Constituent Analyses for Tank Bottoms
(Selected Constituents)

Pollutant	Production Facility				Reclamation Facility	
	Number of Samples (Duplicates) Detected/ Samples (Duplicates) Analyzed	Tank and Vessel Bottoms Concentration Range (mg/L)	Number of Samples (Duplicates) Detected/ Samples (Duplicates) Analyzed	Tank and Vessel Bottoms Concentration Range (mg/Kg)	Number of Samples (Duplicates) Detected/ Samples (Duplicates) Analyzed	Tank and Vessel Bottoms Concentration Range (mg/Kg)
Benzene	2 (2) / 2 (2)	38.747 - 118.965	11 (3) / 11 (3)	0.175 - 2,685.8	7 / 7	7.4 - 7,946.25
Arsenic	4 (1) / 5 (1)	0.0073 - 0.5	9 (4) / 11 (4)	0.47 - 166	7 / 8	0.087 - 39.8
Cadmium	5 (1) / 5 (1)	0.0256 - 0.425	7 (4) / 11 (4)	0.32 - 6,500	7 / 8	0.36 - 9.4
Chromium	5 (1) / 5 (1)	0.1377 - 19.9	11 (4) / 11 (4)	1.7 - 1,170	7 / 8	1.99 - 89.8
Lead	4 (1) / 5 (1)	1.93 - 62.8	11 (4) / 11 (4)	9.1 - 892	7 / 8	3.88 - 2,970
Mercury	4 (1) / 5 (1)	0.00022 - 0.0485	2 (2) / 10 (4)	0.1 - 0.85	6 / 8	< 0.02 - 9.11
Selenium	2 (1) / 5 (1)	0.0198 - 0.297	3 (2) / 10 (4)	0.76 - 4 [(1)]	5 / 8	< 0.05 - 4.1
Radium 226	1 (1) / 1 (1)	1.0 - 1.2 pCi/L	11 (1) / 12 (2)	0 - 313 pCi/g	3 / 3	< 0.7 - 18 pCi/g

Notes:
[(1)] The maximum value of 4 mg/Kg was reported for a duplicate sample (No. 22379) for which its associated sample (No. 22378) result was ND (Not Detected).

2.3.4 Summary of Analytical Data

The variability in analytical results, coupled with the limited number of samples, underscores the fact that these data may not represent the universe of tank bottom wastes. A number of factors could contribute to variability in the characteristics of tank bottoms, including those for which data are presented. The limited data available do not support conclusions regarding which, if any, of the factors may have contributed to the concentrations and variability in concentrations that were observed. However, a number of interrelated factors could contribute to variability, including the following:

- *Variation in vessels*. Different vessels (*e.g.* crude oil stock tanks versus produced water tanks versus heater treaters versus free-water knockouts) will have a significant impact on the concentrations of different analytes within the tank bottoms. Each vessel has a unique function within the process flow. For example, a free-water knockout can be viewed simply as a wide spot in the pipeline; crude oil-coated solids that are readily separable from the crude oil will settle in the vessel and be periodically removed. The characteristic concentrations observed in these solids (*i.e.*, crude oil content) could be expected to differ significantly from the solids which would be found in a produced water tank.

- *Variation in fluids*. The fluids produced at different sites (*e.g.* heavy low-gravity oil versus light high-gravity oil) also would affect the observed concentrations of different analytes. For instance, high-gravity oils would have much higher concentrations of volatile organic compounds (and would also be more flammable) than a heavy low-gravity oil. Differences among crude oils are driven by the differences in the relative proportions of various hydrocarbon and non-hydrocarbon compounds as well as by the presence of various other components, such as BS&W and H_2S. Tank bottoms derived from the different crude oils would show corresponding differences in their chemical characteristics.

- *Differences in formations*. The geologic formations and lithologic conditions comprising the production zones would contribute to variability as well by contributing to differences in the produced fluids and solids. Trace metal concentrations would be expected to vary in different formations. In addition, unconsolidated sands would produce crude oil with much higher solids content. The inorganic fraction, as well as the quantity, of tank bottoms would be relatively high compared to consolidated formations.

- *Treatment processes*. The treatment processes used at different facilities vary (*e.g.* chemical programs, frequency of workover operations) and the process would affect the characteristics of the tank bottoms generated. For example, tank bottom samples collected following a scale treatment program could have higher NORM concentrations. Storage of tank bottoms in open vessels for any length of time could result in reductions in volatile organic constituent concentrations. Pressure and temperature variations among treatments

(*e.g.*, heater treaters versus stock tanks) would also affect the concentration of volatile constituents in the different phases of the produced fluids.

- *Frequency of tank and vessel cleaning and method used*. The various processes used at different facilities (*e.g.* frequency of tank cleaning and methods used in handling/processing tank bottoms) would also affect concentrations. For example, the use of solvents during the cleaning process would affect the organic constituent proportions and concentrations. The use of emulsion breakers would add to variation by changing the nature of the residual material as well as by chemical addition.

- *Sampling methodology and sampling location*. The difficulty in obtaining representative samples also affects the constituent concentrations. For example, it is often necessary to dredge samples from the bottom of vessels and raise the samples up through a column of oil and water (and this was the case for some of the samples obtained during EPA's 1992 sampling program). This would alter the sample constituents by incorporating material from the oil and water and by diluting the bottoms. Finally, the length of time that tank bottoms remain in the vessel could affect constituent concentrations. Some constituents could be concentrated (*e.g.*, metals or long-chain hydrocarbons) while others could be reduced (*e.g.*, volatile organic compounds). To the extent that residence time could effect concentrations, the location in the vessel from which the sample was taken would affect the characteristics of the tank bottoms.

Notwithstanding the difficulty in interpreting the data and drawing conclusions, the fact that a relatively high percentage of samples exhibited the toxicity characteristic for benzene, and lower percentages for lead, and that high percentages exhibited the ignitability characteristic suggest that careful management of tank bottoms is necessary to protect human health and the environment.

2.3.5 Naturally Occurring Radioactive Materials (NORM)

According to one publication, naturally occurring radioactive materials (NORM) can be expected at nearly every petroleum facility (Gray 1991). The author also suggests that some facilities can be contaminated to a point where maintenance and other personnel may be exposed to hazardous concentrations. Hazardous concentrations were not defined in the publications so it is assumed the author is referring to NORM levels

above regulatory levels as being hazardous. NORM regulations do not exist currently at the Federal level[3] however, regulations are being developed at the State level. For example, Louisiana adopted regulations in 1989 (LAC 30.XV.1404) which set regulatory levels for NORM concentrations at 5 pCi/g for radium-226 or radium-228 above background levels. As many as one-third of domestic oil and gas wells may produce some radium-contaminated scale. The geological location of the oil reserve and the type of production operation strongly influence the prevalence of NORM accumulations. NORM concentrations change over time, and the trend is for the relative quantity of NORM to increase as the production field ages and resources are depleted (EPA 1991a).

API conducted a survey of NORM occurrence in oil production and gas processing equipment to identify the geographic areas and specific equipment exhibiting the highest NORM levels (EPA 1991a). Data were collected in 20 States primarily at sites suspected of exhibiting NORM concentrations. The API survey showed a wide variation in NORM levels depending on the geographic location of the equipment. The geographic areas with the highest equipment readings were northern Texas and the Gulf Coast from souythern Louisiana and Mississippi to the Florida panhandle. Very low levels of NORM were observed in California, Utah, Wyoming, Colorado, and northern Kansas (EPA 1991a).

In a separate thirteen-State survey, up to 90 percent of production wells in Mississippi were reported to have NORM, compared to none or a few in Colorado, South Dakota, and Wyoming (McArthur 1988, cited in EPA 1991a). Ten percent of Mississippi wells were estimated to have scale with elevated radium concentrations (cited in EPA 1991a). For example, in 1986 barium sulfate scale was found in production tubing during a workover of a well in Mississippi at levels of 6,000 pCi/g of radium-226 and 1,000 pCi/g of thorium-232 co-precipitated in the scale matrix (EPA 1991a).

Produced with fluids from the reservoir, NORM has been observed to accumulate in sludges, scale, piping and equipment (API 1989a, EPA 1991a). NORM production wastes can also include produced water and sands from separators (EPA 1991). NORM-contaminated sludges and sands as well as scale can accumulate in treatment vessels as tank bottoms. Twenty to one hundred percent of oil and gas facilities

[3] Since there currently are no federal regulations or environmental standards for NORM, radioactivity is not a hazardous waste characteristic. However, in 1978, EPA proposed RCRA hazardous waste rules and a companion RCRA Advance Notice of Proposed Rulemaking (ANPR) (43 Fed. Reg. 58946; December 18, 1978) which did address radioactive wastes in response to concerns about certain radioactive mining wastes that were proposed for classification among "special wastes" as high volume, low hazard wastes. The ANPR proposed that radioactivity be included on the list of hazardous characteristics and described a solid waste (other than source, special nuclear, or by-product material as defined by the Atomic Energy Act of 1954) as a hazardous waste if a representative sample exhibited Ra^{226} concentrations in excess of 5 pCi/g for solid wastes or 50 picoCuries per liter (pCi/L) of Ra^{226} and Ra^{228} combined for liquid wastes, or a total Ra^{226} concentration equal to or exceeding 10 microCuries (µCi) for any discrete source. In 1980, Congress amended RCRA to temporarily exempt certain wastes, including radioactive wastes, from hazardous waste regulations under RCRA Subtitle C. Hence, EPA deferred development of regulations for radioactive wastes until Congress to further action. Furthermore, EPA believed that radioactive wastes could be effectively regulated at the state level so Federal regulations would not be necessary.

in each of the thirteen States surveyed identified some NORM in heater/treaters (McArthur 1988, EPA 1991a).

API found that the highest conbcentrations of NORM were found in wellhead piping and in production piping near the wellhead and the largest volumes of scale were found in water lines associated with separators, heater treaters, and gas dehydration units (EPA 1991a). A statistical evaluation of the external radiation exposure level data from the API survey indicated approximately 64 percent of the gas producing equipment and 54 percent of the oil producing equipment surveyed showed NORM radioactivity at or near background levels (EPA 1991a). These data are reproduced in Tables 2-9 and 2-10.

Sludges may be contaminated with several thousand pCi/gram of the long-lived radon decay products (*e.g.*, lead-210, bismuth-210, and polonium-210). These heavy metal decay products may attach to dust particles and aerosols to become part of the sludge (Gray 1991).

The API survey estimated that sludge is emptied from equipment (vessels and tanks) about every three years on average; and thirty percent of the 620,000 producing wells have equipment contaminated with NORM scale and sludge. For a representative 10-well production facility, it was estimated that 472 cubic feet of NORM-contaminated sludge would be generated over a 10-year period from separators, free-water knockouts, heater treaters, tanks, and sumps.

The higher radiation levels are found closer to the wellhead. Radium concentrations in separators were a factor of ten less than those found in wellhead equipment. NORM scale deposits on wellhead equipment have concentrations of 1000 to 10,000s of pCi/g, the scale deposits in separators are one to 1000 pCi/g, and the radium in sludges in tanks are generally around 50 pCi/g, a reduction up to an order of magnitude (EPA 1991a).

Scales removed from various types of equipment in Aberdeen, Scotland, and Amelia, Louisiana, demonstrated the following radium activity levels (Reed et al. 1991):

- Scales from downhole assemblies ranged from 27 to 6,027 pCi/g, with a mean of 1,351
- Scales from downhole pumps ranged from 14 to 27,243 pCi/g, with a mean of 7,729
- Scale from tubing ranged from 27 to 9,729 pCi/g, with a mean of 1,459.

Sludges from U.S. oil production separators (the area of the U.S. was not described, but the context of the article would suggest Louisiana) showed radium activity levels ranging from 1,000 to 22,220 pCi/g, and sludges from gas separators showed polonium activity of 0.5 to 326 pCi/g (Reed et al. 1991).

In the EPA sampling effort for 1992, samples were analyzed for gross alpha, gross beta, lead-210, radium-226 and radium-228. Table D-8 summarizes the results for production facility tank bottoms. Radium was

detected in seven of eight (89.5%) of the samples. The gross alpha concentrations of radioactivity ranged from 0 to 51.4 pCi/g in production facility tank bottoms. Higher concentrations were found in the tank bottoms from reclamation facilities, ranging from 44 to 600 pCi/g; over an order of magnitude higher than the maximum concentration for production facility samples. (The maximum concentration was found in a sample collected from a tank bottom reclaimer's centrifuge.)

In the Pennsylvania production pit study, radium-226, radium-228, and thorium were detected in each of the 23 samples tested for NORM. Radium-226 levels ranged from 6.5 pCi/g to 1,835 pCi/g; radium-228 ranged from 11.6 pCi/g to 1,639 pCi/g; and thorium ranged from 860 pCi/g to 5,053 pCi/g. The last nine samples collected were also analyzed for uranium (measured in μg/kg) which was detected in all nine samples at levels ranging from 873.8 μg/kg to 2,946 μg/kg.

(text continues on page 37)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 2-10. Summary of Radiation Exposure Levels Associated with NORM in Oil Production Equipment (Source: API 1989 as cited in EPA 1991a)

Equipment	Number of Observations	Number of Observations Above Background	Difference Above Background (μR/hr)				
			Minimum	25th Percentile	Median	75th Percentile	Maximum
OTHER WELLHEADS (except injection and production)	24	5	1.2	1.6	2.0	3.8	5.5
PRODUCTION WELLHEAD	2,324	777	0.1	1.0	2.3	7.9	1,500.0
METERS	306	72	1.0	1.0	3.0	5.8	92.0
PUMPS	1,393	424	0.1	1.0	3.0	14.0	990.0
OTHER MEASUREMENT OR SERVICE EQUIPMENT	2,397	1,007	0.1	1.0	4.0	15.0	3,800.0
STOCK TANKS	7,005	2,696	0.1	2.0	4.0	14.0	2,500.0
MANIFOLDS (including header piping, valves, chokes, etc.)	2,537	895	0.1	1.0	6.0	55.0	3,000.0
SUMPS (including pits, pig traps, ponds, etc.)	454	253	0.1	3.0	7.0	26.0	790.0
SEPARATORS	7,887	3,816	0.1	2.0	8.0	40.0	4,500.0
HEATER TREATERS	2,962	1,495	0.1	2.0	8.0	47.0	3,500.0
WATER TANKS	3,431	2,140	0.1	3.0	8.0	35.0	3,800.0
VAPOR RECOVERY UNITS	115	25	0.2	2.0	17.0	207.0	1,300.0
INJECTION WELLHEADS	102	50	1.0	4.0	20.0	53.0	890.0
WATER LINES (including valves and elbows)	341	176	0.2	6.0	34.0	100.0	2,800.0
FLOW LINES (including valves and elbows)	1,748	419	0.1	7.0	42.0	112.0	3,000.0

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

Table 2-11. Summary of Radiation Exposure Levels Associated with NORM in Gas Processing Equipment (Source: API 1989 as cited in EPA 1991a)

Equipment	Number of Observations	Number of Observations Above Background	Difference Above Background (μR/hr)				
			Minimum	25th Percentile	Median	75th Percentile	Maximum
COMPRESSORS (including associated equipment)	648	119	0.3	1.00	2.0	3.0	490
DEHYDRATORS	244	72	0.3	1.35	3.0	6.7	530
SWEETENERS	234	30	0.2	1.00	3.4	19.0	220
INLET SCRUBBERS	593	156	0.1	1.00	5.0	19.0	700
METERS	101	32	0.3	1.15	5.5	51.0	700
CRYOGENIC UNITS	50	20	1.0	2.00	6.0	22.0	3,000
OTHER TANKS	423	140	0.2	2.00	6.0	30.0	380
OTHER PROCESSING EQUIPMENT	430	165	0.3	2.90	7.0	23.0	990
FRAC TOWERS	272	123	0.2	1.50	9.5	33.0	400
PROPANE REFRIGERATION SYSTEM EQUIPMENT	143	56	0.1	2.00	16.0	69.0	590
BOTTOMS PUMPS	40	30	0.5	3.00	17.0	45.0	220
PROPANE TANKS	124	90	0.5	7.30	25.0	66.0	680
OTHER PUMPS	232	114	0.4	6.80	28.0	96.0	1,400
PROPANE PUMPS	71	53	0.1	9.50	31.0	98.0	1,100
PRODUCT LINES	146	82	0.1	14.00	35.0	110.0	1,080
ALL PUMPS	3	2	3.0	3.00	38.0	73.0	73
REFLUX PUMPS	110	95	0.2	16.00	76.0	290.0	3,000
BACKGROUND				5.0	7.0	9.0	

3.0 TYPICAL WASTE MANAGEMENT METHODS AND POTENTIAL ENVIRONMENTAL IMPACTS

3.1 OVERVIEW

As discussed in chapter 2, the American Petroleum Institute associated waste survey (API 1988a) is the only comprehensive examination to date of the means by which tank bottoms and oily debris are managed in the United States. In the survey, respondents reported the volumes of tank bottoms and oily debris managed by the following methods:

- Recycling/reuse: recycled through crude oil reclaimers
- Roadspreading
- Landspreading
- On-site pits
- On-site burial
- Off-site commercial facilities
- Incineration (tank bottoms only)
- Other

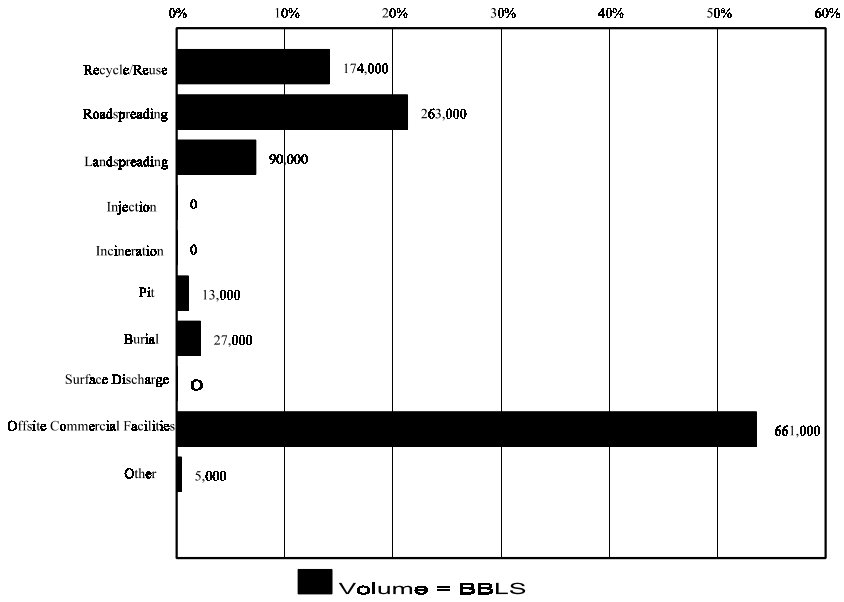

FIGURE 3-1. Percentages and Volumes of Tank Bottoms Managed Using Various Methods
(SOURCE: API 1988a)

The percentages and volumes of tank bottoms managed by each of these methods are shown in Figure 3-1. As can be seen, the volume sent to off-site commercial facilities accounted for over 50 percent of the total. Much of the remaining tank bottoms were roadspread (21 percent), reclaimed (14 percent), or landspread (7 percent).

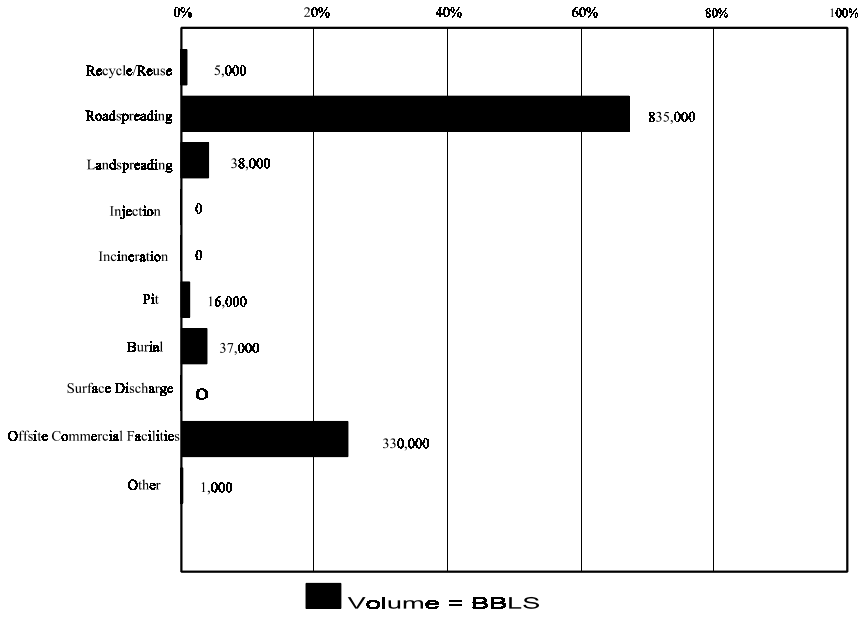

FIGURE 3-2. Percentages and Volumes of Oily Debris Managed Using Various Methods
(SOURCE: API 1988a)

Figure 3-2 shows the percentages and volumes of oily debris managed by the various methods, as estimated by API. As shown, two-thirds of all oily debris was spread on roads, with nearly all the remainder sent to off-site commercial facilities.

The various management methods, and brief discussions of potential environmental impacts that could result if tank bottoms and oily debris are not managed properly using these methods , are discussed in sections 3.2 and 3.3 below.

3.2 TYPICAL WASTE MANAGEMENT METHODS AND POTENTIAL ENVIRONMENTAL IMPACTS

Data from two tables are discussed repeatedly in this section and bear some introduction. Tables 3-1 and 3-2 show the volumes and percentages of tank bottoms and oily debris, respectively, within each State that were estimated by API to be managed by various methods. Table 3-1, for example, shows that 27.3 percent of California tank bottoms was roadspread and Table 3-2 shows that 88.9 percent of California oily debris was roadspread. The States shown are those for which API provided waste management data. Also instructive would have been data that showed percentages, across all States, of tank bottoms and oily debris managed within each State by each method. With such data, it would have been possible to determine, for example, that of all tank bottoms recycled through reclaimers, California accounted for a certain percentage, Texas another percentage, and so on. Unfortunately, the API data do not lend themselves to that sort of presentation: because the API estimates were derived independently for each State and for the U.S. as a whole, totals for the various management methods cannot be summed across States. For example, API estimated that, for the U.S. as a whole, 27,000 barrels of tank bottoms were buried on-site; however, if on-site burial totals for the 10 States for which API derived independent estimates are added, the total comes to over 32,000 barrels, more than the National total. Thus, the volumes managed by specific methods cannot be added across States, and State percentages of the National total cannot be estimated with reliability. It is noteworthy, however, that California so dominates the generation of tank bottoms and oily debris; California was reported to generate far more of these materials, particularly oily

debris, than any other State. API (May 1988) indicated that heavy oil operations generate most tank bottoms in California and steam flood operations most oily debris (in the form of diatomaceous earth filter media).

(text continues on page 42)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 3-1. Waste Management Practices Used for Tank Bottoms, 1985 [A]

State	Waste Generation		Volume Generated (bbl) and Percentage Disposed, by Method of Disposal													
	Number of Barrels Generated	Percentage of U.S. Total	Recycled/reused[B]		Roadspread		Landspread		On-site pits		On-site burial		Off-site [C]		Other	
			Bbls	%	Bbls	%	Bbls	%	Bbls	%	Bbls	%	Bbls	%	Bbls	%
Alaska	7,719	0.6	53	0.7	0	0.0	0	0.0	21	0.3	0	0.0	7,639	99.0	5[D]	0.1
California	594,637	48.3	7,768	1.3	162,197	27.3	52,051	8.8	93	0.0	0	0.0	372,528	62.6	0	0.0
Florida	442	0.0	442	100.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Kansas	114,860	9.3	3,735	3.3	85,633	74.6	980	0.9	0	0.0	5,509	4.8	19,002	16.5	0	0.0
Louisiana	47,414	3.8	16,219	34.2	1,086	2.3	427	0.9	154	0.3	448	0.9	29,081	61.3	0	0.0
Michigan	1,990	0.2	1,596	80.2	0	0.0	0	0.0	234	11.8	0	0.0	160	8.0	0	0.0
New Mexico	7,346	0.6	1,467	20.0	0	0.0	0	0.0	0	0.0	626	8.5	5,253	71.5	0	0.0
Oklahoma	125,295	10.2	28,422	22.7	17,388	13.9	2,365	1.9	2,487	2.0	4,446	3.5	57,910	46.2	12,278	9.8
Texas	198,333	16.1	82,438	41.6	39,006	19.7	3,386	1.7	4,621	2.3	19,712	9.9	47,394	23.9	1,776	0.9
Wyoming	17,831	1.4	10,017	56.2	1,291	7.2	84	0.5	266	1.5	1,412	7.9	4,689	26.3	72[E]	0.4
Total U.S. [F]	1,231,863	100.0	174,000	14.1	263,000	21.4	90,000	7.3	13,000	1.1	27,000	2.2	661,000	53.7	5,000	0.4

NOTES:

A In conducting the survey, API used the following definition of tank bottoms, separator sludges, or pig trap solids: "solid or sludge-like wastes typically cleaned out from the bottom of tanks, separators, treaters, dehydrators, or pig traps. They may include iron sulfide, barium sulfide, paraffin, and corrosion byproducts. They exclude formation or gravel pack sand covered in another category."

B As defined by API: "recycled through oil reclaimers."

C Off-site commercial facility, including off-site injection.

D API reports these 5 were injected.

E API reports these 72 barrels were incinerated.

F Total U.S. includes AZ, IN, KY, MO, NV, NY, OH, PA, SD, TN, and VA. Totals for these States cannot be calculated, individually or collectively, since the values for each reported State and for the total U.S. are independent statistical estimates made by API and are therefore not additive across States. Total U.S. also includes AL, AK, CO, IL, MS, MT, NE, ND, VT, and WV, for which API reported total volumes but not volumes managed by specific methods. Since States' and U.S. totals were calculated independently, totals are additive across rows (i.e., by State) but not columns (i.e., by method).

SOURCE: American Petroleum Institute. 1988 (June). *API 1985 Production Waste Survey. Part II - Associated and Other Wastes Statistical Analysis and Survey Results* Final Report. Data on quantities of tank bottom wastes taken from source. Percentages are calculated.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 3-2. Waste Management Practices Used for Oily Debris, 1985 [A]

State	Waste Generation		Volume Generated (bbl) and Percentage Disposed, by Method of Disposal													
	Number of Barrels Generated	Percent of U.S. Total	Recycled/reused[B]		Roadspread		Landspread		On-site pits		On-site burial		Off-site [(C)]		Other	
			Bbls	%	Bbls	%	Bbls	%	Bbls	%	Bbls	%	Bbls	%	Bbls	%
Alaska	1,507	0.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1,478	98.1	29[D]	1.9
California	831,511	65.9	2,660	0.3	739,460	88.9	19,256	2.3	917	0.1	1,243	0.1	67,949	8.2	25	0.0
Florida	154,464	12.2	0	0.0	0	0.0	0	0.0	2,019	1.3	1	0.0	152,444	98.7	0	0.0
Kansas	5,825	0.5	0	0.0	1,401	24.1	23	0.4	35	0.6	3,112	53.4	1,244	21.4	11[D]	0.2
Louisiana	2,894	0.2	1	0.0	122	4.2	0	0.0	0	0.0	386	13.3	2,356	81.4	28	1.0
Michigan	130,641	10.4	11	0.0	0	0.0	0	0.0	1,990	1.5	0	0.0	128,640	98.5	0	0.0
New Mexico	1,363	0.1	2	0.1	48	3.5	0	0.0	10	0.7	148	10.9	1,155	84.7	0	0.0
Oklahoma	18,403	1.5	0	0.0	2,844	15.5	20	0.1	6,421	34.9	4,808	26.1	3,979	21.6	332	1.8
Texas	63,907	5.1	0	0.0	16,805	26.3	12,035	18.8	4,956	7.8	26,930	42.1	2,901	4.5	280	0.4
Wyoming	13,932	1.1	0	0.0	1,460	10.5	121	0.9	5,518	39.6	4,595	33.0	525	3.8	1,714	12.3
Total U.S. [E]	1,261,342	100.0	5,000	0.4	835,000	66.2	38,000	3.0	16,000	1.3	37,000	2.9	330,000	26.2	1,000	0.1

NOTES:

A In conducting the survey, API used the following definition of oily debris, filters, filter media, and contaminated soils: "oily wastes that might release oil to the environment if improperly managed. They would include stuffing box material, rags, floor sorbants, oil filters, sand, and coal water filter media, and soils collected while closing old pits or cleaning up oil spills."

B As defined by API: "recycled through oil reclaimers."

C Off-site commercial facility, including off-site injection.

D All 29 of Alaska's "other" and 6 of Kansas' "other" were reported as being incinerated.

E Total U.S. includes AZ, IN, KY, MO, NV, NY, OH, PA, SD, TN, and VA. Totals for these States cannot be calculated, individually or collectively, since the values for each reported State and for the total U.S. are independent statistical estimates made by API and are therefore not additive across States. Total U.S. also includes AL, AK, CO, IL, MS, MT, NE, ND, VT, and WV, for which API reported total volumes but not volumes managed by specific methods. Since States' and U.S. totals were calculated independently, totals are additive across rows (i.e., by State) but not columns (i.e., by method).

SOURCE: American Petroleum Institute. 1988 (June). *API 1985 Production Waste Survey. Part II - Associated and Other Wastes Statistical Analysis and Survey Results* Final Report. Data on quantities of oily debris wastes taken from source. Percentages are calculated.

The following subsections describe the major waste management methods identified by API as being used for tank bottoms and oily debris. Also included are brief discussions of the use of the methods in various States, as reported in Tables 3-1 and 3-2 from the API survey. Finally, the potential environmental impacts that improper management can cause are described.

3.2.1 Recycling and Reuse

According to API (1989), the primary environmental consideration in managing tank bottoms should be maximizing hydrocarbon recovery. Suggested techniques include on-site heat treatment, addition of demulsifiers, and agitation; API strongly recommends that off-site reclaimers be considered for materials that cannot be recycled on-site.

Tables 3-1 and 3-2 show that API estimated that a total of 14.1 percent of tank bottoms and 0.4 percent of oily debris were recycled through oil reclaimers in 1985. This is surprisingly low, considering the relatively high incidence of reclamation in some States and the economic benefits that can accrue from reclamation. However, the very low reclamation rate in California, where only 1.3 percent of the State's very high volume of tank bottoms were reclaimed, served to drive the National rate down. Reasons for high (or low) reclamation rates can include the nature of the tank bottoms (e.g., relatively high non-hydrocarbon content, high emulsion rates), regulatory approaches , a shortage of reclaimers to receive bottoms, and other factors. (Crude oil reclamation is discussed in more detail in chapter 4.)

Tank bottoms in several States were sent to reclaimers much more frequently than in others: these include States with very low volumes of tank bottoms (e.g., Florida, where 100 percent were reclaimed, and Michigan, 80 percent) as well as States with large volumes generated (e.g., Oklahoma, 22.7 percent, and Texas, 41.6 percent). As noted, API estimated that the percentage of tank bottoms that were recycled through reclaimers in California was very low.

Very little oily debris was recycled through reclaimers in 1985, as might be expected given the nature of the material. Only in California (0.3 percent) were significant volumes reclaimed.

3.2.2 Roadspreading

Roadspreading refers to the application of road mixes or paving materials formulated with asphaltic tank bottoms and oily debris, and to the application of certain oilfield liquid wastes such as in the case of road oiling. Roadspreading is often limited to lease roads and farm lanes which are typically unpaved. In such instances, and when conducted in accordance with State requirements, roadspreading can be considered a beneficial use of a material that would otherwise require disposal. Various oilfield wastes may be applied to roads (if permitted by State regulations) as dust suppressants, as surface deicers, to provide a better surface, or simply for disposal. Both tank bottoms and oily debris are commonly applied to roads where

permitted by State regulations. (The API survey did not distinguish between roadspreading on private and public roads.) API recommends a pH range from 6 to 9 for roadspread wastes (API 1995).

Nationally, over 21 percent of tank bottoms and 66 percent of oily debris were roadspread in 1985 (see Tables 3-1 and 3-2). States where significant quantities of tank bottoms were spread on roads included California (27 percent of a very large volume), Kansas (nearly 75 percent), and Texas (nearly 20 percent). States where significant quantities of oily debris were roadspread included California (88.9 percent) and Texas (26.3 percent). Since California accounted for nearly two-thirds of the Nation's oily debris, that State also accounted for most of the Nation's roadspread debris and inflated the National rate of roadspreading. The high rate of waste generation in California is, in large part, due to the physical properties of the heavy crude predominantly produced.

A study of the beneficial use of tank bottoms as road mix in the San Joaquin area of California sponsored by the Western States Petroleum Association (WSPA) concluded that road mix provides the following net benefits (WSPA 1993):

- Reduces the amount of materials that would otherwise be disposed of in landfills.
- Reduces PM_{10} (particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers) emissions from unpaved roads.
- Produces negligible reactive organic hydrocarbon compound emissions as compared to landfill emissions.
- Has low hydrocarbon and metals leachability and is non-hazardous by acute testing based on California Code of Regulations (CCR) Title 22, Article 11 criteria.

WSPA sampled road mix raw materials and finished road mix material collected at three sites in the San Joaquin area. Raw materials include tank cleaning slurries from tank bottom or heater treater cleaning operations, and hydrocarbon containing soils. WSPA identified six process steps for road mix production:

- Process Step 1: Tank cleaning,
- Process Step 2: Tank cleaning slurry dewatering by centrifugation and hydrocarbon containing soils or soils collected from sump excavations,
- Process Step 3: Road mix production (air emissions),
- Process Step 4: Finished road mix material stockpile,
- Process Step 5: Spreading and grading,
- Process Step 6: Weathering (air emissions and leachability).

A total of 42 samples were collected variously at each step except Process Step 5. The samples include 20 tank bottoms samples, 10 oily debris samples and 12 air emissions samples.

Ten raw materials samples were analyzed, before and after dewatering (Process Steps 1&2), for total petroleum hydrocarbons (TPH) and volatile organic compounds (VOCs). Ten finished road mix tank bottoms samples from Process Step 4 were also analyzed for TPH and VOCs as were three petroleum-containing soil samples from line leaks and two soil samples from sumps from Process Step 2, and three petroleum-containing soil samples from line leaks and two soil samples from sumps from Process Step 4. Three finished road mix product samples (Process Step 4) were analyzed for the potential leachability of hydrocarbons and metals using EPA's TCLP method, and California's Total Threshold Level Concentrations (TTLC) and Soluble Threshold Level Concentrations (STLC) methods for the leachability of metals. Finally, twelve samples were analyzed during and after road mix production (Process Step 3) for VOCs in air emissions.

For the ten raw materials samples, TPH levels ranged from 38,500 to 68,812 mg/kg before dewatering (Step 1) and from 61,500 to 156,170 after dewatering (Step 2). Benzene, ethylbenzene, toluene, and xylenes were the only VOCs detected in tank bottoms samples prior to dewatering with benzene levels ranging from .10 to .47 mg/kg. VOCs were not detected in tank bottoms after dewatering. TPH levels for the five raw soil materials samples ranged from 18,400 to 81,250 mg/kg while TPH for the five soils as finished road mix ranged from 3,600 to 31,400 mg/kg. No VOCs were detected in any of the soil samples. For the finished road mix tank bottoms, TPH levels ranged from 17,100 to 48,165 mg/kg and no VOCs were detected. For the three finished road mix tank bottoms analyzed for TCLP metals and organics, and soluble metals using California's TTLC and STLC tests, all of the analytes detected were well below regulatory levels. WSPA's analytical results are presented in Appendix G.

API (1989) recommends that tank bottoms, crude-contaminated soil, solid filter media, and other materials destined for roadspreading (which is a favored management method) be tested for flash point, metals content, and density; these parameters should be consistent with approved road oils or mixes. API also recommends that loading rates minimize the potential for runoff. Finally, State and local agencies should be notified (some States require this), as should the landowner (consistent with lease obligations); operators are advised by API to retain records on all activities.

Deuel (1990) recommended "threshold guidance values" for waste:soil mixtures for the land disposal, including roadspreading, of exploration and production wastes: electroconductivity $<$ 4 mmhos/cm, sodium adsorption ratio $<$ 12, exchangeable sodium percentage for salinity $<$ 15 percent, and oil and grease $<$ 1 percent. Deuel was examining salinity and hydrocarbons, not metals or non-hydrocarbon organic constituents that might be present in tank bottoms and oily debris.

At the Cold Lake Production Project, Esso Resources Canada Ltd. requires that "oil sand waste" (predominantly bitumen, fine sand, and water) have a pH from 6.9 to 7.2, chloride less than 1,000 ppm, and phenols less than 0.005 ppm before they are used as road application materials. Run-off that can transport contaminants to roadside soils and vegetation is one of the major concerns (Kennedy et al., 1990).

The primary environmental concern for roadspreading would be surface run-off, from storm water and snowmelt as well as from the application of excess volumes of liquid material. Run-off or overflow that leaves the roadway could carry whatever constituents were on the road's surface from road-applied waste and other sources. These could contaminate soils and sediments and could affect vegetation directly or could be accumulated in plants, then affect animals that use the plants as forage. In addition, volatilization of organics could present a localized problem, as could dust that carried metal or organic constituents. Because workover-generated scale and other materials may be present in tank bottoms or other wastes that are roadspread, NORM could also be a localized concern where very high radioactivity levels occur or where wastes were roadspread over a period of time.

3.2.3 Landspreading

The term "landspreading" encompasses a number of overlapping practices. These include land treatment (by volatilization or biodegradation of organics, with or without the addition of nutrients), land application (for evaporation, infiltration, or simple dilution), landfarming (for biodegradation and/or soil enrichment), and possibly landfilling. API recommends that free oil be removed from landspread wastes and that wastes be spread evenly and disked into the soil (API 1989). Landspreading (by mixture with soils as in landfarming) is API's recommended practice for contaminated soil. The extent to which operators who landspread tank bottoms and oily debris follow these recommendations is not known, although many States regulate various forms of landspreading .

As shown in Tables 3-1 and 3-2, API estimated that 7.3 percent of tank bottoms and three percent of oily debris were disposed/managed by landspreading in 1985 (off-lease but noncommercial landspreading would presumably be included under landspreading, but commercial landspreading would be captured under off-site commercial facilities). California was the only State for which API provided waste management data where significant quantities of tank bottoms were landspread (8.8 percent of that State's total tank bottoms). Texas (18.8 percent) and California (2.3 percent of a very large quantity) were the States where significant quantities of oily debris were landspread. Regulatory constraints on landspreading and/or on alternative management methods might be reasons why there is such variation among States.

Deuel (1990) recommended the same "threshold guidance values" for waste:soil mixtures for the land disposal, including landspreading, of exploration and production wastes as noted above for roadspreading. As noted above under roadspreading, Deuel was examining salinity and hydrocarbons, not metals or non-hydrocarbon organic constituents. API recommends that soil pH be maintained between 6 and 9, soil conductivity be less than 4 mmho/cm, and the oil and grease content be less than 1% in the final soil-waste mixture. API has also developed general guidance values for 10 of 12 metals it considers to be of potential environmental concern (API 1995a). API's recommended guidance values for maximum soils concentration of metals are shown in Table 3-3 along with those from Louisiana State Wide Order 29-B and the Canadian Interim Soil Remediation Criteria for Agriculture as published by API (API 1995a).

Environmental Research & Technology (ERT), in a 1984 report prepared for API, evaluated the ability of land treatment to transform, degrade, or immobilize hazardous constituents in petroleum wastes (specifically, refinery wastes, although some of the wastes were crude oil separator sludges and bottoms). According to ERT, all constituents can be successfully immobilized (metals) or degraded (organics) under "appropriate environmental and operating conditions." Oil removal efficiencies of 70 to 90 percent per year were reported. ERT also cited data that showed substantial degradation of accumulated oil continues after oil applications cease; as soil oil content decreases, however, asphaltenes and heavy aromatics increase (since they degrade more slowly). As expected, metals were attenuated as depth below the treatment zone increased (i.e., metals were immobilized in shallow zones).

In another study (Danielson et al. 1990), the Canadian Petroleum Association and Environment Canada sponsored an eight-year program to determine the feasibility of land treatment for disposing oily sludges, including heavy oil wastes (tank bottoms and slop oil) and untreatable residuals from reclaiming plants. Sites received differential liming and fertilization as well as varying rates of sludge applications over several years, with soil/sludge mixtures tilled to a depth of about 15 centimeters. In general, degradation occurred relatively rapidly at all oil concentrations, with microbial decomposition the major agent. During the first year of application, 14 to 70 percent of oil had been degraded or volatilized (the lowest rate was at the heavy oil site). After four years of application, 49 to 71 percent had degraded (again, the lowest rate at the heavy oil site). Four years after the last application of oil, 73 percent of the oil had degraded at the heavy oil site. At the heavy oil site, barley growth was affected when the oil content of the soil exceeded 4 percent, and between 2.5 and 4 percent, salt concentrations and oil-induced stress together inhibited growth. Following remedial treatments (ripping, fertilization, soil amending), barley yields were similar to those from oil-free soils. Finally, there was no increased plant uptake of metals or other toxic compounds. At all sites, aromatic compounds were not mobile beyond the cultivation zone. However, shallow groundwater beneath and downgradient of the test plots was contaminated, primarily with inorganic constituents (sulfate, magnesium, manganese, ammonium, TDS, and lead--lead was thought to be from surficial deposits, not the sludges), and the contamination continued in years following land treatment; this was thought due to ongoing leaching of the unsaturated zone and slow groundwater movement.

Environmental concerns from landspreading would involve all media: soils, surface and groundwater, and air. Metals, organics, and particularly salts could contaminate soils if bottoms or debris contain excess concentrations of any constituent or if excess volumes are applied. Excess salts can effectively sterilize soils for years, and some metals and organics can be incorporated into plant tissue and present serious risks to animals or humans who consume the plants. Precipitation-induced run-off or excess volumes of applied material can contaminate sediments and surface waters with salts, metals, and/or organic contaminants, and constituents could leach into groundwater as well. Finally, volatilization of organics could present a localized problem, as could dust that carried metals or organic constituents. Because workover-generated scale and other materials may be present in tank bottoms or oily debris, NORM could also be a localized concern where very high radioactivity levels occur or where large volumes of wastes are landspread over a period of time.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table 3-3. API, Louisiana 29-B, and Canadian Maximum Soil Concentration Values for Metals

Element	API Guidance	Louisiana 29-B	Canadian Agriculture
Arsenic	41	10	20
Barium	180,000	20,000 40,000 100,000	750
Boron	2 mg/L	--	2 mg/L
Cadmium	26	10	3
Chromium	1500	500	750
Copper	750	--	150
Lead	300	500	375
Mercury	17	10	0.8
Molybdenum	--	--	5
Nickel	210	--	150
Selenium	--	10	2
Zinc	1400	500	600

All concentrations in mg/kg unless otherwise specified.

Source: API 1995a

3.2.4 On-site Pits

In general, tank bottoms and oily debris are not widely managed in pits. Nationally, as Tables 3-1 and 3-2 show, only a little over one percent of each type of material was so managed. The types of pits used for management were not described by API, but would likely encompass the full range of reserve and production pits used in field operations. Reserve pits are generally used for temporary storage (less than one year), or for permanent disposal of wastes generated during drilling operations. Production pits are generally not long-term. States typically require pit "closure" within specified periods after drilling or workover operations end (depending on the type of pit).

States where a higher percentage of tank bottoms were managed in pits included Michigan (11.8 percent of a very small total), Oklahoma (2.0 percent), and Texas (2.3 percent). California, on the other hand, showed less than 0.5 percent so managed, and Kansas showed none. Presumably, regulatory variability accounted for the variation.

As for oily debris, Oklahoma (34.9 percent), Texas (7.3 percent), and Wyoming (39.6 percent) relied more heavily on pit management than other States. California (0.1 percent) and Kansas (0.6 percent) were again low, as were other States.

Reserve pits

Reserve pits are generally used to store drilling fluids, cuttings, and other wastes that accumulate at drilling sites. In API's drilling wastes survey (as opposed to the associated waste survey cited throughout this report), API obtained information on the types of reserve pits used at 659 newly drilled wells, about one percent of all wells drilled in 1985. Thirty five percent of the reserve pits in the survey were lined, with significant differences among the States in the percentages of lined reserve pits. These differences are due to variations in States' requirements for pit liners based on the geology and hydrology at and around drilling sites. States with the fewest lined pits were California (with one of 93 wells in the survey reporting a lined reserve pit), Illinois (none of 13), Kansas (none of 17), Louisiana (one of 29), Oklahoma (three of 43), West Virginia (two of 11), and Wyoming (eight of 44). States with relatively high percentages of lined pits included Michigan, North Dakota, and Pennsylvania (where all pits were lined), Montana (12 of 13), and Texas (103 of 219).

Reserve pits are typically excavated below-grade and may be surrounded by raised berms or dikes. Depending on environmental conditions and regulatory requirements, reserve pits may be lined with clay or synthetic liners (in the API data presented above, any liner other than bentonite in drilling muds would have qualified the pit as "lined"). In some areas, the excavation may be near or below the water table, in which case API (1989) recommends the use of liners. Liquids may be periodically removed from the pit, oil to go to reclaimers or the production line, water (brine, not fresh water) to be injected, roadspread, landspread, or otherwise managed.

The oldest and most common method of closing reserve pits is by dewatering and backfilling. Fluids are evaporated or otherwise removed (and managed as noted above) and the residue covered with material from the pit wall or soil and compacted. Remaining free liquids may be absorbed with dirt or straw before being covered with soil. Where dewatering is not practical, pit contents can be transported off-site or solidified in place; after removing as much water as possible, cement, fly ash, kiln dust, and polymers may be used to solidify pit contents. Solidification can immobilize, at least for a time, various constituents in the wastes. The solidified material then may be buried, left as it is, or used for landfill cover or road material. (Jones and Leuterman 1990) If the surface of backfilled pits is not carefully graded and revegetated or otherwise protected, over time the cover could erode and lead to uncontrolled releases.

Production pits

A variety of pits may be used for storage of materials on production sites. These include pits constructed for specific purposes (e.g., for workover fluids) as well as general-purpose pits. Construction and operation may be no different than for reserve pits, or they may be less or more sophisticated in design (the former is more common). According to API (1988), unlined production pits are used for fresh water-based fluids and for inert materials such as low-hydrocarbon sand and filter media; lined pits are used for salt water- or oil-based fluids and other high-hydrocarbon material. Generally, production pits are closed by removing free liquids, then backfilling the pit or by removing the solids for on- or off-site disposal. Some types of pits may have to be closed within a specified period after the waste-generating operations (e.g., workovers) are completed. A variety of non-fluid wastes may be managed in various production pits. These include sand, sludges and emulsions, oily debris, and tank bottoms.

Potential environmental impacts

The potential and actual impacts associated with reserve pits are well-described in the 1987 *Report to Congress*. Of most concern while the pit is open are releases to ground or surface water, although soils may be contaminated and there may be releases to air as well. Chloride concentrations in reserve pits may range from 570 to 135,000 mg/l, oil and grease from 800 to 28,000 mg/l, and barium from 30 to over 56,000 mg/l. A wide variety of metals (including cadmium, chromium, and lead) and organic constituents (including benzene, toluene, and other volatile and semivolatile organics) may also be present. No information was obtained on the extent to which tank bottoms and oily debris contribute to the mix of constituents in reserve pits. At and after closure, the potential for leachate to contaminate groundwater would still exist, as has occurred at some sites, as described in the *Report to Congress*.

Because the range of wastes managed in production pits may not be as broad as reserve pits, they may be somewhat less variable in many cases. Like reserve pits, they could contain significant quantities of formation material and hydrocarbons, as well as any added tank bottoms and oily debris; thus, their potential impacts would be similar to reserve pits, except that the relatively brief lifespans of most pits could reduce the possible damages during operations.

3.2.5 On-site Burial

According to API, relatively low percentages of tank bottoms (2.2 percent) and oily debris (2.9 percent) were buried on-site in 1985 (see Tables 3-1 and 3-2). It is not clear if this pertains to burial apart from backfilling or otherwise burying pit contents. It is possible that respondents' mixed their responses for on-site pits and on-site burial. For example, two operators, each of whom managed oily debris in production pits, then buried residual solids on-site, may have responded differently to the survey. It also is possible that operators who landfarmed their bottoms or debris by incorporating them into the soil reported on-site burial, since landfarming was not called out as a discrete management method. At any rate, there is no clear indication of exactly what was encompassed by "on-site burial" in the survey.

Among the States, Kansas (4.8 percent), Oklahoma (3.5 percent), Texas (9.9 percent), and Wyoming (7.9 percent) showed the highest burial rates. Alaska and California showed no tank bottoms were buried on-site, and Louisiana showed only 0.9 percent buried on-site.

Oily debris exhibited similar patterns: Kansas (53.4 percent of a small State total), Oklahoma (26.1 percent), Texas (42.1 percent), and Wyoming (33 percent) showed higher percentages than the average, while California showed only 0.1 percent buried on-site and Alaska none. Louisiana, unlike for tank bottoms, showed a higher-than-average burial rate for oily debris: 13.3 percent (but of a small State total).

API (1989) recommends limiting burial without a protective liner to low-hydrocarbon inert materials (and did not include tank bottoms or oily debris in the materials provided as examples). API also recommended that wastes be analyzed and "generally meet landspreading criteria" (see above) prior to burial. Overall, API recommends that buried wastes should not exhibit any free oil and should not exceed one percent (by weight) oil and grease unless there is a liner or there is no threat to groundwater.
Deuel (1990) recommended the same "threshold guidance values" for waste:soil mixtures for the land disposal, including on-site burial, of exploration and production wastes as noted above for roadspreading. As noted previously, Deuel was examining salinity and hydrocarbons, not metals or non-hydrocarbon organic constituents that might be present in drilling fluids as well as tank bottoms and oily debris.

McFarland et al. (1990) report that selectively burying wastes (i.e., not mixing with soil) at depths over 90 centimeters below the surface may be necessary to avoid upward salt migration that would interfere with natural or artificial revegetation. Their concern was on salts rather than any toxic constituents.

On-site burial should pose direct risks neither to surface waters (so long as the material remains buried and salts or other contaminants do not migrate to the surface) nor to air. Depending on the site, the material buried, and the constituents involved, leachate contamination of groundwater could be of concern. Indirectly, surface water could be affected in such cases if there is groundwater recharge of surface waters. If free liquids are buried with tank bottoms or oily debris, clearly the risk of leaching would be increased. Constituents of concern would include metals, organic constituents such as benzene, salts, and NORM. If the surface is not carefully graded and revegetated or otherwise protected, materials overlying buried wastes could erode and lead to uncontrolled releases, so this can be critical (though generally unremarked in API guidance).

3.2.6 Other (Unspecified) Management Methods

Nationally, as shown in Tables 3-1 and 3-2, API estimated that in 1985 much less than one percent of tank bottoms (0.4 percent) and oily debris (0.1 percent) were managed by means other than those described above and below. It is not clear what these might be (except as indicated in the table notes), but uncertainties in the survey questionnaire could have led to a variety of responses. For example, the survey did not include any provision for off-site but noncommercial management methods. In some oil and gas

fields, centralized noncommercial facilities may be used to manage many exploration and production wastes. Similarly, disposal in landfills and injection were not identified as management methods on the survey.

States where tank bottoms and oily debris were reportedly managed using "other" methods included Oklahoma (9.8 percent of tank bottoms, 1.8 percent of oily debris), Texas (0.9 and 0.4 percent respectively), and Wyoming (0.4 and 12.3 percent, respectively).

Of the "other" methods, only incineration (very limited quantities in three states) and injection (five barrels in Alaska) were identified. Given the limited quantities, the impacts of incineration would be nominal. Incineration would generally destroy at least some organic pollutants but could result in releases of metals and remaining organics to the atmosphere or their accumulation in ash or sludges captured in emission control devices. API recommends that open burning be restricted to oily sorbents and paraffin and that incineration be conducted under appropriate permits.

3.2.7 Off-site Commercial Facilities

Nationally, 53.7 percent of tank bottoms and 26.2 percent of oily debris were managed in off-site commercial facilities (see Tables 3-1 and 3-2). Unless prohibited by State regulations, specific management methods used for wastes at such facilities can include all of the methods described above as well as underground injection, surface discharge, municipal or other landfilling, and other methods. It is also possible that some off-site facilities incorporate various means of crude oil reclamation, although this was not accounted for or otherwise described by API.

For tank bottoms, notable among the States were California (where 62.6 percent of a very large volume was reportedly managed in off-site commercial facilities), Alaska (99 percent), Texas (only 23.9 percent), and Wyoming (only 26.3 percent). For oily debris, notable were Alaska (over 98 percent of a very small total), Florida (nearly 99 percent of a very large total), Michigan (over 98 percent of a very large total), Texas (only 4.5 percent of a large total), and Wyoming (only 3.8 percent of a small total). The availability of commercial facilities, as well as the regulatory availability of other management methods, are likely to account for the differences among States.

API (1989) counsels caution in using off-site facilities due to the joint and several liability provisions of CERCLA and similar State statutes. API recommends periodic inspections of commercial facilities by States and/or operators to verify compliance and identify areas of environmental concern. Finally, API suggests that operators track off-site waste shipments, even where this is not required.

3.3 NORM WASTE MANAGEMENT

According to API, the three categories of NORM waste which must be disposed of include: loose NORM (scale, sludge, and contaminated soil), NORM contaminated tubulars, and NORM contaminated equipment

other than tubulars (*e.g.*, separators, tanks, valves, etc.). EPA has estimated that 25,000 metric tons of NORM contaminated scale and 225,000 metric tons of NORM contaminated sludge are generated in the petroleum industry each year (Smith, et al 1995, EPA 1993). NORM waste disposal methods were studied by API to determine their appropriateness for NORM waste (API 1992). These suggested methods, all of which API reported are subject to approval by appropriate regulatory agencies, are described below.

Plugged and abandoned wells: NORM could be placed in wells during plugging and abandonment operations using the following procedures:

- *NORM Scale, Sludge and Soil*. NORM wastes could be blended with the well control fluids and circulated in the wellbore below the lowermost underground source of drinking water (USDW). NORM fluids should be isolated in the wellbore between cement plugs.

  NORM wastes could be "containerized" in tubulars and disposed of by placing the material inside joints of tubing and placing the tubing in the wellbore as discussed below.

- *NORM-Contaminated Tubulars*. NORM-contaminated tubulars could be installed beneath or between all plugs in the wellbore, or cemented in place within a full cement column. A plug should then be set in the casing below the lowermost USDW and above the top joint of tubing.

Well Injection and Hydraulic Fracturing. Sludge and scale wastes containing NORM could be injected or fractured into formations which are isolated geologically and mechanically from USDWs. These NORM wastes could be mixed using mud or cement mixing equipment. Injection of the NORM waste would be followed by a non-contaminated fluid such as water or mud so that all the NORM wastes are completely displaced into the formation.

Disposal at a Licensed NORM Waste Disposal Site. Norm waste sludges could be dewatered and disposed in an offsite commercial NORM disposal facility. API reported that, as of April, 1992, only one such facility was known to exist.

Landspreading and Burial. Loose NORM could potentially be disposed of by landspreading and both loose NORM and NORM-contaminated equipment could potentially be disposed of by burial. According to API, regulatory agencies have not yet approved of disposal by these methods. Based on a study sponsored by the U.S. Department of Energy (DOE), the Argonne National Laboratory determined that for landspreading of NORM contaminated scales and sludges, the exposure pathway of greatest concern is external irradiation. Argonne recommends that restrictions on landspreading these wastes should be implemented in all States to limit potential radiological doses to the general public (Smith, et al 1995).

Miller et al. (1991) noted that there are three options for disposing of NORM waste, NORM-containing scrap, and NORM site cleanup:

- Consolidate and store the material on company-owned property
- Dispose in a licensed radioactive waste facility
- Dispose as authorized by appropriate regulatory agency(ies).

Because of the concerns for proper disposal, NORM is usually managed and stored onsite (API 1992). Offshore discharge is regulated under an EPA Region VI General NPDES permit made final in mid-1993, which prohibits the ocean discharge of NORM-contaminated solids. The Mineral Management Service (MMS) allows disposal of NORM by injection and encapsulation in abandoned wells. Transportation of NORM for onshore disposal is also allowed. DOT regulations govern the transportation of NORM on the outer continental shelf, and include requirements for shipping papers, markings, labeling, packaging, placarding and emergency response (Shannon 1993). Alaska's Department of Environmental Conservation, in concurrence with EPA and the Alaska Oil & Gas Conservation Commission, authorized the injection of NORM materials as Class II solids, or the mixing of the scale in cement slurries for use in well abandonment (Lowe 1993). Louisiana has promulgated NORM regulations to date, including a moratorium on downhole disposal. Texas has also developed NORM regulations. Other States are either conducting their own surveys for NORM occurrence or are participating in the API studies (EPA 1991, IOGCC State Reviews).

Louisiana radiation regulations require that certain areas be designated as restricted if radiation concentrations or exposures exceed certain limits. Unrestricted disposal of NORM waste and NORM-contaminated material is allowed if the radiation dose (at accessible points or areas) does not exceed 50 microRoentgens per hour. Decontamination or disposal of more radioactive materials must be under appropriate licensing. Land may not be transferred for unrestricted use (e.g., at lease end) if radium-226 activity exceeds background by more than 5 pCi/g averaged over the top 15 cm of soil or 15 pCi/g averaged over 15-cm layers below the top 15 centimeters. Requirements in Texas, on the other hand, exempts NORM waste/material at levels of contamination by radium of 5 pCi per gram, rather than the Louisiana "dose" rate.

In a pathway exposure analysis, Chevron examined disposal in a plugged abandoned well, landspreading, and various burial scenarios. Their analysis found all but shallow burial in arid environments acceptable. They noted that disposal in plugged and abandoned wells was an option "below regulatory concern" and was "most desirable." Landspreading was described as viable for site remediation. Closure of production pits "by usual means" (dewatering and burying) was also found acceptable in humid environments. (Miller et al. 1991, Miller and Bruce 1990)

4.0 WASTE MINIMIZATION

The title of the 1976 amendments to the Solid Waste Disposal Act, the "Resource Conservation and Recovery Act," focussed attention on what was and is the ultimate purpose of RCRA: the prevention of pollution by conserving and recovering resources. The various programs administered by EPA under the Clean Air Act; the Federal Water Pollution Control Act; the Toxic Substances Control Act; the Federal Insecticide, Fungicide, and Rodenticide Act; the Safe Drinking Water Act; and other statutes all have that goal, and have made substantial progress toward its achievement by requiring specific pollution control technologies, placing limits on releases to the environment, and/or monitoring and reporting on toxic materials used or released. In response, those who are subject to the programs often meet requirements by changing industrial processes or feedstocks, by reducing the volume or eliminating releases, and/or by installing treatment technologies. In the 1984 amendments to RCRA, Congress declared it to be National policy that the generation of hazardous waste was to be reduced or eliminated. Finally, in the Pollution Prevention Act of 1990, Congress formally established a National policy of "pollution prevention."

Having long complemented its traditional permit programs, which require treatment or otherwise limit releases, with active encouragement of what has become to be known as "pollution prevention," EPA in May of 1992 responded to the 1990 Act with a formal "Statement of Definition" that placed "pollution prevention" first in a hierarchy of approaches to be used by EPA in its environmental management activities (EPA 1992a). In decreasing order of preference, the hierarchy includes:

- *Pollution prevention*: source reduction and other practices that reduce or eliminate the creation of pollutants through increased efficiency and/or conservation of resources. It includes reducing the amount of hazardous substances, pollutants, or contaminants entering any waste stream or being released prior to recycling, treatment, or disposal; or reduces risks associated with releases.

  Source reduction specifically includes modifications to equipment, technology, processes, and procedures; changes in products; substitution of raw materials; and improvements in housekeeping, maintenance, training, or inventory control.

- *Recycling*: specifically, out-of-process recycling, since in-process recycling is included in pollution prevention above. This would include environmentally sound beneficial reuse of "waste" materials as well as energy recovery.

- *Treatment* prior to disposal or release: this would not include contained disposal

- *Disposal or release*.

Various processes used to manage tank bottoms and oily debris may fall under all of these categories. Waste minimization can be an attractive objective to E&P companies because it lowers treatment and

disposal costs and reduces the potential for future liability resulting from mismanagement of waste. At the same time, however, it may require the use of more expensive or less suitable materials or require changes in processes of operations.

Unlike drilling fluids, which have a high potential for recycling, most associated wastes have limited potential for reuse. The extent to which operators minimized the amount of tank bottoms managed as waste and reduced the quantity of oily debris that could otherwise have been generated and managed cannot be determined but is likely to be substantial.

Heavy hydrocarbons that collect in the bottom of tanks, pits, production separators, and fluid treaters are notable in that they may be reclaimed and recycled. A variety of reclamation methods are used including heat treatment (heater treaters, crude oil reclaimers), chemical treatment (emulsion breakers), and physical treatment (centrifuges, pressure filtration). The following reviews some of the more common waste minimization methods.

4.1 CRUDE OIL RECLAIMING

Crude oil reclaimers provide a service by reclaiming crude oil from production tank bottoms. By reclaiming crude oil from tank bottoms, the amount of waste to be land-disposed is significantly reduced and a valuable product is recovered. This is the recommended method by industry to manage tank bottoms (Stillwell 1991, API 1989). Reclamation of crude oil tank bottoms results in up to a 70 percent reduction in the volume of waste and also provides economic benefits by increasing salable product.

Crude oil reclaimers sell up to three million barrels of oil per year to U.S. refineries, representing approximately 0.1 percent of the total U.S. crude oil production (IOCC 1990, DOE 1990). Without reclamation, this oil would become a waste. According to the 1985 API survey, 14 percent of crude oil tank bottoms generated in the U.S. were sent to crude oil reclaimers. This amounted to two percent of the total volume of associated waste generated (API, 1988b).

The Interstate Oil and Gas Compact Commission (IOGCC), under a grant from EPA, surveyed 28 major oil-producing States to determine the number of reclaimers, the amount of crude oil reclaimed, the amount and type of waste generated, and state regulatory programs concerning reclaimers. The survey identified:

- 320 known crude oil reclaimers in 28 states
- 2,446,100 barrels of crude oil recovered per year
- 561,000 barrels per year of waste generated at reclaiming facilities
- Nine States require permits for reclaiming operations

- General waste management methods include: for water, Class II injection and evaporation pits; for solids, roadspreading, incinerating, landfarming, and landfilling

Appendix B summarizes the survey's findings.

Crude oil reclaiming operations recover crude oil from E&P vessel bottoms, produced water and/or produced water skimmings, oil contaminated soils, and produced sand. They also blend off-specification crude with higher gravity crude for the purpose of producing salable petroleum. Figure 4-1 provides a diagram for a typical crude oil reclaiming operation. The operation from which the diagram was obtained performs reclamation through a combination of gravity separation and/or thermal treatment with temperatures on the order of 150-200°F. An emulsion-breaking surfactant, which also is used in other E&P operations, may be used to improve oil/water separation.

Reclaiming operations generate two major waste streams. One stream is water, which resembles produced water and is managed as such, and the second is an untreatable water/solids/petroleum emulsion (BS&W) which remains when the reclamation process is complete. The wastewater stream is usually injected in a Class II injection well or is discharged into a pit, lined or unlined, for evaporation. The solid waste stream is typically disposed of at a permitted disposal facility or, in some States, roadspread (API January 1991).

As noted in the introduction, in 1988 EPA made a regulatory determination that most wastes generated by oil and gas E&P activities are exempt from regulation as hazardous wastes. However, among those wastes not exempted were "liquid and solid wastes generated by crude oil reclaimers." There was concern that this included all reclaimer wastes, including wastes derived from exempt wastes. This concern was intensified by the 1990 regulations that required waste generators to test their waste using a new method, the Toxicity Characteristic Leaching Procedure, and established new limits for 25 organic constituents, including benzene. The concern prompted a number of determinations by EPA, on a site-specific basis, of the regulatory status of various wastes generated by crude oil reclaimers. As a result, EPA clarified that waste residuals that are generated by crude oil reclaimers and that are solely derived from the processing of exempt wastes (e.g., produced water, bottom sediment and water) remain exempt from Subtitle C regulation (58 FR 15284; March 22, 1993).

4.2 ROADSPREADING

Approximately 30 percent of all associated waste managed on-site are roadspread. Wastes that are not ignitable, and have mixed density values and metal contents consistent with approved road oil and mixes may be used in some States for construction or repair of road surfaces (API 1989). According to the API associated waste study, most associated wastes roadspread on-site are either oily debris and filter media (66 percent of all oily debris so managed) or tank bottom wastes (21 percent).

From an environmental perspective, there are three important factors in the road application of oily wastes. These include consideration of hazardous constituents in the oily waste, proper application procedures, and protection of the environment from run-off from oiled roadways (Kennedy et al. 1990). Chapter 3 above also describes roadspreading.

Some states allow roadspreading of tank bottoms and oily debris on lease roads and in some cases on county roads if certain requirements are met such as waste type, site restrictions, weather conditions, and application rates. Some operators sell these wastes to asphalt plants for future road application.

As part of Chevron's SMART (save money and reduce toxics) program, the company salvages 30,000 tons per year of tank bottom material from its Kern River operation and uses it to pave 300 miles of roadways on the lease (Anonymous 1991). The tanks are cleaned at a rate of 60 per year, and the contents (sand and oily water) are hauled in vacuum trucks to an on-site road-mix facility. There, the material is poured into pits where the sand settles to the bottom and oil and water are skimmed off the top. Then the sand is taken out of the pits and stockpiled nearby until time for it to be formed into berms, where graders and mixers blend and mix it until it can be picked up and put on roadways. Some 700 to 1,500 tons per week of finished product are used on lease roads, where traffic seals and packs it into an asphalt-like roadway. Similar practices have been reported by other companies in California and in other oil producing states where these practices are allowed.

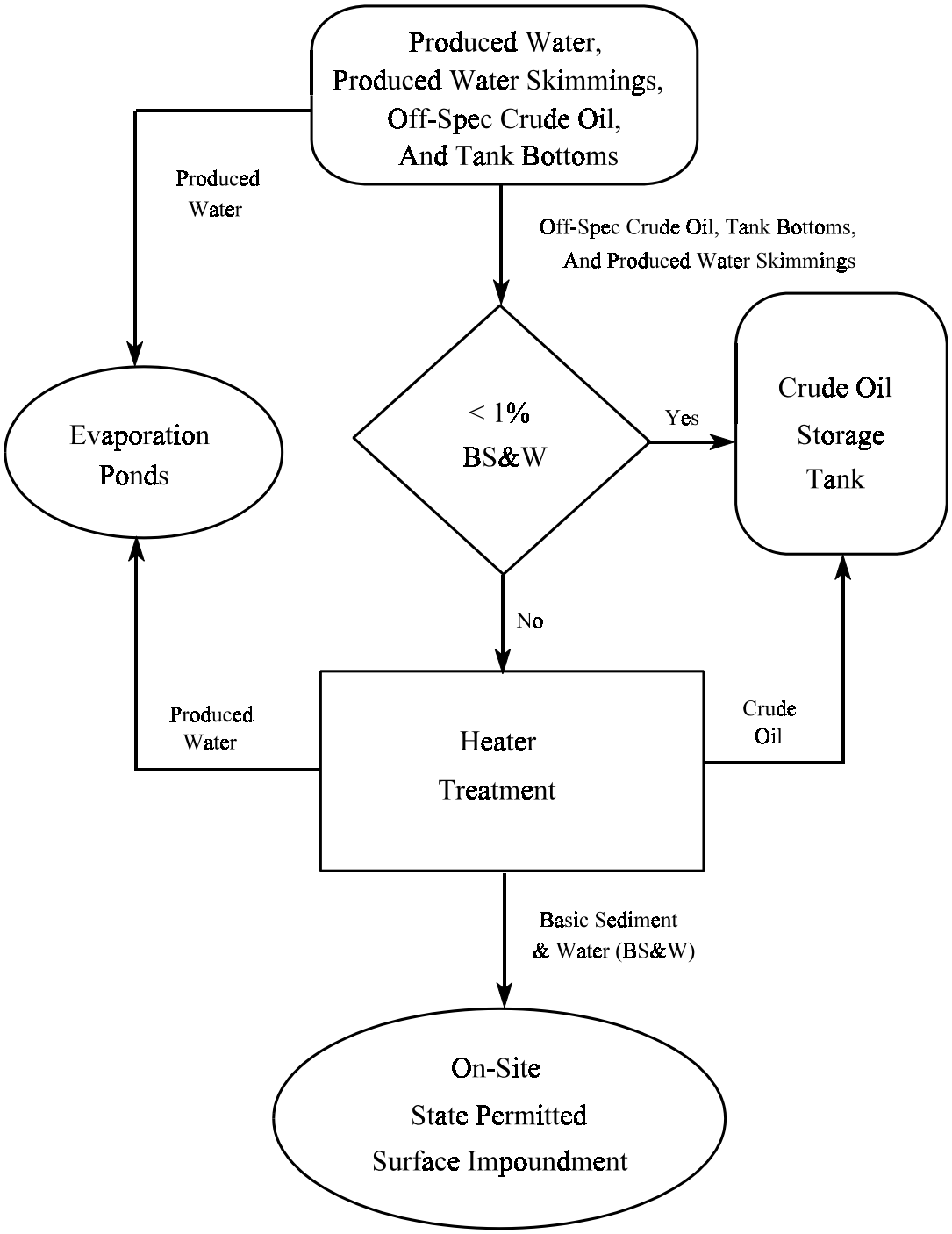

Figure 4-1. Typical Crude Oil Reclaiming Process Flow Diagram

4.3 OTHER WASTE MINIMIZATION EFFORTS

Hydrocarbons entrapped in the bottoms of storage tanks result in production losses to an operator. Placing a recirculating pump inside a storage tank can reduce the amount of heavy hydrocarbons that settle and become incorporated into bottom sludges (API 1989). The heavy hydrocarbons are maintained in suspension until the tank is emptied; then they are transported to the field collection facility or refinery with the production stream. It is unknown how widely this source reduction technique is used in oil production storage tanks (API, November 1991).

Long-term contact between crude oil and atmospheric oxygen promotes the formation of resins and gums. The buildup of these residues inside a storage tank can be reduced by the use of floating-roof tanks or inert gas blanketing, each of which limits the exposure of the stored crude oil to the atmosphere, thus decreasing the amount of resins and gums generated. (Such "covers" also serve to reduce emissions of volatile organic compounds, precursors of ozone, a Clean Air Act criteria pollutant.) They are frequently used for gasoline and other fuel oil tanks, but it is unknown how widely this technique is used in crude oil storage tanks.

5.0 SUMMARY AND CONCLUSIONS

This chapter briefly summarizes many of the major themes that recur throughout this report . Finally, a number of approaches to information collection that could prove fruitful in better characterizing the universe of tank bottoms and oily debris are suggested.

Major themes that appear in various sections of the report generally revolve around data shortcomings and uncertainty that are primarily the result of imperfect sampling and analytical procedures as noted in the discussion of the TCLP and in the Executive Summary. This makes it impossible to draw definitive conclusions about any of the major areas discussed in the report. Nevertheless, a number of tentative findings that are suggested by the data include:

- Tank bottom generation rates are extremely variable, as is true of most exploration and production wastes. Quantities generated would be a function of quantity and nature of the crude oil produced, stored, and treated. The only comprehensive data on waste quantities are those compiled by API in the mid-1980s. The nature of this survey make State-to-State comparisons of questionable validity. The various definitions of oily debris, particularly differences between EPA and the API survey, make it difficult to address this waste.

- The characteristics of tank bottom wastes are extremely variable, with concentrations of constituents ranging over many orders of magnitude. As expected, a significant percentage of tank bottoms samples exhibit one or more hazardous characteristics . Benzene, a common component of hydrocarbons, appears to be the most prevalent toxic constituent, with lead also showing elevated concentrations in some cases. Not surprisingly, many samples of tank bottoms exhibit the hazardous characteristic of ignitability. All of this suggests that tank bottoms must be managed with care to protect human health and the environment. Oily debris data are even more limited and are likely to be even more variable.

- Unlike many associated wastes, there are significant opportunities for waste minimization and pollution prevention. For tank bottoms, crude oil reclamation has proven to be economic in many cases, particularly for lighter oils ($>20^{o}$ API).

- Tank bottoms and oily debris are managed using a wide variety of methods, ranging from incineration to on-site burial, reclamation, and are sometimes used as raw materials for the production of road mix. State regulation of the wastes and management methods is also variable allowing flexibility in waste management practices based on site-specific conditions.

- The American Petroleum Institute survey of associated wastes provides valuable information on the rough proportions of tank bottoms and oily debris generated and managed using various methods. It suffered from a number of shortcomings in survey design (e.g., some management methods that

could overlap with others) and statistical rigor (e.g., using proportional oil production as the sole extrapolation factor with no sensitivity analysis). More important, it is dated.

The wide variability in each of these topics suggests that narrowly focussed study topics could help in identifying and filling data gaps. Clearly, priorities would have to be established in order to select narrowly focussed topics that were "important" from a waste or waste management perspective. Narrowly focussed studies could materially advance the body of knowledge if properly directed and implemented.

- The American Petroleum Institute survey of associated wastes provides valuable information on the rough proportions of tank bottoms and oily debris generated and managed using various methods. It suffered from a number of shortcomings in survey design (e.g., some management methods that could overlap with others) and statistical rigor (e.g., using proportional oil production as the sole extrapolation factor with no sensitivity analysis). More important, it is dated. A more carefully designed survey instrument, perhaps targeted to narrower topics (e.g., specific wastes or specific practices) could be useful. Studies that focus on tank bottoms generated from specific crude oils, or from specific storage or treatment processes, could allow for more targeted data collection and analyses.

- Actual damages resulting from the mismanagement of tank bottoms are not well documented; it is not known whether this is because there are few or no damages or because no systematic examination, targeted at these specific wastes, has been undertaken. Because of extensive co-management of E&P wastes and other factors, the 1987 *Report to Congress* could not attribute specific damages to specific wastes.

- At least some States are likely to possess extensive waste characterization data as well as more detailed information on waste management methods than could be obtained during the IOGCC reviews, which had a much broader scope. Targeted data collection could substantially increase the amount and representativeness of analytical data.

- Sampling procedures and analytical methods do not necessarily provide data that is representative of waste management practices or the fate and transport of waste constituents. Analytical methods are not designed to provide reliable results from oily aqueous and sludge samples.

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APPENDIX A

API Associated Waste Survey Confidence Levels

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table A-1. API-Estimated Generation of Associated Wastes, Associated Confidence Levels, and Tank Bottom Wastes, 1985

State	Volume of Total Associated Wastes[a] (bbls)			95% confidence levels as % of estimated volume [c]	Tank Bottom Wastes (bbls)	
	Lower limit [b]	Total wastes	Upper limit [b]		Volume generated [d]	% of State's associated wastes [d]
Alabama	3,000	8,000	13,000	63	1,598	20
Alaska	55,000	55,000	56,000	2	7,719	14
Arkansas	10,000	19,000	27,000	42	1,525	8
California	2,174,000	2,379,000	2,584,000	9	594,637	25
Colorado	0	806,000	2,026,000	151	4,192	1
Florida	105,000	163,000	220,000	35	442	0
Illinois	0	205,000	441,000	115	50,263	25
Kansas	177,000	290,000	402,000	39	114,860	40
Louisiana	130,000	235,000	340,000	45	47,414	20
Michigan	138,000	161,000	184,000	14	1,990	1
Mississippi	14,000	50,000	86,000	72	14,313	29
Montana	4,000	337,000	671,000	99	2,022	1
Nebraska	1,000	9,000	18,000	100	4,250	47
New Mexico	193,000	355,000	518,000	46	7,346	2
North Dakota	0	330,000	849,000	157	4,009	1
Oklahoma	1,212,000	2,491,000	3,770,000	51	125,295	5
Texas	1,973,000	3,080,000	4,187,000	36	198,333	6
Utah	40,000	47,000	55,000	17	16,343	35
West Virginia	0	422,000	1,272,000	201	115	0
Wyoming	104,000	150,000	196,000	31	17,831	12
Total U.S. [e]	9,357,000	11,759,000	14,161,000	20	1,214,497	10

NOTES:

a Data taken from Table 2-1. See also notes (b) and (c).

b Based on an approximate 95 percent confidence level (i.e., there is a 95 percent probability that the actual volume falls between the lower and upper limits). See API report for qualifications.

c Percentages calculated as: 100 * (upper 95 percent limit - estimated volume)/estimated volume. Lower limits presented by API and here are cut off at 0 bbls.

d Totals from Table 2-4, percentages from Table 2-5.

e Total U.S. includes AZ, IN, KY, MO, NV, NY, OH, PA, SD, TN, and VA. The values for these States alone or in total cannot be calculated since the values in the rows were calculated independently by API (i.e., the lower and upper limits and the estimated volumes for each State were calculated separately) and are not additive. Similarly, the U.S. totals for lower and upper limits were calculated independently by API and are not simply the total of the State limits.

SOURCE: American Petroleum Institute. 1988 (June). *API 1985 Production Waste Survey. Part II - Associated and Other Wastes Statistical Analysis and Survey Results.* Final Report.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table A-2. API-Estimated Generation of Associated Wastes, Associated Confidence Levels, and Oily Debris Wastes, 1985

State	Volume of Total Associated Wastes[a] (bbls)			95% confidence levels as % of estimated volume [c]	Oily Debris Wastes (bbls)	
	Lower limit [b]	Total wastes	Upper limit [b]		Volume generated [d]	% of State's associated wastes [d]
Alabama	3,000	8,000	13,000	63	280	4
Alaska	55,000	55,000	56,000	2	1,507	3
Arkansas	10,000	19,000	27,000	42	1,207	6
California	2,174,000	2,379,000	2,584,000	9	831,511	35
Colorado	0	806,000	2,026,000	151	2,161	0
Florida	105,000	163,000	220,000	35	154,464	95
Illinois	0	205,000	441,000	115	2,331	1
Kansas	177,000	290,000	402,000	39	5,825	2
Louisiana	130,000	235,000	340,000	45	2,894	1
Michigan	138,000	161,000	184,000	14	130,641	81
Mississippi	14,000	50,000	86,000	72	2,662	5
Montana	4,000	337,000	671,000	99	470	0
Nebraska	1,000	9,000	18,000	100	850	9
New Mexico	193,000	355,000	518,000	46	1,363	0
North Dakota	0	330,000	849,000	157	302	0
Oklahoma	1,212,000	2,491,000	3,770,000	51	18,403	1
Texas	1,973,000	3,080,000	4,187,000	36	63,907	2
Utah	40,000	47,000	55,000	17	8,529	18
West Virginia	0	422,000	1,272,000	201	321	0
Wyoming	104,000	150,000	196,000	31	13,932	9
Total U.S. [e]	9,357,000	11,759,000	14,161,000	20	1,243,560	11

NOTES:

a Data taken from Table 2-1. See also notes (b) and (c).

b Based on an approximate 95 percent confidence level (i.e., there is a 95 percent probability that the actual volume falls between the lower and upper limits). See API report for qualifications.

c Percentages calculated as: 100 * (upper 95 percent limit - estimated volume)/estimated volume. Lower limits presented by API and here are cut off at 0 bbls.

d Totals from Table 2-4, percentages from Table 2-5.

e Total U.S. includes AZ, IN, KY, MO, NV, NY, OH, PA, SD, TN, and VA. The values for these States alone or in total cannot be calculated since the values in the rows were calculated independently by API (i.e., the lower and upper limits and the estimated volumes for each State were calculated separately) and are not additive. Similarly, the U.S. totals for lower and upper limits were calculated independently by API and are not simply the total of the State limits.

SOURCE: American Petroleum Institute. 1988 (June). *API 1985 Production Waste Survey. Part II - Associated and Other Wastes Statistical Analysis and Survey Results.* Final Report.

APPENDIX B

Summary of IOGCC Survey of Crude Oil Reclaimers

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table B-1. Summary by State of IOGCC State Survey of Crude Oil Reclaimers

State	Reclaimers	Quantity of Crude Oil Recovered (bbl/yr)	Quantity of Waste (bbl/yr)	State Permit	Waste Management Practices
Alabama	Unknown	Unknown	Unknown	No	Unknown
Arizona	7 oil marketers	Unknown*	Unknown	None unless Az DEQ directs	Oil sold for energy recovery. Primary customers are Mobil asphalt plants.
California	Unknown	Unknown	Unknown	No	Past: waste to landfill or converted into fuel. Current: waste recycled or treated on-site.
Colorado	4 identified	>2,400	Unknown	No	Unknown. Most operations are associated with disposal wells.
Florida	NA	NA	NA	NA	NA
Indiana	Unknown	N/A	N/A	No	N/A
Kansas	40	Unknown	Unknown	NA	NA
Louisiana	11	106,500	240,000	Yes La DNR	Commercial facility or on-site disposal well.
Maryland	2	Unknown	Unknown	Yes	Unknown
Michigan	N/A	N/A	N/A	N/A	N/A
Mississippi	5	51,700	13,000	NA	NA
Missouri	12	NA	NA	Yes Mo DEQ	Incineration
Nebraska	1	4,000	2,500 -nearly all water	Yes	Water disposed of as produce water. Solids are burned in a pit as needed.
Nevada	3	Unknown	Unknown	No	Water is discharged under NPDES or sent to a POTW.
New Mexico	17	132,000	63,600	Yes NM OCD	Disposal at OCD permitted disposal facilities - Class II wells or surface disposal facilities.
New York	None	N/A	N/A	No	N/A
N. Carolina	N/A	N/A	N/A	N/A	N/A

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table B-1. Summary by State of IOGCC State Survey of Crude Oil Reclaimers

State	Reclaimers	Quantity of Crude Oil Recovered (bbl/yr)	Quantity of Waste (bbl/yr)	State Permit	Waste Management Practices
N. Dakota	2	13,000	Residue - 800 Water - 1,200	Yes	One facility sells as road oil. The other facility uses a filter press. Waste filtrate, a dry hard residue, is sent to an approved disposal site.
Oklahoma	137	1,680,000	Unknown	No	Water is disposed of in a Class II injection well. BS&W is usually applied to lease or county roads.
Pennsylvania	None	N/A	N/A	N/A	N/A
S. Carolina	None	N/A	N/A	No	N/A
S. Dakota	None	N/A	N/A	No	N/A
Tennessee	33	NA	NA	No	NA
Texas	45	456,500	240,000	Yes Tx RRC	Disposal wells and solid waste disposal facilities
Utah	None	N/A	N/A	Yes	N/A
Virginia	None	N/A	None	Only as part of on-site oil production operations	N/A
W. Virginia	None	N/A	N/A	No	N/A
Wyoming	1	Unknown	Unknown	No	Land farming and surface retention

* Began a program in October 1990 to furnish this information.

NA = Not Available
N/A = Not Applicable

APPENDIX C

Pre-1992 Analytical Data

Crude Oil Tank Bottom Wastes

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-1. Summary of TCLP Tank Bottoms Analysis from EPA's 1986 Field Sampling Project

Constituent	Sample 1 (mg/L)	Sample 2 (mg/L)
Benzene	0.325	1.18
Naphthalene	12.41	0.02
2-Methylnaphthalene	6.84	0.697
Ethylbenzene	0.196	1.4
Toluene	0.494	0.06
Aluminum	0.23	11.0
Iron	173	25.49
Magnesium	17.8	28.9
Manganese	1.92	6.7
Molybdenum	0.122	0.67
Nickel	0.527	1,360
Sodium	14,000	22.0
Tin	0.402	0.73
Barium	4.83	0.85
Boron	1.58	0.28
Zinc	0.242	291.0
Sulfur	1.78	1.89

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-1. Summary of TCLP Tank Bottoms Analysis from EPA's 1986 Field Sampling Project

Source: EPA, January 31, 1987

Notes: In 1986, EPA conducted a sampling and analysis effort to develop information about wastes from four types of E&P sites: drill sites, production sites, centralized pits, and centralized treatment facilities. Primarily, EPA sampled drilling wastes and produced waters. EPA also sampled tank bottoms and several commingled oil and gas extraction industry wastes disposed of via centralized pits or centralized treatment facilities. In total, 101 samples were collected; of the total, 42 were classified as sludges (2 of which were tank bottoms) and 59 were classified as liquids. EPA defined tank bottoms as sediment, oil, water, and other substances that tend to concentrate in the bottom of production field vessels, especially stock tanks.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-2. Summary of 1985 RCRA §3007 Survey Responses for Refinery Crude Oil Tank Bottoms Generation

Total Number of Facilities	Total Number of Streams	Scaled Waste Quantity (MT)
154	181	31,215
Hazard Type[1]	**Quantity** (MT)	**Number of Streams**
EP Toxic	0.0	1
Ignitable	1225.09	22
Ignitable and EP Toxic	0.0	1
Ignitable and Reactive	0.0	1
Toxic	57.34	5

Chemical Constituents[2]	Number of Streams
Antimony	1
Arsenic	6
Barium	12
Benzene	3
Cadmium	6
Chromium	22
Chromium III	1
Cobalt	4
Copper	4
Hydrogen Sulfide	1
Lead	22
Mercury	6
Naphthalene	2
Nickel	12
Phenol	4
Selenium	5
Sulfide	2
Tetraethyl Lead	1
Toluene	2
Vanadium	11
Zinc	8

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-2. Summary of 1985 RCRA §3007 Survey Responses for Refinery Crude Oil Tank Bottoms Generation
(continued)

[1] Hazard Type refers to how the survey respondents classify their waste stream
[2] Chemical Constituents are the constituents the survey respondents suspect to be in the waste stream

Source: SAIC. *Petroleum Refining Waste Profiles.* June 17, 1992.

Notes: The Waste Identification Branch (WIB) is undertaking an investigation of the petroleum refining industry. This investigation is also mandated by a proposed 1991 consent agreement between EPA and the Environmental Defense Fund (EDF). The consent agreement identifies 14 specific waste streams for which the Agency must make determinations on whether the waste should be listed as hazardous waste and an additional 15 waste streams that the Agency must study. The purpose of this project is to determine whether, if mismanaged, these 29 wastes pose a threat to human health and the environment and to develop a basis for making such a determination. Among the waste streams being studied are crude oil storage tank bottoms at petroleum refineries.

The petroleum refining industry was previously studied by EPA in the 1980's. This original effort involved the distribution, collection and review of a RCRA §3007 survey of approximately 180 refineries (characterizing the industry as of 1983), sampling and analysis of various wastes at approximately 15 sites, and a focussed listing determination effort on wastewater treatment sludges.

As a first step in restarting the Agency's investigation of wastes from petroleum refining, EPA is reassessing all the available information previously collected in the 1985 questionnaire. This table provides an overview of the information collected on the questionnaire from the refineries on their crude oil tank bottom generation, waste management methods, waste characteristics, and suspected constituents (SAIC, June 17, 1992).

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-3. Summary of EPA WIB's Non-CBI Petroleum Refining
Crude Oil Tank Bottom Sample, 1986

Constituent	Crude Tank Bottom Sample (mg/kg)
VOLATILE ORGANIC COMPOUNDS	
Benzene	119
Toluene	360
Xylene	653
Ethylbenzene	116
SEMIVOLATILE ORGANIC COMPOUNDS	
Naphthalene	152
1-Methylnaphathalene	341
2-Methylnaphathalene	39
Phenanthrene	249
Anthracene	19.6
Pyrene	281
5-Methylchrysene	< 15.0
Pyridine	< 15.0
Triophenol	27.6
Aniline	< 15.0
Nitrobenzene	< 15.0
Benzo(a)pyrene	74.5
Benzo(b)fluoranthrene	102
Fluoranthrene	71.5
Benzo(a)anthracene	< 15.0
Dibenzo(a,h)anthracene	42.1
Chrysene	390
7-H-Dibenzo(c,g)carbazole	< 15.0
Indeno(1,2,3-cd)pyrene	< 15.0
Dibenzo(a,i)pyrene	< 15.0
Dibenzo(a,h)pyrene	< 15.0

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-3. Summary of EPA WIB's Non-CBI Petroleum Refining Crude Oil Tank Bottom Sample, 1986

Constituent	Crude Tank Bottom Sample (mg/kg)
(continued)	
METALS	
Aluminum	10,100
Antimony	43.8
Arsenic	<10
Barium	549
Cadmium	<5
Calcium	30,800
Chromium	1,170
Iron	28,700
Lead	107
Magnesium	7,440
Manganese	328
Molybdenum	9.2
Potassium	1,880
Silver	<1.5
Sodium	3,200
Titanium	151
Vanadium	47.8
Zinc	819

Source: EPA. *Refinery Sampling and Analysis: Plant No. 2.* February 10, 1987.

Notes: As part of the initial waste characterization efforts, EPA conducted sampling of crude oil tank bottoms at 4 petroleum refineries. Three of the refineries declared their information as Confidential Business Information (CBI). The characterization data from the refinery which did not claim CBI is presented in this table.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-4. Crude Oil Tank Bottom TCLP Analytical Data Submitted by Star Enterprises' Delaware City Refinery

Constituents	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Sample 4 (mg/L)
TCLP VOLATILE ORGANIC COMPOUNDS				
Benzene	1.8	<0.02	0.34	<0.02
Carbon Tetrachloride	<0.02	<0.02	<0.02	<0.02
Chlorobenzene	<0.02	<0.02	<0.02	<0.02
Chloroform	<0.02	<0.02	<0.02	<0.02
1,2-Dichloroethane	<0.02	<0.02	<0.02	<0.02
1,1-Dichlorethylene	<0.02	<0.02	<0.02	<0.02
Methyl Ethyl Ketone (MEK)	<0.5	<0.05	<0.5	<0.5
Tetranchlorethylene	<0.02	<0.02	<0.02	<0.02
Trichloroethylene	<0.02	<0.02	<0.02	<0.02
Vinyl Chloride	<0.04	<0.02	<0.04	<0.04
TCLP SEMIVOLATILE ORGANIC COMPOUNDS				
o-Cresol	0.97	ND	<0.1	<0.1
m-Cresol	<0.1	ND	<0.1	<0.1
p-Cresol	0.18	ND	<0.1	<0.1
TCLP METALS				
Arsenic	<0.1	<0.05	<0.1	<0.1
Barium	1.7	<0.5	0.6	<0.5
Cadmium	<0.05	<0.02	<0.05	<0.05
Chromium	<0.05	<0.02	0.04	<0.05
Lead	<0.2	0.18	<0.02	0.40
Mercury	<0.005	<0.002	<0.005	<0.005
Selenium	<0.1	<0.05	<0.1	<0.1
Sliver	<0.05	<0.02	<0.05	<0.05

ND = non-detectable

Source: Star Enterprises, Delaware City Refinery

Notes: As part of an on-going listing determination effort, an industry workgroup was established. Workgroup members were asked to voluntarily submit analytical data on the 29 waste streams of concern. Workgroup members are in the process of submitting this data. A final determination is due in the spring of 1996.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-5. Kansas' Crude Oil Reclaimer Tank Bottoms Characterization Data

Constituent	Sample 1 Total GC/MS (mg/kg)	Sample 2Total GC/MS (mg/kg)	Sample 3* TCLP GC/MS (mg/l)	Sample 4 Total GC/MS (mg/kg)	Sample 5 GC/MS (mg/kg)	Sample 6 GC/MS (mg/kg)	Sample 7 GC/MS (mg/kg)	Sample 8 GC/MS (mg/kg)
Benzene	56.8	134	0.33	7.4	NA	NA	NA	NA
Chlorobenzene	<0.5	<1.8	<0.05	<1.8	NA	NA	NA	NA
1,4 Dichlorobenzene	<100	<2.5	<0.05	<2.5	NA	NA	NA	NA
1,2 Dichloroethane	<0.6	<1.5	<0.05	<1.5	NA	NA	NA	NA
Arsenic	NA	NA	NA	NA	1.054	0.45	0.13	0.087
Barium	NA	NA	NA	NA	63.9	9.31	<2.0	<2.0
Cadmium	NA	NA	NA	NA	0.36	1.03	0.68	0.63
Chromium	NA	NA	NA	NA	2.43	3.43	2.04	1.99
Lead	NA	NA	NA	NA	8.84	11.3	3.88	4.86
Mercury	NA	NA	NA	NA	<0.02	<0.1	<0.1	<0.1
Selenium	NA	NA	NA	NA	0.072	<0.05	<0.05	<0.05
Silver	NA	NA	NA	NA	0.22	<0.05	<0.05	<0.05

(continued)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-5. Kansas' Crude Oil Reclaimer Tank Bottoms Characterization Data
(continued)

* The lab sheets stated that the sample was collected in an inappropriate plastic sample container and sample quantity was barely sufficient to perform analyses requested.

Source: Kansas provided EPA with data from eight tank bottom samples.

Notes: Samples 1 through 4 characterization data were of questionable quality. The photocopies submitted were barely readable and no quality assurance analyses (QA/QC) were provided for the samples. The lab sheet was not submitted to explain the large range in the detection limits or the analysis methods used. Analyses were done for constituents other than those shown but they were unreadable. The one sample (Sample 3), in which the Toxicity Characteristic Leaching Procedure (TCLP) was performed, was footnoted for unreliability. Without QA/QC information, the samples cannot be relied upon.
Only total metals analyses were requested on samples 5 through 8. As stated on the lab sheets, the results of total analyses are reported because the TCLP states that if a total analysis demonstrate that the analytes of interest are present in a waste but below the regulatory level, the TCLP Extraction need not be run. Since the ratio between sample and liquid is 20:1 in all TCLP fractions, a leachate concentration may be obtained by dividing all results by 20 and assigning the concentration unit of "mg/l" to each result. However, due to the sample's oily matrix the TCLP value is probably higher.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-6. New Mexico's Crude Oil Reclaimer Tank Bottom
TCLP Characterization Data

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Sample 3 (ppm)
TCLP VOLATILE ORGANIC COMPOUNDS			
Benzene	900*	1,400*	104*
TCLP METALS			
Arsenic	0.15	<0.06	<0.005
Barium	1.7	<6	<0.05
Cadmium	0.28	<0.1	0.01
Chromium	0.16	0.1	<0.05
Lead	0.9	<2	<0.2
Mercury	0.004	<0.5	<0.001
Selenium	<0.005	<0.06	<0.005
Silver	0.21	<0.4	<0.03

* Characteristically hazardous

Source: Information provided by the State of New Mexico during the crude oil reclaimers investigation.

Notes: New Mexico provided quality assurance analyses for all analytes. All three samples of tank sludges provided by New Mexico were characteristic for benzene.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-7. API Crude Oil Reclaimer Tank Bottoms TCLP Characterization Data

Constituent	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Sample 4 (mg/L)	Sample 5 (mg/L)	Sample 6 (mg/L)	Sample 7 (mg/L)	Sample 8 (mg/L)	Sample 9 (mg/L)	Sample 10 (mg/L)	Sample 11 (mg/L)	Sample 12 (mg/L)	Sample 13 (mg/L)
TCLP VOLATILE ORGANIC COMPOUNDS													
Benzene	7.7*	4.6*	20*	2.2*	5.2*	4.6*	3.7*	7.1*	0.092	27*	0.37	3.0*	420*
TCLP METALS													
Arsenic	<0.6	<2	<0.6	<0.5	<0.5	<0.5	<1.0	1.1	<0.5	<1.3	<1.0	<1.0	<1.5
Barium	7.5	24	0.99	0.33	3.7	1.4	5.7	4.1	<0.5	1.6	2.3	2.6	45.6
Cadmium	<0.03	<0.1	<0.03	<0.03	<0.03	<0.03	0.05<	0.055	<0.03	0.32	<0.05	<0.05	0.28
Chromium	0.08	<0.2	<0.06	<0.05	<0.05	<0.05	<0.1	0.07	<0.05	<0.13	<0.1	0.47	0.41
Lead	<0.3	2	4.2	<0.3	<0.3	0.8	<0.5	9.2*	<0.3	<0.62	<0.5	<0.5	<0.72
Mercury	<0.003	<0.008	<0.004	<0.002	<0.002	<0.003	<0.002	<0.003	<0.002	<0.0075	<0.002	<0.002	0.033
Selenium	<0.06	<0.08	<0.07	<0.05	<0.05	<0.05	<0.05	<0.06	<0.05	<0.062	<0.05	<0.05	<0.098
Silver	<0.06	<0.2	<0.06	<0.05	<0.05	<0.05	<0.1	<0.2	<0.05	<0.1	<0.1	<0.1	<0.15
GENERAL CHEMISTRY ANALYTES													
Ignitability**	55°F*	66°F*	72°F*	127°F*	82°F*	66°F*	102°F*	66°F*	>160°F	79°F*	81°F*	64°F*	66°F*

Source: The data was provided by API to EPA for the crude oil reclaimers investigation, as part of an ongoing study by API of associated wastes characteristics and management.

* Characteristically hazardous
** Flash Point

Notes: API provided a quality assurance summary for the analyses, in addition to total concentration for metals, volatile organic compounds (VOCs), semi-volatile organic compounds, and general inorganics. This table provides a summary of the TCLP analyses, for selected constituents of concern, and general inorganics for crude oil tank bottoms (TCLP constituents not listed were non-detect).

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-8. API Process Vessel Bottoms TCLP Characterization Data

Constituent	Free-Water Knockout Bottoms Sample (mg/L)	Heater Treater Bottoms Sample (mg/L)
TCLP VOLATILE ORGANIC COMPOUNDS		
Benzene	0.21	0.94*
TCLP METALS		
Arsenic	<1.0	<1.0
Barium	3.4	1.6
Cadmium	<0.05	<0.05
Chromium	<0.1	0.14
Lead	1.0	9.6*
Mercury	<0.002	<0.002
Selenium	<0.05	<0.05
Silver	<0.1	<0.1
GENERAL CHEMISTRY ANALYTES		
Ignitability**	<160°F	77°F*

Source: The data was provided by API to EPA for the crude oil reclaimers investigation, as part of an ongoing study by API of associated wastes characteristics and management.

* Characteristically hazardous
** Flash Point

Notes: API provided characterization data on the various types of wastes generated by crude oil reclaimers including crude oil tank bottoms, produced water tank, produced water skimmings, BS&W pit skimmings, and process vessel bottoms.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-9. API Tank Bottoms (12 Samples) Compositional Data Ranges
STLC Total Concentration Values

Constituent	Low (mg/Kg)	High (mg/Kg)	Number of Samples Exceeding STLC
STLC METALS			
Antimony	<1.0	<10.0	-
Arsenic	0.05	64.0	-
Barium	<1.0	120.0	-
Beryllium	0.08	0.4	-
Cadmium	<0.1	0.5	-
Chromium (6)	<0.1	6.0	-
Chromium (3)	<0.1	90.0	-
Cobalt	<0.5	8.0	-
Copper	<0.1	216.0	1
Fluoride	<1.0	75.0	-
Lead	<1.0	90.0	-
Mercury	0.016	7.75	2
Molybdenum	<1.0	12.0	-
Nickel	<1.0	146.5	2
Selenium	<0.1	0.5	-
Silver	<0.1	0.6	-
Thallium	<0.3	9.3	-
Vanadium	<4.0	49.0	1
Zinc	0.1	78.8	-

Source: API. *Exploration and Production Industry Associated Wastes Report.* May 1988.

Notes: In the 1988 API Associated wastes report, 12 tank bottom samples were collected and analyzed. The analysis was done using the California Assessment Manual's (CAM) Soluble Threshold Limit Concentration (STLC). This table shows the aggregated data reflecting the ranges in heavy metal values.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table C-10. Summary of the Canadian Petroleum Association's Vessel Bottom CGSB Leachate Characterization Data

Constituent	Treater Bottom Sludge			Tank Bottom Sludge			Spill Material		
	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Sample 1 (mg/L)	Sample 2 (mg/L)	Sample 3 (mg/L)	Sample 1 *	Sample 2 (mg/L)	Sample 3 (mg/L)
CGSB LEACHATE EXTRACTION PROCEDURE METALS									
Arsenic	0.003	0.0003	0.0061	0.0069	NT	0.016	NT	0.0084	0.0035
Barium	1.95	1.76	0.5	22.3	NT	1.6	NT	0.74	0.35
Boron	0.71	0.45	0.23	0.32	NT	0.88	NT	0.96	0.18
Cadmium	0.001	0.001	0.001	0.001	NT	0.001	NT	0.001	0.001
Chromium	0.001	0.001	0.001	0.001	NT	0.001	NT	0.001	0.001
Lead	0.02	0.02	0.01	0.01	NT	0.01	NT	0.001	0.001
Mercury (ug/L)	0.05	0.1	0.1	0.05	NT	0.26	NT	0.25	0.21
Selenium	0.0002	0.0002	0.0002	0.0002	NT	0.0002	NT	0.0002	0.0002
Cyanide	0.002	0.002	0.002	0.002	NT	0.002	NT	0.001	0.005
Nitrate	0.32	0.17	0.15	0.005	NT	0.19	NT	0.5	0.5
GENERAL CHEMISTRY ANALYTES									
Flash Point	NA	41°F	NA	NA	75°F	NA	NA	NA	NA

NA - Not applicable
NT - Not tested
* No leachate analyses preformed on this sample

Source: CPA. *Physical and Chemical Characteristics of Oilfield Production Facility Waste Sludges and Solids* February 1991.

Notes: The Canadian Petroleum Association and Environment Canada did a joint study to develop a data base of physical and chemical characteristics for six different waste sludges and solids produced by upstream oil production operations. The study involved assembling the data base using information obtained from a comprehensive field sampling and laboratory analytical program. The sampling and analysis involved obtaining three samples of each sludge type from different production facilities. Those sludges sampled include process pond sludge, flare knock-out drum sludge, flare pit sludge, treater bottom sludge, tank bottom sludge, and spill material. The leachate test was conducted using the Canadian General Standards Board Class 9, Miscellaneous Substances CGSB Leachate Extraction Procedure. These are in accordance with U.S. EPA SW-846 "Test Methods for Evaluating Solid Waste."

APPENDIX D

Analytical Results of EPA's 1992 Associated Waste Sampling Program

(Detected Analytes Only)

Crude Oil Tank Bottom Wastes

EPA's 1992 Associated Waste Sampling Program

EPA undertook a sampling effort in 1992 to characterize a number of associated wastes, including crude oil tank bottoms. During this effort, EPA collected samples of 10 tank bottoms (plus four duplicate samples) from nine oil and gas production facilities and four samples from tank bottom reclamation facilities located in Texas, Oklahoma, Louisiana, and New Mexico. In addition, one sample of disposed tank bottoms was collected from one production facility's on-site disposal area. Samples included crude oil stock tank bottoms, heater treater bottoms, and produced water tank bottoms. Tables D-1 and D-2, respectively, illustrate the type and location of the oil and gas production and reclamation facilities where samples were taken, as well as brief descriptions of the samples. Table D-3 summarizes the analyses performed. When sufficient volumes were available, samples were analyzed for metals, volatile and semivolatile organic compounds, general chemistry analytes, and radionuclides. Toxicity Characteristic Leaching Procedure (TCLP) analyses were conducted on four samples, three from production facilities (of which one was analyzed only for metals) and one from a reclamation facility; TCLP analyses were performed either on duplicate samples obtained for that purpose (Sample No. 23145 and 23169, the latter only for metals) or on aliquots from larger samples (Sample No. 23180 and 23634). TCLP results are compared to concentrations established under RCRA Subtitle C to identify wastes that exhibit the hazardous characteristic of toxicity. The tank bottoms sampled are exempt from Subtitle C, so the characterization of tank bottoms below is for illustration purposes only.

For tank bottoms from oil and gas production facilities, the maximum and minimum concentrations of the parameters detected for metals, volatile organic compounds, semivolatile organic compounds, general chemistry analytes, and radionuclides are shown in Tables D-4 through D-8 respectively. Some production facility samples were analyzed as liquids and some as solids, depending on solids content; the tables show minimum and maximum concentrations for each type of sample (in µg/L for liquids, mg/Kg for solids). Tables D-9 through D-13, respectively, show the maximum and minimum concentrations detected for the samples collected from the reclaimers. Finally, Tables D-14 through D-18, respectively, show the concentrations of the parameters detected for the single sample of disposed tank bottoms. Following Table D-18 are the analytical data for each sample.

Discussion of the analytical results below is focused primarily on the samples gathered from the oil and gas production facilities. Many of the analyte concentrations observed for reclamation facility samples are within the ranges of concentrations observed for the oil and gas production facility samples. Where those concentrations differ significantly, the crude oil reclamation facility samples are discussed in more detail.

One sample (No. 23638), tank bottoms collected from the bottom of a 500-bbl production tank at a south-central Oklahoma production facility, may have exhibited the hazardous ignitability characteristic (see Table D-5). None of the remaining samples from oil and gas production facilities exhibited a hazardous characteristic. However, two samples collected from the crude oil reclamation facilities did exhibit a hazardous characteristic. One (No. 23135), dredged from a tank bottoms storage tank in northeast Texas,

exhibited the hazardous ignitability characteristic (see Table D-10). The other (No. 23634), collected from a container which received tank bottoms from an experimental centrifuge, exhibited the toxicity characteristic for benzene (see Table D-12).

Maximum and minimum concentrations for some metals differed by several orders of magnitude. One sample (No. 23156), dredged from a produced water storage tank at a southeast Louisiana production facility, dominated the maximum observed concentrations for metals. Another (No. 23169), dredged from a storage tank at a southwest Texas production facility and analyzed as a duplicate of No. 23168, exhibited concentrations two to five times higher than No. 23168 for almost all metals detected; this may have been the result of laboratory difficulties. Most metal concentrations reported for the disposed tank bottom sample were within the range of the oil and gas production facility samples. However, several of the maximum metals concentrations from the reclamation facility samples were much higher than the maximum metals concentrations in samples from the production facilities. These included cadmium (4 x higher), copper (2 x higher), lead (>3 x higher), mercury (>10 x higher), and nickel (2 x higher).

As noted, the various production facility samples were analyzed variously as either solid or liquid samples. For comparative purposes, the concentrations of metals were compared to Primary Maximum Contaminant Levels (MCLs). This was only for illustrative purposes since the samples analyzed were "waste" samples, rather than environmental samples, and substantial attenuation would occur before exposures, if any, resulted. Of the eight samples analyzed for metals as liquid samples, seven (of seven where detected) exceeded the Primary Maximum Contaminant Level (MCL) for lead. Six samples exceeded the Primary MCLs for barium (six of eight where detected) and cadmium (six of six where detected). Five samples exceeded the Primary MCLs for arsenic (of eight where detected), chromium (of seven where detected), copper (of six where detected), and nickel (of seven where detected). Four samples (of five where detected) exceeded the Primary MCL for mercury. Two samples (of four where detected) exceeded the Primary MCL for selenium.

Similar variations in production facility sample maximum and minimum concentrations were observed for many organic analytes. Benzene was detected in all samples and ranged from 175 to 2,685,800 µg/Kg in eleven samples. Toluene showed similar results. The wide variation across samples is likely due to differences in processes and formation fluids at each respective facility. Only ten of the fifty-seven volatile organic compound (VOC) analytes were detected in one or more samples. Only thirty-seven of the one-hundred seventy-six semi-volatile organic analytes were detected. All of the VOCs detected in the reclamation facility samples were within the range of the production facility samples with the exception of one (No. 23150) which exceeded, by almost three times, the maximum detected production facility concentrations for benzene and toluene (7,946,250 and 10,028,350 µg/Kg, respectively). Volatiles detected in the disposed tank bottom sample were one to two orders of magnitude less than the minimum concentrations detected in the oil and gas production facility samples. Several of the semi-volatile organic compound concentrations were two to five times higher in the reclamation facility samples. Semi-volatile

organic compound concentrations for the disposed tank bottom sample were near the minimum concentrations observed in the oil and gas production facility samples.

Most oil and gas production facility samples exhibited relatively low concentrations of naturally occurring radioactive materials (NORM). The sample collected from the tank bottom reclaimer's centrifuge (No. 23634) exhibited concentrations of gross alpha (601 $\pm$ 32.8 pCi/g) and gross beta (390 $\pm$ 13.2 pCi/g), over an order of magnitude higher than the maximum concentration for production facility samples (see Table D-13). Of samples analyzed as liquids, a production facility sample (51.4 pC/l) and the disposed tank bottom sample (17.9 pC/l) exceeded the Primary MCL for gross alpha (15 pC/l).

Finally, sample splits were requested and provided by EPA at five facilities; however, split sample data was provided to EPA for only one facility (Facility J). Tables 20, 21, and 22 present split sample data for detected volatile organics, detected semi-volatile organics, and metals respectively.

EPA identified sample 23180 and duplicate sample 23181 as being the same as the operator's sample labeled FI Booth Produced Sand and sample 23188 was identified as being the same as the operator's sample labeled Thompson Field Buried Sand. However, discrepancies in some sets of data suggest that samples might have been identified incorrectly in the field, in the laboratory, or in EPA's sample control center. Note that for volatile organics, data for samples 23180 and 23181 match closely but for semi-volatile organics the data for duplicate sample 23181 more closely resembles sample 23188. Volatile and semi-volatile organics were not detected in the operator's split samples. The only metals data that corresponds are the data for samples 23181 and the operator’s Thompson Field Buried Sand. From this limited information it is difficult to determine whether OSW's samples were incorrectly identified and, if so, whether this occurred in the field, in the laboratory, or in EPA's sample control center. Nevertheless, these data provide general insight into the constituents and concentrations of constituents that can be found in certain oilfield tank bottoms.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-1. Production Facility Tank Bottoms Samples
Collected During EPA 1992 Sampling Program

Facility	SCC Episode	Facility Type/Location	Sample number and description		Waste ?
C	4406	Salt water disposal facility Southeast Louisiana	23144: 23145:	Dredged from 210-barrel produced water receiving tank. Duplicate for TCLP analyses	Yes Yes
E	4408	Crude oil production facility Southeast Louisiana	23156:	Dredged from ~25,000-bbl produced water storage tank. Limited quantity of sample collected.	Yes
G	4410	Producing field (wells/battery, mostly oil) Southwest Texas	23168: 23169:	Dredged from storage tank. Duplicate for TCLP analyses. Organics analyzed as duplicate for 23168, metals as TCLP.	No No
H	4410	Producing field (wells/battery, mostly oil) Southwest Texas	23170:	Dredged from storage tank.	No
J	4439	Oil production facility Southeast Texas	23180: 23181: 23182: 23188:	Collected from in-ground tank after free oil had been removed. Duplicate of 23180 Collected for TCLP (not used--laboratory analyzed aliquot of 23180 for TCLP also) Collected from disposal site--burial under two feet of overburden follows "washing" with water	Yes Yes Yes Yes
K	4455	Oil production facility (wells/tanks) West-central Texas	23627:	Collected from hatch in bottom of crude oil storage tank (no oil in tank at time of sampling)	Yes

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-1. Production Facility Tank Bottoms Samples Collected During EPA 1992 Sampling Program

Facility	SCC Episode	Facility Type/Location	Sample number and description		Waste ?
O	4459	Centralized oil field production facility West Texas	23638:	Collected from bottom of 500-bbl production tank (empty except for layer of bottoms)	No
Q	4462	Oil production facility (CO_2 EOR) South-central Oklahoma	23642: 23644:	Tank bottoms sample collected from 500-bbl crude oil tank Heater-treater vessel bottoms collected from above-ground pile removed from H-T about one week earlier	No Yes
T	4465	Oil collection facility Oklahoma City, Oklahoma	23654:	Collected from BS&W storage tank following removal of water from tank	No

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-2. Reclamation Facility Tank Bottoms Samples Collected During EPA 1992 Sampling Program

Facility	SCC Episode	Facility Type/Location	Sample number and description	Waste ?
A	4404	Tank bottom reclaimer Northeast Texas	23135: Dredged from tank bottoms storage tank (~ 25,000 bbl)	No
D	4407	Crude oil reclaimer Southeast Texas	23150: Dredged from 25,000-bbl storage tank	No
N	4458	Crude oil reclaimer Southeast New Mexico	23633: Collected from bottom of 500-bbl BS&W storage tank (empty except for layer of bottoms)	Yes
			23634: Collected from container that received bottoms from conveyor leaving experimental centrifuge	Yes

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-3. EPA 1992 Sampling Program: Tank Bottom Analyses By Facility Type

Facility Type	Number of Samples Analyzed (Plus Number of Duplicates Analyzed)					
	TCLP	Metals	Volatile Organics	Semivolatile Organics	General Chemistry	Radio-nuclides
Production Facility	3	10 (3)	10 (3)	10 (3)	9 (1)	7 (1)
Crude Oil Reclaimer	1	4	4	4	4	3
Disposed Tank Bottoms	0	1	1	1	1	1

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-4. EPA 1992 Sampling Program: Production Facility Tank Bottoms - General Chemistry Analytes

Analyte	Units (solid)	Detects Per Total Analyzed	Maximum	Minimum	Units (aqueous)	Detects Per Total Analyzed	Single Sample Concentration
Acidity	NA	NA	*	*	mg/L CaCO3	1/1	99.6
pH	std. units	9/9	8.72	5.02	std. units	1/1	6.05
Carbon, total organic	mg/Kg	6/6	626,000	2,290	mg/L	1/1	657,000
Chloride	mg/Kg	6/6	83,900	5.50	mg/L	1/1	52,000
Corrosivity	mmpy	4/6	0.90	0.11	mmpy	0/1	*
Cyanide, Total	mg/Kg	2/9	0.733	0.419	mg/L	0/1	*
Flashpoint, closed cup	deg. F	4/8	210	>75	deg. F	1/1	190
Fluoride	mg/Kg	3/6	78	17.30	mg/L	0/1	*
Nitrogen, Nitrate+Nitrite	mg/Kg	2/6	13	10.5	mg/L	0/1	*
Oil & Grease, Total	mg/Kg	9/9	698,600	4,100	mg/L	1/1	603,000
Oil Content, percent	%	9/9	92.80	0.79	NA	NA	*
Oxygen Demand, Biochemcial 5-day Tot.	mg/Kg	6/6	219,480	291	mg/L	1/1	32,800
Oxygen Demand, Chemical	NA	NA	*	*	mg/L	1/1	380,050
Phenols	NA	NA	*	*	mg/L	1/1	1.358
Reactive Cyanide	mg/Kg	1/9	0.26	0.26	NA	NA	*
Reactive Sulfide	mg/Kg	3/9	120	53.50	NA	NA	*
Salinity	NA	NA	*	*	Salinity #	1/1	0.020
Solids, percent	%	3/3	78	30.80	NA	NA	*

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-4. EPA 1992 Sampling Program: Production Facility Tank Bottoms - General Chemistry Analytes
(continued)

Analyte	Units (solid)	Detects Per Total Analyzed	Maximum	Minimum	Units (aqueous)	Detects Per Total Analyzed	Single Sample Concentration
Solids, Total Dissolved	NA	NA	*	*	mg/L	1/1	293,000
Solids, Total Suspended	NA	NA	*	*	mg/L	1/1	27,800
Specific Conductance	NA	NA	*	*	umhos/cm	NA	*
Sulfide	mg/Kg	4/6	519.4	111	mg/L	1/1	356

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-5. EPA 1992 Sampling Program: Production Facility Tank Bottoms - Metals

Metals	Detects Per Total Analyzed	Maximum (µg/Kg)	Minimum (µg/Kg)	Detects Per Total Analyzed	Maximum (µg/L)	Minimum (µg/L)	Detects Per Total Analyzed	TCLP Maximum (µg/L)	TCLP Minimum (µg/L)
Aluminum	8/8	2,240,000	20,300	5/5	159,000	14,000	3/3	2,070	165
Antimony	0/8	*	*	1/5	229	229	1/3	43.2	43.2
Arsenic	8/8	166,000	470	5/5	500	7.3	3/3	59.8	2.3
Barium	8/8	2,910,000	1,500	5/5	816,000	895	3/3	5,220	1,670
Beryllium	7/8	390	110	2/5	19.7	19.6	1/3	1.6	1.6
Boron	6/8	25,800	3,700	2/5	19,900	4,850	3/3	1,610	850
Cadmium	6/8	2,000	320	5/5	425	78.2	1/3	7	7
Calcium	8/8	23,600,000	1,410,000	5/5	6,310,000	881,000	3/3	6,310,000	146,000
Chromium	8/8	71,000	1,700	5/5	19,900	1,400	2/3	13.4	10.5
Cobalt	5/8	6,900	1,100	3/5	402	76.4	0/3	*	*
Copper	8/8	309,000	4,000	5/5	18,800	3,610	1/3	18.4	18.4
Iron	8/8	27,800,000	2,010,000	5/5	2,610,000	556,000	3/3	73,000	4,980
Lead	8/8	892,000	9,100	5/5	62,800	1,930	2/3	420	50
Magnesium	8/8	3,490,000	392,000	5/5	1,290,000	22,600	3/3	18,200	5,800
Manganese	8/8	440,000	8,700	5/5	20,300	4,890	3/3	1,400	905
Mercury	2/8	850	460	5/5	48.5	0.22	0/3	*	*
Molybdenum	4/8	9,400	2,100	5/5	4,190	328	1/3	10.5	10.5
Nickel	6/8	315,000	8,800	5/5	4,980	678	2/3	89.3	73.8

(continued)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-5. EPA 1992 Sampling Program: Production Facility Tank Bottoms - Metals
(continued)

Metals	Detects Per Total Analyzed	Maximum (µg/Kg)	Minimum (µg/Kg)	Detects Per Total Analyzed	Maximum (µg/L)	Minimum (µg/L)	Detects Per Total Analyzed	TCLP Maximum (µg/L)	TCLP Minimum (µg/L)
Selenium	4/8	2,300	760	3/5	297	19.8	1/3	33.3	33.3
Silver	0/8	*	*	2/5	22	10.5	0/3	*	*
Sodium	7/8	58,700,000	2,620,000	5/5	46,600,000	641,000	NA	*	*
Strontium	8/8	402,000	26,500	5/5	290,000	19,300	3/3	6,640	3,310
Sulfur	8/8	11,400,000	420,000	5/5	872,000	22,900	3/3	42,200	4,130
Thallium	4/8	1,700	280	1/5	3,470	3,470	1/3	26.4	26.4
Tin	5/8	17,100	2,900	4/5	586	189	0/3	*	*
Titanium	8/8	22,000	360	5/5	3,180	136	0/3	*	*
Vanadium	8/8	41,300	1,400	5/5	628	139	0/3	*	*
Yttrium	6/8	5,100	590	5/5	106	22.4	2/3	24.4	3.9
Zinc	8/8	3,020,000	20,400	5/5	150,000	4,140	3/3	2,950	567

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-6. EPA 1992 Sampling Program: Production Facility Tank Bottoms - Volatile Organic Compounds

Compound	Detects Per Total Analyzed	Maximum (ug/Kg)	Minimum (ug/Kg)	Detects Per Total Analyzed	Single Sample Concentration TCLP (ug/L)
ACETONE	8/13	4,849,472	3,689	0/2	*
BENZENE	13/13	2,685,800	175	1/2	27
CARBON TETRACHLORIDE	2/13	121	34	0/2	*
CHLOROBENZENE	1/13	>20,000	>20,000	0/2	*
ETHYLBENZENE	13/13	2,384,350	1,716	1/2	26
METHYLENE CHLORIDE	1/13	816,300	816,300	0/2	*
M-XYLENE	13/13	3,096,700	15	1/2	14
O- + P-XYLENE	13/13	1,505,950	23	1/2	25
TOLUENE	13/13	3,562,700	2,134	1/2	56
4-METHYL-2-PENTANONE	4/13	120,156	36,580	0/2	*

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-7. EPA 1992 Sampling Program: Production Facility Tank Bottoms - Semivolatile Organic Compounds

Compound	Detects Per Total Analyzed	Maximum (ug/Kg)	Minimum (ug/Kg)	Detects Per Total Analyzed	Maximum (ug/L)	Minimum (ug/L)	Detects Per Total Analyzed	TCLP Maximum (ug/L)	TCLP Minimum (ug/L)
B-NAPHTHYLAMINE	1/10	1,820	1,820	0/3	*	*	0/2	*	*
BENZO(GHI)PERYLENE	1/10	698	698	0/3	*	*	0/2	*	*
BIPHENYL	3/10	16,088	7,046	0/3	*	*	1/2	11	11
BIS(2-ETHYLHEXYL)PHTHALATE	1/10	2,659	2,659	0/3	*	*	0/2	*	*
BUTYL BENZYL PHTHALATE	1/10	2,321	2,321	0/3	*	*	0/2	*	*
CHRYSENE	1/10	5,156	5,156	0/3	*	*	0/2	*	*
DIBENZOTHIOPHENE	1/10	24,270	24,270	0/3	*	*	0/2	*	*
DIBENZO(A,H)ANTHRACENE	1/10	3,304	3,304	0/3	*	*	0/2	*	*
DI-N-OCTYL PHTHALATE	1/10	10,600	10,600	0/3	*	*	0/2	*	*
FLUORENE	3/10	9,735	4,079	1/3	24,235	24,235	0/2	*	*
HEXACHLOROETHANE	1/10	418	418	0/3	*	*	0/2	*	*
NAPHTHALENE	5/10	268,370	9,777	0/3	*	*	2/2	136	30
N-DECANE (N-C10)	9/10	6,056,300	103,983	3/3	5,228,700	427,143	1/2	47	47
N-DOCOSANE (N-C22)	9/10	4,137,000	57,259	3/3	693,659	120,312	0/2	*	*
N-DODECANE (N-C12)	10/10	5,073,600	11,296	3/3	5,902,300	1,909,294	1/2	60	60
N-EICOSANE (N-C20)	8/10	3,238,900	178,960	3/3	755,800	137,175	1/2	11	11
N-HEXACOSANE (N-C26)	7/10	1,735,610	447	3/3	476,347	61,710	0/2	*	*
N-HEXADECANE (N-C16)	8/10	5,780,300	368,090	3/3	3,560,000	1,308,095	1/2	39	39
N-NITROSOMORPHOLINE	1/10	290,510	290,510	0/3	*	*	0/2	*	*

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-7. EPA 1992 Sampling Program: Production Facility Tank Bottoms - Semivolatile Organic Compounds
(continued)

Compound	Detects Per Total Analyzed	Maximum (ug/Kg)	Minimum (ug/Kg)	Detects Per Total Analyzed	Maximum (ug/L)	Minimum (ug/L)	Detects Per Total Analyzed	TCLP Maximum (ug/L)	TCLP Minimum (ug/L)
N-OCTACOSANE (N-C28)	6/10	1,000,260	525	3/3	1,011,170	175,857	0/2	*	*
N-OCTADECANE (N-C18)	7/10	5,013,100	>153,800	3/3	1,303,429	170,574	1/2	10	10
N-TETRACOSANE (N-C24)	8/10	2,398,500	60,012	3/3	507,247	161,246	0/2	*	*
N-TETRADECANE (N-C14)	9/10	5,496,900	1,962	3/3	5,596,200	1,798,143	1/2	18	18
N-TRIACONTANE (N-C30)	6/10	597,690	1,010	3/3	1,083,350	133,714	0/2	*	*
P-CRESOL	0/10	*	*	0/3	*	*	1/2	17	17
P-CYMENE	5/10	301,970	8,957	2/3	230,750	74,555	1/2	11	11
PENTACHLOROPHENOL	1/10	1,890	1,890	0/3	*	*	0/2	*	*
PHENANTHRENE	6/10	147,590	8,042	2/3	165,518	71,282	0/2	*	*
PHENOL	1/10	68	68	0/3	*	*	0/2	*	*
1-METHYLFLUORENE	6/10	572,030	26,651	1/3	149,963	149,963	1/2	15	15
1-METHYLPHENANTHRENE	7/10	653,520	15,337	1/3	215,187	215,187	0/2	*	*
1,4-DICHLOROBENZENE	1/10	351	351	0/3	*	*	0/2	*	*
2-ISOPROPYLNAPHTHALENE	4/10	2,522,310	4,924	0/3	*	*	1/2	230,840	230,840
2-METHYLNAPHTHALENE	9/10	809,230	21,914	2/3	485,765	278,429	2/2	39	36
2,4-DIMETHYLPHENOL	1/10	30	30	0/3	*	*	0/2	*	*
3,6-DIMETHYLPHENANTHRENE	2/10	709,070	454,050	1/3	289,130	289,130	0/2	*	*
4-AMINOBIPHENYL	1/10	119,423	119,423	0/3	*	*	0/2	*	*

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-8.
EPA 1992 Sampling Program: Production Facility Tank Bottoms - Radionuclides

Radionuclide	Detects Per Total Analyzed	Maximum (pCi/g)	Minimum (pCi/g)	Detects Per Total Analyzed	Maximum (pCi/L)	Minimum (pCi/L)
GROSS ALPHA	5/6	51.4	0.0	2/2	19.1	12.8
GROSS BETA	6/6	33.9	1.1	2/2	27.4	15.5
LEAD 210	2/4	4.7	0.0	2/2	1.3	1.2
RADIUM 226	5/6	3.1	0.0	2/2	1.2	1.0
RADIUM 228	5/6	1.9	0.0	1/2	0.3	0.3

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-9.
EPA 1992 Sampling Program: Reclamation Facility Tank Bottoms - General Chemistry Analytes

Analyte	Units (solid)	Detects Per Total Analyzed	Maximum	Minimum
pH	std. units	4/4	8.60	5.53
Carbon, total organic	mg/Kg	2/2	847,000	273,000
Chloride	mg/Kg	2/2	16,987	2,686
Corrosivity	mmpy	2/2	0.70	0.12
Cyanide, Total	mg/Kg	3/4	2.910	0.144
Flashpoint, closed cup	deg. F	3/4	>210	90
Fluoride	mg/Kg	2/2	188	75.9
Nitrogen, Nitrate+Nitrite	mg/Kg	1/1	9.03	9
Oil & Grease, Total	mg/Kg	4/4	684,124	114,287
Oil Content, percent	%	4/4	90.1	24.2
Oxygen Demand, Biochemcial 5-day Tot.	mg/Kg	2/2	20,924	9,152
Reactive Sulfide	mg/Kg	1/4	165.7	165.7
Solids, percent	%	2/2	69.3	64.9
Sulfide	mg/Kg	2/2	521.2	176.7

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-10. EPA 1992 Sampling Program: Reclamation Facility Tank Bottoms - Metals

Metal	Detects Per Total Analyzed	Maximum (ug/Kg)	Minimum (ug/Kg)	Detects Per Total Analyzed	Single Sample Concentration TCLP (ug/L)
Aluminum	4/4	3,770,000	17,200	1/1	291
Antimony	1/4	1,400	1,400	0/1	*
Arsenic	3/4	39,800	5,000	0/1	*
Barium	4/4	476,000	22,700	1/1	814
Beryllium	3/4	400	180	1/1	1.9
Boron	3/4	35,800	4,800	1/1	437
Cadmium	3/4	9,400	3,600	1/1	6.1
Calcium	4/4	53,700,000	98,800	1/1	581,000
Chromium	3/4	89,800	39,000	0/1	*
Cobalt	3/4	15,900	8,200	0/1	*
Copper	4/4	577,000	5,600	0/1	*
Iron	4/4	111,000,000	740,000	1/1	83,200
Lead	3/4	2,970,000	148,000	0/1	*
Magnesium	3/4	5,920,000	1,120,000	1/1	29,400
Manganese	4/4	451,000	3,200	1/1	1,100
Mercury	2/4	9,110	3,500	0/1	*
Molybdenum	3/4	30,100	7,700	1/1	13.6
Nickel	4/4	122,000	4,000	0/1	*

(continued)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-10. EPA 1992 Sampling Program: Reclamation Facility Tank Bottoms - Metals
(continued)

Metal	Detects Per Total Analyzed	Maximum (ug/Kg)	Minimum (ug/Kg)	Detects Per Total Analyzed	Single Sample Concentration TCLP (ug/L)
Selenium	1/4	4,100	4,100	0/1	*
Silver	1/4	230	230	01	*
Sodium	3/4	20,300,000	14,200,000	0/1	*
Strontium	4/4	1,120,000	9,100	1/1	7,550
Sulfur	4/4	72,900,000	2,330,000	1/1	58,900
Thallium	1/4	7,300	7,300	1/1	22.9
Tin	3/4	27,100	2,800	0/1	*
Titanium	4/4	52,100	320	0/1	*
Vanadium	4/4	20,600	3,400	0/1	*
Yttrium	3/4	3,400	1,100	0/1	*
Zinc	3/4	7,960,000	1,320,000	0/1	*

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-11. EPA 1992 Sampling Program: Reclamation Facility Tank Bottoms - Volatile Organic Compounds

Compound	Detects Per Total Analyzed	Maximum (ug/Kg)	Minimum (1) (ug/Kg)	Detects Per Total Analyzed	Single Sample Concentration TCLP (ug/L)
ACETONE	3/4	412,460	53,064	0/1	*
BENZENE	4/4	7,946,250	>20,000	1/1	1,195
CARBON DISUFIDE	2/4	1,792	1,373	0/1	*
ETHYLBENZENE	4/4	1,833,000	>20,000	1/1	689
METHYLENE CHLORIDE	2/4	35	32	0/1	*
M-XYLENE	4/4	2,861,200	68,996	1/1	348
O- + P-XYLENE	4/4	1,452,100	36,045	1/1	172
TOLUENE	4/4	10,028,350	>20,000	1/1	2,379
4-METHYL-2-PENTANONE	2/4	26,119	9,302	0/1	*

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-12. EPA 1992 Sampling Program: Reclamation Facility Tank Bottoms - Semivolatile Organic Compounds

Compound	Detects Per Total Analyzed	Maximum (ug/Kg)	Minimum (ug/Kg)	Detects Per Total Analyzed	Single Sample Concentration (ug/L)	Detects Per Total Analyzed	Single Sample Concentration TCLP (ug/L)
BENZOIC ACID	0/3	*	*	0/1	*	1//1	75
BIPHENYL	1/3	68,923	68,923	0/1	*	0/1	*
CHRYSENE	1/3	12,445	12,445	1/1	9,898	0/1	*
DIBENZOFURAN	1/3	56,432	56,432	0/1	*	1/1	19
DIBENZOTHIOPHENE	1/3	126,500	126,500	0/1	*	0/1	*
NAPHTHALENE	2/3	202,890	72	1/1	39,630	0/1	*
N-DECANE (N-C10)	3/3	1,966,440	950,182	1/1	202,554	0/1	*
N-DOCOSANE (N-C22)	3/3	3,173,333	80,936	1/1	629,373	0/1	*
N-DODECANE (N-C12)	3/3	3,024,700	1,188,330	1/1	925,962	0/1	*
N-EICOSANE (N-C20)	3/3	3,839,633	346,640	1/1	670,631	0/1	*
N-HEXACOSANE (N-C26)	2/3	1,795,000	541,636	1/1	402,235	0/1	*
N-HEXADECANE (N-C16)	3/3	3,974,033	620,530	1/1	1,304,115	0/1	*
N-OCTACOSANE (N-C28)	2/3	1,669,133	414,055	1/1	14,029	0/1	*
N-OCTADECANE (N-C18)	3/3	4,415,633	289,950	1/1	1,368,154	0/1	*
N-TETRACOSANE (N-C24)	3/3	2,373,633	176,610	1/1	440,750	0/1	*
N-TETRADECANE (N-C14)	3/3	5,583,900	475,150	1/1	1,448,846	0/1	*
N-TRIACONTANE (N-C30)	2/3	1,833,033	415,759	1/1	273,677	0/1	*
P-CRESOL	0/3	*	*	0/1	*	1/1	24

(continued)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-12. EPA 1992 Sampling Program: Reclamation Facility Tank Bottoms - Semivolatile Organic Compounds
(continued)

Compound	Detects Per Total Analyzed	Maximum (ug/Kg)	Minimum (ug/Kg)	Detects Per Total Analyzed	Single Sample Concentration (ug/L)	Detects Per Total Analyzed	Single Sample Concentration TCLP (ug/L)
P-CYMENE	1/3	100,400	100,400	1/1	32,347	0/1	*
PHENANTHRENE	1/3	86,050	86,050	1/1	52,847	0/1	*
STYRENE	0/3	*	*	1/1	7,180	0/1	*
1-METHYLPHENANTHRENE	1/3	231,843	231,843	1/1	158,961	0/1	*
2-ISOPROPYLNAPHTHALENE	2/3	694,533	270,660	0/1	*	0/1	*
2-METHYLNAPHTHALENE	3/3	705,733	102,880	1/1	74,605	1/1	43
2,4-DIMETHYLPHENOL	1/3	12	12	0/1	*	0/1	*

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris
(U.S. EPA, January 2000)
Table D-13. EPA 1992 Sampling Program:
Reclamation Facility Tank Bottoms - Radionuclides

Radionuclide	Detects Per Total Analyzed	Maximum (pCi/g)	Minimum (pCi/g)
GROSS ALPHA	3/3	601.0	44.1
GROSS BETA	2/3	390.0	28.4
LEAD 210	2/2	9.5	2.0
RADIUM 226	3/3	18.0	<0.7
RADIUM 228	3/3	0.3	0.0

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris
(U.S. EPA, January 2000)
Table D-14. EPA 1992 Sampling Program:
Disposed Tank Bottoms - General Chemistry Analytes

Analyte	Units (solid)	Single Sample Concentration
pH	std. units	8.18
Carbon, total organic	mg/Kg	24,000
Chloride	mg/Kg	20.3
Nitrogen, Nitrate+Nitrite	mg/Kg	16.50
Oil & Grease, Total	mg/Kg	13,100
Oil Content, percent	%	4.19
Oxygen Demand, Biochemcial 5-day Tot.	mg/Kg	419

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris
(U.S. EPA, January 2000)
Table D-15. EPA 1992 Sampling Program:
Disposed Tank Bottoms - Metals

Metal	Single Sample Concentration (ug/Kg)
Aluminum	22,200,000
Arsenic	740
Barium	537,000
Beryllium	2,500
Boron	74,700
Cadmium	4,800
Calcium	50,300,000
Chromium	15,600
Cobalt	28,700
Copper	42,000
Iron	4,760,000
Lead	89,900
Magnesium	9,650,000
Manganese	907,000
Nickel	32,100
Sodium	15,600,000
Strontium	98,400
Sulfur	953,000
Thallium	470
Tin	4,800
Titanium	131,000
Vanadium	17,300
Yttrium	53,300
Zinc	33,100

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris
(U.S. EPA, January 2000)
Table D-16. EPA 1992 Sampling Program:
Disposed Tank Bottoms - Volatile Organic Compounds

Compound	Single Sample Concentration (ug/Kg)
ACETONE	166
BENZENE	28
CARBONTETRACHLORIDE	152
ETHYLBENZENE	525
M-XYLENE	19
O- + P-XYLENE	43
TOLUENE	220

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris
(U.S. EPA, January 2000)
Table D-17. EPA 1992 Sampling Program:
Disposed Tank Bottoms - Semivolatile Organic Compounds

Compound	Single Sample Concentration (ug/Kg)
DI-N-OCTYL PHTHALATE	9,373
NAPHTHALENE	3,926
N-DODECANE (N-C12)	12,070
PENTAMETHYLBENZENE	7,286
PHENANTHRENE	8,749
1-METHYLFLUORENE	29,462
1-METHYLPHENANTHRENE	17,823
2-METHYLNAPHTHALENE	23,921

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris
(U.S. EPA, January 2000)
Table D-18.
EPA 1992 Sampling Program:
Disposed Tank Bottoms - Radionuclides

Radionuclide	(pCi/L)
GROSS ALPHA	17.9
GROSS BETA	21.2
LEAD 210	1.6
RADIUM 226	2.0
RADIUM 228	1.4

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-19. Facility J Split Samples
Detected Volatile Organics

Analyte	Sample number / Units						
	23180	23181	Operator's FI Booth	23180	23188	Operator's Thompson	Operator's Thompson
	ug/Kg	Duplicate ug/Kg	ug/Kg	TCLP ug/L	ug/Kg	ug/Kg	TCLP mg/L
ACETONE	3689.00	4598.00	ND	ND	166.00	ND	NA
BENZENE	175.00	618.00	ND	27.00	28.00	ND	ND
ETHYLBENZENE	1716.00	1745.00	ND	26.00	525.00	ND	NA
METHYL ETHYL KETONE (2-BUTANONE)	ND	ND	ND	ND	ND	ND	ND
METHYLENE CHLORIDE	121.00	34.00	ND	ND	152.00	ND	NA
M-XYLENE	15.00	17.00	ND	14.00	19.00	ND	NA
O- + P-XYLENE	24.00	23.00	ND	25.00	43.00	ND	NA
TOLUENE	2134.00	2276.00	ND	56.00	220.00	ND	ND

NA Not analyzed
ND Not Detected

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-20. Facility J Split Samples
Detected Semi-Volatile Organics

Analyte	Sample number / Units						
	23180	23181	Operqator's FI Booth	23180	23188	Operator's Thompson	Operator's Thompson
	ug/Kg	Duplicate ug/Kg	ug/Kg	TCLP ug/L	ug/Kg	ug/Kg	TCLP mg/L
DI-N-OCTYL PHTHALATE	ND	10600.00	ND	ND	9373.00	ND	NA
FLUORENE	5913.00	4079.00	ND	ND	ND	ND	NA
NAPHTHALENE	9777.00	ND	ND	30.00	3926.00	ND	NA
N-DODECANE (N-C12)	14840.00	11296.00	NA	ND	12070.0	NA	NA
N-TETRADECANE (N-C14)	ND	17347.00	NA	ND	ND	NA	NA
PENTAMETHYLBENZENE	ND	ND	NA	ND	7286.00	NA	NA
PHENANTHRENE	11304.00	8042.00	ND	ND	8749.00	ND	NA
1-METHYLFLUORENE	36524.00	26651.00	NA	15.00	29462.0	NA	NA

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-20. Facility J Split Samples
Detected Semi-Volatile Organics

Analyte	Sample number / Units						
	23180	23181	Operqator's FI Booth	23180	23188	Operator's Thompson	Operator's Thompson
	ug/Kg	Duplicate ug/Kg	ug/Kg	TCLP ug/L	ug/Kg	ug/Kg	TCLP mg/L
1-METHYLPHENANTHRENE	21981.00	15337.00	NA	ND	17823.0	NA	NA
2-METHYLNAPHTHALENE	42205.00	21914.00	8500	36.00	23921.0	ND	NA

NA Not analyzed
ND Not detected

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-21. Facility J Split Samples
Metals

Analyte	Sample number / Units					
	23180	23181	Operator's FI Booth	23180	23188	Operator's Thompson
	mg/Kg	Duplicate mg/Kg	mg/Kg	TCLP ug/L	mg/Kg	mg/Kg
Aluminum	2240.00	645.00	4190.00	2070.00	22200.00	947.00
Antimony	ND	ND	ND	ND	ND	ND
Arsenic	1.20	1.00	ND	59.80	0.74	ND
Barium	61.10	246.00	39.20	2360.00	537.00	249.00
Beryllium	0.25	0.11	0.40	ND	2.50	ND
Boron	8.60	3.70	17.90	1610.00	74.70	ND
Cadmium	0.45	0.32	ND	ND	4.80	ND
Calcium	4920.00	1740.00	4630.00	225000.00	50300.00	1560.00
Chromium	1.70	1.60	3.40	13.40	15.60	2.20
Cobalt	2.60	1.20	2.90	ND	28.70	ND
Copper	5.20	4.00	4.40	ND	42.00	4.20

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table D-21. Facility J Split Samples
Metals

Analyte	Sample number / Units					
	23180	23181	Operator's FI Booth	23180	23188	Operator's Thompson
	mg/Kg	Duplicate mg/Kg	mg/Kg	TCLP ug/L	mg/Kg	mg/Kg
(continued)						
Iron	4380.00	2450.00	5190.00	4980.00	4760.00	2610.00
Lead	9.10	14.10	7.50	50.00	89.90	16.00
Lithium	NA	NA	5.00	NA	NA	ND
Magnesium	1000.00	392.00	1240.00	18200.00	9650.00	430.00
Manganese	86.20	81.30	93.90	1160.00	907.00	78.10
Mercury	ND	ND	NA	ND	ND	NA
Molybdenum	ND	ND	ND	ND	ND	ND
Nickel	ND	ND	4.20	ND	32.10	ND
Potassium	NA	NA	1320.00	NA	NA	ND
Selenium	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND
Sodium	16300.00	3900.00	7680.00	NA	15600.00	3790.00
Strontium	102.00	45.60	NA	6520.00	98.40	NA
Sulfur	950.00	420.00	NA	42200.00	953.00	NA
Thallium	0.28	0.38	ND	ND	0.47	ND
Tin	ND	3.30	ND	ND	4.80	ND
Titanium	11.80	10.10	40.80	ND	131.00	16.40
Vanadium	1.80	1.40	4.60	ND	17.30	1.80
Yttrium	5.10	3.10	NA	24.40	53.30	NA
Zinc	31.50	20.40	31.30	567.00	33.10	22.10

NA Not analyzed
ND Not detected

APPENDIX E

Analytical Results of EPA's 1992 Coastal Sampling Program

(Detected Analytes Only)

Crude Oil Tank Bottom Wastes

EPA's 1992 Coastal Sampling Program

EPA also conducted a sampling program in 1992 as part of an effort to develop effluent limitation guidelines for discharge from coastal oil and gas facilities. EPA collected tank bottoms from six oil and gas production facilities located in coastal regions of Louisiana and Texas. Samples included crude oil stock tank bottoms, heater treater bottoms, produced water tank bottoms, and solids from parallel plate coalescer treatment of produced water. Table E-1 illustrates the type and location of the production facilities where samples were taken, as well as brief descriptions of the samples. Table E-2 summarizes the analyses performed; because insufficient volumes of some samples could be collected, not all analyses were performed on all samples. Finally, Tables E-3 through E-7, respectively, list the detected analytes reported for the samples. No TCLP analyses were conducted on the samples. Where samples were analyzed as aqueous samples, analytical results allow for comparison to concentrations established under RCRA Subtitle C to identify wastes that exhibit the hazardous characteristic of toxicity. The wastes sampled are exempt from Subtitle C, so the characterization of wastes below is for illustration purposes only.

A total of five samples (three samples and two duplicates) were analyzed for volatile organic compounds; of these, four (two samples and two duplicates) were aqueous samples. All four aqueous samples exhibited the hazardous characteristic of toxicity for benzene, with concentrations ranging from 38,747 µg/L (Sample 22378) to 118,965 µg/L (Sample 23099). No other constituent was detected at a concentration that exceeded the toxicity characteristic threshold. Toluene concentrations for the same samples ranged from 62,592 µg/L (Sample 22378) to 172,035 µg/L (Sample 23098).

A total of five samples were analyzed for metals; of these, only one (Sample 23424) was analyzed as liquid. This sample exceeded the Primary MCL for barium (45,947 µg/L), cadmium (25.6 µg/L), and chromium (137.7 µg/L); as well as the Secondary MCL for chloride (43,000 mg/L), iron (245,760 µg/L), manganese (2,765.3 µg/L), and silver (182.7 µg/L).

Concentrations of some detected semivolatile organic compounds differed by several orders of magnitude. The same was observed for radionuclides.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-1. Production Facility Tank Bottom Samples Collected During EPA 1992 Coastal Sampling Program

Facility	SCC Episode	Facility Type/Location	Sample number and description
C1	4379	Crude oil & gas production facility Bull Camp, Louisiana	22361: Tank bottoms sample taken from 5,000 bbl storage tank for produced water from FWKO and heater-treater. Contained visible paraffin particles.
C2	4396	Crude oil production facility Clam Lake, Texas	23083: Tank bottoms sample taken from 3,000 bbl storage/settling tank for produced water from FWKO
C3	4397	Crude oil & gas production facility Caplen, Louisiana	23098: Tank bottoms sample taken from 1,000 bbl storage/settling tank for produced water from gun barrel, which followed 3-phase separator 23099: (duplicate sample)
C4	4454	Crude oil & gas production facility Lake Salvador, Louisiana	23620: Tank bottoms sample composited from partial samples taken from two 1,000 bbl storage/settling tanks for produced water from heater-treater
C5	4436	Crude oil & gas production facility Bayou Sale, Louisiana	23424: Treatment solids (liquid sample) from parallel plate coalescer treatment of produced water, which followed gun barrel
C6	4380	Crude oil & gas production facility Chacahoula, Louisiana	22378: Open air storage (in 55-gallon drums) of heater-treater cleanout wastes (sands) 22379: (duplicate sample)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-2. EPA 1992 Coastal Sampling Program: Tank Bottom Analyses

Number of Samples Analyzed (Plus Number of Duplicates Analyzed)					
TCLP	**Metals**	**Volatile Organics**	**Semivolatile Organics**	**General Chemistry**	**Radio-nuclides**
0	5 (2)	3 (2)	3 (2)	4 (2)	6 (2)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-3. EPA 1992 Coastal Sampling Program: Tank Bottoms - Detected General Chemistry Analytes

Analyte	Heater Treater Sand (22378) mg/Kg	Heater Treater Sand Dup-22378 (22379) mg/Kg	Treatment Solids (23424) mg/L	Tank Bottoms (23098) µg/L	Tank Bottoms Dup-23098 (23099) µg/L	Tank Bottoms (23083) µg/L
Acidity	NA	NA	110	NA	NA	NA
pH [1]	6.7	6.7	6.45	7.63	7.76	10.5
Carbon, Total Organic	20,000	64,000	1,376	112,061	120,159	190,843
Chloride	25,000	24,000	43,000	6,388	8,055	909
Corrosivity (mm/yr)	0.54	0.54	0.44	ND	ND	ND
Fluoride	1.30	1.30	0.66	203	232	198
Ignitability (°F)	128	136	200	ND(10)	ND	ND
Nitrogen, ammonia	NA	NA	40	NA	NA	NA
Nitrogen, Nitrate+Nitrite	19	9.30	1.30	ND(10)	ND(10)	ND(10)
Oil & Grease [2]	84,000	89,000	882	133,657	102,839	219,480
Oil Content (%)	ND	ND	ND	12.7	13.7	19
Oxygen Demand, Biochemical [1]	34,000	16,000	1,524	92,000	84,000	48,000
Oxygen Demand, Chemical	NA	NA	1,717	NA	NA	NA
Phenols, Total	NA	NA	5.5	NA	NA	NA
Reactive Cyanide	ND	ND	ND	ND(250)	ND(250)	ND(250)
Reactive Sulfide, Total Releasable	200	120	ND	ND(500)	ND(500)	ND(500)
Salinity (unitless)	NA	NA	54.1	NA	NA	NA

(continued)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-3. EPA 1992 Coastal Sampling Program: Tank Bottoms - Detected General Chemistry Analytes
(continued)

Analyte	Heater Treater Sand (22378) mg/Kg	Heater Treater Sand Dup-22378 (22379) mg/Kg	Treatment Solids (23424) mg/L	Tank Bottoms (23098) µg/L	Tank Bottoms Dup-23098 (23099) µg/L	Tank Bottoms (23083) µg/L
Solids, percent or total	80.0%	76.0%	ND	599,688 µg/L	582,767 µg/L	668,093 µg/L
Solids, Total Disolved	NA	NA	68,773	NA	NA	NA
Solids, Total Suspended [2]	NA	NA	1,790	NA	NA	NA
Specific Conductivity (umho)	ND	ND	110,000	ND	ND	ND
Sulfate	NA	NA	ND(10)	ND	ND	ND
Sulfide	1,800	2,000	32.8[3]	14.9	41.6	ND

Notes: ND = not detected. Values in parentheses are detection limits.
NA = not analyzed for in this aliquot.
[1] Composite samples.
[2] Grab samples.
[3] This value is considered "acceptable quality, but may be minimum value" due to an error in sample preparation at the laboratory.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-4. EPA 1992 Coastal Sampling Program: Tank Bottoms - Detected Metals

Metals	Heater-Treater Sand (22378) µg/Kg	Heater-Treater Sand-Duplicate (22379) µg/Kg	Treatment Solids (23424) µg/L	Tank Bottoms (23098) µg/Kg	Tank Bottoms Dup-23098 (23099) µg/Kg	Tank Bottoms (23083) µg/Kg	Tank Bottoms (22361) µg/Kg
Aluminum	??	??	20,286.00	??	??	??	??
Antimony	??	??	ND	ND	ND	ND	ND
Arsenic	??	??	ND	??	??	ND	ND
Barium	??	??	45,947.00	??	??	??	??
Berylium	??	??	ND(6)	??	??	ND	ND
Boron	??	??	37,294.00	??	??	??	??
Cadmium	??	??	25.60	??	??	ND	ND
Calcium	??	??	1,622,500.00	??	??	??	??
Chromium	??	??	137.70	??	??	??	??
Cobalt	??	??	116.50	??	??	??	??
Copper	??	??	145.00	??	??	??	??
Iron	??	??	245,760.00	??	??	??	??
Lead	??	??	ND	??	??	??	??
Magnesium	??	??	304,040.00	??	??	??	??
Manganese	??	??	2,765.30	??	??	??	??
Mercury	??	??	ND	ND	ND	ND	ND
Molybdenum	??	??	118.00	ND	ND	ND	??
Nickel	??	??	150.60	??	??	??	??

(continued)

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-4. EPA 1992 Coastal Sampling Program: Tank Bottoms - Detected Metals
(continued)

Metals	Heater-Treater Sand (22378) µg/Kg	Heater-Treater Sand-Duplicate (22379) µg/Kg	Treatment Solids (23424) µg/L	Tank Bottoms (23098) µg/Kg	Tank Bottoms Dup-23098 (23099) µg/Kg	Tank Bottoms (23083) µg/Kg	Tank Bottoms (22361) µg/Kg
Selenium	ND (2,050)[a]	4,000	ND(15)	ND(2,700)	ND(21,900)	ND	ND
Silver	ND	ND	182.7	ND	ND	ND	ND(610)
Sodium	16,600,000	15,100,000	24,272,000[b]	22,600,000	23,200,000	13,300,000	32,800,000
Strontium	ND	ND	ND	256,000	236,000	131,000	ND
Sulfur	5,360,000	5,890,000	ND	2,670,000	2,260,000	4,280,000	1,570,000
Thallium	ND (2,050)	2,700	46	ND	ND	ND	ND(2,830)
Tin	3,800	2,500	449.6	ND	ND	5,500	349,000
Titanium	52,000	60,800	20.9	14,800	15,200	44,100	14,600
Vanadium	8,300	9,500	114.4	2,900	3,000	5,500	18,600
Yttrium	4,700	5,800	45.4	5,500	4,700	3,900	2,300
Zinc	188,000	269,000	2017	80,200	66,500	63,800	11,700,000

Notes: ND = not detected. Values in parentheses are detection limits.
[a]These values are considered "low quality" due to poor matrix spike recoveries in the lab.
[b]These values are considered "acceptable quality, but may be maximum values" due to results of in-lab quality control analyses.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-5. EPA 1992 Coastal Sampling Program: Tank Bottoms - Detected Volatile Organic Compounds

Compound	Heater-Treater Sand (22378) µg/L	Heater-Treater Sand-Duplicate (22379) µg/L	Tank Bottoms (23083) µg/Kg	Tank Bottoms (23098) µg/L	Tank Bottoms Dup-23098 (23099) µg/L
BENZENE	38,747	41,859	283,445	108,730	118,965
ETHYLBENZENE	23,219	38,920	296,995	122,495	134,010
M-XYLENE	13,179	17,797	161,610	70,885	53,670
METHYLENE CHLORIDE	135.36	134.21	116,645	ND	ND
O- + P-XYLENE	ND(100)	ND(100)	355,835	47,875	44,125
TOLUENE	62,592	80,410	ND	172,035	155,690
TRICHLOROFLUOROMETHANE	21,495[a]	25,119[a]	ND	142,930[b]	131,765[b]
2-BUTANONE	ND(500)	ND(500)	ND	ND(250,000)	ND(250,000)
2-HEXANONE	ND	ND	ND(250,000)	ND	ND
2-PROPANONE	ND(500)	65,544	ND(250,000)	ND(250,000)	ND(250,000)

Notes: ND = not detected. Values in parentheses are detection limits.
[a] Laboratory indicated that this compound was present due solely to contamination in the labeled compound spiking mixture.
[b] These values are considered "acceptable quality, but may be maximum values" due to in-lab contamination.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-6. EPA 1992 Coastal Sampling Program: Tank Bottoms - Detected Semivolatile Organic Compounds

Compound	Heater Treater Sand (22378) µg/Kg	Heater Treater Sand - Duplicate (22379) µg/Kg	Tank Bottoms (23098) µg/Kg	Tank Bottoms Dup-23098 (23099) µg/Kg	Tank Bottoms (23083) µg/Kg
ACENAPHTHENE	ND(3,333,330)	8,511,330	ND	ND	ND
ACETOPHENONE	ND	ND	ND	ND	50,997
ANTHRACENE	ND	ND	ND	ND	10,442
BIPHENYL	ND(3,333,330)	25,620,330	ND	ND	50,769
DIBENZOFURAN	ND(3,333,330)	15,397,000	ND	ND	ND
DIBENZOTHIOPHENE	5,128,670	4,873,330	ND(3,333)	6,826	ND
FLUORENE	ND(3,333,330)	19,521,000	ND	ND	ND
NAPHTHALENE	55,396,670	57,003,330	ND(3,333)	46,547	47,000
N-DECANE (N-C10)	90,656,670	101,200,000	169,263	14,370	7,303
N-DOCOSANE (N-C22)	ND(3,333,330)	99,370,000	199,183	90,500	53,659
N-DODECANE (N-C12)	206,026,670	212,330,000	167,913	716,843	50,642
N-EICOSANE (N-C20)	139,153,330	ND(3,333,330)	33,309[a]	179,493[a]	248,413
N-HEXACOSANE (N-C26)	42,840,000	45,276,670	123,717	43,000	20,380
N-HEXADECANE (N-C16)	250,070,000	264,113,330	454,467[a]	346,467[a]	554,033
N-OCTACOSANE (N-C28)	15,706,670	5,543,670	150,747	49,390	23,677
N-OCTADECANE (N-C18)	225,183,330	227,426,670	463,687	315,833	376,850
N-TETRACOSANE (N-C24)	64,200,000	69,356,670	187,440[a]	71,343[a]	147,553
N-TETRADECANE (N-C14)	318,566,670	329,553,330	332,153	253,220	439,433

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-6. EPA 1992 Coastal Sampling Program: Tank Bottoms - Detected Semivolatile Organic Compounds
(continued)

Compound	Heater Treater Sand (22378) µg/Kg	Heater Treater Sand - Duplicate (22379) µg/Kg	Tank Bottoms (23098) µg/Kg	Tank Bottoms Dup-23098 (23099) µg/Kg	Tank Bottoms (23083) µg/Kg
N-TRIACONTANE (N-C30)	21,186,330	16,789,000	393,873	ND(3,333)	29,075
PHENANTHRENE	ND(3,333,330)	26,779,670	ND(3,333)	19,739	ND
1-METHYLFLUORENE	88,670,000	ND(3,333,330)	ND(3,333)	75,005	31,473
1-METHYLPHENANTHRENE	35,726,670	38,270,000	ND	ND	10,717
1-PHENYLNAPHTHALINE	ND	ND	ND(3,333)	5,124	ND
2-ISOPROPYLNAPHTHALENE	ND	ND	39,190	ND(3,333)	ND
2-METHYLNAPHTHALENE	98,843,330	96,533,330	155,923	ND(3,333)	ND
2-PHENYLNAPHTHALINE	ND	ND	ND(3,333)	6,871	6,012
2,4,6-TRICHLOROPHENOL	139,153,000	ND(3,333,330)	ND	ND	ND
3,6-DIMETHYLPHENANTHRENE	ND	ND	62,333	19,858	ND
4-AMINOBIPHENYL	ND	ND	ND	ND	31,026

Notes: ND = not detected. Values in parentheses are detection limits.
[a] These values are considered "of acceptable quality, but may be minimum values" due to matrix interferences in the lab.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table E-7. EPA 1992 Coastal Sampling Program: Tank Bottoms - Detected Radionuclides

Radionuclide	Tank Bottoms (23620) pCi/g	H.Treater Sand (22378) pCi/g	H.Treater Sand Dup-22378 (22379) pCi/g	Treatment Solids (23424) pCi/g	Tank Bottoms (23098) pCi/g	Tank Bottoms Dup-23098 (23098) pCi/g	Tank Bottoms (23083) pCi/g	Tank Bottoms (22361) pCi/g
GROSS ALPHA	ND	834	872	ND	ND(13.5)	ND(10.9)	ND(13.4)	ND(9.3)
GROSS BETA	ND	668	599	ND	ND(11.7)	21.4	12.7	12
LEAD-210	ND(0.2)	11.7	10.2	ND(14.5)	10.7	ND(4.1)	4.2	ND
RADIUM-226	6.9	ND(8)	ND(5.7)	313	2.6	4.5	3.1	6.8
RADIUM-228	6.5	ND(1.4)	ND(1.3)	364	ND(3.3)	2.7	ND(3.3)	3.5

Note: ND = not detected. Values in parentheses are detection limits.

APPENDIX F

ANALYTICAL RESULTS OF 1993 GAS RESEARCH INSTITUTE SAMPLING STUDY

Gas Research Institute
Sampling and Analysis of Wastes Generated from Natural Gas Industry Operations Study

From October 1990 - March 1992, the Gas Research Institute (GRI) conducted sampling at 23 facilities in 11 States. The effort focused on wastes generated from gas/processing/conditioning, underground storage, and mainline compression operations. The 63 samples collected were comprised of a wide variety of solids, sludges, and aqueous and non-aqueous liquids. These included two samples of tank bottoms/sludges (one from a produced water storage tank and one from brine treatment/knockout tank), obtained from two mainline compressor stations. While wastes from these types of operations have generally not been considered exempt, their composition should be consistent with similar tank bottom wastes produced at field production operations.

Selected sampling results for the two tank bottom/sludge samples are presented in Table F-1. Of specific note, the two samples were analyzed for all metals and volatile/semi-volatile organic constituents with Toxic Characteristic (TC) standards. Both samples showed exceedances of the TC level for benzene. No other constituents were found above TC levels (using the TCLP method). Total constituent data were not available for the tank bottoms/sludges. In addition, one sample exhibited the characteristic of reactivity (hydrogen sulfide concentration of 1,458 mg/kg compared to the criteria of 500 mg/kg). According to the GRI Study report, the elevated levels of reactive sulfide in the brine treatment tank sample to a "site-specific microbially-induced corrosion problem."

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table F-1. Results of GRI Sampling of Tank Bottoms/sludges
Sampling Conducted 1990-1992

Analyte	**Facility #/Sample #**	
	19/AN-02US-20-04	20/AN-01US-09-01
Conventional Parameters/RCRA Characteristics (ppm)		
Chlorides	8,800	9,500
Sulfide, total	1,610	1,060
Sulfide, reactive	1	1,458
pH	NA	NA
Ignitability	NA	NA
Metals - TCLP analyses (mg/L)		
Arsenic	0.008	0.02
Barium	1.8	5.8
Cadmium	ND	ND
Chromium	ND	ND
Lead	0.07	ND
Mercury	ND	ND
Selenium	ND	0.01
Silver	ND	ND
Organics - TCLP Analyses (mg/L)*		
Benzene	13	3.3
2-Methylphenol	0.34[1]	0.38
4-Methylphenol	0.81[1]	0.059
Nitrobenzene	ND[1]	0.47

NA = Not analyzed for
ND = Not detected

*Analyses were conducted for all organic parameters with TC regulatory levels, however, the above parameters were the only organic TC constituents detected using the TCLP

[1]TCLP extraction performed after 7 day holding time. Data are deemed qualitative.

APPENDIX G

ANALYTICAL RESULTS OF 1993 WESTERN STATES PETROLEUM ASSOCIATION CALIFORNIA ROAD MIX STUDY

Western States Petroleum Association
Analytical Results of 1993 California Road Mix Study

In March 1993, the Western States Petroleum Association (WSPA) published a report on the results of a WSPA sponsored study to characterize road paving material produced from crude oil-containing materials from oilfield operations in California. The WSPA study examined the volumes of crude oil-containing materials used by the petroleum industry for road paving, and emissions from the road mix material. The study evaluated:

- the chemical constituents present in the recovered hydrocarbon raw materials used in road mix,
- the potential impacts to air, soil or water during production and application of the road mix material, and
- the physical and chemical characteristics of the finished road mix material compared to commercial specifications.

Ten raw materials samples were analyzed, before and after dewatering, for total petroleum hydrocarbons (TPH) and volatile organic compounds (VOCs). Ten finished road mix tank bottoms samples were also analyzed for TPH and VOCs as were three petroleum-containing soil samples from line leaks, four soil samples from sumps and three petroleum-containing soil samples from line leaks. Three finished road mix product samples were analyzed for the potential leachability of hydrocarbons and metals using EPA's TCLP method, and California's Total Threshold Level Concentrations (TTLC) and Soluble Threshold Level Concentrations (STLC) methods for the leachability of metals. Finally, twelve samples were analyzed during and after road mix production for VOCs in air emissions.

For the ten raw materials samples, TPH levels ranged from 38,500 to 68,812 mg/kg before dewatering and from 61,500 to 156,170 after dewatering. Benzene, ethylbenzene, toluene, and xylenes were the only VOCs detected in tank bottoms samples prior to dewatering with benzene levels ranging from .10 to .47 mg/kg. VOCs were not detected in tank bottoms after dewatering. TPH levels for the five raw soil materials samples ranged from 18,400 to 81,250 mg/kg while TPH for five soils as finished road mix ranged from 3,600 to 31,400 mg/kg. No VOCs were detected in any of the soil samples. For finished road mix tank bottoms, TPH levels ranged from 17,100 to 48,165 mg/kg and no VOCs were detected. For three finished road mix tank bottoms analyzed for TCLP metals and organics, and soluble metals using California's TTLC and STLC tests, all of the analytes detected were well below regulatory levels.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

HYDROCARBON ANALYSIS OF RAW MATERIALS
(TANK BOTTOMS)
PROCESS STEP 1
(Analytical Results of 1993 WSPA California Road Mix Study)

CONSTITUENT	SAMPLE NUMBER AND ANALYTICAL RESULTS (mg/kg)										MEAN ± SD
	A-1	A-2	A-4	A-5	B-1	B-2	B-5	C-1	C-4	C-9	
Total Petroleum Hydrocarbons[1]	52,400	60,900	48,000	68,812	45,400	52,200	42,500	41,800	53,700	38,500	50,421 ± 9,286
Aromatic Volatile Organics[2]											
Benzene	0.28	0.33	0.15	0.10	0.26	0.31	0.47	0.25	0.15	0.30	
Chlorobenzene	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	
1,4-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
1,3-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
1,2-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Ethylbenzene	1.35	1.85	1.40	2.20	2.90	3.50	4.00	1.80	1.40	1.90	
Toluene	3.57	4.10	3.40	3.20	4.80	5.10	3.80	3.60	3.20	3.50	
Xylenes	3.11	2.90	1.90	2.30	3.30	2.80	3.20	2.40	2.40	2.20	
Total Aromatic Volatile Organics[3]	8.64	9.58	7.25	8.20	11.66	12.11	11.87	8.45	7.55	8.30	9.36 ± 1.85
Nonhalogenated Volatile Organics											
C2-C12[4]	11.7	14.5	12.3	15.5	124.4	130.1	129.0	14.2	16.8	15.5	
C13-C23[5]	270	380	265	450	640	750	750	430	290	350	
C24-C30[6]	21,000	26,300	16,200	32,600	11,000	29,500	35,000	35,400	45,000	24,100	
Total Nonhalogenated Volatile Organics[7]	21,300	26,700	16,500	33,100	11,800	30,400	35,900	35,800	45,300	24,500	28,130 ±10,042

(1) Determined by EPA Method 418.1, C2 to C35+ hydrocarbons.
(2) Determined by EPA Method 8020.
(3) Calculated as the sum of the values plus one-half the detection limit.
(4) Determined by EPA Method 8015, C2-C12 as gasoline.
(5) Determined by EPA Method 8015, C13-C23 as diesel.
(6) Determined by EPA Method 8015, C24-C30 as heavy oil.
(7) Total nonhalogenated volatile organics as the sum of C2 to C12, C13 to C23 and C24-C30 constituents, rounded to nearest 100.

SD: Standard Deviation

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

HYDROCARBON ANALYSIS OF RAW MATERIALS
(TANK BOTTOMS)
DEWATERED PROCESS STEP 2
(Analytical Results of 1993 WSPA California Road Mix Study)

CONSTITUENT	SAMPLE NUMBER AND ANALYTICAL RESULTS (mg/kg)										MEAN ± SD
	A-1	A-2	A-4	A-5	B-1	B-2	B-5	C-1	C-4	C-9	
Total Petroleum Hydrocarbons[1]	127,860	156,170	126,340	143,360	116,520	116,100	83,400	61,500	88,250	66,400	108,591 ± 32,286
Aromatic Volatile Organics[2]											
Benzene	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
Chlorobenzene	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	
1,4-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
1,3-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
1,2-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Ethylbenzene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	
Toluene	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	
Xylenes	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	
Total Aromatic Volatile Organics[3]	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95 ± 0
Nonhalogenated Volatile Organics											
C2-C12[4]	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
C13-C23[5]	340	525	360	625	680	840	925	580	430	525	
C24-C30[6]	48,000	68,100	43,700	68,900	29,800	67,300	69,500	51,800	74,000	41800	
Total Nonhalogenated Volatile Organics[7]	48,300	68,600	44,100	69,500	30,500	68,100	70,400	52,400	74,400	42,300	56,873 ±15,190

(1) Determined by EPA Method 418.1, C2 to C35+ hydrocarbons.
(2) Determined by EPA Method 8020.
(3) Calculated as the sum of the values plus one-half the detection limit.
(4) Determined by EPA Method 8015, C2-C12 as gasoline.
(5) Determined by EPA Method 8015, C13-C23 as diesel.
(6) Determined by EPA Method 8015, C24-C30 as heavy oil.
(7) Total nonhalogenated volatile organics as the sum of C2 to C12, C13 to C23 and C24-C30 constituents, rounded to nearest 100.

SD: Standard Deviation

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

SUMMARY OF RAW MATERIALS ANALYSIS
TANK BOTTOMS
USING EPA METHOD 8240
PROCESS STEP 2
(Analytical Results of 1993 WSPA California Road Mix Study)

CONSTITUENTS	SAMPLE DESIGNATION AND ANALYTICAL RESULTS (ppm)						POTENTIAL REGULATORY LEVEL[1]
	A-1	A-4	B-1	B-5	C-1	C-4	
Acetone	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Benzene	<0.01	0.06	<0.01	0.04	<0.01	<0.01	
Bromodichloromethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Bromoform	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Bromomethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
5-Butanone (MEK)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Carbon Disulfide	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Carbon Tetrachloride	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Chlorobenzene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Chlorodibromomethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Chloroethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
5-Chloroethyl Vinyl Ether	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Chloroform	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Chloromethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
1,1-Dichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
1,2-Dichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
1,1-Dichloroethene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Trans 1,2-Dichloroethene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
1,2-Dichloropropane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Cis 1,3-Dichloropropene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Trans 1,3-Dichloropropene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Ethylbenzene	<0.01	0.810	<0.01	<0.01	0.24	0.22	
2-Hexanone	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Methylene Chloride	<0.01	<0.01	0.120	<0.01	<0.01	<0.01	
4-Methyl pentanone	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Styrene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
1,1,2,2-Tetrachloroethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
1,1,2-Trichloromethane	<0.01	<0.01	0.130	0.110	0.080	0.080	
Toluene	<0.01	0.235	<0.01	2.31	0.160	0.560	
1,1,1-Trichloroethane	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	
1,1,2-Trichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Trichloroethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Trichlorofluoromethane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Vinyl Acetate	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Vinyl Chloride	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Total Xylenes	<0.01	0.175	<0.01	0.495	0.240	0.630	
Total Volatiles[2]	0.20	1.44	1.80	3.11	0.876	1.65	

[1] Various regulatory levels may apply to each individual component based on its waste classification (e.g., RCRA, California Hazardous, etc.). A more complete listing of potential regulatory limits will be developed.

[2] Total volatiles calculated using one-half the detection limit.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

ANALYSIS OF AIR EMISSIONS DURING ROAD MIX PRODUCTION (PROCESS STEP 3)
(Analytical Results of 1993 WSPA California Road Mix Study

COMPOUND	SAMPLE NUMBER AND DETECTED ANALYTES (mg/kg)											
	B-3	B-4	B-9	B-10	A-6	A-7	A-8	A-9	C-2	C-5	C-6	C-8
Acetone	.068	.053	.060	.052	.049	.033	.052	.011	.013	.024	.043	.071
Benzene	.052	ND	ND	ND	ND	.008	.010	ND	.041	.055	.039	.041
Ethylbenzene	.026	ND	ND	ND	.020	ND	.014	ND	.016	.024	.014	.011
Toluene	.072	.023	.022	.018	ND	.012	.011	ND	.086	.114	.049	.038
Trichloroethylene	ND	.014	.010	ND	ND	ND	ND	.011	ND	ND	ND	ND
Total Xylenes	.032	.020	ND	.031	ND	ND	.010	ND	.051	.060	.067	.051
Alaphatic and Acrylic Hydrocarbons (Carbon Range)	6.144 (C4-C14)	5.821 (C9-C14)	8.011 (C9-C14)	6.220 (C9-C11)	.080 (C9)	.065 (C9)	.020 (C9)	ND	.290 (C9-C14)	.675 (C9-C14)	.325 (C9-C14)	.071 (C9-C14)

Source: Western States Petroleum Association (1993)

ND = Nondetectable. Detection limit = .005 ppm

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

ANALYSIS OF HYDROCARBON AIR EMISSIONS AFTER ROAD MIX PRODUCTION (PROCESS STEP 3)
(Analytical Results of 1993 WSPA California Road Mix Study

COMPOUND	SAMPLE NUMBER AND DETECTED ANALYTES (mg/kg)											
	B-3	B-4	B-9	B-10	A-6	A-7	A-8	A-9	C-2	C-5	C-6	C-8
Acetone	.043	.030	.033	.038	.021	.016	.013	ND	ND	.010	.033	.051
Benzene	.034	ND	ND	ND	ND	ND	ND	ND	.026	.039	.025	.020
Carbon Disulfide	ND	.006	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
trans 1,2-Dichloropropene	ND	ND	ND	.021	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	.006	ND	ND	ND	ND	ND	ND	ND	.010	.015	.008	.013
Styrene	ND	ND	ND	ND	ND	ND	ND	ND	.005	ND	ND	ND
Toluene	.043	.012	.014	.085	ND	ND	ND	ND	.061	.092	.035	.029
Total Xylenes	.025	ND	ND	.015	ND	ND	ND	ND	.034	.063	.082	.044
Alaphatic and Acrylic Hydrocarbons (Carbon Range)	4.010 (C4-C14)	4.010 (C9-C14)	6.020 (C9-C14)	4.010 (C9-C11)	.010 (C9)	.010 (C9)	.008 (C9)	ND	.260 (C9-C14)	.540 (C9-C14)	.310 (C9-C14)	.025 (C9-C14)

Source: Western States Petroleum Association (1993)

ND = Nondetectable. Detection limit = .005 ppm

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

HYDROCARBON ANALYSIS OF FINISHED ROAD MIX
(TANK BOTTOMS)
PROCESS STEP 4
(Analytical Results of 1993 WSPA California Road Mix Study)

CONSTITUENT	SAMPLE NUMBER AND ANALYTICAL RESULTS (mg/kg)										MEAN ± SD
	A-6	A-7	A-8	A-10	B-3	B-4	B-9	C-2	C-5	C-10	
Total Petroleum Hydrocarbons[1]	38,750	35,150	48,165	45,400	17,100	26,210	18,200	21,000	18,500	22,300	29,077 ± 11,805
Aromatic Volatile Organics[2]											
Benzene	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	
Chlorobenzene	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	
1,4-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
1,3-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
1,2-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	
Ethylbenzene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	
Toluene	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	<2.50	
Xylenes	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	<1.50	
Total Aromatic Volatile Organics[3]	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95 ± 0
Nonhalogenated Volatile Organics											
C2-C12[4]	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	
C13-C23[5]	75	44	82	71	55	66	87	93	74	63	
C24-C30[6]	14,100	19,400	27,000	20,600	5,700	15,100	14,400	17,200	14,400	13,100	
Total Nonhalogenated Volatile Organics[7]	14,200	19,400	27,100	20,700	5,800	15,200	14,500	17,300	15,000	13,200	16,240 ±5,548

[1] Determined by EPA Method 418.1, C2 to C35+ hydrocarbons.
[2] Determined by EPA Method 8020.
[3] Calculated as the sum of the values plus one-half the detection limit.
[4] Determined by EPA Method 8015, C2-C12 as gasoline.
[5] Determined by EPA Method 8015, C13-C23 as diesel.
[6] Determined by EPA Method 8015, C24-C30 as heavy oil.
[7] Total nonhalogenated volatile organics as the sum of C2 to C12, C13 to C23 and C24-C30 constituents, rounded to nearest 100.

SD: Standard Deviation

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

SUMMARY OF TCLP EXTRACTIONS
AND ANALYSIS RESULTS
FINISHED ROAD MIX TANK BOTTOMS
PROCESS STEP 6
(Analytical Results of 1993 WSPA California Road Mix Study)

CONSTITUENTS	CFR 261.24 REGULATORY LIMITS (mg/L)	SAMPLE DESIGNATION AND ANALYTICAL RESULTS (mg/L)		
		A-6	B-4	C-2
Arsenic	5.0	<0.05	<0.05	<0.50
Barium	100	0.51	0.48	0.44
Cadmium	1.0	<0.002	<0.002	<0.002
Chromium	5.0	0.87	1.69	0.77
Lead	5.0	<0.05	<0.025	<0.025
Mercury	0.2	<0.05	<0.050	<0.50
Selenium	1.0	<0.001	<0.001	<0.001
Silver	5.0	<0.003	<0.003	<0.003
Copper	NA(1)	0.30	<0.32	<.30
Nickel	NA	0.75	<0.08	0.17
Zinc	NA	0.91	0.86	0.71
Benzene	NA	<0.05	<0.05	<0.50
Toluene	NA	<0.10	<0.10	<0.10
Ethylbenzene	NA	<0.20	<0.20	<0.20
Xylenes	NA	<0.20	<0.20	<0.20
Benzo(a) Anthracene	NA	<0.50	<0.50	<0.50
Benzo(a) Pyrene	NA	<0.50	<0.50	<0.50
Chrysene	NA	<0.50	<0.50	<0.50
O-Cresole	NA	<1.00	<1.00	<1.00
p-Cresole	200.0	<1.00	<1.00	<1.00
2,4-Dimethylphenol	200.0	<0.50	<0.50	<0.50
Naphthalene	NA	<0.50	<0.50	<0.50
Phenanthrene	NA	<0.50	<0.50	<0.50
Phenol	NA	<0.50	<0.50	<0.50
Pyrene	NA	<0.50	<0.50	<0.50

NA = Not Applicable. Formal TCLP standards for these compounds have not been established.
< = Detection Limit

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

SUMMARY OF ANALYTICAL RESULTS
TOTAL THRESHOLD LEVEL CONCENTRATIONS (TTLC) AND
SOLUBLE THRESHOLD LEVEL CONCENTRATIONS (STLC)
FINAL PRODUCT TANK BOTTOMS
PROCESS STEP 6
(Analytical Results of 1993 WSPA California Road Mix Study)

CONSTITUENTS	REGULATORY LEVEL[1] (ppm)		SAMPLE DESIGNATION AND ANALYTICAL RESULTS (ppm)					
			A-6		B-4		C-2	
	TTLC	STLC	TTLC	STLC	TTLC	STLC	TTLC	STLC
Antimony	500	15	33	<1.0	18	<1.0	28	<1.0
Arsenic	500	5	2.8	<1.0	3.5	<1.0	3.5	<1.0
Barium	10,000	100	73	<1.0	66	<1.0	51	<1.0
Beryllium	75	0.75	<0.5	--	<0.5	--	<0.5	--
Cadmium	100	1.0	<0.5	--	<0.5	--	<0.5	--
Chromium (III)	2,500	560	115	<10	185	<10	266	<10
(VI)	500	5.0	ND	--	ND	--	ND	--
Cobalt	8,000	80	<1.0	--	<1.0	--	<1.0	--
Copper	2,500	25	145	6.8	65	<1.0	35	<1.0
Fluoride	18,000	180	124	26	173	18	110	5.4
Lead	1,000	5.0	31	<1.0	22	<1.0	139	<1.0
Mercury	20	0.2	<0.2	--	<0.2	--	<0.2	--
Molybdenum	3,500	350	16.7	<1.0	22.4	<1.0	20.7	<1.0
Nickel	2,000	20	46	<1.0	41	<1.0	20	<1.0
Selenium	100	1.0	<0.5	--	<0.5	--	<0.5	--
Silver	500	5.0	<1.0	--	<1.0	--	<1.0	--
Thallium	700	7.0	<1.0	--	<1.0	--	<1.0	--
Vanadium	2,400	24	16	<1.0	35	<1.0	20	<1.0
Zinc	5,000	250	105	1.4	100	1.7	240	5.8

ND = Not Detected.
-- = Not Analyzed
[1] California Code of Regulations, Title 22 Standards.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

HYDROCARBON ANALYSIS OF RAW MATERIALS
SOILS AND SUMPS
PROCESS STEP 2
(Analytical Results of 1993 WSPA California Road Mix Study)

CONSTITUENT	SAMPLE NUMBER AND ANALYTICAL RESULTS (mg/kg)					MEAN ± SD
	A-11	B-7	C-3	A-3	C-7	
Sample Type	Soil	Soil	Soil	Sump	Sump	
Total Petroleum Hydrocarbons[1]	18,400	25,400	68,400	19,440	81,250	42,578 ± 29,905
Aromatic Volatile Organics[2]						
Benzene	<0.05	<0.05	<0.05	<0.05	<0.05	
Chlorobenzene	<0.50	<0.50	<0.50	<0.50	<0.50	
1,4-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	
1,3-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	
1,2-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	
Ethylbenzene	<1.00	<1.00	<1.00	<1.00	<1.00	
Toluene	<2.50	4.75	<2.50	<2.50	<2.50	
Xylenes	<1.50	5.94	<1.50	<1.50	<1.50	
Total Aromatic Volatile Organics[3]	2.95	11.64	2.95	2.95	2.95	4.69 ±3.89
Nonhalogenated Volatile Organics						
C2-C12[4]	ND	18.5	ND	ND	ND	
C13-C23[5]	22	39	88	11	27	
C24-C30[6]	6,300	18,500	56,100	3,400	62,500	
Total Nonhalogenated Volatile Organics[7]	6,300	18,600	56,200	3,400	62,500	29,400 ±28,018

[1] Determined by EPA Method 418.1, C2 to C35+ hydrocarbons.
[2] Determined by EPA Method 8020.
[3] Calculated as the sum of the values plus one-half the detection limit.
[4] Determined by EPA Method 8015, C2-C12 as gasoline.
[5] Determined by EPA Method 8015, C13-C23 as diesel.
[6] Determined by EPA Method 8015, C24-C30 as heavy oil.
[7] Total nonhalogenated volatile organics as the sum of C2 to C12, C13 to C23 and C24-C30 constituents, rounded to nearest 100.

SD: Standard Deviation

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

HYDROCARBON ANALYSIS OF FINISHED ROAD MIX
SOILS AND SUMPS
PROCESS STEP 4
(Analytical Results of 1993 WSPA California Road Mix Study)

CONSTITUENT	SAMPLE NUMBER AND ANALYTICAL RESULTS (mg/kg)					MEAN ± SD
	A-9	B-10	C-6	A-12	C-8	
Sample Type	Soil	Soil	Soil	Sump	Sump	
Total Petroleum Hydrocarbons[1]	12,200	3,600	27,200	13,500	31,400	17,580 ± 11,451
Aromatic Volatile Organics[2]						
Benzene	<0.05	<0.05	<0.05	<0.05	<0.05	
Chlorobenzene	<0.50	<0.50	<0.50	<0.50	<0.50	
1,4-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	
1,3-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	
1,2-Dichlorobenzene	<0.10	<0.10	<0.10	<0.10	<0.10	
Ethylbenzene	<1.00	<1.00	<1.00	<1.00	<1.00	
Toluene	<2.50	<2.50	<2.50	<2.50	<2.50	
Xylenes	<1.50	<1.50	<1.50	<1.50	<1.50	
Total Aromatic Volatile Organics[3]	2.95	2.95	2.95	2.95	2.95	2.9 ±0
Nonhalogenated Volatile Organics						
C2-C12[4]	ND	ND	ND	ND	ND	
C13-C23[5]	ND	ND	ND	ND	ND	
C24-C30[6]	4,400	2,100	11,300	5,200	14,200	
Total Nonhalogenated Volatile Organics[7]	4,400	2,100	11,300	5,200	14,200	7,440 ±5,083

[1] Determined by EPA Method 418.1, C2 to C35+ hydrocarbons.
[2] Determined by EPA Method 8020.
[3] Calculated as the sum of the values plus one-half the detection limit.
[4] Determined by EPA Method 8015, C2-C12 as gasoline.
[5] Determined by EPA Method 8015, C13-C23 as diesel.
[6] Determined by EPA Method 8015, C24-C30 as heavy oil.
[7] Total nonhalogenated volatile organics as the sum of C2 to C12, C13 to C23 and C24-C30 constituents, rounded to nearest 100.

SD: Standard Deviation
ND: Not Detected

APPENDIX H

ANALYTICAL RESULTS OF 1994 PENNSYLVANIA PRODUCTION PIT STUDY

Pennsylvania Department of Environmental Resources
Bureau of Oil and Gas Management
Characterization and Disposal Options for Oilfield Wastes in Pennsylvania

In 1980, the Pennsylvania Department of Environmental Resources (DER) conducted an assessment of surface impoundments which located 19,000 open pits associated with oil and gas activities. Of these, approximately 10,000 were associated with the production of oil.

Through a separate study, DER characterized wastes in pits and tanks associated with oil production to identify appropriate waste disposal and site remediation options. Basic sediment samples were taken from 51 pits located throughout the major oil producing areas of the state. Sampling sites were chosen according to geographic location, producing formation, and production methods (i.e., primary or secondary production). Forty five pits were associated with primary production and six were associated with secondary production (waterflooding).

Samples were collected for organics, inorganics, and naturally occurring radioactive materials (NORM) analyses. The first five samples were analyzed for total organics. A toxicity characteristic leachate procedure (TCLP) analysis was performed on the remaining 46 samples. The TCLP extracts were analyzed for benzene, ethylbenzene, naphthalene, xylene and toluene. Of these, only benzene is a toxicity characteristic (TC) contaminant. None of the TCLP results for benzene exceeded the regulatory level.

Samples from each site were analyzed using the TCLP for arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver, all of which are TC metals. None of the TCLP results for metals exceeded regulatory levels.

Samples from 49 sites were analyzed for oil and grease content. Samples from ten pits had an oil and grease content between 10 and 54 percent, 25 were between 1 and 10 percent, and 14 were less than 1 percent.

Samples from 48 sites were analyzed for salinity by measuring the specific conductance of a saturated paste extract. Samples from 22 pits exceeded DER's maximum criteria for salinity of 4 mmhos/cm.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

Table H-1. Site Information

Site No.	County	Formation	Production	Status
1	McKean	Bradford	Secondary	Inactive
2	McKean	Bradford	Primary/Secondary	Active
3	McKean	Bradford	Secondary	Active
4	McKean	Bradford	Primary	Active
5	McKean	Bradford	Primary	Active
6	McKean	Bradford	Primary	Inactive
7	McKean	Bradford	Primary	Inactive
8	McKean	Bradford	Primary	Active
9	McKean	Bradford	Primary	Active
10	McKean	Bradford	Primary	Inactive
11	McKean	Bradford	Secondary	Reclaimed
12	McKean	Bradford	Primary	Active
13	McKean	Bradford	Primary	Active
14	McKean	Bradford	Primary	Active
15	McKean	Bradford	Secondary	Inactive
16	McKean	Bradford	Primary	Active
17	McKean	Bradford	Secondary	Inactive
18	McKean	Bradford	Primary	Active
19	Warren	Bradford	Primary	Active
20	Warren	Bradford	Primary	Active
21	Warren	Bradford	Primary	Inactive
22	Warren	Bradford	Primary	Active
23	Warren	Bradford	Primary	Active
24	Warren	Bradford	Primary	Active
25	Warren	Venango	Primary	Active
26	Warren	Bradford	Primary	Inactive
27	Warren	Bradford	Primary	Active

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)

Table H-1. Site Information

Site No.	County	Formation	Production	Status
28	Venango	Venango	Primary	Active
29	Venango	Venango	Primary	Active
30	Venango	Venango	Primary	Active
31	Venango	Venango	Primary	Active
32	Venango	Venango	Primary	Active
33	Venango	Venango	Primary	Active
34	Venango	Venango	Primary	Active
35	Venango	Venango	Primary	Active
36	Venango	Venango	Primary	Active
37	Venango	Venango	Primary	Active
38	Venango	Venango	Primary	Active
39	Venango	Venango	Primary	Active
40	Venango	Venango	Primary	Active
41	Venango	Venango	Primary	Active
42	Venango	Venango	Primary	Active
43	Forest	Venango	Primary	Active
44	Forest	Venango	Primary	Active
45	Forest	Venango	Primary	Inactive
46	Forest	Bradford	Primary	Active
47	Forest	Bradford	Primary	Inactive
48	Forest	Bradford	Primary	Inactive
49	Washington	Venango	Primary	Active
50	Washington	Venango	Primary	Inactive
51	Allegheny	Venango	Primary	Active

Source: Pennsylvania Department of Environmental Resources, Bureau of Oil and Gas, 1994.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table H-2. Results of TCLP Metals Tests

Site No.	As	Ba	Cd	Cr	Pb	Se	Ag	Hg
Regulatory Level	5 (mg/l)	100 (mg/l)	1 (mg/l)	5 (mg/l)	5 (mg/l)	1 (mg/l)	5 (mg/l)	0.2 (mg/l)
1	<0.01	0.345	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
2	<0.01	1.13	<0.05	<0.05	0.102	<0.01	<0.05	<0.001
3	<0.01	2.19	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
4	0.014	0.479	<0.05	<0.05	0.115	<0.01	<0.05	<0.001
5	<0.01	0.627	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
6	0.011	19.1	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
7	<0.01	0.302	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
8	0.017	0.549	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
9	<0.01	0.23	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
10	<0.01	0.452	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
11	<0.01	0.79	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
12	<0.01	0.535	<0.05	<0.05	<0.1	0.016	<0.05	<0.001
13	<0.01	0.72	<0.05	<0.05	<0.1	0.013	<0.05	<0.001
14	<0.01	16.1	<0.05	<0.05	<0.1	0.01	<0.05	<0.001
15	0.013	10.7	<0.05	<0.05	<0.1	0.013	<0.05	<0.001
16	<0.01	0.608	<0.05	<0.05	<0.1	0.013	<0.05	<0.001
17	<0.01	2.89	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
18	<0.01	0.143	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
19	0.013	0.332	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
20	0.026	0.185	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
21	0.021	0.434	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
22	0.016	0.669	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
23	<0.01	1.26	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
24	0.015	0.117	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
25	<0.01	0.279	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
26	<0.01	0.798	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
27	<0.01	0.177	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
28	<0.01	5.3	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table H-2. Results of TCLP Metals Tests

Site No.	As	Ba	Cd	Cr	Pb	Se	Ag	Hg
Regulatory Level	5 (mg/l)	100 (mg/l)	1 (mg/l)	5 (mg/l)	5 (mg/l)	1 (mg/l)	5 (mg/l)	0.2 (mg/l)
29	<0.01	0.35	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
30	0.011	3.01	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
31	0.012	1.23	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
32	0.016	3	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
33	0.011	.681	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
34	0.015	.687	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
35	<0.01	.709	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
36	<0.01	.332	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
37	<0.01	0.849	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
38	0.031	0.07	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
39	<0.01	1.12	<0.05	<0.05	<0.1	0.01	<0.05	<0.001
40	<0.01	0.85	<0.05	<0.05	<0.1	0.012	<0.05	<0.001
41	<0.01	0.57	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
42	<0.01	2.31	<0.05	<0.05	<0.1	0.014	<0.05	<0.001
43	<0.01	0.859	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
44	0.012	1.81	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
45	0.02	2.58	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
46	0.019	0.653	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
47	<0.01[1]	0.76	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
48	0.021	0.892	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
49	<0.01	1.36	<0.05	<0.05	0.27	<0.01	<0.05	<0.001
50	<0.01	1.28	<0.05	<0.05	<0.1	<0.01	<0.05	<0.001
51	<0.01	0.806	<0.05	<0.05	0.146	<0.01	<0.05	<0.001

[1]Reported as <0.001.

Source: Pennsylavania Department of Environmenatl Resources, Bureau of Oil and Gas, 1994.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table H-3. Results of Organics Tests

Site No.	Benzene	Ethylbenzene	Napthalene	Xylene	Toluene
Regulatory Level	.05 (mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
1	<10[1]	<10[1]	5[1]	8[1]	<10[1]
2	10[1]	<100[1]	<100[1]	340[1]	80[1]
3	25[1]	5[1]	10[1]	35[1]	5[1]
4	<10[1]	<10[1]	<10[1]	2[1]	<10[1]
5	<100[1]	<100[1]	20[1]	40[1]	17[1]
6	0.08	<0.05	0.01	0.305	<0.05
7	<0.01	<0.01	<0.01	<0.01	<0.01
8	<0.01	<0.01	<0.01	<0.01	<0.01
9	0.004	0.003	0.002	0.041	0.001
10	<0.01	0.002	0.001	0.015	0.009
11	<0.01	0.002	<0.01	0.01	0.008
12	0.04	0.012	<0.01	0.2	<0.01
13	0.05	0.049	<0.01	0.536	<0.01
14	0.012	<0.01	<0.01	0.056	0.01
15	<0.01	<0.01	<0.01	0.014	<0.01
16	0.06	<0.01	<0.01	0.044	0.025
17	0.079	<0.01	0.021	0.082	0.01
18	<0.01	<0.01	<0.01	<0.01	<0.01
19	0.014	<0.01	<0.01	0.067	<0.01
20	0.062	0.018	<0.01	0.179	0.04
21	<0.002	0.023	<0.002	0.03	0.02
22	0.027	<0.01	<0.01	0.019	0.016
23	<0.01	0.018	<0.01	0.011	0.02
24	0.1	<0.01	<0.01	1.78	0.24
25	0.016	<0.01	<0.01	0.049	0.03
26	<0.05	<0.05	<0.05	<0.05	<0.05
27	<0.05	<0.05	<0.05	<0.05	<0.05
28	0.015	0.01	<0.05	0.12	<0.05
29	0.0043	0.0054	<0.0005	0.0331	0.0123

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table H-3. Results of Organics Tests

Site No.	Benzene	Ethylbenzene	Napthalene	Xylene	Toluene
Regulatory Level	.05 (mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
30	0.0904	0.047	0.076	0.2883	0.1185
31	0.0006	0.0013	<0.0005	0.0045	0.0023
32	0.045	0.01	<0.01	0.209	0.135
33	0.0009	0.0035	<0.0005	0.0259	0.0046
34	0.0016	<0.01	<0.01	0.0083	0.006
35	0.0011	0.0028	<0.0005	0.0011	0.0042
36	0.11	0.0127	<0.01	0.099	0.0625
37	0.035	<0.01	<0.01	0.048	0.014
38	0.05	<0.01	<0.01	0.071	0.015
39	<0.01	<0.01	<0.01	0.016	<0.01
40	<0.01	<0.01	<0.01	<0.01	<0.01
41	<0.01	<0.01	<0.01	<0.01	<0.01
42	<0.01	<0.01	<0.01	<0.01	<0.01
43	<0.01	<0.01	<0.01	<0.01	<0.01
44	0.25	<0.05	<0.05	0.23	0.027
45	<0.01	<0.01	<0.01	0.048	<0.01
46	0.035	0.02	<0.01	0.178	0.16
47	<0.01	<0.01	<0.01	<0.01	<0.01
48	<0.01	<0.01	<0.01	0.062	<0.01
49	<0.01	<0.01	<0.01	<0.01	<0.01
50	<0.01	<0.01	<0.01	<0.01	<0.01
51	<0.01	<0.01	<0.01	0.0317	0.012

[1]Total organics analysis, all others are TCLP.

Source: Pennsylavania Department of Environmenatl Resources, Bureau of Oil and Gas, 1994.

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table H-4. Total Metals, Oil and Grease, and Specific Conductance

Site No.	Cd mg/kg	Cu mg/kg	Cr mg/kg	Pb mg/kg	Ni mg/kg	Zn mg/kg	Hg mg/kg	% Solids	% Water	Spec. Cond. mmhos/ cm	Oil & Grease mg/kg
1	<0.5	9.4	3.7	15	<4	68.6	<0.1				250,000
2	<0.8	22.6	15.3	54.1	13.2	182	<0.001	66	34		190,000
3	<0.8	30	13	37	19.1	3,060	0.11	61	39	29.30	120,000
4	<0.5	9.4	9.4	20	14	46.9	<0.001	71	29	5.87	9,700
5	<0.5	22.5	5.9	53	4.8	46	<0.1		100		540,000
6	<0.7	55.6	17.9	32	31.3	82.3	<0.1	68	32	1.05	20,000
7	<0.7	165	17.6	25.3	19.2	55.4	<0.1	76	24	0.91	3,400
8	0.6	13.9	12	21.5	15.9	53.2	<0.1	79	21	0.57	99,000
9	<0.7	21.4	17	28.5	18	60.6	<0.1	73	27	3.13	22,000
10	<0.8	15.2	24.8	18	14.9	54.3	<0.1	67	33	0.21	17,500
11	1.4	9.6	14.5	39.8	15.9	58.7	<0.1	70	30	11.97	10,100
12	<1.7	9.2	15	<17	<7	40.3	<0.1	58	42	27.54	3,100
13	<1.4	28.5	16.2	16	6.1	48.6	<0.1	70	30	8.03	28,000
14	<1.8	13	13	34.5	9.5	46.7	<0.1	56	44	0.92	55,000
15	<2.0	55.7	17.1	25.5	<8.0	93.7	<0.1	50	50	2.58	190,000
16	<1.0	38.4	10.8	30.2	<4	44.5	<0.1		100	6.41	360,000
17	<1.9	84.3	22.5	30.4	<7.8	91.5	0.111	52	48	0.92	150,000
18	<1.3	14.4	28.1	19.3	<5.3	54.9	0.127	76	24	1.33	11,000
19	<0.7	23.2	18.2	21.3	23.1	60.3	<0.1	71	29	41.10	3,700
20	<1.0	22.1	20	39.2	21.7	82	<0.1	48	52	11.15	180,000
21	0.9	15	16.6	27.8	22.8	61.1	<0.1	58	42	33.60	14,000
22	<0.8	16.3	31.3	36.7	30.3	71	<0.1	62	38	13.94	16,000
23	<0.6	21.7	19	24.4	26.6	53.9	<0.1	81	19	3.15	24,000
24	<0.8	15	16.8	19.4	20.8	48.9	<0.1	62	38	51.70	
25	<0.7	15.9	22.1	21.6	26	54.3	<0.1	70	30	85.60	
26	<0.7	15.2	24.4	22.9	17.2	56	<0.1	75	25	0.44	18,000
27	<0.7	10.9	7.2	28	7.4	37.6	<0.1	68	32	1.59	390,000
28	<0.7	16.7	22.7	29	18.7	52.7	<0.1	68	32	1.53	5,800

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table H-4. Total Metals, Oil and Grease, and Specific Conductance

Site No.	Cd mg/kg	Cu mg/kg	Cr mg/kg	Pb mg/kg	Ni mg/kg	Zn mg/kg	Hg mg/kg	% Solids	% Water	Spec. Cond. mmhos/ cm	Oil & Grease mg/kg
29	<0.7	12.6	20.8	23.5	18.4	54.2	<0.1	70	30	26.20	640
30	<0.9	18.3	23.9	17.7	22.5	58.3	<0.1	54	46	30.50	2,000
31	<0.8	19.3	21.8	36	27	72.4	<0.1	63	37	0.38	36,000
32	<0.8	16.6	12.9	19	14.5	32.8	<0.1	66	34	80.50	1,800
33	<0.9	17.1	18.8	17.2	16	49.9	<0.1	57	43	1.33	12,000
34	<0.9	11	20.7	17.9	17	54.4	<0.1	55	45	2.60	21,000
35	<0.9	9	15.6	19.2	14.7	41.9	<0.1	58	42	1.25	36,000
36	<1.0	10.8	15.6	16.7	14.3	38.6	<0.1	53	47	11.52	84,000
37	<1.0	15.3	17.4	17.2	18.8	52.6	<0.1	52	48	51.70	2,400
38	<1.0	25.3	25.3	31.9	33.2	107	<0.1	53	47	65.60	27,000
39	<1.7	28.6	17.9	19.8	<6.8	30.7	<0.1	59	41	5.40	5,300
40	<1.8	13	17.8	32.1	8.1	58.7	0.197	54	46	29.80	14,000
41	<1.6	12.2	12.1	21.4	<6.2	44.4	<0.1	65	35	31.12	3,200
42	<3.6	18	18	47.2	<15	214	0.126	27	73	19.36	170,000
43	<1.6	19.3	23.3	20.1	23.6	62.7	<0.1	64	36	1.07	11,000
44	<1.7	38.7	23.4	28.5	17.6	78	<0.1	61	39	9.51	50,000
45	<1.7	21.2	24.5	24.5	20.2	151	<0.1	60	40	0.72	35,000
46	<1.4	12	16.6	<14	22	47.9	<0.1	72	28	2.98	46,000
47	<1.9	22.1	26.6	32	18.7	107	<0.1	53	47	0.50	5,000
48	<1.8	12	16	30	12	46	<0.1	54	46	3.02	9,700
49	<1.6	18.4	21.6	25.2	10.6	63.5	<0.1	63	37	1.86	3,400
50	<1.6	26.9	25.5	59	10.2	142	<0.1	61	39	0.93	16,000
51	<1.5	21.4	26.9	24	15.1	94.8	<0.1	68	32	3.02	13,000

Source: Pennsylvania Department of Environmental Resources, Bureau of Oil and Gas, 1994

Associated Waste Report:
Crude Oil Tank Bottoms and Oily Debris (U.S. EPA, January 2000)
Table H-5. NORM Analysis Results

Site No.	U Nat (µg/kg)	Ra 226	Ra 228	Mn 54	Fe 59	Co 58	Co 60	Zn 65	Nb 95	I 131	Cs 134	Cs 137	Ba 140	La 140	Th tot
12	1650.66	360.62	477.86	0	0	0	0	0	0	0	0	20	0	0	3252
13	1403.94	259.81	383.07	0	0	0	0	0	0	0	0	0	0	0	2446
14	1565.69	204.46	443.06	0	0	0	0	0	0	0	0	6	0	0	3320
15	1565.69	22.97	200.06	0	0	0	0	0	0	0	0	12	0	0	2515
16	1376.26	243.08	313.70	0	0	0	0	0	0	0	0	0	0	0	1892
17		1835.65	720.34	0	0	0	0	0	0	0	0	16	0	0	1780
18		680.27	805.57	0	0	0	0	0	0	0	0	0	0	0	2896
19		1344.88	1179.79	0	0	0	0	0	0	0	0	6	0	0	3569
20		663.83	1003.15	0	0	0	0	0	0	0	0	32	0	0	1340
21		855.75	1335.97	0	0	0	0	0	0	0	0	18	0	0	2167
22		679.87	1530.69	0	0	0	0	0	0	0	0	12	0	0	3390
23		585.06	1325.25	0	0	0	0	0	0	0	0	4	0	0	2316
24		761.17	950.51	0	0	0	0	0	0	0	0	12	0	0	2282
25		1271.33	1611.04	0	0	0	0	0	0	0	0	31	0	0	4868
26		761.97	1639.11	0	0	0	0	0	0	0	0	0	0	0	1458
27		420.68	1129.46	0	0	0	0	0	0	0	0	31	0	0	860
39	1564.86	611.23	557.23	0	0	0	0	0	0	0	0	10	0	0	4212
40	2945.97	637.31	651.53	0	0	0	0	0	0	0	0	46	0	0	5053
41	1982.76	870.30	971.55	0	0	0	0	0	0	0	0	20	0	0	3084
42	873.87	496.81	440.11	0	0	0	0	0	0	0	0	14	0	0	2977
49		44.14	24.46	0	0	0	0	0	0	0	0	16	0	0	3861
50		40.09	13.80	0	0	0	0	0	0	0	0	12	0	0	4122
51		6.57	11.62	0	0	0	0	0	0	0	0	8	0	0	3243

Units are pCi/kg unless otherwise noted.
Source: Pennsylvania Department of Environmental Resources, Bureau of Oil and Gas, 1994