OVERVIEW OF EXPLORATION AND PRODUCTION WASTE VOLUMES AND WASTE MANAGEMENT PRACTICES IN THE UNITED STATES

Based on

API Survey of Onshore and Coastal Exploration and Production Operations for 1995

and

API Survey of Natural Gas Processing Plants for 1995

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EXECUTIVE SUMMARY

During 1996, the American Petroleum Institute (API) conducted a survey of onshore oil and gas exploration and production (E&P) operations and natural gas processing plant operations for the year 1995. The survey sought data on current waste volumes and waste management practices, produced water management, and drilling practices. The 1995 survey was designed to update a similar survey of producers' waste management practices that was published by API in 1987, and was based on data for 1985. This report provides an evaluation of the results of the 1995 survey pertaining to E&P waste volumes and waste management practices. The survey covers the three primary categories of wastes produced by the oil and gas exploration and production industry:

- *Produced water* – the saline water brought to the surface with oil and gas;
- *Drilling waste* – the rock cuttings and fluids that are produced from drilling a new wellbore into the subsurface; and
- *Associated wastes* – a broad category of a variety of small volume waste streams that encompasses all other types of wastes "associated" with oil and natural gas production.

The total volume of wastes generated annually by the oil and gas industry has decreased substantially over the past decade. In 1995, the onshore oil and gas E&P industry generated an estimated 17,900 million barrels of produced water, 149 million barrels of drilling wastes, and 20.5 million barrels of associated wastes. In addition, natural gas processing contributed an estimated 9.5 million barrels of produced water and 0.10 million barrels of dehydration wastes. A decade earlier, in 1985, the E&P industry generated 21,000 million barrels of produced water, 361 million barrels of drilling wastes, and 12 million barrels of associated wastes.[1] The decreased volume of wastes generated by E&P operations in 1995 is consistent with the general decline in E&P industry activity between 1985 and 1995 (lower oil production, fewer producing wells, fewer new wells drilled) which affects the two largest waste streams – produced water and drilling wastes.

Table ES-1 summarizes the total estimated volumes of E&P wastes disposed in 1995 by waste disposal method. Because E&P wastes are predominately liquid wastes, over 90 percent of E&P wastes are injected. Another 2 percent of E&P wastes are reused or reclaimed. A brief discussion of the 1995 results for each category of E&P waste follows in Table ES-1.

Table ES.1. 1995 Estimated Volume of Oil and Gas E&P Wastes Disposed by Method (million barrels)

Disposal Method	Produced Water[1]	Drilling Wastes	Associated Wastes[2]	Total Waste Volume	% Disposed by Method
Injection (includes EOR[3])	16,386.5	19.3	7.9	**16,413.7**	**90.7 %**
Evaporation	0	69.9	2.3	**72.2**	**0.4 %**
Burial Onsite	0	31.2	0	**31.2**	**0.2 %**
Commercial E&P Waste Facility	90.3	3.0	3.1	**96.4**	**0.5 %**
Reuse, Recycle, Reclaim	358.1	10.4	3.9	**372.4**	**2.1 %**
Discharge	537.0	1.5	0	**538.5**	**3.0 %**
Land Spread	0	10.4	1.0	**11.4**	**>0.1 %**
Road Spread	1.8	0b	0.5	**2.3**	
All Other	537.0	3.0	1.9	**541.9**	**3.0 %**
Total	**17,910.7**	**148.7**	**20.6**	**18,080.0**	**100.0 %**

[1] Includes produced water removed at gas plants.
[2] Includes wastes from gas processing plants.
[3] Enhanced oil recovery

[1] The 1985 survey excluded completion fluids from the associated wastes volume, while the 1995 survey includes these wastes in the total volume of associated wastes.

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Produced Water. In 1995, E&P operations produced an estimated 17,900 million barrels of water, of which 92 percent was injected. Seventy-one percent of the total volume of produced water was injected for enhanced oil recovery (EOR) in 1995. Another 21 percent of produced water was disposed in Class II injection wells.[2] In 1985, 62 percent of produced water was injected for EOR and 30 percent was disposed in Class II injection wells. An estimated 6 percent of produced water was discharged under NPDES permits in 1985. By 1995, only 3 percent of produced water was discharged, with almost all of the discharged volume from coalbed methane operations. In 1995, 2 percent of the total volume of produced water was put to beneficial use and 3 percent was disposed by various "other" disposal methods such as percolation pits, onsite evaporation, and public water treatment works.

Drilling Wastes. The total volume of drilling wastes estimated in 1995 was based on the calculation of waste volume per foot varied by well depth that was developed during the 1985 survey, and subsequently confirmed by later analyses. Consequently, the volume of drilling wastes estimated for 1995 is consistent with the 1985 estimate, adjusted for the substantial decline in drilling activity. Nonetheless, other improvements in drilling practice between 1985 and 1995 are indicated by the 1995 E&P operations survey. By 1995, 69 percent of reserve pits were lined, up from 35 percent lined in 1985. Moreover, an estimated 25 percent of new wells were drilled with a closed mud system and did not require reserve pits. An estimated 92 percent of onshore drilling wastes in the most recent survey were derived from freshwater based mud systems, compared to 64 percent of drilling wastes in 1985. In 1995, 68 percent of drilling wastes were disposed onsite through evaporation and burial, compared to 41 percent in 1985. Disposal by surface discharge and landspreading decreased from an estimated 17 percent of drilling wastes in 1985 to 8 percent in 1995.

Associated Wastes. Associated wastes represent only about 0.11 percent of E&P wastes estimated nationwide. Although, the estimated volume of associated wastes increased from 1985 to 1995, this may be attributed to general characteristics of the survey (inclusion of certain waste streams and exclusion of other waste streams), as well as industry trends toward better tracking and reporting of E&P wastes. A key factor in the difference is the exclusion of completion fluid volumes from the 1985 survey to avoid potential double counting of those wastes with produced water (with which they are typically co-mingled). The 1995 survey explicitly addressed completion fluid volumes so that they could be included. In addition, a marked increase in the volume of workover/stimulation wastes (from operators' attempts to keep older wells operating profitably) likely contributed to the increase in associated wastes. In 1995, an estimated 89 percent of associated wastes were aqueous fluid. The remaining 11 percent of associated wastes consist of oily solids and glycol-based wastes from dehydration. In 1995, the estimated volume of tank bottoms and oily sludge declined by 21 percent, from 2.5 million barrels in 1985 to less than 2 million barrels in 1995. Over 68 percent of associated wastes were disposed by a combination of injection into Class II wells, evaporation, re-use and reclamation. Disposal by surface discharge and land/road spreading dropped from 24 percent in 1985 to less than 8 percent in 1995.

Natural Gas Processing Plants Natural gas processing plants contribute only a small fraction of E&P wastes, and were not covered by the 1985 waste survey. Gas plants managed an estimated 10 million barrels of produced water in 1995, 93 percent of which were disposed by injection into Class II wells. In 1995, gas plants produced 0.1 million barrels of associated wastes, an average of 167 barrels of waste per plant. Seventy-nine percent of gas processing plant wastes consist of scrubber liquids and sludge, 3 percent consist of glycol compounds and used filter media, and the remaining 18 percent consist of miscellaneous other waste streams. Seventy-six percent of gas processing plant wastes were disposed by injection and 13 percent were disposed at commercial E&P waste facilities and industrial or municipal disposal facilities.

The results of API's 1995 E&P operations survey demonstrate increased use of improved drilling practices and improved waste management practices.[3] The survey results suggest a trend towards overall reduction of oily tank bottoms and sludges, glycol dehydration wastes, and drilling wastes from operations

[2] Class II injection wells are those associated with the oil and gas industry, using a numbering scheme described in the Safe Drinking Water Act.

[3] For more information about how advanced exploration and production technologies are producing waste reductions and other environmental benefits, see "Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology," issued by the U.S. Department of Energy, Office of Fossil Energy, 1999.

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using oil based mud. Over 90 percent of E&P wastes continue to be disposed by injection, and underground injection continues to offer the best method to safely and efficiently dispose of liquid E&P wastes.

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1. INTRODUCTION

Exploring for and producing oil and natural gas results in the production of substantial volumes of wastes, the largest portion of which is naturally occurring material removed from the subsurface. Because exploration and production in the United States takes place at nearly 900,000 separate sites across the country, no mechanism exists for tabulating the total volume of wastes produced and managed by the industry. Nevertheless, it is important to the industry to understand its waste volumes and how they are managed. In the past, the American Petroleum Institute (API) has used statistical surveys of industry operations to estimate waste volumes and characterize management practices. The oil and gas industry's wastes are characterized in three primary categories:

- *Produced water* – the saline water brought to the surface with oil and gas;
- *Drilling waste* – the rock cuttings and fluids that are produced from drilling a new wellbore into the subsurface; and
- *Associated wastes* – a broad category of a variety of small volume waste streams that encompasses all other types of wastes "associated" with oil and natural gas production.

In the fall of 1995, API conducted a survey of onshore oil and gas exploration and production (E&P) operations and natural gas processing plant operations. The survey collected data on current waste volumes and waste management practices, field equipment and facilities, produced water management, and drilling practices.[4] The purpose of the survey was to update current understanding of waste management practices in the oil and gas exploration and production industry. The last comprehensive survey of industry waste management practices was API's *1985 Production Waste Survey.* During the decade between 1985 and 1995, substantial changes occurred in the U.S. oil and gas industry as illustrated in Table 1.1. In 1995, API determined that an update of the 1985 waste management survey was needed to understand how waste management had changed in response to the other changes in the industry. The management and disposal of oil and gas exploration and production wastes continues to be an important concern to states, industry, and the public. The survey results presented here demonstrate how the industry has responded to internal and external concerns about waste management, as well as highlighting some of the challenges that can be undertaken to further enhance protection of human health and the environment.

Section 2 of this report discusses survey results pertaining to production pits, tanks, land treatment operations, and produced water. Section 3 discusses survey results pertaining to associated wastes, drilling practices, drilling wastes and waste management. Section 4 provides a summary of the survey results. Appendix G provides a discussion of the survey methodology including design of the survey forms, design of the survey sample, and methodology for extrapolation of reported data. A brief summary of the survey methodology is provided below. Throughout the report, the 1995 survey results are compared to API's *1985 Production Waste Survey* wherever possible.

[4] The survey form was modified just prior to mailing to include some questions related to equipment such as engines, turbines, and boilers. These data were collected to provide input to a data collection effort by the U.S. Environmental Protection Agency for some specific air emission control related rulemakings. The data collected were provided to EPA on an aggregated basis. The focus of this report, like the primary focus of the survey, is on wastes, and thus the other data collected are not reported here.

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Table 1.1. Comparison of U.S. Exploration and Production Activity, 1985 and 1995

	1985	1995	Percent Change
Total U.S. Crude Oil Production	3,274.6 million barrels	2,394.3 million barrels	-27%
Total U.S. Natural Gas Production	17.2 trillion cubic feet	19.5 trillion cubic feet	+13%
Total U.S. Natural Gas Liquids Prod.	753 million barrels	791 million barrels	+5%
Total U.S. Production	7,093.6 MMboe[c]	6,661.2 MMboe[c]	-6%
Producing Oil Wells[a]	642,408 oil wells	569,508 oil wells	-11%
Stripper Oil Wells[b]	452,543 stripper oil wells	434,422 stripper oil wells	-4%
Producing Gas & Condensate Wells	243,344 gas wells	298,541 gas wells	+23%
New Wells Completed	71,108 wells	21,695 wells	-69%
Total Footage Drilled	316,778,000 feet	117,886,366 feet	-63%

[a] Federal offshore wells are not included.
[b] Stripper wells are a subset of total producing oil wells, and includes those wells that produce 10 barrels of oil per day or less.
[c] Million barrels of oil equivalent – converts natural gas to oil equivalent based on heating values.
Source: API, Basic Petroleum Data Book, January 1999, Volume XIX, Number 1: Tables III-2, III-10, III-12, III-14, III-15; Table IV-4; Table XIII-3, XIII-9.

1.1. Overview of Survey Methodology

Two forms were developed for API's 1995 survey: *API Survey of Onshore and Coastal Exploration and Production Operations for 1995 and API Survey of Natural Gas Processing Plants for 1995.* The onshore operations survey form is included as Appendix H and the gas processing plant survey form is included as Appendix I. A detailed discussion of survey methodology is included as Appendix G.

The operations survey form was designed to focus on all the facilities operated by an E&P company within a single field. An E&P company selected for the survey was asked to complete one survey form per selected field. Participating companies were selected for the survey sample from databases maintained by Petroleum Information (PI) Corporation. For a given geological basin/state/company size combination, a company's probability of being included in the sample was proportional to its 1994 production in the basin/state combination. The PI database that served as a sampling frame for the 1995 Onshore and Coastal E&P Operations survey did not contain production information for the Appalachian states. For these states, API contacted the Oil and Gas Associations of each state and asked for a list of member companies. API sent survey forms to a selection of the member companies and asked the companies to complete the forms for any two of their fields in the designated state.

All of the responses received for a state were aggregated. The total responses received for each state were used to generate a single extrapolation factor for the state, such as number of tanks per oil production facility or volume of completion fluids generated per well completion. Reported data from the operations survey were extrapolated on production, estimated number of production facilities, or number of wells, as appropriate to the survey question under consideration. Similarly, reported data from the gas plants survey were extrapolated on gas throughput or number of gas plants as appropriate.

1.2. Estimated Production Facilities, 1995 Production, Active Wells, and Other Supplemental Data

Appendix A contains two tables which summarize the supplemental data used in this report to estimate total state values for various elements of the operations survey – waste volumes, produced water volumes, waste management practices, drilling practices, and production facilities. Appendix A, Table 1 lists the 1995 producing wells and estimated number of production facilities for each state. Appendix A, Table 2

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provides 1995 oil, gas, and natural gas liquids production by state.[5] The bases for extrapolation for all the survey elements discussed in this report are the following:

- Production Pits – extrapolated on the estimated number of 1995 production facilities; supplemented by state estimates and reported data
- Oil Tank Batteries – estimated to be equivalent to the number of oil production facilities
- Condensate Tank Batteries – extrapolated on the number of active gas wells.[6] Extrapolation factor determined from survey data.
- Total Tanks – extrapolated on the estimated number of tank batteries
- Produced Water Volume – extrapolated on 1995 oil and gas production; supplemented by state estimates, reported data and estimates from Petroleum Information
- Associated Wastes: Completion Fluids – extrapolated on 1995 completed wells
- Associated Wastes: Workover/Stimulation Fluids – extrapolated on 1995 active wells
- Associated Wastes: Tank Bottoms/Oil Sludge – extrapolated on 1995 production
- Associated Wastes: Dehydration/Sweetening Wastes – extrapolated on 1995 gas production
- Drilling Wastes – extrapolated on 1995 footage drilled using drilling waste extrapolation factors identified in API's *1985 Production Waste Survey*

For the gas processing plant survey, the following survey elements were extrapolated to regional and nationwide values:

- Production Pits – extrapolated on number of gas plants in a region provided by the *Oil and Gas Journal (OGJ), Gas Processing Survey.*
- Non-pressurized tanks – extrapolated on number of gas plants in a region
- Produced water – extrapolated on total gas throughput for a region provided by the *OGJ*, *Gas Processing Survey*
- Dehydration wastes – extrapolated on gas throughput.

[5] A consulting engineer with over 30 years of experience in the industry estimated the number of production facilities in each state. He based his estimates on data from PI, as well as prior analyses, engineering relationships, and professional experience.

[6] Although the total number of oil tank batteries is estimated as the number of oil production facilities, this estimation cannot be used for condensate tank batteries because condensate is not always associated with gas production. If all condensate tank batteries are estimated as the number of gas production facilities, the result is an unreasonably large number of condensate tank batteries and associated tanks. As an alternative, the number of condensate tank batteries is estimated using a national extrapolation factor of six gas wells per tank battery determined from the reported data.

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2. SURVEY RESULTS: PRODUCTION PITS, TANKS, LAND TREATMENT OPERATIONS, AND PRODUCED WATER

2.1. Production Pits

2.1.1. E&P Operations - Pits

Production pits include all types of pits operated except those associated with drilling operations. Examples of production pits include evaporation, blowdown, produced water, percolation, workover, and emergency pits. These types of pits are used when needed to enhance the safety or efficiency of field operations. Active pits are defined as pits currently in service as part of field operations, whether or not they contain fluids. Inactive pits are pits that are no longer part of the field operating system but have not been closed. Reported data on production pits are presented in Appendix B, Table 1. Survey respondents reported a total of 2,444 production pits of which 97 percent are active and 59 percent are lined. Several states have encouraged operators to close production pits and phase out the use of many types of pits in E&P operations. Louisiana has ordered the closure of pits in many areas of the state since 1986. Texas and Oklahoma report a very small number of pits relative to the size of the E&P industry in these states and none of the respondents from Appalachian states report production pits.

Appendix B, Table 2 shows estimated total production pits extrapolated based on the number of production facilities. (The estimated number of oil and gas production facilities for each state is shown in Appendix A, Table 1.) For selected states, the numbers of pits estimated in Table B.2 are based on data collected by state regulatory agencies. These state data were used to represent certain states because they are believed to be more accurate than the estimates extrapolated from the survey responses. Generally, one production pit is assumed per oil production facility. If survey respondents for a given state reported production pits associated with gas production, then one production pit was assumed for each gas production facility as well. No production pits were extrapolated for states that did not report pits for the E&P operations survey. Due to relatively low survey response rates on this question, the extrapolated number of pits for individual states is highly uncertain. The estimated total numbers of pits from Table B.2 are best interpreted as an estimate of the potential order of magnitude of production pits in an individual state. Nationwide, an estimated 55,000 pits are associated with production operations. Based on the survey data reported in Table B.1, 97 percent of the 55,000 estimated pits are assumed to be active pits and 60 percent are assumed to be lined pits.

2.1.2. Gas Plants - Pits

Gas plant pits include all types of pits operated at the plant except small collection sumps. The pits included are identical to many types of production pits for E&P operations, namely: evaporation, blowdown, produced water, and emergency pits. Table 2.1 summarizes the reported numbers of gas plant production pits as well as the extrapolated number of gas plant pits. Survey respondents reported a total of 78 pits of which 97 percent are active and 62 percent are lined. The estimated number of pits was extrapolated on the number of gas plants in a region. No pits were estimated for regions that did not report pits for the survey. Approximately 875 gas plant pits are estimated to be associated with gas processing plants. The total of gas plant pits plus production pits from E&P operations are estimated to be about 56,000 pits nationwide.

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Table 2.1. Gas Processing Plants – Pits

Region	# Plants in Region[a]	Reported Data from Survey				Estimated Number of Active Pits[b]
		Number of Pits Operated	Number of Active Pits	Number of Inactive Pits	% Active Pits with Liners	
Alaska	3	11	11	0	45%	11
California	25	0	0	0	0	0
Eastern U.S.	47	0	0	0	0	0
Mid-West	92	0	0	0	0	0
New Mexico	27	8	8	0	63%	43
Rockies	104	14	14	0	64%	208
Southeast	68	4	4	0	0%	18
Texas	233	41	39	2	72%	606
Total	**599**	**78**	**76**	**2**	**62%**	**875**

[a] Based on 1996 OGJ Survey.
[b] Extrapolated based on number of plants.

2.2. Tank Batteries and Total Tanks

2.2.1. Tanks and Tank Batteries – E&P Operations

Survey respondents were asked to report either tank batteries on individual leases, or the number of central or primary separation facilities in unitized fields where storage tanks are present. Produced water injection facilities and produced water disposal facilities are not included in the count of tank batteries/central facilities. Survey respondents were also asked to report the numbers and types of tanks at the tank batteries. The E&P operations survey forms sent to operators in the Appalachian states asked only for the number of tanks in operation and did not ask for an estimate of tank batteries or central facilities.

Appendix B, Table 3 summarizes the reported data for oil tank batteries, oil tanks and other tanks associated with oil production. Appendix B, Table 4 summarizes the reported data for condensate tank batteries, condensate tanks, and other tanks associated with gas production. Table B.3 indicates that the typical oil tank battery contains two oil tanks, one produced water tank, and an emergency tank and/or "waste" tank. For condensate tank batteries, the data reported in Table B.4 suggest that the typical condensate tank battery contains one condensate tank, one or two produced water tanks, and may include an emergency or "waste" tank.[7] Combining the reported data from Tables B.3 and B.4, suggests that the typical tank battery services five to six wells and is comprised of four tanks: two oil or condensate tanks, one produced water tank, and one emergency tank or waste oil/water tank.

Because no survey data were collected on tank batteries for Appalachian operations, it cannot be determined whether the reported components of a typical tank battery represent Appalachian operations. The combined data from Tables B.3 and B.4 for Appalachian operations suggests that the ratio of product tanks to produced water tanks for Appalachian operations is 1:2 (i.e., one oil or condensate tank to two produced water tanks). Also, only about one-third of oil or condensate tanks in Appalachian operations appear to be associated with either a waste tank or emergency tank.

Estimated total numbers of tank batteries and tanks associated with E&P operations for individual states were extrapolated from the reported data. Appendix B, Table 5 summarizes the estimated oil tank

[7] Reported data for condensate tank batteries includes some responses for Arkansas and Kansas that report very large numbers of produced water tanks per tank battery. Although these responses are outliers compared to the other reported data, they are not necessarily invalid responses. If the outlying responses are removed from the reported data, the typical condensate tank battery appears to include only two to three tanks: one condensate tank, one produced water tank, and possibly a waste or emergency tank.

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batteries associated with oil production and Appendix B, Table 6 summarizes the estimated condensate tank batteries associated with gas production. The number of oil tank batteries was estimated as the number of oil production facilities (as illustrated in Appendix A). The number of condensate tank batteries was estimated by applying the ratio of six gas wells per tank battery to the number of active gas wells. The number of tank batteries estimated for each state was then multiplied by the average number of tanks per tank battery determined for that state from the survey responses received for the state (shown in Tables B.3 and B.4). If a state had no survey data, a national average of four tanks per oil tank battery or two tanks per condensate tank battery was assumed.[8]

Table 2.2. summarizes the national estimate of tank batteries and tanks associated with E&P operations. A typical ratio of oil or condensate tanks, produced water and "other" tanks can be determined from the survey data in Appendix Tables B.3 and B.4. If these ratios are applied to the estimated total number of tanks in Table 2.2, the total number of oil tanks is estimated to be approximately 627,500 and the total number of condensate tanks is estimated to be 204,300. Therefore, the estimated total number of tanks associated with E&P operations (oil tanks plus condensate tanks) is approximately 831,800 tanks. About 75 percent of these tanks are estimated to be associated with oil production operations. The remaining 25 percent are estimated to be associated with gas production operations.

Table 2.2. National Estimate of Total Tank Batteries and Tanks Associated with E&P Operations

	Estimated Oil Tank Batteries	Associated Tanks (Oil Production)	Estimated Condensate Tank Batteries	Associated Tanks (Gas/ Condensate Production)	Total Tanks (oil plus gas/condensate production)
All States Excluding Appalachian Region	144,100	517,800	27,800	109,600	627,400
Appalachian Region Only	27,400	109,700	20,500	94,700	204,400
Estimated National Total (includes Appalachian Region)	**171,500**	**627,500**	**48,300**	**204,300**	**831,800**

2.2.2. Non-pressurized Tanks – Gas Plants

The number of tanks reported includes all non-pressurized tanks used at the plant for storage of produced water, condensate, and liquid products and all tanks used for emergency conditions. Table 2.3 shows the estimated number of tanks associated with gas plants. The reported data for gas plant tanks is summarized in Appendix B, Table 7. Nationwide, gas plants are estimated to have about five associated non-pressurized tanks. The typical gas plant has approximately two liquid product tanks per plant, one condensate tank, and one or two produced water tanks. About 40 percent of plants are estimated to have an emergency tank. Table 2.3 also indicates the regional variation from the national estimate. For example, the New Mexico region is estimated to have about six to seven tanks per gas plant. A typical gas plant in New Mexico is estimated to have three liquid product tanks, two condensate tanks, and one emergency tank. About 60 percent of New Mexico plants are estimated to have a produced water tank as well.

[8] Alternate estimates of total tanks for the Appalachian states were obtained by applying a survey-derived ratio of six oil wells per tank to a state's total active oil wells and 1.3 gas wells per tank to a state's total active gas wells. The alternate estimates for the Appalachian states are included in Appendix Tables B.5 and B.6. The alternate estimate of tanks associated with oil production appears to be quite low and is not included in Table 2.2. The alternate estimate of tanks associated with condensate production is reasonably close to the estimate obtained from applying the method used for non-Appalachian states. The alternate estimate of tanks associated with condensate production is included in Table 2.2 because this estimate incorporates survey reported data for the Appalachian region.

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Table 2.3. Estimate of Total Non-Pressurized Tanks Associated with Gas Plants

Region	# Plants in Region[a]	Estimated Number of Produced Water Tanks[b]	Estimated Number of Condensate Tanks[b]	Estimated Number of Liquid Product Tanks[b]	Estimated Number of Emergency Tanks[b]	Estimated Total Non-Pressurized Tanks[b]
Alaska	3	0	0	18	1	19
California	25	no data	no data	no data	no data	0
Eastern U.S.	47	20	94	275	27	416
Mid-West	92	153	123	92	0	368
New Mexico	27	16	54	81	22	173
Rockies	104	134	149	401	89	773
Southeast	68	59	59	59	5	181
Texas	233	466	186	342	124	1,118
Total	**599**	**848**	**665**	**1268**	**267**	**3,048**

[a] Based on 1996 OGJ survey.
[b] Extrapolated based on number of plants.

2.3. Landspreading/Land Treatment Operations

Landspreading/land treatment operations dispose of solid wastes through application to the land or incorporation into the soil. This process uses the physical, chemical, and biological capabilities of the soil to decompose constituents of the wastes. Nutrients and water may be added to enhance biodegradation and the treatment area may be tilled periodically to improve aeration. In this context, "landspreading" or "land treatment" excludes the practice of landspreading or burying drill cuttings and other drilling wastes. An example of the type of land treatment operation included here might be land treatment or bioremediation of hydrocarbon contaminated soil on leased land surrounding a production facility. Land treatment operations typically require a state permit but some states prohibit land treatment. Question 18 of the E&P operations survey simply asked operators if on-site landspreading or land treatment operations are carried out in the field for which they were reporting. Thirty respondents (19 percent) report on-site land treatment operations and 127 respondents (81 percent) report no land treatment operations:

	On-site Land Treatment - Yes	On-site Land Treatment – No
Total Responses:	30 (19%)	127 (81%)

2.4. Produced Water

2.4.1. Estimated Volume of Produced Water – E&P Operations

The estimated total volume of produced water by state is shown in Appendix C, Table 1. An estimated national total of 17.9 billion barrels of water was produced in 1995. As indicated in Table C.1, the estimated total produced water for most states was obtained from state data, state estimates, or industry sources (Petroleum Information estimates). Where indicated, a produced water volume was extrapolated based on 1995 oil production using extrapolation factors estimated from survey responses for question six on the E&P operations survey form.

The API *1985 Production Waste Survey* reports two estimates for produced water. The first estimate, 16.3 billion barrels, was obtained from state records, operator inventories and EPA estimates. The second estimate, 20.9 billion barrels, was based on statistical analysis of data received from a supplemental

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survey form sent to individual companies. The 1985 estimates suggest that, on average, 5.0 barrels to 6.4 barrels of water were produced per barrel of oil. The 1995 estimate indicates that, a decade later, the produced water cut increased to approximately 7.5 barrels of water per barrel of oil. The 1995 estimate of produced water, 17.9 billion barrels, represents a 14 percent decline from the 1985 estimate of 20.9 billion barrels. This corresponds to the 27 percent decline in U.S. oil production over the same period. The apparent decline in produced water volume was not as great as the decline in oil production for two reasons. First, declining oil production between 1985 and 1995 was offset, in part, by a 13 percent increase in gas production. Although, gas wells generally produce less water than oil wells, water production associated with gas production can be substantial in some regions. Second, as oil production declined, associated water production increased on a per barrel basis, reflecting a growing population of aging oil wells

2.4.2. Produced Water Disposal – E&P Operations

The reported volumes of produced water and reported disposal methods are tabulated in Appendix C, Table 2. Survey respondents reported the production of approximately 4.8 million barrels of water per day or 1,750 million barrels annually. The survey respondents represent about 10 percent of the estimated national total volume of produced water. Table 2.4 below summarizes the frequency of produced water disposal methods estimated from the aggregate survey response. Nationwide, 71 percent of produced water is injected into producing reservoirs to enhance recovery of oil and natural gas. Another 21 percent of produced water is injected for disposal. Subsurface formation water and waste fluids produced by the oil and gas industry are injected into Class II wells as required under the Safe Drinking Water Act. Thus, approximately 92 percent of produced water is managed through Class II well injection into subsurface reservoirs, generally considered the safest and most effective method for handling these type fluids. Although only 3 percent of produced water is discharged; almost all of the discharged volume is obtained from coalbed methane operations in Alabama and is discharged under NPDES permits. Less than half of one percent of produced water is disposed at commercial disposal facilities.

Table 2.4. 1995 Produced Water Disposal Method – Reported Data

Produced Water Disposal Method	Percentage of Produced Water Disposed by Method
Inject for Enhanced Oil Recovery (EOR)	71.0 %
Inject for Disposal Onsite	18.0 %
Treat and Discharge [a]	3.0 %
Inject for Disposal Offsite	2.5 %
Beneficial Reuse [b]	2.0 %
Inject at Commercial Disposal Facility	< 0.5%
Road Spread	< 0.01%
Other [c] (“percolation ponds”)	3.0 %

[a] Over 99 percent of surface discharged water originates from coalbed methane operations in Alabama. The remaining discharged water is comprised of small volumes reported from gas production operations in Appalachian states.
[b] Beneficial reuse takes place under NPDES permits and allows produced water to be used for irrigation, livestock watering, and similar uses in the Western U.S.
[c] Almost the entire volume in the “Other” category is reported by operators in California and appears to represent a produced water management method unique to California.

The percentage of produced water disposed by the methods summarized in Table 2.4 was applied to the 17,900 million barrels total volume estimated in Appendix C.1. An estimated 16,500 million barrels were injected into Class II wells in 1995, of which 12,700 million barrels were used for enhanced oil recovery

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and 3,800 million barrels were disposed. Approximately 500 million barrels were discharged via NPDES permit, an estimated 400 million barrels were re-used for beneficial purposes, and 500 million barrels were disposed by other methods.

As Appendix C, Table 2 indicates, there is significant regional variation from the nationwide aggregate produced water disposal methods presented in Table 2.4 above. For example, surface discharge of produced water is permitted for large coalbed methane operations in Alabama. Consequently, the percentage of water disposed by NPDES discharge in Alabama is quite large relative to other states, and represents a special case resulting from the coalbed methane operations in that state. The Appalachian States (KY, OH, PA, NY, VA, WV) and the Rocky Mountain States (CO, WY, UT, MT) provide further examples of regional variation in produced water disposal methods. In the Appalachian states, 85 percent of produced water is injected, 15 percent is reported as being surface discharged, and 6 percent of produced water is disposed at commercial facilities. Only 30 percent of injected produced water is used for enhanced oil recovery operations in the Appalachian states. In contrast, 85 percent of produced water is injected for EOR in the Rocky Mountain States, 7 percent is injected onsite for disposal, but less than 1 percent of produced water is disposed at offsite commercial facilities. In the Rocky Mountain States approximately 7 percent of produced water is reused for beneficial purposes (e.g., livestock watering, irrigation).

Table 2.5 compares the produced water disposal methods reported in API's *1985 Production Waste Survey* with the disposal methods reported in API's 1995 E&P operations survey. While the total percentage of produced water injected remained constant between 1985 and 1995; the percentage injected for enhanced recovery increased significantly by 1995. Disposal by injection was not distinguished as onsite, offsite, or commercial disposal in the 1985 survey. The percentage of produced water disposed by NPDES surface discharge decreased by half between 1985 and 1995. This was mainly due to a prohibition of coastal discharges in Louisiana and Texas, which was phased in during the early 1990s. In 1995, disposal by NPDES surface discharge is limited to a few unique, regional operations.

Table 2.5. Comparison of 1985 and 1995 Produced Water Disposal Methods

Produced Water Disposal Method	% Produced Water Disposed by Method 1985	% Produced Water Disposed by Method 1995
Inject for Enhanced Oil Recovery (EOR)	62 %	71 %
Injected for Disposal	30 %	21 %
NPDES Discharge	6 %	3 %[a]
Reuse	0 %	2 %
Other (percolation, evaporation, public treatment works)	2 %	3 %
Total	**100%**	**100%**

[a] Nearly all surface discharge is from coalbed methane operations in Alabama.

2.4.3. Produced Water – Gas Processing Plants

Gas plant survey respondents reported the removal of over 6,000 barrels of produced water per day. This is water that was not separated from the gas in the field but must be removed prior to processing. When extrapolated on gas throughput, the total volume of produced water from gas processing plants is estimated to be at least 9.5 million barrels per year. Table 2.6 summarizes the reported data and extrapolated volume of produced water for each gas plant region. The Alaskan region reported no volume of produced water. If an estimated volume of produced water is assumed for Alaska, then the total estimated volume of produced water from gas plants may be as much as 10.9 million barrels per year.

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Table 2.6. Gas Plants, Produced Water Volume – Reported Data and Estimated Volumes

Region	# Plants in Region[a]	Gas Plant Throughput for Region [a] (MMcfd)	Reported Gas Throughput for Region (MMcfd)	Reported Volume Produced Water (barrels/day)	Vol. Produced Water per Vol. Gas Throughput (bbl/MMcf)	Estimated Volume Produced Water (barrels/day)
Alaska	3	8,600	7,900	0	b	b
California	25	700	300	201	0.67	**460**
Eastern U.S.	47	2,000	990	247	0.25	**500**
Mid-West	92	5,900	110	71	0.66	**3,900**
New Mexico	27	2,100	1,100	148	0.13	**300**
Rockies	104	4,400	2,700	328	0.12	**530**
Southeast	68	12,900	6,200	520	0.08	**1,100**
Texas	233	11,500	2,700	4,532	1.69	**19,400**
Total (excl. Alaska)	**596**	**39,500**	**14,100**	**6,047**	**0.62**	**26,190[b]**

[a] Based on 1996 Oil & Gas Journal survey.
[b] Due to processes used in Alaska, all produced water may be removed before it reaches the gas plant. If we assume a volume of 0.43 bbl/MMcf for Alaska, total estimated produced water volume is 29,890 bbl/d.

Appendix F, Table 1 shows the reported volumes of produced water disposed from gas plants by method for each gas plant region. The national results are summarized in Table 2.7 which shows that 93 percent of produced water from gas plants is reported to be disposed by injection into Class II wells. Approximately 38 percent of the injected volume is disposed onsite. About 46 percent of the injected volume is disposed offsite into Class II wells with 9 percent going to commercial well disposal facilities. The remaining produced water not injected is disposed by other miscellaneous methods.

Table 2.7. Gas Plants; Produced Water Disposal Method – Reported Data

Produced Water Disposal Method	Percentage of Produced Water Disposed by Method	Volume of Produced Water Disposed by Method (barrels/day)
Inject for Disposal Offsite	46 %	2,781
Inject for Disposal Onsite	38 %	2,306
Inject at Commercial Disposal Facility	9 %	534
Reuse	1 %	50
Treat and Discharge	0 %	0
Road Spread	0 %	0
Other	6 %	376
Total	100 %	6,047
"Other" methods include: co-mingle w/ oil product, treat & evaporate, evaporation pits, inject for EOR in adjacent oil fields, steam vent to atmosphere		

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3. SURVEY RESULTS: ASSOCIATED WASTES, GAS DEHYDRATION/SWEETENING WASTES, DRILLING WASTES, AND WASTE MANAGEMENT PRACTICES

3.1. Associated Wastes and Waste Management

3.1.1. Types of Associated Wastes

Associated wastes include a wide range of small volume waste streams that are associated with exploration and production of oil and natural gas. These wastes are often grouped under the term "associated wastes" as the third category of wastes (along with produced water and drilling wastes) that are exempt from regulation as hazardous wastes under the Resource Conservation and Recovery Act.[9] The 1995 E&P operations survey considered four categories of wastes that together comprise the majority of associated wastes:

- Completion Fluids – All fluids from initial well completion activities, including any initial acid stimulation or hydraulic fracturing.
- Workover/Stimulation Fluids – All fluids from subsequent workover and stimulation operations.
- Tank Bottoms/Oily Sludges – Tank sediment and water, produced sand and other tank bottoms.
- Dehydration/Sweetening Wastes – Includes glycol-based compounds, glycol filters, molecular sieves, amines, amine filter, precipitated amine sludge, iron sponge, scrubber liquids and sludge, backwash, filter media and other wastes associated with the dehydration and sweetening of natural gas.

Appendix D, Table 1 lists the 1995 reported volumes of associated wastes by state. Completion fluids and workover fluids comprise 91 percent of the reported volume of associated wastes. Tank bottoms and sludge comprise almost 9 percent of the reported volumes, and dehydration/sweetening wastes comprise only 0.25 percent.

The associated waste streams considered in the 1995 E&P operations survey differ somewhat from the API *1985 Production Waste Survey*. The types and volumes of associated wastes considered in the *1985 Production Waste Survey* are summarized in Table 3.1. The 1*985 Production Waste Survey* estimated the total volume of associated wastes generated in 1985 to be 11.76 million barrels; the 1995 survey estimates the total volume of associated wastes generated annually to be about 20.5 million barrels. The most significant difference is the 1995 survey defined completion fluids and workover/stimulation fluids as two separate categories of associated wastes, whereas the 1985 survey combined the two waste streams into a single category. In the 1985 survey, workover fluids were described as: *"…workover, swabbing, unloading, and completion fluids recovered from a well bore that are not recombined with the production stream. They include spent acid or stimulation fluids and swab tank fluids sent directly to disposal. They exclude fluids sent down flow lines, hauled to field batteries or NPDES permitted pits because these fluids are captured in other waste categories or under produced water disposal statistics."* Unlike the 1985 survey, the 1995 survey captures the volume of completion and workover fluids injected into Class II wells as associated waste. Consequently, the large percentage of completion and workover fluids that were reported disposed by injection in 1995 were not captured as associated waste in the 1985 survey, but were instead included in the estimated volume of produced water. For this reason, the percentage of associated wastes comprised of aqueous liquids in 1995 is almost twice the percentage of aqueous liquid associated waste in 1985. The 1985 survey also includes oil-contaminated soil as associated waste, as well as a number of other small waste streams such as solvents, cooling tower blowdown water, and used oils that were not

[9] A fourth category of wastes, 'industrial wastes' includes wastes generated at E&P sites that are not uniquely associated with oil and gas E&P operations and thus are not exempt from regulation as hazardous under RCRA. These include wastes such as paint and used solvents. Industrial wastes were not addressed by the survey.

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included in the 1995 survey. Approximately 25 percent of the total associated wastes estimated in 1985 were contributed by waste streams not considered in the 1995 E&P operations survey.

Table 3.1. Summary of Total Estimated Associated Wastes from 1985 Production Waste Survey (barrels)

Associated Waste	% Waste	Est. Waste Volume (bbls./yr.)
Workover Fluids	48 %	5,656,000
Produced Sand	11 %	1,276,000
Oily Debris (contaminated soil, rags, etc.)	11 %	1,261,000
Tank Bottoms	10%	1,232,000
Dehydration/Sweetening Unit Wastes	4 %	460,000
Untreatable Emulsions	3 %	355,000
Used Solvents/Degreasers	2 %	252,000
Cooling Water	2 %	219,000
Used Oils	2 %	212,000
Spent Iron Sponge	< 1 %	54,000
Other Liquid Wastes	5 %	591,000
Other Solid Wastes	2 %	192,000
Total		**11,760,000**

3.1.2. Estimated Volume of Associated Wastes – 1995 E&P Operations Survey

Appendix D, Table 2 shows the estimated volumes of associated wastes by state. Completion fluids were extrapolated based on the number of completed wells, workover/stimulation fluids were extrapolated on the number of active wells, tank bottoms were extrapolated on total production, and dehydration/sweetening wastes were extrapolated on gas production. Table 3.2 summarizes the national total volume of associated wastes estimated from the 1995 E&P operations survey.

Table 3.2. 1995 E&P Operations Survey – Total Estimated Volume of Associated Wastes

Associated Waste	% Waste	Est. Waste Volume (bbls./yr.)
Completion Fluids	43 %	8,778,000
Workover/Stimulation Fluids	46 %	9,527,000
Tank Bottoms/Oily Sludge	10 %	1,987,000
Dehydration/Sweetening Unit Wastes	1 %	193,000
Total		**20,485,000**
Total (excluding completion fluids as in the 1985 Survey)		(11,707,000)

In 1985, the injected volume of workover and completion fluids was largely counted with the 1985 volume of produced water. Consequently, the total 1995 volume of associated wastes minus the 1995 volume of completion fluids provides an estimate of the total 1995 volume of associated wastes, 11.7 million barrels, that is directly comparable to the total 1985 volume of 11.76 million barrels (illustrated in Tables 3.1 and 3.2). The 1995 volume of associated wastes may be underestimated because oily debris and other miscellaneous waste streams were not included in the 1995 data. For example, in 1985 oily debris contributed approximately 11 percent of associated wastes, or about 1.3 million barrels, but this waste stream is not included in 1995. Another 1.0 million barrels, or about 9 percent of the 1985 total associated

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wastes, were contributed by miscellaneous solid and non-aqueous waste streams that were not included in 1995.

There are several other noteworthy differences between the 1995 estimated volumes of associated wastes and the 1985 estimated volumes. Aqueous fluids comprise 89 percent of associated wastes in 1995. The remaining 11 percent of associated wastes are solids, sludges, and glycol compound wastes. In 1985, solids, sludges, and non-aqueous liquids were estimated to comprise 45 percent of associated wastes, and workover fluids, cooling tower blowdown water, and miscellaneous other liquid wastes comprised the remaining 55 percent of associated wastes. In 1995, the estimated total volume of workover fluid was 68 percent greater than the total volume of workover fluid estimated in 1985. This increase probably reflects a substantial increase in the number of well workovers, recompletions, and well stimulations between 1985 and 1995. In 1995, the estimated volume of tank bottoms/oily sludge (includes produced sand) was about 21 percent less than the 1985 estimated volume of 2.51 million barrels (produced sand plus tank bottoms). Because tank bottoms were extrapolated on production, the decreased volume of tank bottoms/oily sludge between 1985 and 1995 reflects the 27 percent decline in crude oil production during the period. The estimated total volume of dehydration/sweetening wastes in 1995 is less than half the volume of dehydration/sweetening wastes estimated in 1985. The 1995 estimated volume of dehydration wastes is surprisingly low considering that total U.S. gas production increased by 13 percent between 1985 and 1995 and the number of active gas wells increased by 23 percent. The apparent decline in the estimated volume of dehydration wastes may be the result of a combination of factors: 1) Recycled glycol waste fluids were not reported in the survey; 2) By 1995, the percentage of production that is "new" gas increased relative to total gas production, and new production tends to be dry gas that does not require dehydration; 3) The survey response was insufficient to characterize gas dehydration wastes for the total United States.[10]

In comparing the estimated volumes of associated wastes between 1985 and 1995, another factor to consider is better record keeping. At the time of the 1985 survey, the term "associated wastes" was new and many companies simply did not keep track of these waste streams (which tend to be only a few barrels per well annually). By 1995, increased environmental awareness and the availability of better information management systems enhanced the accuracy of the data reported on the survey forms. Thus, a portion of the apparent "increase" in associated wastes may simply be due to better tracking and reporting of these waste streams within companies.

3.1.3. Associated Waste Disposal

Table 3.3. reports the estimated associated waste disposal practices for the aggregate associated waste stream for the total United States. The disposal practices reported in Table 3.3 reflect the large volume of aqueous liquid associated wastes that were identified in the 1995 survey. In 1995, the most common disposal practice was injection, 7.78 million barrels, followed by recycling, reclamation or beneficial reuse, 3.89 million barrels. Approximately, 3 million barrels were disposed at commercial E&P waste facilities and 2.25 million barrels were evaporated.

[10] In the 1995 survey, only 17 respondents reported dehydration waste in a total of 11 states. It is possible that the sample reporting gas dehydration wastes were not representative of gas dehydration operations in the U.S. as a whole.

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Table 3.3. Estimated Associated Waste Disposal Practices for the Total U.S.; Total Associated Waste Stream – 1995 E&P Operations Survey

Associated Waste Disposal Method	% Waste	Total Estimated Waste Volume (bbls./year)
Disposal by Injection	38 %	7,784,000
Recycle, Reuse, Oil Reclamation	19 %	3,892,000
Commercial E&P Waste Facility	15 %	3,073,000
Evaporate from Pits	11 %	2,253,000
Land Spread	5 %	1,024,000
Road Spread	2.5 %	512,000
Incinerate	0.4%	82,000
Municipal or Industrial Landfill	<0.1 %	20,500
Other: (land treatment, burial onsite, disposal pits, other commercial disposal)	9%	1,844,000
Total (Bbls./Yr.)	**100%**	**20,484,500**

Table 3.4 shows the total volume of associated wastes by disposal practice estimated in the *1985 Production Waste Survey.* In 1985, the largest volume of associated wastes, 6.1 million barrels, was disposed in offsite commercial facilities. In 1995, only half this volume, 3.1 million barrels was estimated to be disposed at commercial E&P facilities. It is possible that the additional 3 million barrels disposed at offsite commercial facilities in 1985 includes some of the associated waste streams and volumes not identified in the 1995 survey, such as oil contaminated soil, spent solvents, emulsions, and miscellaneous oily debris. Between 1985 and 1995, the estimated volume of associated wastes disposed by land spreading or road spreading declined by over 40 percent from 2.7 million barrels to 1.5 million barrels. In 1995, 10 million barrels were estimated disposed by injection and evaporation compared to 1.18 million barrels in 1985. This reflects the inclusion of completion fluids as an associated waste in 1995, as well as the significant increase in workover/stimulation fluids between 1985 and 1995.

Table 3.4. Estimated Volume of Associated Wastes by Disposal Techniques From 1985 Production Waste Survey

Associated Waste Disposal Method	% Waste	Total Estimated Waste Volume (bbls./year)
Offsite Commercial Facility	52 %	6,114,000
Road Spread	14 %	1,646,000
Land Spread	9 %	1,058,000
Injection	7 %	823,000
Recycle	7 %	823,000
Onsite Burial	5 %	588,000
Evaporation/Onsite Pit	3 %	353,000
Surface Discharge	1 %	116,000
Other: (incinerate, burned as fuel)	2%	235,000
Total (Bbls./Yr.)	**100.0%**	**11,756,000**

Table 3.5 and Table 3.6 show the estimated volume of wastes disposed by waste disposal practice for each of the associated waste streams considered in the 1995 E&P operations survey. Appendix D, Table 3 and Table 4 contain the reported data on which Table 3.5 and Table 3.6 are based. Associated waste disposal practices vary significantly depending upon the type of waste stream. Appendix D, Table 5 and Table 6 show the reported volumes of associated wastes disposed by state. These tables indicate variations in associated waste disposal practices between states and regions.

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Table 3.5. Estimated Volumes of Associated Wastes by Disposal Method; Completion Fluids and Workover Fluids, 1995 E&P Operations Survey

Associated Waste Disposal Methods	% Completion Fluids	Est. Volume Completion Fluids (bbls/yr.)	% Workover Fluids	Est. Volume Workover Fluids (bbls./yr.)
Disposal by Injection	21 %	1,843,000	59 %	5,621,000
Recycle, Beneficial Reuse, Oil Reclamation	33 %	2,897,000	<0.1 %	10,000
Commercial E&P Waste Facility	29 %	2,546,000	4 %	381,000
Evaporate from Pits	8 %	702,000	16 %	1,524,000
Land Spread	6 %	527,000	2 %	191,000
Road Spread		0	0.4%	38,000
Incinerate		0	1 %	95,000
Municipal or Industrial Landfill		0		0
Other: (land treatment)	3 %	263,000	17.5 %	1,667,000
Total	**100%**	**8,778,000**	**100%**	**9,527,000**

Table 3.6. Estimated Volumes of Associated Wastes by Disposal Method; Tank Bottoms/Oily Sludge and Dehydration Wastes, 1995 E&P Operations Survey

Associated Waste Disposal Methods	% Tank Bottoms	Est. Volume Tank Bottoms/ Sludge (bbls./yr.)	% Dehydration Wastes	Est. Volume Dehydration Wastes (bbls./yr.)
Disposal by Injection	24 %	477,000	4 %	7,700
Recycle, Beneficial Reuse, Oil Reclamation	37 %	735,000	7 %	13,500
Commercial E&P Waste Facility	2 %	40,000	32 %	61,700
Evaporate from Pits	0.2 %	4,000		0
Land Spread	16.5 %	328,000	8 %	15,400
Road Spread	18 %	358,000	48.5 % [a]	93,500
Incinerate	<0.1 %	2,000	0.1 %	200
Municipal or Industrial Landfill	<0.1 %	2,000		0
Other: (onsite burial, other commercial disposal, disposal pits)	2 %	40,000	0.5 %	1,000
Total	**100%**	**1,986,000**	**100%**	**193,000**

[a] Of the 17 survey respondents reporting gas dehydration waste, a single respondent accounted for almost half the total reported volume of dehydration waste. This same respondent reported all dehydration waste was roadspread in 1995. If this response is excluded from the reported data, then the total extrapolated volume of dehydration/sweetening waste is 99,000 barrels with an estimated 62.5 percent disposed at commercial E&P waste disposal facilities.

Comparison of the associated waste disposal practices and waste volumes reported in 1985 and 1995 suggest that significant changes occurred over the decade:

- The estimated total volume of associated wastes did not decrease between 1985 and 1995 despite the decline in oil production during that period. Between 1985 and 1995 the volume of aqueous liquid wastes increased relative to the volume of solid and oily wastes, with a corresponding increase in the volume of associated wastes disposed by Class II injection and evaporation.

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- The volume of workover/stimulation fluids increased between 1985 and 1995, possibly reflecting an increase in workovers, recompletions, and well stimulations during that time.

- The volume of tank bottoms/oily sludge declined between 1985 and 1995. The decreased volume of oily wastes may, in part, be the result of the decline in oil production during that time, as well as improved waste minimization and waste treatment efforts.

- There appears to be an almost 50 percent decrease in the use of offsite commercial E&P facilities for associated waste disposal between 1985 and 1995. The estimated volume of associated wastes disposed at commercial facilities was 3 million barrels in 1995, down from 6 million barrels in 1985. This result suggests that a greater percentage of associated wastes were managed onsite in 1995 than in 1985.

- The estimated volume of associated waste disposed by surface disposal methods such as surface discharge, land spreading, and road spreading declined between 1985 and 1995.

3.2. Gas Processing Plant Wastes and Waste Management

3.2.1. Types of Gas Processing Plant Wastes

Like other types of wastes uniquely associated with oil and natural gas production, gas processing plant wastes are exempt from regulation as hazardous under the Resource Conservation and Recovery Act (RCRA). Exempt gas plant wastes include glycol and glycol-based compounds, glycol filters, molecular sieves, amines, amine filters, precipitated amine sludge, iron sponge, scrubber liquids and sludge, backwash, filter media, and miscellaneous other wastes associated with dehydration or sweetening of natural gas. The 1995 survey of gas processing plant wastes considered four categories of wastes that represent the primary exempt waste streams from gas processing operations. The waste streams considered include:

- Spent glycol/glycol compounds
- Used filters and filter media
- Scrubber liquids and sludge
- All other dehydration and sweetening wastes.

Detailed survey data reported for each gas plant dehydration waste stream are presented by region in Appendix F, Tables 2, Table 3, Table 4, and Table 5. Appendix F, Table 6 summarizes the reported volumes of gas processing plant wastes for the total United States.

3.2.2. Gas Processing Plant Waste Disposal Methods and Estimated Volumes of Waste

The total estimated volume of gas processing plant wastes for the United States is shown in Table 3.7. No wastes were extrapolated for the Alaska region because no wastes were reported for that region. The total estimated volume of wastes from gas processing plants is less than 1 percent of the estimated national total volume of associated wastes. Scrubber liquids and sludge comprise an estimated 79 percent of the waste stream from gas plants. Glycol compounds and used filters/filter media each contribute 1 percent to 2 percent of the gas plant dehydration waste stream. The remaining 18 percent of the wastes include other unspecified dehydration wastes.

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Table 3.7. Gas Processing Plant Wastes – Estimated Volumes (extrapolated on gas throughput)

Region	Gas Throughput for Region (MMcfd)	Est. Volume Spent Glycol/ Glycol Compounds (bbls./yr.)	Est. Volume Used Filters/ Filter Media (bbls/yr.)	Est. Volume Scrubber Liquids & Sludge (bbls./yr.)	Est. Volume All Other Dehydration/ Sweetening Wastes (bbls./yr.)	Est. Total Reported Volume of Gas Plant Wastes (bbls./yr.)
Alaska	8,637	0	0	0	0	**0**
California	679	50	60	460	0	**570**
Eastern U.S.	2,005	220	1	120	0	**340**
Mid-West	5,894	0	10	0	830	**840**
New Mexico	2,122	0	50	40	2,140	**2,230**
Rockies	4,384	710	420	70	1,950	**3,150**
Southeast	12,864	210	150	66,370	9,280	**76,010**
Texas	11,502	10	820	13,470	4,090	**18,390**
Total	**48,087**	**1,200**	**1,510**	**80,530**	**18,290**	**101,530**

Table 3.8. lists the estimated volume of gas processing plant wastes by disposal method. The reported volumes of gas plant wastes by disposal method are summarized in Appendix F, Table 7. Table 3.8 suggests that scrubber liquids comprise the largest component of gas processing plant wastes. Consequently, most gas plant wastes, 78.5 percent, are disposed by injection or evaporation. Thirteen percent of gas plant wastes are disposed offsite at commercial E&P waste facilities or landfills. Data were not collected on gas processing plant wastes in the 1985 production survey, so no comparison can be made with 1985 waste volumes and disposal practices.

Table 3.8. Gas Processing Plants; Estimated Volume of Wastes by Disposal Method

Waste Disposal Method	Percentage of Gas Processing Plant Wastes Disposed by Method	Estimated Volume of Wastes Disposed by Method (barrels/year)
Disposal by Injection	76 %	77,200
Commercial E&P Waste Disposal Facility	9 %	9,100
Land Spread Onsite	6 %	6,100
Industrial or Municipal Landfill	4 %	4,100
Evaporate from Pits	2.5 %	2,500
Recycle or Reuse	1 %	1,000
Incinerate	0.25%	300
Road Spread Onsite	0.01 %	10
Other	1 %	1,000
Total	**100%**	**101,310**
"Other" methods include: "co-mingle w/ oil product, waste disposal contractor, onsite burial w/ permit, incineration in "waste-to energy" plant"		

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3.3. Drilling and Drilling Waste Management

3.3.1. Drilling Techniques

Traditionally, wells are drilled using one of two techniques. Most wells are drilled using a rotary rig with drilling mud to cool the bit and lubricate the hole. Wells drilled with a rotary rig generally have a reserve pit to store and dispose the used drilling fluids and cuttings. An older drilling technique, common in Appalachia, uses a truck-mounted cable tool drilling rig. But new technologies have made in-roads. In sensitive areas, reserve pits are increasingly replaced with storage tanks in what is termed as a "closed system." Certain types of wells are drilled using pneumatic tools and air, gas, or foam in place of drilling mud. The survey requested information on drilling techniques to better understand the percentage of wells drilled with techniques other than a rotary rig and open mud systems. Appendix E, Table 1 summarizes the reported data on drilling techniques used for new wells in 1995.

Survey respondents reported a total of 1,244 new wells drilled. Operators from the Appalachian states reported 124 new wells, or approximately 10 percent of the total. With a few regional exceptions, the 1995 E&P operations survey indicates that the majority of new wells in the onshore U.S. were drilled using a reserve pit to store and dispose used drilling muds and cuttings. The primary regional exceptions are Alaska (100 percent wells reported drilled with closed system), New Mexico (73 percent of new wells drilled with air or gas), and Appalachia (96 percent drilled with air, gas, or pneumatics).

Table E.1 shows that for the total United States, 66 percent of new wells were reported drilled with a mud system discharging to reserve pits, 23 percent of new wells were drilled with a closed system (no reserve pits), 11 percent were drilled with air or gas (no drilling mud), and less than 0.1 percent were reported drilled with a cable tool.[11] Sixty-nine percent of mud reserve pits was reported to be lined. For the Appalachian states reporting, 96 percent of new wells were drilled with air and the remaining 4 percent were drilled using a reserve pit. No respondents from Appalachian states reported wells drilled with a cable tool. If the Appalachian component is removed from the reported data in Table E.1, for the remaining states, 74 percent of new wells were drilled using a reserve pit, 25 percent with a closed system, and only 1 percent was drilled with air or gas.

A significant improvement in drilling practices between 1985 and 1995 is indicated by the difference in drilling techniques reported in the 1995 E&P operations survey and the drilling techniques inferred from the 1985 survey.[12] Between 1985 and 1995, the percentage of lined reserve pits increased from 35 percent to 69 percent. By 1995, one quarter of new wells were drilled with a closed system and did not require reserve pits.

3.3.2. Percentage of Drilling Wastes by Base Drilling Fluid

Appendix E, Table 2 contains reported percentages of drilling wastes by base drilling fluid. Table E.2 indicates that most of the new wells, with a few local exceptions, are drilled with freshwater base mud. Alaska is the only state that reports a significant percentage of new drilling with synthetic based drilling mud (30 percent). Most drilling with oil based mud is reported only in Louisiana and Oklahoma. Drilling with saltwater-based mud is reported in only six states known to have salt bearing formations.

In Appendix E, Table 3, the percentage of drilling wastes by base drilling fluid (from Table E.2) were applied to reported drilling waste volumes to estimate a national percentage of drilling wastes by base drilling fluid. Table E.3 shows that in 1995, 92.5 percent of drilling wastes were derived from freshwater based drilling fluid, 5.5 percent of drilling wastes were derived from saltwater based drilling fluids, oil based drilling fluid produced less than 1.5 percent of wastes, and the remaining 0.5 percent were derived from

[11] Only one well was reported drilled with a cable tool.

[12] In the API *1985 Production Waste Survey,* 91 percent of wells were reported drilled with a mud system. The remaining 9 percent of new wells reported as "other" in 1985 is inferred to represent air- or gas-drilled wells. Of the 91 percent of new wells drilled with mud systems in 1985, 2 percent were drilled with a polymer mud system, which are inferred to be closed systems. Nationwide, an estimated 35 percent of reserve pits was estimated to be lined.

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synthetic based drilling fluid. The *1985 Production Waste Survey* reported that 64 percent of drilling wastes were derived from freshwater based mud systems; 23 percent of drilling wastes were derived from saltwater based muds; oil based muds produced 7 percent of drilling wastes; and polymer or "other" muds produced the remaining 6 percent of drilling wastes. The decline in drilling waste from oil-based drilling reflects the availability of better water-based and synthetic-based drilling formulas, along with industry practice to substitute more environmentally friendly materials where feasible.

3.3.3. Volume of Drilling Wastes

Table 3.9 provides an estimate of the volume of drilling wastes generated within each state during 1995. Drilling waste volumes for the 1995 survey were estimated by multiplying the total 1995 footage drilled by the average waste extrapolation factor determined for the state (by depth category) in the *API 1985 Production Waste Survey*.[13] The estimated national total volume of drilling wastes for 1995 is 148.7 million barrels or approximately 1.21 barrels of waste per foot drilled. This estimated 1995 volume is less than half the 361 million barrels of drilling wastes estimated in 1985. Because the approach used to estimate the 1995 volume of drilling wastes does not account for improvements in the efficiency of drilling systems between 1985 and 1995, the actual volumes of drilling wastes may be over stated.

Appalachian States The 1995 E&P operations survey form sent to operators in the Appalachian states asked respondents to report volumes of drilling waste. This information had not been collected for the Appalachian states in the *1985 Production Waste Survey*. Appendix E, Table 4 shows the reported drilling waste volumes and reported footage drilled for the Appalachian region. Only eight respondents in the region reported drilling in 1995 and almost 97 percent of the reported footage was drilled with air rather than a mud system. The remaining 3 percent of reported footage was drilled with a mud system.

The reported data collected for the Appalachian region (0.07 barrels waste/foot) may represent typical waste volumes generated by air drilling, and may not be representative of typical drilling waste volumes generated for the Appalachian region as whole. In Appendix E, Table 5 the estimated waste extrapolation factor for air drilling, 0.07 barrels/foot, (from Table E.4) is applied to the Appalachian states, as well as other states, which report significant air drilling in the 1995 survey (New Mexico, Oklahoma, and Utah). Table E.5 provides alternative estimates of drilling wastes for these states (NM, OK, UT, KY, NY, OH, PA, TN, VA, WV) that are considerably lower than the drilling waste volumes estimated in Table 3.9. If the alternative drilling waste volumes estimated for the selected states in Table E.5 are substituted for the drilling waste volume estimated in Table 3.9, the estimated national total volume of drilling waste for 1995 becomes 132.8 million barrels, or approximately 1.08 barrels of waste per foot drilled.

[13] *API 1985 Production Waste Survey*, Table 90, Total Drilling Waste Volumes Discharged to the Reserve Pit.

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Table 3.9. Estimated Total Volume of Drilling Wastes

STATE	Est. Total Footage Drilled in 1995 – Survey Reported Data [a] (feet)	Est. Volume Total Drilling Waste per Foot Drilled [b] (bbls/ft)	Est. Vol. Drilling Waste for 1995 Drilling - Survey Reported Data [c] (barrels)	1995 Total Footage Drilled [d] (Completed Wells)	Est. Total Volume Drilling Wastes for State [e] (barrels)
AK	132,000	0.84	110,880	1,911,300	**1,605,492**
AL	0	3.26	0	1,087,500	**3,545,250**
AR	0	2.05	0	1,289,500	**2,643,475**
AZ		1.92	0	5,400	**10,368**
CA	830,325	0.61	506,498	2,994,100	**1,826,401**
CO	72,000	0.87	62,640	4,117,600	**3,582,312**
FL		3.71	0	15,500	**57,505**
IL	55,800	0.51	28,458	749,100	**382,041**
IN		0.62	0	172,200	**106,764**
KS	1,024,428	0.9	921,985	5,344,700	**4,810,230**
KY	83,500	1.43	119,405	1,465,100	**2,095,093**
LA	175,390	1.95	342,011	11,526,800	**22,477,260**
MI	11,900	1.1	13,090	1,573,900	**1,731,290**
MO		1.13		0	**0**
MS	0	2.94		1,370,100	**4,028,094**
MT	58,616	1.52	89,096	898,500	**1,365,720**
ND	0	1.05		841,500	**883,575**
NE	0	0.55		159,800	**87,890**
NM	60,911	1.29	78,575	5,752,500	**7,420,725**
NV		1.57		104,600	**164,222**
NY	18,200	1.28	23,296	108,000	**138,240**
OH	44,650	0.56	25,004	3,073,700	**1,721,272**
OK	133,600	1.11	148,296	11,857,800	**13,162,158**
OR		0.36		0	**0**
PA	98,600	1.03	101,558	2,357,100	**2,427,813**
SD		1.03		9,300	**9,579**
TN		2.39		93,000	**222,270**
TX	2,488,209	1.13	2,811,676	57,847,100	**65,367,223**
UT	100,250	1.68	168,420	929,400	**1,561,392**
VA	93,793	0.41	38,455	139,900	**57,359**
WV	254,160	0.54	137,246	1,585,000	**855,900**
WY	24,000	1.27	30,480	3,443,900	**4,373,753**
Total	**5,760,332**	**1.2**	**5,757,070**	**122,823,900**	**148,720,666**

[a] Extrapolated from survey form question 22a: reported # new wells drilled in each depth zone x average drilling depth reported for each depth zone
[b] Average for state from API 1985 Production Waste Survey
[c] (Column 2) x (Column 3)
[d] Oil and Gas Journal, Energy Statistics Sourcebook, 12th edition, Table "Footage Drilled by State"
[e] (Column 3) x (Column 5)

3.3.4. Types of Drilling Wastes and Drilling Waste Disposal

Appendix E, Table 6 summarizes the disposal methods reported for liquid drilling wastes. The percentage of liquid wastes disposed by each method is expressed as a percentage of total drilling wastes. In California for example, survey respondents report that 19 percent of total drilling wastes are liquid wastes disposed by evaporation. Appendix E, Table 7 summarizes the disposal methods reported for solid drilling wastes. The percentage of solid wastes disposed by each method is expressed as a percentage of total drilling wastes. In Texas for example, survey respondents report that 13 percent of total drilling wastes are solid wastes disposed by burial onsite.

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Table 3.10 illustrates that, for the total United States, almost 74 percent of drilling wastes were characterized as liquid wastes and 26 percent were characterized as solid drilling wastes. The estimated waste volumes disposed by various disposal methods are summarized in Appendix E, Table 8 for liquid drilling wastes and in Appendix E, Table 9 for solid drilling wastes.

Table 3.10. Summary of Estimated Drilling Wastes by Type of Waste From 1995 E&P Operations Survey (barrels)

Estimated Total Liquid Wastes	109,443,000	73.6 %[a]
Estimated Total Solid Wastes	39,257,000	26.4 %
Estimated Total Drilling Waste Volume	148,700,000	100 %
[a] Estimated relative percentages of solid and liquid drilling waste are derived from Appendix E, Tables 8 and 9, "Estimated Volumes of Liquid and Solid Drilling Waste for States with Reported Data."		

The relative volumes of solid and liquid drilling wastes reported in Table 3.10. were derived in the following manner. The estimated volume of drilling wastes for each state (shown in Table 3.9.) was multiplied by the reported percentage of wastes disposed by each method (shown in Appendix E, Table 6 and Appendix E, Table 7). This was done only for states that reported drilling wastes in the 1995 survey. This exercise produced an estimate of the volume of drilling wastes disposed by each method for each state with reported data. These estimated volumes were aggregated to obtain an estimate of the relative volume of solid and liquid drilling wastes for the total United States, and an estimate of the aggregate drilling waste disposal practices for the total United States.

In the 1985 waste survey, liquid drilling wastes were estimated to comprise almost 90 percent of drilling wastes. Ten percent of drilling wastes were estimated to be solids, primarily drill cuttings. Table 3.11 summarizes the types of drilling wastes identified in the API *1985 Production Waste Survey*. Comparison of Tables 3.10 and Table 3.11 indicate a significant increase in the relative volumes of solid drilling wastes to liquid wastes from 1985 to 1995.

Table 3.11. Summary of Estimated Drilling Wastes by Type of Waste From 1985 Production Waste Survey (barrels)

Mud and Completion Fluid	226,801,000	62.75%
All Other Water	87,724,000	24.3 %
Formation Testing Fluids	916,000	0.25 %
Other Fluids	8,222,000	2.3 %
Total Liquid Wastes	**323,663,000**	**89.6 %**
Drill Cuttings	35,674,000	9.9%
Circulated Cement	1,876,000	0.5 %
Other Solids	196,000	
Total Solid Wastes	**37,746,000**	**10.4 %**
Total Volume	361,409,000	

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Two factors may contribute to the apparent increase in solid drilling wastes relative to liquid drilling wastes in the 1995 survey:

1. There appears to be more air drilling represented in the 1995 E&P operations survey relative to the 1985 survey due, in part, to an increase in air-drilled coalbed methane wells by 1995 and in part, to greater representation of Appalachian operations in the 1995 survey. If Appalachian states are omitted from total drilling waste estimate, the percentage of solid drilling wastes are estimated to be 25 percent.

2. In the 1985 survey, drilling mud was characterized as a liquid waste, and a significant portion of drilling mud was reported hauled offsite for disposal as a liquid waste. In the 1995 survey, most drilling wastes were reported disposed onsite through evaporation of the liquid portion and burial of the solid portion. The 1995 E&P operations survey may have more effectively captured the solid component of drilling mud as a solid drilling waste. The mud solids remaining after onsite evaporation of freshwater based liquid drilling waste would generally be incorporated with drill cuttings and disposed through onsite burial. This would increase the volume of solid drilling wastes relative to liquid drilling wastes in the 1995 E&P operations survey.

Table 3.12 shows the aggregate nationwide drilling waste disposal practices estimated from the 1995 E&P waste survey. Nationwide, over two-thirds of drilling wastes (68 percent) were disposed onsite through evaporation and burial. Injection and reuse of liquid wastes account for another 20 percent of drilling wastes. Approximately 8 percent of drilling wastes were disposed on the land surface through land spreading and surface discharge. Disposal at commercial E&P waste facilities appears to be a minor disposal practice used for less than 3 percent of onshore drilling wastes.

Table 3.12. Estimated Drilling Waste Disposal Practices - 1995 E&P Operations Survey

Evaporate On or Offsite	47 %	Liquid Drilling Waste
Burial Onsite	21 %	Solid Drilling Waste
Injection (includes injection down annulus)	13 %	Liquid Waste
Reuse for Drilling	7 %	Liquid Waste
Land Spread Onsite	6 %	Solid and Liquid Waste
Land Spread Offsite	1 %	Solid and Liquid Waste
Commercial Disposal Facility	2 %	Solid Waste
Treat and Discharge	1 %	Liquid Waste
Recycle, Road Spread, Municipal Landfill	<0.5 %	Solid and Liquid Waste
Other	< 1.5 %	Includes: grind and inject – solid waste; commercial disposal – liquid waste; onsite remediation – solids & liquid waste; disposal pits – solid waste.
Total	**100%**	

The greatest change in drilling waste disposal practices between 1985 and 1995 appears to be a marked increase in onsite disposal and a decrease in surface discharge of liquid drilling wastes. In the *1985 Production Waste Survey,* 28 percent of drilling wastes were estimated to be hauled offsite for disposal. By 1995, less than 3 percent of drilling wastes were disposed at offsite commercial facilities. This increase in onsite disposal, particularly onsite evaporation, may be a function of the increased use of lined reserve pits. The estimated drilling waste disposal practices from the *1985 Production Waste Survey* are summarized in Table 3.13 for comparison with the 1995 E&P operations survey results.

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Table 3.13. Comparison of 1985 and 1995 Estimated Drilling Waste Disposal Practices

Drilling Waste Disposal Method	% Drilling Wastes Disposed by Method	
	1985	1995
Evaporate Onsite	29 %	47 %
Hauled Offsite	28 %	2 %
Injection	13 %	13 %
Buried Onsite	12 %	21 %
Discharge to Surface	10 %	1 %
Land Spread	7 %	7 %
Reuse for Other Drilling	0 %	7 %
Other (includes solidification, incineration)	1 %	2 %
Total	**100%**	**100%**

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4. SUMMARY OF RESULTS

Following is a summary of the extrapolated results of the survey questions evaluated in this report. The results presented here are national totals estimated for onshore operations for the total United States. The detailed survey results presented in the foregoing sections demonstrate that there is significant regional variation in E&P operations, the volume of wastes generated, and waste management practices.

- **Production Pits – E&P Operations**

  Nationwide, an estimated 55,000 pits are associated with production operations; 97 percent of production pits are estimated to be active. An estimated 60 percent of production pits are lined.

- **Production Pits – Gas Plants**

  An estimated 875 production pits are associated with gas plants in the total United States; 97 percent of pits are estimated to be active. An estimated 62 percent of gas plant pits are lined.

- **Tank Batteries and Tanks – E&P Operations and Gas Plants**

  The estimated total number of oil tank batteries is 171,500 batteries. The estimated total number of condensate tank batteries is 48,300 batteries. The estimated total number of tanks associated with E&P operations is approximately 832,000 tanks. Over 3,000 additional non-pressurized tanks are estimated to be associated with gas processing plants.

- **Produced Water – E&P Operations**

  An estimated national total of 17,900 million barrels of water was produced in 1995. This volume represents approximately 7.5 barrels of produced water per barrel of oil. Most produced water, an estimated 92 percent, was injected into Class II wells for enhanced oil recovery or disposal. Three percent of produced water, primarily from coal bed methane wells in Alabama, was treated and discharged under NPDES permits. Two percent of produced water was beneficially reused, and 3 percent was disposed by other methods.[14]

- **Produced Water – Gas Plants**

  An estimated 9.5 million barrels of water was produced by gas plants in 1995. Ninety-three percent of produced water from gas plants was disposed by injection into Class II wells. Only 1 percent was reused, and 6 percent was disposed by a variety of miscellaneous methods including co-mingling with oil production, evaporation, EOR injection into adjacent oil fields, and steam venting to the atmosphere.

- **Associated Wastes**

  The total estimated volume of associated wastes produced in 1995 was 20.5 million barrels. This total is comprised of 8.9 million barrels of completion fluids, 9.5 million barrels of workover/stimulation fluids, 2.0 million barrels of tank bottoms/oily sludge, and 0.2 million barrels of dehydration/sweetening wastes. Of the aggregate associated wastes, 38 percent were disposed by injection, 19 percent were recycled, reused, or reclaimed, 15 percent were disposed at offsite commercial E&P waste facilities, 11 percent were evaporated, and 8 percent were land spread or road spread.

- **Gas Processing Plant Wastes**

  The total estimated volume of gas processing plant wastes produced in 1995 was 0.1 million barrels. This total is comprised of approximately 80,500 barrels of scrubber liquids and sludge, 1,200 barrels of spent glycol compounds, 1,500 barrels of used filters and filter media, and 18,300 barrels of miscellaneous other dehydration wastes. Seventy-six percent of gas processing plant wastes were disposed by injection, 1 percent were recycled or reused, 9 percent were disposed at commercial E&P waste facilities, 3 percent were evaporated, 6 percent were land spread, and 4 percent were sent to landfills.

[14] "Other" produced water disposal methods include percolation ponds, which are used only in California.

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- **Drilling Technique**

Drilling practices improved significantly between 1985 and 1995. In 1995, 66 percent of wells nationwide were drilled with reserve pits compared to 89 percent of wells drilled with reserve pits in 1985. In 1995, 69 percent of reserve pits were lined compared to 35 percent in 1985. Almost 25 percent of wells were drilled with a closed system in 1995 compared to an inferred 2 percent of wells in 1985.

- **Drilling Wastes**

The results from the 1995 E&P waste survey indicate an apparent decline in the use of oil and saltwater based drilling fluids since 1985. In 1995, an estimated 93 percent of drilling wastes were derived from freshwater based mud systems compared to 64 percent of drilling wastes in 1985. In 1995, 6 percent of drilling wastes were produced from saltwater-based mud systems compared to 23 percent in 1985. Finally, only 2 percent of drilling wastes were derived from oil based muds in 1995 compared to 7 percent of wastes in 1985. Polymer and "other " drilling fluids produced the remaining 6 percent of drilling wastes in 1985. In 1995, synthetic based drilling fluids produced less than 0.5 percent of drilling wastes from onshore operations.

In 1995, almost 74 percent of drilling wastes were characterized as liquid wastes and 26 percent were characterized as solid wastes. The total drilling wastes generated in 1995 are estimated to be 148.7 million barrels or about 1.21 barrels/wastes per foot drilled. An alternative drilling waste estimate incorporates the survey-derived waste estimation factor for air-drilled wells of 0.07 barrels of waste per foot drilled. This alternative national estimate of the total volume of drilling wastes is 132.8 million barrels or about 1.08 barrels of waste per foot drilled. Most drilling wastes in 1995 were disposed onsite. Forty-seven percent of drilling wastes was evaporated, 21 percent were buried onsite, 13 percent of drilling wastes were injected and 7 percent were reused for drilling other wells. Seven percent of drilling wastes were land spread and only 2 percent were disposed at commercial E&P waste facilities.

- **Summary of Total Waste Volumes Disposed by Method in the United States**

Table 5.1. 1995 Estimated Volume of E&P Wastes Disposed by Method (million barrels)

Disposal Method	Produced Water [a]	Drilling Wastes	Associated Wastes [b]	Total Waste Volume	% Total Wastes Disposed by Method
Injection (includes EOR)	16,386.5	19.0	7.9	**16,413.7**	**90.8 %**
Evaporation	0	69.9	2.3	**72.2**	**0.4 %**
Burial Onsite	0	31.2	0	**31.2**	**0.2 %**
Commercial E&P Waste Facility	90.3	3.0	3.1	**96.4**	**0.5 %**
Reuse, Recycle, Reclaim	358.1	10.4	3.9	**372.4**	**2.1 %**
Discharge	537.0	1.5	0	**538.5**	**3.0 %**
Land Spread	0	10.4	1.0	**11.4**	**>0.1 %**
Road Spread	1.8	-	0.5	**2.3**	
All Other	537.0	3.0	1.9	**541.9**	**3.0 %**
Total	**17,910.7**	**148.7**	**20.6**	**18,080.0**	**100.0%**

[a] Includes produced water removed at gas plants.
[b] Includes associated wastes generated at gas plants.

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