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STEP
Strategies for Today's
Environmental Partnership

Characterization of Exploration and Production Associated Waste

Health and Environmental Sciences Department
Publication Number DR53
November 1996

STEP
Strategies for Today's
Environmental Partnership

One of the most significant long-term trends affecting the future vitality of the petroleum industry is the public's concerns about the environment. Recognizing this trend, API member companies have developed a positive, forward-looking strategy called STEP: Strategies for Today's Environmental Partnership. This program aims to address public concerns by improving our industry's environmental, health and safety performance; documenting performance improvements; and communicating them to the public. The foundation of STEP is the API Environmental Mission and Guiding Environmental Principles.

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- To work with others to resolve problems created by handling and disposal of hazardous substances from our operations.
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- To promote these principles and practices by sharing experiences and offering assistance to others who produce, handle, use, transport or dispose of similar raw materials, petroleum products and wastes.

Characterization of Exploration and Production Associated Wastes

Health and Environmental Sciences Department

API PUBLICATION NUMBER DR53

PREPARED BY:

AMERICAN PETROLEUM INSTITUTE
PRODUCTION WASTE ISSUE GROUP

NOVEMBER 1996

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EXECUTIVE SUMMARY

During the exploration and production of crude oil and natural gas, the oil and gas industry generates a number of wastes that are uniquely associated with its operations. These include produced water, drilling wastes, and so-called "associated wastes." Associated wastes, which include crude oil impacted soil, tank bottoms, and workover fluids, comprise approximately 11 million barrels, or 0.1 percent of the total volume of exploration and production (E&P) wastes generated annually (API, 1988). The 1980 amendments to the Resource Conservation and Recovery Act (RCRA) exempted associated wastes from regulation by EPA under its Subtitle C hazardous waste requirements. Currently, associated wastes are regulated by state agencies under state laws.

The industry aggressively advocates the use of cost-effective waste management options that are protective of human health and the environment. In 1989, the American Petroleum Institute's (API) Production Waste Issue Group (PWIG) of the Executive Committee on Environmental Conservation, initiated a waste characterization and groundwater modeling study to gain a better understanding of the fate and effects of E&P waste in the environment.

A limited composition and constituent concentration database for different categories of associated wastes was developed and the data were then used as input to a soil and groundwater model developed by API that simulates the effects of a variety of land-based waste management practices. It should be stressed that the results presented in this report must be considered with an understanding of how each waste is managed and the probable transport and fate of waste constituents in order to evaluate any potential effects on human health and the environment.

Concurrent with API's study, the Gas Research Institute (GRI) conducted a complementary study to develop characterization data for wastes associated with natural gas industry operations (Myerski *et al.*, 1993).

The products expected from API's study were:

1. An initial constituent database for associated wastes;
2. Sampling and analytical experience;
3. An assessment of potential impacts to groundwater posed by land-managed associated wastes; and
4. Recommendations for future studies.

SAMPLING AND ANALYSIS

Sample collection and analysis were conducted in two phases. In Phase I (1989), 31 samples were collected and analyzed for a comprehensive list of organic and inorganic constituents. During Phase II (1990-1991), 89 additional samples were collected and analyzed for a more narrowly focused set of constituents and characteristics. In all, samples representing 12 different associated waste categories were collected from on-shore E&P sites in seven states. Samples of oil-based drill cuttings and used oil, neither of which are considered associated wastes by EPA, were also collected. However, for simplicity, all analyses of materials sampled during both phases are presented in this report. Oil-based drill cuttings are exempt from regulation under RCRA Subtitle C. Used oil is considered non-exempt from RCRA Subtitle C regulation; however, under existing EPA regulations, used oil may be reintroduced into the crude stream for recycling if the used oils are from normal operations and are to be refined with normal process streams at a petroleum refinery facility (see 40 CFR Section 279).

A conservative approach was taken when collecting samples. A conscious effort was made to sample materials in a manner to capture the highest concentrations of constituents of potential environmental concern. Materials sampled ranged from freshly contaminated soil to a host of potential wastes from various process streams. Care was taken to address all significant wastes and potential wastes, obtain representative samples, and employ appropriate quality assurance/quality control (QA/QC). Some of the sampling difficulties encountered could be minimized in future efforts by following an established plan for associated waste sampling.

Many associated waste samples contained percent levels of oil and parts per million (ppm) levels of volatile organic compounds (benzene, toluene, ethyl benzene, and xylenes; "BTEX"). A few samples were found to contain ppm levels of the semi-volatile compounds 1-methyl naphthalene and phenanthrene. A number of metals were detected: ppm levels of lead, chromium, copper, nickel, vanadium and zinc were found in many samples. Calcium, sodium, and potassium were found along with barium, a common drilling fluid additive. Since BTEX and semi-volatile compounds are naturally occurring constituents of crude oil and natural gas liquids, and the metals detected are ubiquitous in the environment, these results are not unexpected. Therefore, the transport and fate of these constituents in various media, such as soil and groundwater, must be evaluated before any significance can be placed upon the magnitude of the concentrations found.

This study revealed several practical problems with the sampling and analysis of associated wastes. The two primary, and often related, sampling problems were: 1) obtaining a representative sample, and 2) scheduling the sampling event. For example, sampling methods must be carefully selected to obtain samples that are representative of much larger volumes of generated materials that are typically quite heterogeneous. Care must be taken to schedule sampling so that a true waste can be captured during an actual maintenance procedure (e.g., cleaning out a storage tank or removing waste glycol from a gas plant). The infrequency of certain maintenance events sometimes necessitated the sampling of materials which were still part of the process stream and would not normally be considered wastes.

Many of the samples caused severe matrix interference problems with the EPA SW-846 methods used in this study. Matrix interference issues have been previously addressed in SW-846 and in comments on SW-846 in regard to petroleum matrices (USEPA, 1986). Low concentrations of organic constituents within an organic matrix would not have been detected, if present. These findings clearly show that associated wastes, especially those containing high levels of organic materials, require specialized analytical methods.

This study generated a useful set of analytical data to serve as an initial, but limited, database describing the characteristics of associated wastes. When comparing the data in this study with data in future studies, the data quality elements of precision and accuracy should be evaluated. The RCRA Characteristics data collected in this study should be compared to other predictive tools (i.e., alternative leaching protocols and fate and transport modeling) to determine the validity of continuing to use the EPA methods, such as the Toxicity Characteristic Leaching Procedure (TCLP), for associated wastes.

FATE AND TRANSPORT MODELING

The composition and constituent concentration data generated in the sampling and analysis phase of this study were used to assess the potential impact on groundwater posed by land-managed associated waste. These data were entered into the API-developed Vadose and Saturated Zone Exposure (VADSAT) model which simulates the fate and transport of constituents from a land-management unit to a user-designated drinking water well, directly downgradient. VADSAT accounts for most of the major processes that affect organic constituents moving through the shallow subsurface including: adsorption, dilution and biodegradation.

Industry practices of land spreading, road spreading, and burial were modeled with VADSAT. The modeling investigation considered six associated waste types, four chemical species, two infiltration scenarios, eleven hydrogeological environments, and two hypothetical receptor locations. A total of 1,144 VADSAT Monte Carlo simulations were performed, each simulation involving iteration of 1,000 sets of parameter values. This analysis produced a statistical distribution of possible receptor well concentrations for a wide range of hydrogeologic conditions.

Associated waste management scenarios were converted to input understood by VADSAT using data from a range of sources. Physical and chemical properties data not available from the sampling and analysis portion of this study were obtained from reference works. Hydrogeological settings were described by statistics compiled by API (Newell *et al.*, 1989). Representative volumes of associated waste managed per disposal incident were compiled from information provided by API member companies.

SUMMARY OF RESULTS AND FINDINGS

1. An initial constituent database for associated wastes was established.

   The data presented throughout this report indicate that the sampled associated wastes contain few Petroleum Refinery List semi-volatile organic compounds, varying types and concentrations of metals, and a number of volatile organic compounds (VOCs), primarily benzene, toluene, ethylbenzene, and xylene (BTEX). These analytical results were not unexpected because BTEX and semi-volatile compounds are naturally occurring constituents of crude oil and natural gas, and the metals detected are ubiquitous in the environment.

2. Sampling and analytical difficulties were identified.

- Proper scheduling of sampling is a key component.

  Due to scheduling problems, it was often extremely difficult to collect actual waste samples. All of the categories sampled, except pit/sump waste, crude oil impacted soil, and dehydration condensate water, are generated intermittently from specific operations such as workovers or tank cleaning. These operations or maintenance procedures are infrequent and are usually scheduled only a few days in advance. They are subject to cancellation due to higher priority work, making it difficult for a sampling team to be present when an actual waste is generated. For some samples, such as tank bottoms and waste glycol, process fluids were the bulk of the sample collected since true wastes were not available. In all cases, the collected sample was expected to contain equivalent or higher concentrations of constituents of possible environmental concern than contained in a true waste.

- Obtaining representative samples was difficult.

  Adding to scheduling problems is the extreme difficulty of obtaining representative samples. The sampling team collected samples of up to one liter from waste volumes ranging from one barrel (208 liters) to a maximum of 14,000 barrels. The materials were sometimes stratified and, in some cases, the composition changed from hour to hour. It is very difficult to obtain a representative sample from large volume heterogeneous materials.

- The EPA analytical methods were ineffective with many of the samples which contained high levels of organic constituents. Matrix interferences frequently interfered with test results.

  Matrix interference problems were frequently encountered when trying to analyze certain samples by EPA analytical methods (e.g., the TCLP method). Matrix interference involves problems created from substances in the samples that cause either a chemical or physical interference during the analysis of the sample. Approximately 60 percent of the samples in this study indicated a matrix interference problem with at least one constituent analyzed. The large concentrations of n-alkanes can mask the presence of other hydrocarbons and raise the detection limits for compounds of interest.

- Comparison of analytical results from two different laboratories was limited due to the number of "non-detect" results. Where positive analytical results could be compared, the agreement was limited.

  The analytical results for four duplicate samples collected by API and the Gas Research Institute (GRI) were comparable for those analyses which did not experience matrix interference problems. API and GRI agreed to collect and analyze four split samples to better understand the variance in analytical results from two different labs, ENSECO and ENSR. The four samples used for this comparison were molecular sieve from a dehydrator, spent molecular sieve from an isobutane sweetener, waste glycol, and glycol dehydrator condensate water. Whereas some differences were encountered in sulfide measurements, the TCLP constituent data were similar. Matrix interference problems created high detection limits which made it difficult to compare the majority of the TCLP volatile organics data.

3. E&P associated waste management practices were modeled to assess their potential impact to groundwater.

   The VADSAT model was run in a Monte Carlo mode to calculate the peak concentration over time of a chemical species corresponding to the 85 percent cumulative probability of non-exceedence at hypothetical downgradient receptor wells. In other words, there is only a 15 percent probability of generating higher peak concentrations. The VADSAT-predicted concentrations were far below the standard analytical detection limits for the compounds benzene, toluene, ethylbenzene, and xylenes (BTEX) at receptor wells located 500 and 1500 feet downgradient. Of the three waste management practices modeled, burial produced the highest predicted concentrations due to greater waste thicknesses.

   Modeling results showed that a number of subsurface processes combine to naturally attenuate organic components of associated wastes that may leach to groundwater. Water filtering through the waste management unit carries soluble organic constituents to the water table, where it mixes with a larger body of groundwater and is diluted. Further dilution occurs due to the longitudinal and transverse dispersion. Biodecay lowers the aqueous phase concentrations. Adsorption results in constituent retardation and allows more time for biodecay to occur. These processes collectively result in reduced concentrations at downgradient receptor wells.

   VADSAT simulations of the subsurface fate and transport of BTEX leaching from associated wastes in the API database suggest that these wastes do not pose a threat to groundwater when managed in accordance with API guidance on landspreading, roadspreading and burial.

RECOMMENDATIONS

1. The data presented in this report should be used in modeling studies to predict the environmental impact of various land-based waste management techniques.

   The objective of this study was to establish a composition and constituent concentration database for different categories of associated wastes. No conclusions regarding the environmental impact of these wastes can be drawn from this data without an understanding of how each waste is managed and the probable transport and fate of the waste constituents. An understanding of the potential impact on soil and groundwater can best be achieved through modeling studies of the type described in this report.

2. The data provided in this study should be supplemented with data from API member companies, from studies performed outside of API, and from additional API studies, where appropriate.

   The sampling effort completed in this study resulted in the collection of 120 samples from 12 different categories of associated waste and two waste categories not typically considered to be associated wastes. Although this effort provides a substantial amount of information on the concentrations of constituents that may be present in associated wastes, more data would improve the statistical reliability of the data set.

3. Future studies of associated wastes should sample only waste streams prior to treatment or disposal and avoid sampling process streams.

   The scheduling difficulties encountered by the sampling teams are well documented in this report. It is important to design any additional sampling programs so that samples taken are of true wastes. Sampling procedures must be designed to assure collection of a representative material.

4. Laboratories performing analyses of associated waste must use appropriate techniques to reduce matrix interference problems. Where possible, API should support efforts to develop new analytical methods that address complex oily matrices.

   For example, laboratories should be required to perform sample cleanup procedures, such as Method 3611 and Method 3650 or techniques supported by user-prescribed QA/QC criteria (i.e., EPA "Performance Based Methods") to achieve improved data quality for semivolatile organic analyses.

5. The RCRA Characteristics data collected in this study should be evaluated only by comparison with other predictive tools and techniques developed specifically for oil and gas waste management practices.

   The RCRA Characteristic data (particularly TCLP data) from this study were collected for comparative purposes only. The RCRA TCLP analytical technique is intended to estimate the possible impact a particular waste may have in a domestic landfill environment. With the information from this study, and the information to be generated from soil and groundwater modeling, the oil and gas industry can evaluate the applicability of RCRA Characteristics analytical techniques to its wastes and waste management practices. Any new protocols deemed more appropriate for predicting the leachability of oily wastes should be compared to the TCLP to understand under which conditions, if any, the TCLP is appropriate. Also, because most associated wastes contain significant amounts of solids and water, the appropriateness of RCRA ignitability testing should be evaluated prior to requesting the test.

6. Based on the extensive list of constituents examined in this study, future associated waste studies should analyze for the following constituents.

   Arsenic, Barium, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Potassium, Sodium, Vanadium, Zinc, Polynuclear Aromatics (PNAs), Benzene, Ethyl Benzene, Toluene, Xylenes; general chemical constituents such as pH, reactive sulfide, oil/water/solids, oil and grease/total petroleum hydrocarbons (TPH) and chloride. Other site specific constituents known to be present should also be analyzed.

Section 1
BACKGROUND

The oil and gas industry generates a number of wastes that are uniquely associated with its operations. These wastes include produced water, drilling wastes, and "associated wastes." Associated wastes, which include crude oil impacted soil, tank bottoms, and workover fluids, comprise approximately 0.1 percent of the total volume of E&P wastes generated annually (API, 1987).

The 1980 amendments to the Resource Conservation and Recovery Act (RCRA) exempted E&P wastes from the law's hazardous waste requirements. At the same time, Congress directed EPA to study E&P wastes and recommend appropriate regulatory action.

EPA completed its study of E&P wastes and issued a Regulatory Determination in June 1988 (EPA, 1988). EPA concluded that E&P wastes do not pose a significant threat to human health and the environment when properly managed and, for the most part, these wastes were being adequately regulated under existing state and federal programs. EPA determined that E&P wastes should continue to be exempt from the hazardous waste regulation of RCRA and should continue to be regulated by state agencies using existing state and federal authorities.

Since the Regulatory Determination, the EPA, states, and industry have continued to work to improve the management of E&P wastes. In January 1989, API issued a comprehensive guidance document on E&P waste management practices (API, 1989). The document describes recommended waste management procedures which are believed to be protective of human health and the environment.

In 1989, the API initiated a multi-year waste characterization and groundwater modeling study to improve its knowledge of the fate and effects of E&P wastes in the environment. Different categories of associated wastes were characterized through a sampling and analysis program that produced an initial composition and constituent concentration database. The characterization data was then used as input for a fate and transport model (VADSAT), developed subsequently by API, to simulate E&P waste management practices.

In all, samples representing 12 different associated waste categories were collected from onshore E&P sites in seven states. Samples of oil-based mud drill cuttings and used oil, neither of which are typically considered associated wastes, were also collected. For simplicity, all samples collected are referred to as associated wastes for the purpose of this report.

Section 2
METHODS

SAMPLING INFORMATION

Sample Collection

The sampling program was designed to obtain a wide cross section of associated wastes generated at onshore E&P facilities, over a wide geographic area, and capture samples expected to contain the highest levels of constituents of potential environmental concern. In some cases, budget and time constraints necessitated the collection of samples of process streams. This was a compromise since, in many cases, samples collected do not represent wastes in E&P operations. In addition, many samples represent material that normally would be subject to further processing to recover hydrocarbon for sale. Collection of these process and intermediate materials did create samples that would be expected to contain constituents of potential environmental concern similar to the wastes they represented.

Sampling was conducted in two phases. Phase I was initiated on August 24, 1989 and ended December 19, 1989. A total of 31 samples were collected. The experience gained in arranging for, collecting, and transporting the Phase I samples led to modifications in the program and additional streams were identified for sampling. Phase II sample collection began on September 4, 1990 and concluded on April 1, 1991, with 89 samples collected. Because the study was conducted in two parts, there was some inconsistency in the sample types collected and the analyses performed during Phase I and Phase II.

A total of 120 samples were collected from E&P sites in distinct geographical regions over seven states: Texas, Oklahoma, New Mexico, Michigan, California, West Virginia and Louisiana. Fourteen categories of wastes were sampled, including 12 associated wastes, and used oil and oil-based mud cuttings. Table 2-1 summarizes the number of samples collected in each category, while Appendix A provides more detailed sample information.

Table 2-1. Summary of Associated Waste Samples Collected

Waste Type	No. of Samples Collected
Crude Oil Impacted Soil	32
Natural Gas Dehydration & Sweetening	17
• Dehydration Condensate Water	(3)
• Waste Glycol Solution	(8)
• Molecular Sieve	(3)
• Used Amine Solution	(1)
• Spent Iron Sponge	(2)
Oil-Based Mud Cuttings*	5
Produced Sand	1
Pigging Wastes	5
Skimming Pit and Sump Wastes	4
Rig Wash	5
Tank Bottoms	18
Used Oil (Natural Gas & Diesel Crankcase)*	12
Workover Fluids & Stimulation Flowback	21

* Drilling fluids, produced waters, and so-called "associated wastes" are exempt from hazardous waste regulation under Section 3001 (b)(2)(A) of RCRA. Used Oil is not an exempt "associated waste." For simplicity, all sampled wastes are referred to as "associated wastes" for the purpose of this report.

Sampling Procedures - General

General sampling procedures were designed to maximize sampling efficiency and capture samples containing constituents of potential environmental concern. This was done with the understanding that, on occasion, the samples collected would not necessarily be representative of actual wastes. Of necessity, some samples were collected from process streams, and were obviously not wastes. Subsequently, results have shown the pitfalls of such sampling as explained in the Executive Summary of this report and in Table 2-2. Waste sampling should follow protocols outlined in SW-846 and ASTM Vol 11.04.

Table 2-2. Representative Sampling

Collection of tank bottoms samples via a thieving device provides an example of how a sampling method could impact a waste's chemical composition. Obtaining tank bottom samples through a tank roof hatch with a thieving device unquestionably results in a non-representative sample for a number of reasons.

- Sample is not exposed to the tank cleaning process.
  Normal procedures require that the tank be drained, then opened to the atmosphere until the oxygen and hydrocarbon levels in the tank are safe for human entry. Once safe, the tank bottoms may be removed by shoveling, washing with a high pressure water hose, or a combination of both methods. Thieved samples would not have this kind of exposure to volatilization and oxidation. In addition, the thieved samples may be pulled through crude oil and emulsion layers adding additional chemical components in the process and possibly altering the sample.

- Stratification.
  Tank bottoms are generated when solids settle to the bottom of the tank. Often, the solids are laid down in layers. The sample device may not be able to collect from all layers: it may only be able to collect the top layer consisting of mostly crude oil.

- Lack of tank bottoms.
  The pumper or operator may routinely take thieved samples of tank bottoms to monitor solids buildup. Because this action cleans the area below the tank hatch, it may be impossible to collect a sample of tank bottoms.

- "Striker plates."
  Striker plates, or other devices placed in the crude oil storage tank to prevent tank gauging devices from hitting the tank bottom, may prevent the same buildup of bottoms material present throughout the remainder of the tank. These samples could contain unrepresentative levels of organic compounds and/or metals.

Therefore, in the case of tank bottoms, it has been determined that valid samples may be collected only during actual cleanout when the tank bottoms are being prepared for handling subsequent to removal of overlying materials.

Sampling Techniques - General

Samples were collected according to standard EPA protocols contained in SW-846, stored and transported at a temperature of 4°C and shipped via overnight carrier to the analytical laboratory. Exceptions to the preceding are noted in the discussion of individual sample types. Actual sampling techniques varied according to the sample matrix. For example, crude oil bearing soils and oily cuttings were generally collected using a stainless steel trowel. Some dehydration and workover fluids were collected directly from equipment valves. Tank bottoms and other samples were collected by a bailer, oil thief or stainless steel trowel.

Sample Jars and Containers were provided by the contract laboratory (ENSECO) as follows:

• TCLP -	Volatile organic compounds	4 oz. glass
	All other analytes	32 oz. glass
• SOLIDS -	Organics, metals	16 oz. glass
	RCRA Characteristics	8 oz. glass
• AQUEOUS -	Volatile organic compounds	3 X 40 ml glass, HCl preservative
	Semivolatile organic compounds	2 X 1 L glass,
	Metals	16 oz. polyethylene bottle, HNO_3 preservative
	Cyanide	8 oz. polyethylene bottle, 50% NaOH preservative
	Sulfide	8 oz. polyethylene bottle, Zn Acetate/NaOH preservative
	pH, chloride	32 oz. polyethylene bottle

Sampling Considerations

A sampling program of this magnitude presents a host of challenges — scheduling, budget, consistency in collection, and of course, what, where, and how to sample. The objective of the sampling was to obtain random waste samples, collected in a consistent manner, and to ensure the samples were as "fresh" as possible to assure the highest concentration of constituents of potential environmental concern.

The sampling difficulties encountered during this project could be minimized in future efforts by following a formal sampling plan. Budget and time constraints necessitated the collection of samples of process streams. This was a compromise since, in many cases, samples collected do not represent wastes in E&P operations. In addition to process streams, many samples represent material that would be subject to further processing to recover hydrocarbon for sale. But collection of these process and intermediate materials did represent samples that would be expected to contain concentrations of constituents of potential environmental concern that were as high or higher than the wastes they represented.

Timing a sampling trip can be difficult. Collecting tank bottom samples is one example of how scheduling can be a problem. The only time tank bottoms become a priority is when buildup causes carryover of sediments or water into the crude oil sales line. Generally, crude oil stock tanks only require removal of oil/water/solids sludge buildup (tank bottoms) every three to five years. Therefore, as long as the quality of the crude oil being sold is unaffected, bottoms cleanout is a low priority and subject to cancellation for higher priority work.

To overcome these time and budget constraints, the sampling team found it more efficient to arrange sampling events with several companies targeting all categories of waste in broad geographic locations such as Kansas or East Texas. This approach worked well for unpredictable sampling events such as workovers and crude oil impacted soil sampling. With the sampling team in a particular area, the team could sample an event within a few minutes or hours of a call. At times, it was necessary to sample process streams or intermediate waste streams. This occurred when waste generation was infrequent and the work was subject to cancellation or delay. These categories included tank bottoms, waste glycol and amine, spent mol sieve, and spent iron sponge.

Each category of waste required different approaches to sampling. The following are general examples:

<u>Crude Impacted Soils</u> - sample at active or recent crude oil spill sites.

<u>Natural Gas Dehydration & Sweetening</u>

- Dehydration Condensate Water - collects in sumps or vessels downstream of the glycol reboiler prior to disposal. Samples were collected from the holding sumps or vessels or piping valves connecting the sumps or vessels.
- Molecular Sieve - Waste is generated infrequently and there is usually no method of obtaining a process sample. The intent was to be present for sampling when a vessel was opened for cleanout.
- Spent Iron Sponge - Waste is generated infrequently and there is usually no method of obtaining a process sample. The intent was to be present for sampling when a vessel was opened for cleanout.
- Used Amine Solution - Infrequent waste generation of spent amine waste required the team to sample process streams of active sour gas treaters. The rich amine stream upstream of the reboiler was expected to contain the highest concentration of volatile organics, so samples were collected at that point. Refer to the Amine Sampling Section of this report for more detail.
- Used Glycol Solution - Infrequent waste generation of spent glycol required the team to sample process streams of active dehydrators. The rich glycol stream upstream of the reboiler was expected to contain the highest concentration of volatile organics, so samples were collected at that point. Refer to the Glycol Sampling Section of this report for more detail.

Oil-Based Mud Cuttings - Waste samples were taken either from the shale shaker as they were generated or removed from the interior of mounds of cuttings awaiting disposal.

Pigging Wastes - Waste samples were taken from crude oil gathering line sumps or removed from ball receivers as they were opened at the inlet of natural gas processing plants.

Produced Sand - The single sample of waste was removed from a settling tank specifically placed in the production stream to remove produced sand from the produced fluids. The waste sand was being removed at the time of sampling.

Skimming Pit and Sump Wastes - These vessels are generally exposed to air; therefore, sampling was accomplished by skimming emulsion and hydrocarbon from the surface and/or if solids were present, thieving solids from the bottom of the vessel.

Rig Wash - Samples were collected in the sump to ensure the highest expected level of constituents of potential environmental concern would be present.

Tank Bottoms - Tank bottom samples were thieved from tanks still in service. Samples were collected in this manner for two reasons: to ensure that the highest expected level of constituents of potential environmental concern would be present and, principally, because it was very difficult to schedule tank cleanouts and sample collection to coincide. Refer to the Tank Bottoms Sampling Section of this report for more detail.

Used Engine Lube Oil - Samples were taken directly from the engine crankcase or engine oil cooler piping of engines in service.

Workover Wastes - Samples were taken at the wellhead through valves, or from pits or holding tanks where the waste was held prior to disposal.

ANALYTICAL METHODS

This section discusses the general analytical test procedures used, and their limitations for E&P waste characterization. All analyses followed standard EPA methodologies and protocols and full quality assurance/quality control (QA/QC) procedures. Appendix B contains additional details on the analytical methods utilized, QA/QC, and constituents analyzed.

During Phase I, conducted in 1989, it was requested that all samples be analyzed for oil/water/solids [MODT: modified oven drying technique (API, 1987)] Appendix IX volatile organic compounds, Petroleum Refinery List semi-volatile organic compounds, Appendix IX metals and RCRA Characteristics — ignitability, corrosivity and reactivity, TCLP volatile organic compounds, TCLP semi-volatile organic compounds, and TCLP metals (USEPA, 1986). (See Appendix B.)

The Petroleum Refinery List, a subset of the Appendix IX list, contains compounds of concern to the petroleum industry, such as PNAs and phenols. To improve the reliability of the analysis of these compounds, cleanup procedures (Methods 3650 and 3611) are used to remove interfering aliphatic hydrocarbons.

Analytical methods contained in EPA document SW-846 (*Test Methods for Evaluating Solid Waste*) were employed to identify both organic and inorganic constituent types and concentrations in the wastes. The RCRA Characteristic data (including TCLP data) were collected for comparative purposes only. The RCRA TCLP test is the only approved EPA leaching method for waste evaluation. It is intended to estimate the possible impact that a particular waste may have in a municipal landfill environment. It does not apply to exempt E&P wastes. Further, EPA has recognized that predicting a material's leachability requires consideration of the disposal conditions and the use of fate and transport models that reasonably simulate how constituents would be released from a source and move through the subsurface. They also recognize that no universal test procedure (including TCLP) is likely to be developed that will accurately replicate all disposal conditions (Freidman, 1992).

RCRA ignitability testing (EPA Method 1010) was conducted on all waste types except spent amine. The test is considered reliable when performed on non-aqueous liquids, but unreliable for aqueous, solid and semi-solid samples (Hanson and Freidman, pers. comm.). Therefore, ignitability results from aqueous, solid and semi-solid samples tested in this study should be considered unreliable. For each waste type discussed in Section 3 of this report, results of ignitability testing on appropriate matrices will be noted. All ignitability results are reported in Appendix C.

Based on Phase I results, the sampling plan for Phase II (conducted in 1990-91) called for a reduced suite of analyses including: oil/water/solids (MODT), Appendix IX volatile organic compounds, RCRA ignitability, RCRA corrosivity, RCRA reactivity, TCLP volatile organic compounds, and TCLP metals. The Petroleum Refinery List semi-volatile organic compounds and metals, and the TCLP semi-volatile organic compound tests were not performed. The oil/water/solids contents were not determined for used oil, glycol, or amine because the sample consisted primarily of the known process fluid. In other cases, tests were not performed because only limited sample volumes were available. These decisions allowed a greater number of samples to be analyzed for parameters of concern and eliminate tests which were less informative.

While samples were analyzed for a broad range of constituents (See Tables 1-6, Appendix B), very few were detected. For clarity, constituents which were not detected in any sample are not included in the analytical results in the body of the report, or in the table in Appendix C.

In cases where matrix interferences caused high detection limits, it is possible that some constituents were present in the samples but were not detected. The analytical results summary tables for each waste type (presented in Section 3 of this report) state the range of detection limits experienced for each constituent (e.g., benzene) in that group of samples. By examining the range of detection limits, the reader can evaluate the bias associated with mean constituent concentration values calculated using only samples where the constituent was detected.

Section 3
ANALYTICAL RESULTS

This section summarizes sampling, testing, and analytical results for each category of samples evaluated. It includes information on sampling, and laboratory and matrix interference issues which influenced the results. Summary tables of total analysis test information is included for each waste category. Appendix C contains more detailed results for total analysis testing, as well as the results for RCRA ignitability, corrosivity and reactivity and TCLP analyses. Quality Assurance/Quality Control information is indicated by footnotes in the Appendix C data tables.

Finally, a discussion of the overall data is made, along with a limited comparison of these data with results obtained in the Gas Research Institute's study on associated wastes in the natural gas production industry (Myerski *et al.*, 1993).

CRUDE OIL IMPACTED SOILS

Crude oil impacted soils in E&P operations typically result from equipment leaks and spills. Leaks and spills come from such equipment as valves, stuffing boxes, tanks, ruptured flow lines, gas plants, workover equipment, etc. Crude oil impacted soils can also contain a variety of other contaminants, ranging from glycol to workover completion fluids. Crude oil impacted soils are often exposed to weathering before they are discovered. Generally, when discovered, excess fluid is removed from the soil surface and returned to the production process, if possible.

Sampling and Analysis

Thirty-two crude oil impacted soil samples were taken from East Texas (5), West Texas (16), Oklahoma (8), California (1), West Virginia (1), and New Mexico (1). Four were Phase I samples and twenty-eight were Phase II samples. Samples were collected from fifteen facilities. Sampling locations included, but were not limited to: stock tank loading valves, stuffing boxes on wells being pumped by beam pumping units, centrifugal pumps, workovers, crude oil flow line and gas gathering systems leaks, and spills from overfilling of storage tanks. Collection was made by excavating the top three inches of soil with a stainless steel trowel.

Twenty-nine of the soil samples were analyzed for oil, water, and solids content. All thirty-two samples were analyzed for total Appendix IX volatile organic compounds. Four samples were analyzed for total Appendix IX metals and Petroleum Refinery List semi-volatile organic compounds.

All samples were analyzed for RCRA ignitability, corrosivity and reactivity. All samples were evaluated for some TCLP volatile organic constituents. One sample was analyzed for TCLP semi-volatile organic compounds, and 30 samples were analyzed for TCLP metals.

Results

Crude oil impacted soil samples were typically solid (30-85 percent solids) with variable amounts of oil (2-55 percent oil) and water (2-25 percent water).

Five volatile organic compounds were found at measurable levels: benzene, carbon disulfide, ethyl benzene, toluene, and xylene (Table 3-1). Acetone and dichloromethane were also detected, but these results are considered qualitatively unreliable due to the occurrence of these compounds as lab contaminants (see Appendix B).

Table 3-1. Total Appendix IX Volatile Components Detected in Crude Oil Impacted Soil

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Acetone	32	7	25 (1-1000)	65	3 - 260
Benzene	32	7	25 (0.5-500)	60	2.8 - 270
Carbon Disulfide	32	1	31 (0.5-500)	54[c]	N/A
Dichloro Methane	32	1	31 (0.5-500)	120[c]	N/A
Ethyl Benzene	32	16	16 (0.5-500)	109	3.5 - 930
MethylEthyl Ketone	32	0	32 (1-1000)	N/A	N/A
Toluene	32	17	15 (0.5-500)	148	1.2 - 1200
Xylenes	32	27	5 (0.5-2.5)	188	0.6 - 1100

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

Two semi-volatile compounds were detected: 1-methyl naphthalene and phenanthrene (Table 3-2).

Table 3-2. Petroleum Refinery List Semi-Volatile Organic Compounds Detected in Crude Oil Impacted Soil

Compounds	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Chrysene	4	0	4 (5-100)	N/A	N/A
1-Methyl Naphthalene	4	2	2 (5-100)	43	21 - 45
Naphthalene	4	0	4 (5-100)	N/A	N/A
Phenanthrene	4	1	3 (5-100)	10[c]	N/A

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

Sixteen different metals were detected: aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, lead, mercury, nickel, potassium, sodium, vanadium, and zinc (Table 3-3).

RCRA Characteristics data showed: pH ranged from 4.1 to 8.8; reactive sulfide was detected in four out of thirty-two samples, reactive cyanide in one out of thirty-two. Six samples had a flash point of less than 140°F; however, the results are unreliable because the sample matrices were not non-aqueous liquids.

Trichloroethylene, benzene, and toluene were the only organic compounds found in the TCLP leachate. Out of the 32 samples analyzed, trichloroethylene was found in 1, benzene was found in 13, and toluene was found in 20. The following metals were detected in the TCLP leachate: barium, 28 out of 30 samples; cadmium and chromium, 1 out of 30 samples; and lead, 4 out of 30 samples. RCRA Characteristic results are found in Appendix C.

Table 3-3. Total Appendix IX Metals Detected in Crude Oil Impacted Soil

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Aluminum	4	4	0 (N/A)	2195	480 - 5400
Antimony	4	0	4 (5-50)	N/A	N/A
Arsenic	4	2	2 (0.5-0.8)	72	4.2-140
Barium	4	4	0 (N/A)	285	12 - 940
Beryllium	4	2	2 (0.2-2)	0.5	0.4 - 0.6
Cadmium	4	3	1 (5[c])	1.8	0.5 - 3
Calcium	4	4	0 (N/A)	90,438	750 - 273,000
Chromium	4	3	1 (10[c])	7	2 - 11
Cobalt	4	1	3 (1-10)	6[c]	N/A
Copper	4	3	1 (10[c])	14	4 - 23
Lead	4	3	1 (50[c])	38	7 - 81
Mercury	4	1	3 (0.1)	0.1[c]	N/A
Nickel	4	3	1 (40[c])	14	9 - 24
Potassium	4	1	3 (500-1000)	500[c]	N/A
Selenium	4	0	4 (0.5-5)	N/A	N/A
Silver	4	0	4 (1-10)	N/A	N/A
Sodium	4	1	3 (500)	1000[c]	N/A
Thallium	4	0	4 (0.5-10)	N/A	N/A
Tin	4	0	4 (8-50)	N/A	N/A
Vanadium	4	3	1 (10[c])	9	3 - 13
Zinc	4	4	0 (N/A)	82	13 - 250

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A - Not applicable

Discussion

A concerted effort was made to find samples at recent spill sites where excess fluids had not yet been removed. This ensured that the highest expected level of constituents of potential environmental concern would be present. Twenty-eight samples were from areas where a leak or spill had occurred within the previous 24 hours. In addition, many of the samples were taken from locations that had been subjected to several spills over the years.

The results for total analysis testing are not unexpected, since the BTEX compounds and semi-volatile compounds are naturally occurring constituents of crude oil, and the metals detected are widespread in the environment. No site-specific background samples were collected to which metal analyses could be compared. Table 3-4 is useful for qualitatively comparing concentrations of detected metals to concentration ranges of metals in soils in the U.S. Trichloroethylene (TCE), which was detected in the TCLP leachate of a spill from a heater treater drain line, is a questionable result. Although trichloroethylene is a common degreasing agent, it is not associated with this process. The occurrence of TCE in only one of thirteen samples would further support this observation.

Table 3-4. Soil Concentrations for Metals in the U.S.

Metal	Soil Concentrations[1] Average and (Range)(ppm)
Aluminum	72,000 (700 - >100,000)
Arsenic	7.2 (<0.1 - 97)
Barium	580 (10 - 5,000)
Beryllium	0.92 (<1 - 15)
Cadmium[2]	0.27 (0.005 - 2.4)
Calcium	24,000 (100 - 320,000)
Chromium	54 (1 - 2,000)
Cobalt	9.1 (<3 - 70)
Copper	25 (<1 - 700)
Lead	19 (<10 - 700)
Mercury	0.09 (<0.01 - 4.6)
Nickel	19 (<5 - 700)
Potassium	15,000 (50 - 63,000)
Sodium	12,000 (<500 - 100,000)
Vanadium	80 (<7 - 500)
Zinc	60 (<5 - 2,900)

[1] Shacklette, H.T., and Boerngen, J.G. 1984. Element Concentrations in Soils and Other Surficial Material of the Conterminous U.S.: U.S. Geological Survey Professional Paper 1270. USGS. Washington, D.C.

[2] Holmgren, G.G.S., M.W. Meyer, R.B. Daniels, J. Kubota, and R.L. Chaney. Cadmium, Lead, Zinc, Copper, and Nickel in Agricultural Soils in the United States. Journal of Environmental Quality, Vol. 16, 1986.

TANK BOTTOMS

Tank bottoms describe solids consisting of heavy hydrocarbons, sand, clay, and mineral scale that collect in the bottoms of oil and gas separators, treating vessels, and crude oil stock tanks. Crude oil and natural gas produced from a well generally contain produced water and formation solids that are emulsified with the crude oil. These natural contaminants must be removed in order to sell the crude oil or gas. The removal process begins by separating the produced crude oil into three phases: oil, water, and gas using separators and/or treater vessels. The crude oil and produced water are piped from the separator to a "heater treater" where any oil/water/solids emulsions are broken down and separated. Emulsion breaking chemicals or heat may be used to enhance the separation process.

The crude oil then goes to storage tanks and the water is transferred to produced water storage tanks in preparation for reinjection or disposal. Solids may settle to the bottom of each vessel and tank in the process, and must be removed periodically .

Sampling and Analysis

Eighteen tank bottom samples were collected from West Texas (5), Oklahoma (8), Louisiana (1), West Virginia (2), and California (2). Ten Phase I samples and eight Phase II samples were taken. The samples were collected at nine different facilities from the top/side/bottom hatch or a valve on the tank. Vessels that were sampled included: crude oil storage tanks (13), produced water storage tanks (1), free water knock-out tanks (3), and heater treater vessel bottoms (1).

Samples were "thieved" from vessels that were still in service or troweled from the vessel as it was cleaned.

Eighteen tank bottom samples were analyzed for oil/water/solids and total Appendix IX volatile organic compounds. Ten of the samples were analyzed for total Appendix IX metals and Petroleum Refinery List semi-volatile organic compounds.

All 18 samples were evaluated for RCRA ignitability, corrosivity and reactivity, and TCLP metals. All samples were analyzed for some TCLP volatile organics. Ten samples were analyzed for TCLP semi-volatile organic compounds, and inorganic chlorides by EPA Method 300.0.

Results

Tank bottom samples were extremely variable, consisting of 3-58 percent solids, 5-74 percent water, and 6-92 percent oil.

Four total Appendix IX volatile organic compounds were found at measurable levels: benzene, ethyl benzene, toluene, and xylene (Table 3-5).

Table 3-5. Total Appendix IX Volatile Components Detected in Tank Bottoms

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Acetone	18	1	17 (1-5000)	60[c]	N/A
Benzene	18	14	4 (0.5-500)	670	6.3-5500
Carbon Disulfide	18	0	18 (0.5-2500)	N/A	N/A
Dichloro Methane	18	0	18 (0.5-2500)	N/A	N/A
Ethyl Benzene	18	16	2 (13-7400)	722	0.9-7400
MethylEthylKetone	18	0	18 (1-5000)	N/A	N/A
Toluene	18	17	1 (1[c])	2661	0.7-32,000
Xylenes	18	18	0 (N/A)	3747	8.8-52,000

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.
[b] Non-detected concentrations were not used in calculating the mean.
[c] Represents one value.
N/A Not Applicable

Acetone was also detected; however, these results may be qualitatively unreliable due to the common occurrence of this compound as a laboratory contaminant. Three Petroleum Refinery List semi-volatile compounds were detected: 1-methyl naphthalene, napthalene and phenanthrene (Table 3-6).

Table 3-6. Petroleum Refinery List Semi-Volatile Organic Compounds Detected in Tank Bottoms

Compounds	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Chrysene	10	0	10 (13-70)	N/A	N/A
1-Methyl Naphthalene	10	6	4 (20-200)	150	59-240
Naphthalene	10	6	4 (20-200)	104	40-270
Phenanthrene	10	4	6 (30-200)	32	14-49

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.
[b] Non-detected concentrations were not used in calculating the mean.
N/A Not Applicable

Fourteen total Appendix IX metals were detected: aluminum, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, lead, mercury, nickel, sodium, vanadium, and zinc (Table 3-7).

Table 3-7. Total Appendix IX Metals Detected in Tank Bottoms

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Aluminum	10	9	1 (10[c])	505	13-1200
Antimony	10	0	10 (5-30)	N/A	N/A
Arsenic	10	9	1 (0.5[c])	9	0.7-32
Barium	10	10	0 (N/A)	628	3-5400
Beryllium	10	0	10 (0.2-1)	N/A	N/A
Cadmium	10	2	8 (0.5)	3	2.3-3
Calcium	10	9	1 (30[c])	18,404	350-114,000
Chromium	10	9	1 (1[c])	19	5-54
Cobalt	10	5	5	3	1-5
Copper	10	9	1 (1[c])	73	4-210
Lead	10	8	2 (5)	325	12-970
Mercury	10	2	8 (0.1)	0.75	0.1-1.4
Nickel	10	10	0 (N/A)	26	5-100
Potassium	10	0	10 (500-3000)	N/A	N/A
Selenium	10	0	10 (0.5-5)	N/A	N/A
Silver	10	0	10 (1-5)	N/A	N/A
Sodium	10	9	1 (500[c])	5492	760-12,000
Thallium	10	0	10 (0.5-50)	N/A	N/A
Tin	10	0	10 (5-30)	N/A	N/A
Vanadium	10	9	1 (5[c])	7.1	1-25
Zinc	10	9	1 (1[c])	149	10-400

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

The RCRA Characteristics data showed: pH ranged from 6.1 to 8.9; reactive sulfide was detected in 9 of 18 samples, while reactive cyanide was not detected in any of the 18 samples. Of the 18 samples, 15 exhibited a flash point <140°F. However, due to the water and solids content of these samples, the reliability of these results is questionable. The volatile organic compounds found in the TCLP leachate were: methylene chloride, detected in 1 of 13 samples; benzene, detected in 17 of 18 samples; and toluene, found in 11 of 13 samples analyzed. Of the ten samples analyzed for TCLP semi-volatile organic compounds, one sample contained detected concentrations of phenol, a-creosol, and m & p-creosol. Metals were detected in the TCLP leachate of 18 samples as follows: arsenic (1), barium (17), cadmium (3), chromium (5), lead (6), and mercury (1). The RCRA Characteristic results are found in Appendix C.

The inorganic chloride analyses show the mean salinity as chloride is 1.05%w +/- 0.75 with a range of 0.03 to 2.51%w. These values are low-to-typical for crude oils.

Discussion

Ten of the eighteen tank bottom samples were thieved from tanks still in service while another five samples were collected from taps, hoses or strainers. Samples were collected in this manner principally because it was very difficult to schedule tank cleanouts and sample collection. Ideally, it is best to sample a tank bottom just before it is placed in a waste management unit or disposed. As with the case of many samples collected in this study, this is not always possible or practical. Therefore, samples collected beneath product, produced water or emulsions are likely to contain higher levels of constituents of potential environmental concern. It is expected that the levels of constituents found in these samples may be elevated relative to tank bottoms commonly managed at E&P sites.

WORKOVER FLUIDS

Workover fluids are generated from three general types of workover operations: well control, drilling or milling operations, and stimulation or cleanup of an oil and gas bearing formation. This study focused on sampling the flowback from spent stimulation fluids because they come in contact with crude oil, natural gas condensate, natural gas, saltwater, and minerals comprising the reservoir rock. The drilling/milling and well control type fluids may or may not come into contact with the oil and gas bearing formation and often these fluids are simply produced water. Stimulation fluids are usually more chemically complex. An acid stimulation fluid, for example, may be made using produced saltwater but is more likely to be freshwater mixed with an acid, commonly hydrochloric acid, or a salt such as potassium chloride, sodium chloride, and/or calcium chloride.

Although not totally distinct, stimulation fluids can be broken down into three types: hydraulic fracturing, wellbore cleanup acidizing, and acid stimulation (acid fracturing). Each of these methods is designed to open new pathways for the flow of oil and gas to the wellbore.

Hydraulic fracturing is accomplished when fluid is pumped down the well under pressure sufficient to "fracture" or split the rock formation containing the crude oil and gas. Once opened, sand or some other propping agent such as walnut hulls is pumped into the "fracture" as a slurry to keep the fracture from closing. The slurry of sand is made by mixing a "gel" such as guar gum (a natural gum produced by plants) or synthetic polymer with fresh or salt water to make the fluid viscous and able to suspend the sand.

Acidizing to stimulate a well is performed when the formation is composed of acid soluble material such as limestone. The acid creates openings by dissolving or etching the limestone until all the acid is consumed. When hydrochloric acid reacts with limestone, it is neutralized, creating a salt (calcium chloride), carbon dioxide gas, and water. Acids used in this type of stimulation work generally contain corrosion inhibitors (typically an amine), friction reducers and buffers such as citric acid.

Acids are also used for wellbore cleanups, where mineral deposits and heavy hydrocarbon accumulations are removed from the formation surface or casing perforations. Accumulations inhibit the ability for oil and gas to flow into the well thereby restricting production until removed. The deposits in the well may include calcium carbonate, calcium sulfate, iron sulfide, and paraffins or other heavy hydrocarbons. Acid fluids for wellbore cleanup typically contain mutual solvents and/or solvents such as xylene to dissolve the hydrocarbon buildup. Workover fluids are generally oil/water/solids mixtures.

Sampling and Analysis

Twenty-one workover fluid samples were collected from East Texas (6), West Texas (10), Oklahoma (3), and New Mexico (2) during Phase II. The samples came from fourteen different facilities and were collected from flowlines or bailed with a stainless steel bailer from collection tanks. Sampling locations included, but were not limited to: the wellhead, swabbing tree, discharge line, flowline, fracture tanks, and valves near the circulation pump. Job sizes varied from 184 barrels to 14,000 barrels of workover fluid injected.

Three samples were analyzed for oil, water, and solids content. All twenty-one samples were analyzed for total Appendix IX volatile organic compounds; RCRA ignitability, corrosivity and reactivity; and TCLP metals. Twenty samples were tested for TCLP volatile organic compounds.

Results

Six total Appendix IX volatile organic compounds were found at measurable levels in the samples analyzed: benzene, carbon disulfide, ethyl benzene, methyl ethyl ketone, toluene, and xylene (Table 3-8). Acetone was also detected, but these results may be qualitatively unreliable due to the common occurrence of this compound as a laboratory contaminant.

Table 3-8. Total Appendix IX Volatile Components Detected in Workover Fluids

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/L)][a]	Mean Concentration of Detected Constituents[b] (mg/L)	Range of Detected Concentrations (mg/L)
Acetone	21	15	6 (0.01-250)	2	0.25-8.7
Benzene	21	17	4 (0.05-10)	35	0.01-540
Carbon Disulfide	21	1	20 (0.005-130)	5.2[c]	N/A
Dichloro Methane	21	0	21 (0.005-12,000)	N/A	N/A
Ethyl Benzene	21	16	5 (0.005-1.2)	38	0.032-500
Methyl Ethyl Ketone	21	1	20 (0.01-250)	0.18[c]	N/A
Toluene	21	19	2 (1.2)	107	0.015-1900
Xylenes	21	20	1 (1.2[c])	153	0.013-2600

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

The RCRA Characteristics data showed: pH ranged from 0.058 to 7.8; reactive sulfide was detected in 6 out of 21 samples; reactive cyanide in 2 out of 21 samples. A flash point <140°F was measured in 7 of the 21 samples; however, the results are thought to be unreliable for produced water or other aqueous fluids or solids.

The volatile organic compounds found in the TCLP leachate of the 20 samples tested were: methyl ethyl ketone (5), carbon disulfide (1), benzene (16), and toluene (18). Metals were detected in the TCLP leachate of 21 samples: barium (20), cadmium (2), chromium (8), lead (5), and mercury (1). The RCRA Characteristics results are found in Appendix C.

Discussion

Sampling was focused on flowback of spent stimulation fluids because they come in contact with crude oil, natural gas condensate, natural gas, saltwater, and minerals comprising the reservoir rock. Workover samples were taken directly from the flowlines or after discharge into a pit or holding vessel. This ensured that the highest expected level of constituents of potential environmental concern would be present.

Samples were collected after one well pipe volume was recovered from the well to ensure the sample collected had been in contact with the oil and gas bearing formation. Workover wastes sampled should be considered representative of actual workover waste from stimulation operations at the stage of flowback for that particular job, except where sampling resulted in capturing free oil such as those samples taken at the wellhead and other valves where oil and water had not had the opportunity to separate prior to sampling. In practice, crude oil returned with the flowback is recovered and sold as product.

PRODUCED SAND

Sand and other formation solids from a petroleum producing formation often build up in the wellbore in both producing and injection wells. In producing wells with high gas and/or fluid production rates, sand is carried to the surface where it builds up in the vessels. In producing wells with low gas and/or fluid flow rates, it may build up in the wellbore to the extent of blocking the inflow of petroleum. It can also cause fouling of the downhole pumps that lift the fluids to the surface facilities. When produced sand becomes a problem, it is removed from the wellbore via a workover operation and removed from surface vessels by washing or by shoveling.

Sampling and Analysis

One produced sand sample was collected from a Louisiana facility during Phase I sampling. The produced sand sample was analyzed for oil, water, and solids content, and for total Appendix IX volatile and Petroleum Refinery List semi-volatile organic compounds and metals. The sample was also tested for RCRA ignitability, corrosivity and reactivity; inorganic chlorides by EPA Method 300.0; TCLP volatile and semi-volatile organic compounds; and TCLP metals.

Results

The sample contained 3 percent oil, 18 percent water, and 79 percent solids. Four total Appendix IX volatile organic compounds were detected: benzene, ethyl benzene, toluene, and xylene (Table 3-9).

Table 3-9. Total Appendix IX Volatile Components Detected in Produced Sand

Compound	Number of Samples Analyzed	Number of Detections	Reporting Limit for Non-Detections (mg/kg)	Detected Concentration (mg/kg)
Acetone	1	0	20	N/A
Benzene	1	1	N/A	20
Carbon Disulfide	1	0	10	N/A
Dichloro Methane	1	0	10	N/A
Ethyl Benzene	1	1	N/A	17
Methyl Ethyl Ketone	1	0	20	N/A
Toluene	1	1	N/A	93
Xylenes	1	1	N/A	130

N/A Not Applicable

No Petroleum Refinery List semi-volatile organic compounds were detected (Table 3-10).

Table 3-10. Petroleum Refinery List Semi-Volatile Organic Compounds Detected in Produced Sand

Compound	Number of Samples Analyzed	Number of Detections	Reporting Limit for Non-Detections (mg/kg)	Detected Concentration (mg/kg)
Chrysene	1	0	28	N/A
1-Methyl Naphthalene	1	0	28	N/A
Naphthalene	1	0	28	N/A
Phenanthrene	1	0	28	N/A

N/A Not Applicable

Ten total Appendix IX metals were detected: aluminum, barium, calcium, chromium, copper, lead, nickel, sodium, vanadium, and zinc (Table 3-11). Chlorides were detected at a level of 13,600 mg/kg.

The RCRA Characteristics data showed a pH of 5 with no reactive sulfide or cyanide detected. The ignitability test resulted in a flash point >160°F; however, it is considered unreliable for this type of material.

Table 3-11. Total Appendix IX Metals Concentrations Detected in Produced Sand

Compound	Number of Samples Analyzed	Number of Detections	Reporting Limit for Non-Detections (mg/kg)	Detected Concentration (mg/kg)
Aluminum	1	1	N/A	977
Antimony	1	0	5	N/A
Arsenic	1	0	1	N/A
Barium	1	1	N/A	140
Beryllium	1	0	2	N/A
Cadmium	1	0	0.5	N/A
Calcium	1	1	N/A	4130
Chromium	1	1	N/A	5
Cobalt	1	0	1	N/A
Copper	1	1	N/A	9
Lead	1	1	N/A	16
Mercury	1	0	0.1	N/A
Nickel	1	1	N/A	4
Potassium	1	0	500	N/A
Selenium	1	0	0.5	N/A
Silver	1	0	1	N/A
Sodium	1	1	N/A	10,100
Thallium	1	0	0.5	N/A
Tin	1	0	5	N/A
Vanadium	1	1	N/A	2
Zinc	1	1	N/A	44

N/A - Not applicable

Two volatile organic compounds were found in the TCLP leachate: benzene and toluene. No semi-volatile organic compounds were detected in the TCLP leachate. Three metals were detected in the TCLP leachate: barium, chromium, and lead. The RCRA Characteristic results are found in Appendix C.

Discussion

The sample was collected from a solids settling tank in service to collect produced sand. The tank was opened for cleaning and the sample was collected as it was shoveled out of the tank. The sample should be representative of the type waste being generated at this facility, but not necessarily indicative of the type material that would be bailed from a wellbore.

USED OIL

Used oil wastes generated at E&P sites include various lubrication oils used in engines, compressors, pumps, and gear boxes of equipment and related machinery. Compressor and pump lube oils may come in contact with crude oil, natural gas and produced water. (NOTE: Used oil is not typically considered an associated waste. Because used oil samples were collected along with several true associated waste samples, the results are reported here for convenience.)

Sampling and Analysis

Twelve used oil samples were taken from East Texas (2), West Texas (2), New Mexico (1), Oklahoma (4), Louisiana (1), West Virginia (1), and California (1). Six Phase I and six Phase II samples were taken. Samples were collected directly from the engine crankcase or oil cooling piping at ten different locations. Six samples were taken while the compressor was running.

Two samples were analyzed for oil/water/solids. All twelve samples were analyzed for total Appendix IX volatile organic compounds, while six samples were also analyzed for total Appendix IX metals and Petroleum Refinery List semi-volatile organic compounds. The RCRA ignitability, corrosivity and reactivity and TCLP metals tests were performed on twelve samples. Ten samples were tested for TCLP volatile organic compounds. Of these 10 samples, six were analyzed for 19 organic compounds and six were analyzed for 10 organic compounds. Six samples were evaluated for TCLP semi-volatile organic compounds.

Results

The samples analyzed for oil, water and solids content were 98-100 percent oil, with negligible water or solids. Four total Appendix IX volatile organic compounds were found at measurable levels: benzene, ethyl benzene, toluene, and xylene (Table 3-12). Acetone and dichloromethane were also detected, but the results may be qualitatively unreliable due to the common occurrence of these compounds as laboratory contaminants.

Table 3-12. Total Appendix IX Volatile Components Detected in Used Oil

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Acetone	12	1	11 (0.5-100)	3[c]	N/A
Benzene	12	6	6 (0.5)	25	1.4-120
Carbon Disulfide	12	0	12 (0.25-50)	N/A	N/A
Dichloro Methane	12	1	11 (0.25-50)	0.55[c]	N/A
Ethyl Benzene	12	2	10 (0.25-50)	0.79	0.58-1
Methyl Ethyl Ketone	12	0	12 (0.5-100)	N/A	N/A
Toluene	12	6	6 (0.5)	44	2.1-240
Xylenes	12	6	6 (0.5)	54	1.6-310

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

Only one Petroleum Refinery List semi-volatile compound was detected: phenanthrene (Table 3-13).

Table 3-13. Petroleum Refinery List Semi-Volatile Organic Compounds Detected in Used Oil

Compounds	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Chrysene	6	0	6 (40-200)	N/A	N/A
1-Methyl Naphthalene	6	0	6 (40-200)	N/A	N/A
Naphthalene	6	0	6 (40-200)	N/A	N/A
Phenanthrene	6	1	5 (40-200)	57[c]	N/A

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

Five total Appendix IX metals were detected: barium, calcium, copper, selenium and zinc (Table 3-14).

Table 3-14. Total Appendix IX Metals Detected in Used Oil

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Aluminum	6	0	6 (0.1-10)	N/A	N/A
Antimony	6	0	6 (5)	N/A	N/A
Arsenic	6	0	6 (0.5-1)	N/A	N/A
Barium	6	2	4 (1)	550	370-730
Beryllium	6	0	6 (0.2)	N/A	N/A
Cadmium	6	0	6 (0.5)	N/A	N/A
Calcium	6	3	3 (20-30)	391	92-578
Chromium	6	0	6 (1-5)	N/A	N/A
Cobalt	6	0	6 (1)	N/A	N/A
Copper	6	5	1 (1[c])	4	1-7
Lead	6	0	6 (5)	N/A	N/A
Mercury	6	0	6 (0.1)	N/A	N/A
Nickel	6	0	6 (4)	N/A	N/A
Potassium	6	0	6 (500)	N/A	N/A
Selenium	6	1	5 (0.5)	1.4[c]	N/A
Silver	6	0	6 (1)	N/A	N/A
Sodium	6	0	6 (500)	N/A	N/A
Thallium	6	0	6 (0.5-1)	N/A	N/A
Tin	6	0	6 (5-21)	N/A	N/A
Vanadium	6	0	6 (1)	N/A	N/A
Zinc	6	5	1 (4[c])	136	4-390

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

The RCRA Characteristics testing showed: pH ranged from 4.2 to 9.3; reactive sulfide detected in three out of twelve samples; reactive cyanide detected in one out of twelve samples. Ignitability testing, if properly performed, is appropriate for used oil analyses. Ignitability results showed one sample with a flash point of 72°F and another at 154°F; eight samples had results >160°F and two were above 200°F.

The volatile organic compounds found in the TCLP leachate were: benzene, detected in 4 out of 10 samples; and toluene, found in 4 out of 8 samples analyzed. No TCLP semi-volatile organic compounds were detected. Metals were detected in the TCLP leachate of 12 samples as follows: barium, 11 samples; cadmium, 6 samples; chromium, 4 samples; and lead, 5 samples. The RCRA Characteristic results are found in Appendix C.

Discussion

Used oil samples were collected from natural gas and diesel fired internal combustion engines. These engines are the prime movers for compressors and pumps used at E&P sites and generate the bulk of the used oil stream; gearbox lube oil was not sampled. All of the samples were collected directly from the equipment to ensure the highest expected level of constituents of potential environmental concern.

Sample number 007531-0001 had VOCs that were two orders of magnitude above the rest of the samples and had a flash point of 72°F, less than half of the rest of the samples. From these data, it is possible that this sample was a natural gas liquid. The sample was taken from a compressor. The finfan cooler on the skid generally cools interstage gas, engine jacket water and sometimes the engine lube oil. The piping of this system can be complicated and confusing. It is possible that the sample was inadvertently collected from an interstage gas cooling line and that it consisted of condensed natural gas liquids.

DEHYDRATION AND SWEETENING MATERIALS

Water and hydrogen sulfide gas are impurities in natural gas that must be removed before it can be sold to end users. "Dehydration" and "sweetening" are the terms that describe the treatment processes used to remove these impurities.

GLYCOL WASTE

Glycol waste is generated when a glycol natural gas dehydrator is drained or cleaned. A glycol dehydration unit consists of an absorber tower, a reboiler, heat exchangers, filter, pump and piping (see Figure 3-1). Wet natural gas is placed in contact with glycol in an absorber tower to remove water vapor. Wet gas flows into the bottom of the absorber and upwards where it contacts concentrated glycol being pumped into the top and flowing down over trays contained inside. The concentrated glycol absorbs water vapor from the gas. Dry natural gas flows out the top of the tower, then to a meter where dry natural gas is sold. The dilute glycol and water mixture flows to an energy conserving heat exchanger then to a reboiler where the

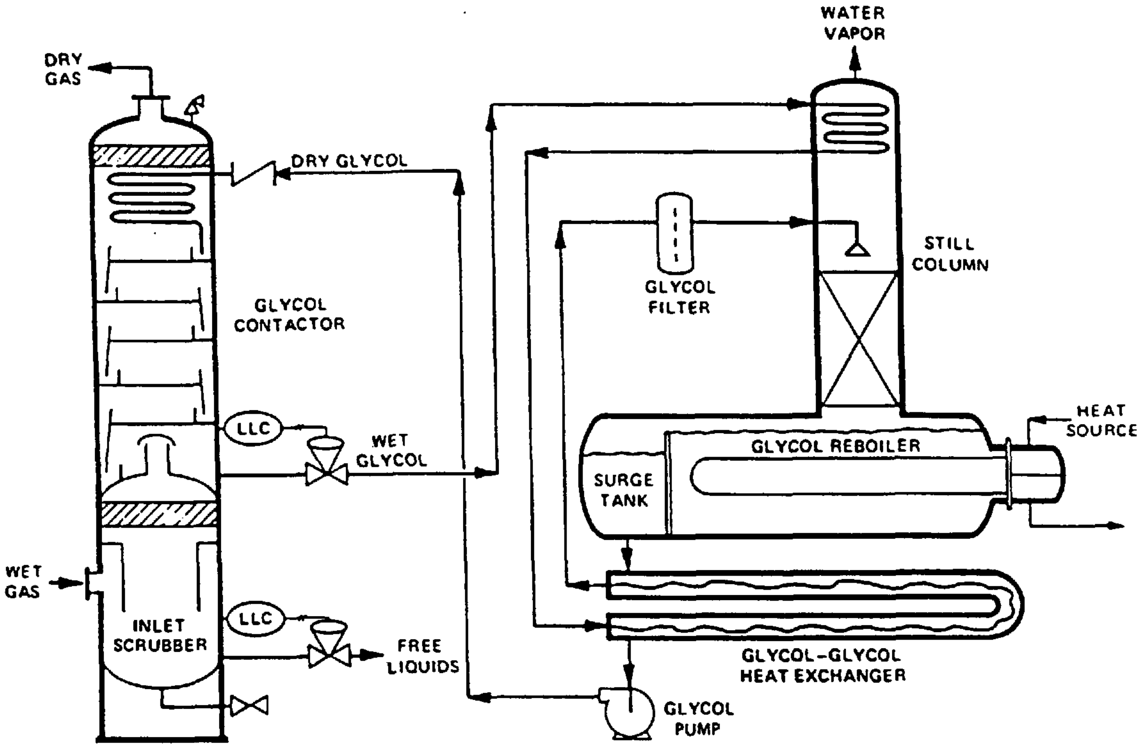

Figure 3-1. Glycol Dehydrator

dilute mixture is heated to 325°F to 350°F. Water is vaporized and passes out of the stack as steam becoming dehydration condensate water. The reconcentrated glycol is recycled (pumped) back to the top of the absorber where the process starts over again. Additional glycol is added to the dehydrator to replace losses due to mechanical carryover, volatilization, and thermal degradation in the reboiler.

Occasionally, glycol in the unit becomes fouled with salt and/or formation solids and cannot be regenerated in the dehydrator unit. If the glycol cannot be regenerated on site, it may be transported to a reclaimer (more sophisticated equipment) or disposed as waste. Waste glycol may contain both hydrocarbon and metal constituents as it comes into contact with produced water, produced hydrocarbon, and formation solids.

Sampling and Analysis

Eight glycol waste samples were taken from West Texas (3), Oklahoma (3), Louisiana (1), and California (1). Four Phase I and four Phase II samples were taken. The samples were collected from eight different facilities from valves between the absorber tower and the reboiler.

Eight waste glycol samples were analyzed for total Appendix IX volatile organic compounds and four samples were analyzed for total Appendix IX metals and Petroleum Refinery List semi-volatile organic compounds. The RCRA ignitability, corrosivity and reactivity, and TCLP metals tests were performed on eight samples, while four samples were tested for TCLP volatile and semi-volatile organic compounds. Another four samples were evaluated for TCLP metals.

Results

Four total Appendix IX volatile organic compounds were found at measurable levels: benzene, ethyl benzene, toluene, and xylene (Table 3-15). Acetone was also detected, but the results for acetone may be qualitatively unreliable due to the common occurrence of this compound as a laboratory contaminant.

Table 3-15. Total Appendix IX Volatile Components Detected in Glycol Waste

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Acetone	8	1	7 (1-330)	4[c]	N/A
Benzene	8	7	1 (0.5[c])	1090	4.5-6700
Carbon Disulfide	8	0	8 (0.5-160)	N/A	N/A
Dichloro Methane	8	0	8 (0.5-160)	N/A	N/A
Ethyl Benzene	8	7	1 (0.5[c])	106	1.7-470
Methyl Ethyl Ketone	8	0	8 (1-330)	N/A	N/A
Toluene	8	7	1 (0.5[c])	870	8.9-4000
Xylenes	8	7	1 (0.5[c])	457	4.4-2000

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

No Petroleum Refinery List semi-volatile organic compounds were detected (Table 3-16).

Table 3-16. Petroleum Refinery List Semi-Volatile Organic Compounds Detected in Glycol Waste

Compounds	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Chrysene	4	0	4 (10-100)	N/A	N/A
1-Methyl Naphthalene	4	0	4 (10-100)	N/A	N/A
Naphthalene	4	0	4 (10-100)	N/A	N/A
Phenanthrene	4	0	4 (10-100)	N/A	N/A

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

N/A Not Applicable

Seven total Appendix IX metals were detected including: barium, calcium, chromium, copper, sodium, tin, and zinc (Table 3-17).

Table 3-17. Total Appendix IX Metals Detected in Glycol Waste

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Aluminum	4	0	4 (10)	N/A	N/A
Antimony	4	0	4 (5)	N/A	N/A
Arsenic	4	0	4 (0.5-1.0)	N/A	N/A
Barium	4	1	3 (1)	2[c]	N/A
Beryllium	4	0	4 (0.2)	N/A	N/A
Cadmium	4	0	4 (0.5)	N/A	N/A
Calcium	4	2	2 (30)	208	21-394
Chromium	4	1	3 (1)	1[c]	N/A
Cobalt	4	0	4 (1)	N/A	N/A
Copper	4	2	2 (1)	1	1-1
Lead	4	0	4 (5)	N/A	N/A
Mercury	4	0	4 (0.1)	N/A	N/A
Nickel	4	0	4 (4)	N/A	N/A
Potassium	4	0	4 (500)	N/A	N/A
Selenium	4	0	4 (0.5-5)	N/A	N/A
Silver	4	0	4 (1)	N/A	N/A
Sodium	4	1	3 (500)	1730[c]	N/A
Thallium	4	0	4 (0.5-1)	N/A	N/A
Tin	4	1	3 (5-11)	13[c]	N/A
Vanadium	4	0	4 (1)	N/A	N/A
Zinc	4	1	3 (1-2)	5[c]	N/A

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

The RCRA Characteristics testing showed: pH ranged from 4.2 to 11.8; reactive sulfide was not detected; reactive cyanide was found in one of the eight samples. The volatile organic compounds found in the TCLP leachate were: benzene, detected in 4 of 4 samples analyzed; and toluene, in 3 of the 3 samples analyzed. Metals were detected in the TCLP leachate of four samples: arsenic and mercury (2), barium and cadmium (1). Three of the four samples tested for ignitability had flashpoints greater than 160 °F. The remaining sample exhibited a flashpoint of 124 °F. The RCRA Characteristic results are found in Appendix C.

Discussion

Generally, glycol waste is generated when the unit is drained for cleaning or glycol replacement. Waste glycol generated is generally a mixture of both dilute glycol upstream of the reboiler and reconcentrated glycol downstream. Samples of this nature were not available for this study; therefore, samples from operating dehydration units were obtained.

The samples collected here were from eight different facilities from valves between the absorber tower and the reboiler. The dilute glycol upstream of the reboiler contains condensed produced water, glycol, and volatile organic compounds from the natural gas stream. The reconcentrated glycol downstream of the reboiler should contain less volatile organic compounds than the glycol upstream. Samples collected upstream of the reboiler were expected to contain the highest level of constituents of potential environmental concern. The samples collected for this study were process material and not necessarily indicative of waste glycol which would be a combination of all the fluids in the unit - the dilute glycol with its contaminants upstream of the reboiler and the reconcentrated glycol downstream. It is expected that levels of constituents found in these samples may not be representative of actual waste streams commonly managed at E&P sites.

DEHYDRATION CONDENSATE WATER

Dehydration condensate water is generated during glycol regeneration (see previous discussion of Glycol Waste and Figure 3-1). This water may contain volatile hydrocarbons and traces of glycol.

Sampling and Analysis

Three dehydration condensate water samples were collected from West Texas (2) and Oklahoma (1) during Phase II. The samples were collected from three facilities using a stainless steel bailer or by collecting the sample directly from a valve. Sampling locations included a blow case, a drip pot and a valve at the sump.

Samples were analyzed for total Appendix IX volatile organic compounds; RCRA ignitability, corrosivity and reactivity; TCLP volatile organic compounds; and TCLP metals.

Results

Dehydration condensate water samples were not analyzed for oil/water/solids content because the samples were typically water, with small concentrations of other constituents. Ignitability results for the three samples were 151°F, 156°F, and greater than 160°F. These results should be considered unreliable because, in each case, the sample matrix was aqueous.

Four total Appendix IX volatile organic compounds were detected: benzene, ethyl benzene, toluene, and xylene (Table 3-18). Acetone was also detected, but the results may be qualitatively unreliable due to the common occurrence of this compound as a laboratory contaminant.

Table 3-18. Total Appendix IX Volatile Components Detected in Dehydration Condensate Water

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/L)][a]	Mean Concentration of Detected Constituents[b] (mg/L)	Range of Detected Concentrations (mg/L)
Acetone	3	1	2 (10-50)	2.5[c]	N/A
Benzene	3	3	0 (N/A)	235	26-630
Carbon Disulfide	3	0	3 (1-25)	N/A	N/A
Dichloro Methane	3	0	3 (1-25)	N/A	N/A
Ethyl Benzene	3	1	2 (5-25)	2.5[c]	N/A
Methyl Ethyl Ketone	3	0	3 (2-50)	N/A	N/A
Toluene	3	3	0 (N/A)	97	24-170
Xylenes	3	3	0 (N/A)	23	18-32

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.
[b] Non-detected concentrations were not used in calculating the mean.
[c] Represents one value.
N/A Not Applicable

The RCRA Characteristics data showed: pH ranged from 5.6-8.8; reactive sulfide was detected in one sample; and no reactive cyanide was found. Benzene and toluene were the volatile organic compounds found in the TCLP leachate of all three samples. The following metals were detected in the TCLP leachate: arsenic and cadmium in one of three samples, and barium in all three samples. The RCRA Characteristic results are found in Appendix C.

Discussion

The samples were taken from collection vessels before the water was transferred to wastewater disposal systems and one sample was bailed through a natural gas condensate layer in the sump. These samples were collected in a manner to ensure capture of the highest expected level of constituents of potential environmental concern. Generally, collected dehydration condensate water undergoes phase separation hydrocarbon recovery and is further treated, as necessary. In most cases, this waste is injected into Class II wells.

SPENT MOLECULAR SIEVE

Another method of gas dehydration is molecular (mol) sieve. Mol sieve material is usually round pellets of aluminum silica similar in size to BBs or buckshot. During the dehydration process, natural gas flows through a packed bed of mol sieve where the water adsorbs to the hydrophilic silicate surfaces. Mol sieve is regenerated with heat to remove the adsorbed water. Usually, two or more mol sieve units are operated in parallel with one unit processing wet natural gas while the other unit(s) are regenerated.

Mol sieve material occasionally becomes fouled with hydrocarbon or, in sour systems, free sulfur, and cannot be regenerated. Also, mol sieve can become "crushed" and packed, causing sections of the bed to be bypassed, reducing its dehydration capacity. If mol sieve cannot be regenerated, it must be disposed of as waste.

Sampling and Analysis

Three mol sieve samples were collected from two West Texas facilities during Phase II. One sample was taken from a natural gas plant in West Texas during a plant "turnaround" (sample #013143-0002). The mol sieve vessel was being unloaded into the bucket of a tractor and the sample was removed from the waste pile in the bucket using a stainless steel trowel. It was the only sample iced and transported to the lab within 24 hours per the QA/QC protocols. The other two samples (#011212-0001 and #011212-0002) were collected by plant personnel from a dehydrator mol sieve and isobutane sweetener mol sieve, respectively. They were held for approximately one month before transport to the lab. Whether the beds were being used for dehydration or were in regeneration was not recorded.

Two mol sieve samples were analyzed for oil/water/solids. All three samples were analyzed for total Appendix IX volatile organic compounds; RCRA ignitability, corrosivity and reactivity; TCLP total volatile organic compounds; and TCLP metals.

Results

Mol sieve samples were typically 86.4-88 percent solids with 12-13.6 percent water and no oil. One ignitability test result for one sample was 140°F while the other two were above 160°F. Ignitability results should be considered unreliable because the samples were solid matrices. Five total Appendix IX volatile organic compounds were detected: benzene, ethyl benzene, methyl ethyl ketone, toluene, and xylene (Table 3-19). Acetone was also detected, but the results may be qualitatively unreliable due to the common occurrence of this compound as a laboratory contaminant.

Table 3-19. Total Appendix IX Volatile Components Detected in Mol Sieve

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Acetone	3	1	2 (1-6.7)	80[c]	N/A
Benzene	3	1	2 (0.5)	40[c]	N/A
Carbon Disulfide	3	0	3 (0.5-3.3)	N/A	N/A
Dichloro Methane	3	0	3 (0.5-3.3)	N/A	N/A
Ethyl Benzene	3	1	2 (0.5)	14[c]	N/A
Methyl Ethyl Ketone	3	1	2 (1-6.7)	2.5[c]	N/A
Toluene	3	2	1 (0.5[c])	65	0.72-130
Xylenes	3	2	1 (0.5[c])	48	1.8-94

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.
[b] Non-detected concentrations were not used in calculating the mean.
[c] Represents one value.
N/A Not Applicable

The RCRA Characteristics data showed a pH range from 7.8-9.2, with reactive sulfide detected in one sample. No reactive cyanide was found. Benzene and toluene were the volatile organic compounds found in the TCLP leachate of one sample, while methyl ethyl ketone was detected in another sample. Both arsenic and barium were detected in the TCLP leachate of one sample. The RCRA Characteristic results are found in Appendix C.

Discussion

Mol sieve waste is usually generated when the vessels must be cleaned and replenished with new material. For this study, the team was able to schedule only one sampling trip where mol sieve could be sampled as it was removed from the vessel. This sample is representative of actual mol sieve waste. The other two sampling events are representative of weathered mol sieve waste.

SPENT IRON SPONGE

Iron sponge is sometimes used to remove hydrogen sulfide from natural gas streams containing low concentrations of hydrogen sulfide. Iron sponge consists of wood chips coated with iron oxide. The "sponge" is placed in a vessel and the natural gas is bubbled through it. The hydrogen sulfide reacts with the iron oxide to form iron sulfide. The process does not lend itself to regeneration so when the iron sponge is "spent," the sponge becomes a waste.

Sampling and Analysis

Two iron sponge samples were collected from West Texas during Phase II. The samples were from two different facilities.

One sample was intended to be collected by the contractor as the vessel was opened for cleanout. However, delays occurred and the contractor was not able to be on site. The sample was eventually collected from the interior of the pile a few hours after the vessel had been opened and the material removed. The second sample (No. 013143-0001) was collected from a waste disposal site where it has been buried under two feet of soil for approximately one month. The site was excavated specifically for the purpose of obtaining a sample.

One spent iron sponge sample was analyzed for oil/water/solids. Both samples were analyzed for total Appendix IX volatile organic compounds; RCRA ignitability, corrosivity and reactivity; TCLP volatile organic compounds; and TCLP metals.

Results

The one sample analyzed for oil/water/solids, contained 6 percent oil, 28.3 percent water, and 65.7 percent solids. Four total Appendix IX volatile organic compounds were detected in the two samples analyzed: benzene, ethyl benzene, toluene, and xylene (Table 3-20). Acetone was also detected, but the results may be qualitatively unreliable due to the common occurrence of this compound as a laboratory contaminant.

Table 3-20. Total Appendix IX Volatile Components Detected in Spent Iron Sponge

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Acetone	2	1	1 (2[c])	5.6[c]	N/A
Benzene	2	1	1 (1[c])	16[c]	N/A
Carbon Disulfide	2	0	2 (1)	N/A	N/A
Dichloro Methane	2	0	2 (1)	N/A	N/A
Ethyl Benzene	2	1	1 (1[c])	1.7[c]	N/A
Methyl Ethyl Ketone	2	0	2 (2)	N/A	N/A
Toluene	2	1	1 (1[c])	25[c]	N/A
Xylenes	2	1	1 (1[c])	4.6[c]	N/A

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.
[b] Non-detected concentrations were not used in calculating the mean.
[c] Represents one value.
N/A Not Applicable

The RCRA Characteristics tests showed a pH range from 7.5-8.4, with reactive sulfide detected in one sample. No reactive cyanide was detected. TCLP volatile organics testing revealed benzene and toluene in the leachate of one sample, and methylene chloride in the leachate of another. Barium was the only TCLP metal detected; it appeared in both samples. Flash points for both samples were >160°F. Although spent iron sponge is known to be pyrophoric, the RCRA ignitability test results should be considered unreliable because of the semi-solid nature of the material.

Discussion

Scheduling of these events was very difficult. The spent iron sponge samples were collected from a pile (within 24 hours after removal from the vessel), and from a subsurface location (one month after burial). The samples are representative of actual wastes; however, they may not be expected to contain the highest levels of constituents of potential environmental concern since each was exposed to the environment to some degree prior to sampling. No VOCs were detected in the sample that had been buried for one month while VOCs were detectable in the other sample.

Further, ignitability tests are not reliable for spent iron sponge, however, the material may be pyrophoric and should have a hazard determination made based on 40 CFR 262.11(c)(2). Although spent iron sponge may contain reactive sulfides, the proper handling or process for removal from the vessel generally eliminates sulfides from the material. The reaction of the spent iron sponge (Fe_xS_y) with oxygen (0_2) generates Fe_2O_3 and SO_2 and heat. The same reaction will occur with water and generate a mixture of sulfur oxide species; there are no reactive sulfides expected in the buried material.

USED AMINE

The most common treatment for removing hydrogen sulfide and carbon dioxide from natural gas in E&P operations is to pass the natural gas through an amine solution. The process and regeneration are similar to those described for glycol dehydration (See Figure 3-1). Untreated natural gas flows upward through an absorber or contact tower where acid gas is removed by chemical reaction with a 10 to 35 percent amine solution being pumped into the top of the tower where it flows down over trays contained inside. Treated natural gas flows out the top of the tower to a meter where it is sold. The amine solution containing the acid gas is called "sour amine." The sour amine solution is discharged from the bottom of the absorber to an energy conserving heat exchanger, through carbon filtration (unit specific), and then into the top of a still. The sour amine solution is regenerated in the still with clean amine solution (called "sweet amine") leaving the bottom of the still and acid gas leaving the top of the still. Acid gases may be oxidized through the flare system or processed further for sulfur recovery.

Amine treating is possible because amine and acid gases, such as hydrogen sulfide and carbon dioxide, react at ordinary temperatures. The reaction is reversed at temperatures of 220°F to 240°F. Amines employed in this process are either monoethanolamine (MEA), diethanolamine (DEA) or triethanolamine (TEA). MEA is probably the most common amine in use in E&P operations.

There are several ways that amine solutions may become fouled and not able to be regenerated in the amine treating unit. Iron sulfide and amine thiosulfates are common contaminants. If the amine solution cannot be regenerated on site, it may be sent to a reclaimer (with more sophisticated equipment) or disposed as waste. Waste amine solution can contain both hydrocarbon and metal constituents, since it comes into contact with produced water, produced hydrocarbon and formation solids carried into the treater.

Sampling and Analysis

One amine waste sample was collected from West Texas during Phase I. The amine waste sample was analyzed for total Appendix IX volatile and Petroleum Refinery List semi-volatile organic compounds, and total Appendix IX metals. The sample was also analyzed for RCRA corrosivity and reactivity.

Results

Two total Appendix IX volatile organic compounds were detected: benzene and toluene (Table 3-21).

Table 3-21. Total Appendix IX Volatile Components Detected in Used Amine

Compound	Number of Samples Analyzed	Number of Detections	Detection Limit (mg/kg)	Detected Concentration (mg/kg)
Acetone	1	0	1	N/A
Benzene	1	1	3.7	3.7
Carbon Disulfide	1	0	0.5	N/A
Dichloro Methane	1	0	0.5	N/A
Ethyl Benzene	1	0	0.5	N/A
Methyl Ethyl Ketone	1	0	1	N/A
Toluene	1	1	1.5	1.5
Xylenes	1	0	0.5	N/A

N/A Not Applicable

No Petroleum Refinery List semi-volatile organic compounds were detected (Table 3-22).

Table 3-22. Petroleum Refinery List Semi-Volatile Organic Compounds Detected in Used Amine

Compound	Number of Samples Analyzed	Number of Detections	Reporting Limit for Non-Detections (mg/kg)	Detected Concentration (mg/kg)
Chrysene	1	0	0.01	N/A
1-Methyl Naphthalene	1	0	0.01	N/A
Naphthalene	1	0	0.01	N/A
Phenanthrene	1	0	0.01	N/A

N/A Not Applicable

Two total Appendix IX metals were detected: barium and zinc (Table 3-23). The RCRA Characteristics data showed a pH of 9.2 and a reactive sulfide of 4.4. No reactive cyanide was detected. The RCRA Characteristic results are found in Appendix C.

Table 3-23. Total Appendix IX Metals Detected in Used Amine

Compound	Number of Samples Analyzed	Number of Detections	Detection Limit (mg/kg)	Detected Concentration (mg/kg)
Aluminum	1	0	10	N/A
Antimony	1	0	5	N/A
Arsenic	1	0	5	N/A
Barium	1	1	N/A	2
Beryllium	1	0	0.2	N/A
Cadmium	1	0	0.5	N/A
Calcium	1	0	30	N/A
Chromium	1	0	1	N/A
Cobalt	1	0	1	N/A
Copper	1	0	1	N/A
Lead	1	0	5	N/A
Mercury	1	0	0.1	N/A
Nickel	1	0	4	N/A
Potassium	1	0	500	N/A
Selenium	1	0	0.5	N/A
Silver	1	0	1	N/A
Sodium	1	0	500	N/A
Thallium	1	0	1	N/A
Tin	1	0	11	N/A
Vanadium	1	0	1	N/A
Zinc	1	1	N/A	1

N/A Not Applicable

Discussion

Generally, amine waste is generated when the unit is drained for cleaning or amine solution replacement. A sample of this nature was not available for this study. Therefore, a sample from an operating treating unit was collected. To collect a sample with the highest expected level of constituents of potential environmental concern, only a "sour" amine was sampled. The sample was collected from a valve upstream of the still/reboiler section of the unit. The amine solution in this section contains condensed produced water, acid gases and volatile organic compounds from the natural gas stream. This sample was process material and would not necessarily be indicative of waste amine which would be a combination of all fluids in the unit. The sweet amine downstream of the reboiler should contain less volatile organic compounds. Therefore, it is expected that the levels of some constituents found in this sample are elevated relative to the mixed sweet/sour amine solution commonly managed as a waste on E&P sites.

The waste amine was not tested for ignitability because it is an aqueous solution. The monoethanol amine (MEA) has an open cup flash of 200°F, and would not fail the characteristic before dilution with water.

PIT AND SUMP SAMPLES

Sump wastes generated at E&P sites are generally the result of a collection of drains. Pit and sump waste can contain a variety of E&P fluids. This study focused on sumps that collect leaks at produced water injection and transfer pumps, and blowdown (produced water, condensate water, and hydrocarbon) from scrubbers and other vessels.

Sampling and Analysis

Four pit and sump samples were collected from West Texas (2), Oklahoma (1), and California (1). Two Phase I and two Phase II samples were taken. The samples were collected from four different facilities by bailing the sample from the sumps.

Two pit and sump samples were analyzed for oil/water/solids. All four samples were analyzed for total Appendix IX volatile organic compounds, and two samples were analyzed for both the total Appendix IX metals and Petroleum Refinery List semi-volatile organic compounds.

All four samples were evaluated for RCRA ignitability, corrosivity and reactivity; TCLP volatile organic compounds; and TCLP metals. Two samples also underwent testing for TCLP semi-volatile organic compounds.

Two samples underwent inorganic chlorides analysis by EPA Method 300.0.

Results

Pit and sump samples were extremely varied, containing 11.5-68.3 percent oil, 22.5-45.7 percent water, and 8.7-44.8 percent solids. Ignitability test results for one sample were 153°F, while the remaining samples were greater than 160°F. The two samples tested for organic chlorides exhibited low salinity.

Five total Appendix IX volatile organic compounds were found at measurable levels: acetone, benzene, ethyl benzene, toluene, and xylene (Table 3-24).

Table 3-24. Total Appendix IX Volatile Components Detected in Pit and Sump Samples

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Acetone	4	1	3 (1-1000)	53[c]	N/A
Benzene	4	2	2 (0.5-25)	607	13-1200
Carbon Disulfide	4	0	4 (0.5-500)	N/A	N/A
Dichloro Methane	4	1	3 (0.5-500)	2.4[c]	N/A
Ethyl Benzene	4	3	1 (0.5[c])	710	8.8-1900
Methyl Ethyl Ketone	4	0	4 (1-1000)	N/A	N/A
Toluene	4	3	1 (0.5[c])	2254	11-6600
Xylenes	4	3	1 (0.5[c])	4092	26-12,000

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.
[b] Non-detected concentrations were not used in calculating the mean.
[c] Represents one value.
N/A Not Applicable

Two Petroleum Refinery List semi-volatile compounds were detected: chrysene and phenanthrene (Table 3-25). Butyl benzyl phthalate was also detected, but these results are considered qualitatively unreliable due to the common occurrence of this compound as a laboratory contaminant (see Appendix B). Phthalate readings were not reported because results are considered to be of limited use.

Table 3-25. Petroleum Refinery List Semi-Volatile Components Detected in Pit and Sump Samples

Compounds	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Chrysene	2	1	1 (40[c])	16[c]	N/A
1-Methyl Naphthalene	2	0	2 (15-40)	N/A	N/A
Naphthalene	2	0	2 (15-40)	N/A	N/A
Phenanthrene	2	1	1 (15[c])	71[c]	N/A

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.
[b] Non-detected concentrations were not used in calculating the mean.
[c] Represents one value.
N/A Not Applicable

Twelve different total Appendix IX metals were detected. Two samples contained aluminum, arsenic, barium, calcium, chromium, copper, nickel, sodium, vanadium, and zinc (Table 3-26). Lead and potassium were each found in one sample.

Table 3-26. Total Appendix IX Metals Concentrations Detected in Pit and Sump Samples

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Aluminum	2	2	0 (N/A)	2342	85-4600
Antimony	2	0	2 (5)	N/A	N/A
Arsenic	2	2	0 (N/A)	0.8	0.5-1.1
Barium	2	2	0 (N/A)	1302	4-2600
Beryllium	2	0	2 (0.2)	N/A	N/A
Cadmium	2	0	2 (0.5)	N/A	N/A
Calcium	2	2	0 (N/A)	11,365	2130-20,600
Chromium	2	2	0 (N/A)	8.5	3-14
Cobalt	2	0	2 (1)	N/A	N/A
Copper	2	2	0 (N/A)	9	9
Lead	2	1	1 (5[c])	44[c]	N/A
Mercury	2	0	2 (0.1)	N/A	N/A
Nickel	2	2	0 (N/A)	16.5	9-24
Potassium	2	1	1 (500[c])	1300[c]	N/A
Selenium	2	0	2 (0.5-1)	N/A	N/A
Silver	2	0	2 (1)	N/A	N/A
Sodium	2	2	0 (N/A)	9100	800-17,400
Thallium	2	0	2 (1-10)	N/A	N/A
Tin	2	0	2 (5-11)	N/A	N/A
Vanadium	2	2	0 (N/A)	7.5	2-13
Zinc	2	2	0 (N/A)	24	22-25

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.
[b] Non-detected concentrations were not used in calculating the mean.
[c] Represents one value.
N/A Not Applicable

Results from RCRA Characteristics tests showed: pH ranged from 4.6 to 9.6; reactive sulfide was detected in two of the four samples; reactive cyanide was not detected. The ignitability test results are deemed unreliable for these samples because they contained significant amounts of water and solids. The volatile organic compounds detected in the TCLP leachate were: benzene and methylene chloride, each found in one of four samples; and toluene, found in three of the four samples. Barium was detected in the TCLP leachate of all four samples. No semi-volatile organic compounds were detected in the leachate. The RCRA Characteristic results are found in Appendix C.

Discussion

The acetone detected in one sample cannot be attributed to laboratory contamination because the concentration of 53 mg/kg is greater than five (5) times the detection limit (see Appendix B). The results for methylene chloride can be attributed to laboratory contamination (EPA, 1987). Sample (11686-003-SA) generated two phases (oil and aqueous) during TCLP extraction. According to the method, each phase is analyzed separately, and the results are mathematically recombined.

The pit and sump samples were taken from sumps that collect produced water prior to injection, transfer pump leaks and sometimes blowdown from scrubbers and other vessels. These wastes vary considerably from facility to facility depending on the drains connected. The wastes are generally transferred to another system for settling and hydrocarbon recovery before disposal.

RIG WASH

Rig wash consists of the liquids and solids produced from washing a drilling rig floor. Generally, water and detergents are used to wash drilling fluids, cuttings, and other debris from the rig floor to keep the area clean and prevent accidents caused by slippage. The solids and liquids are collected in a sump or cellar located under the drilling rig. The sump may be earthen or lined.

Sampling and Analysis

Five samples were collected from Oklahoma (1), West Texas (1), and Michigan (3) during Phase II. The samples were collected from three different facilities. One sample was analyzed for oil/water/solids, and five samples were analyzed for total Appendix IX volatile organic compounds; RCRA ignitability, corrosivity and reactivity; and TCLP metals. Four samples were evaluated for the full range of volatile organic compounds in the TCLP leachate, while an additional sample was tested for selected TCLP volatile organic compounds.

Results

The rig wash sample analyzed for oil/water/solids contained 1 percent oil, 44.2 percent water, and 54.8 percent solids. Six total Appendix IX volatile organic compounds were found at measurable levels: acetone, benzene, ethyl benzene, methyl ethyl ketone, toluene, and xylene (Table 3-27). The results for acetone may be qualitatively unreliable due to the common occurrence of this compound as a laboratory contaminant.

Table 3-27. Total Appendix IX Volatile Components Detected in Rig Wash

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/L)][a]	Mean Concentration of Detected Constituents[b] (mg/L)	Range of Detected Concentrations (mg/L)
Acetone	5	4	1 (2.5[c])	0.43	0.041-1.4
Benzene	5	2	3 (0.005-1.2)	0.04	0.032-0.045
Carbon Disulfide	5	0	5 (0.005-1.2)	N/A	N/A
Dichloro Methane	5	0	5 (0.005-1.2)	N/A	N/A
Ethyl Benzene	5	3	2 (0.01-1.2)	0.015	0.0074-0.03
Methyl Ethyl Ketone	5	2	3 (0.005-2.5)	0.07	0.064-0.071
Toluene	5	4	1 (0.005[c])	0.83	0.016-3.2
Xylenes	5	5	0 (N/A	1.31	0.03-6.4

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

The results from the RCRA Characteristics tests showed a pH range from 6.8 to 11.8; reactive sulfide was detected in two out of the five samples, reactive cyanide in one out of five. The volatile organic compounds detected in the TCLP leachate were: toluene, detected in two of the four samples analyzed; and methyl ethyl ketone, found in one of the four samples tested. Of the five samples tested for metals in the TCLP leachate, barium was detected in four samples, with cadmium and mercury each detected in one sample. Only one sample exhibited a flash point <140°F; however, this result is judged to be unreliable because the sample was an aqueous matrix. The RCRA Characteristic results are found in Appendix C.

Discussion

All of the rig wash samples were collected immediately after they entered the sump. Rig wash by definition is variable in nature. Therefore samples are expected to vary in composition. Within the context of this variability, the samples taken for this study are considered to be representative of rig wash streams at these facilities.

OIL-BASED MUD CUTTINGS

When oil and natural gas wells are drilled, fluids known as muds are circulated through the drill pipe, through and around the bit and up the hole. The primary functions of muds are to control formation pressure, remove rock cuttings, lubricate and cool the bit, and seal the wellbore to prevent fluid loss. Oil-based muds are used for particular situations such as when high well temperatures are encountered, to prevent severe corrosion of drill pipe, to alleviate pipe sticking, or in sensitive formations which would be dissolved by water-based muds.

Drilling muds are water- or oil-based mixtures of clays and weighting materials with small amounts of various additives. Cuttings are small pieces of the formation that have been in contact with the drilling mud itself (in this case, an oil-based mud) and may be cuttings from the oil and natural gas bearing formations. Because water-based mud cuttings were sampled by API (1987) and EPA (for the 1987 Report to Congress), this study focused on oil-based mud cuttings.

Sampling and Analysis

Five oil-based mud cutting samples were taken from West Texas (1), New Mexico (1), and Oklahoma (3). Three Phase I and two Phase II samples were taken.

Five samples were analyzed for oil/water/solids and total Appendix IX volatile organic compounds. Three samples were analyzed for total Appendix IX metals and Petroleum Refinery List semi-volatile organic compounds. Five samples were tested for RCRA ignitability, corrosivity and reactivity. Three samples were analyzed for all six TCLP volatile organic compounds, while an additional sample was tested for trichloroethylene, methyl ethyl ketone and benzene in the leachate. Two samples were evaluated for TCLP semi-volatile organic compounds and four underwent TCLP metals testing. Three samples were analyzed for inorganic chlorides by EPA Method 300.0.

Results

The oil-based mud cutting samples contained 9.8-34.7 percent oil, 1.9-10.9 percent water and 57.2-88.3 percent solids. Three total Appendix IX volatile organic compounds were found at measurable levels: ethyl benzene, toluene, and xylene (Table 3-28).

Table 3-28. Total Appendix IX Volatile Components Detected in Oily Mud Cuttings

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Acetone	5	0	5 (5-500)	N/A	N/A
Benzene	5	0	5 (2.5-250)	N/A	N/A
Carbon Disulfide	5	0	5 (2.5-250)	N/A	N/A
Dichloro Methane	5	0	5 (2.5-250)	N/A	N/A
Ethyl Benzene	5	3	2 (100-250)	11	6.2-18
Methyl Ethyl Ketone	5	0	5 (5-500)	N/A	N/A
Toluene	5	2	3 (10-250)	3.45	3.2-3.7
Xylenes	5	3	2 (100-250)	39	27-47

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

N/A Not Applicable

Three Petroleum Refinery List semi-volatile organic compounds were detected: 1-methyl naphthalene, napthalene and phenanthrene (Table 3-29).

Table 3-29. Petroleum Refinery List Semi-Volatile Components Detected in Oily Mud Cuttings

Compounds	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Chrysene	3	0	3 (85-390)	N/A	N/A
1-Methyl Naphthalene	3	3	0 (N/A)	687	500-910
Naphthalene	3	2	1 (390[c])	205	180-230
Phenanthrene	3	2	1 (390[c])	205	180-230

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

Fourteen total Appendix IX metals were detected including: aluminum, arsenic, barium, beryllium, calcium, chromium, copper, lead, mercury, nickel, potassium, sodium, vanadium, and zinc (Table 3-30).

Table 3-30. Total Appendix IX Metals Detected in Oily Mud Cuttings

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Aluminum	3	3	0 (N/A)	4940	4000-6700
Antimony	3	0	3 (5-10)	N/A	N/A
Arsenic	3	3	0 (N/A)	2	1.4-3
Barium	3	3	0 (N/A)	8067	3600-10,700
Beryllium	3	2	1 (0.4[c])	0.25	0.2-0.3
Cadmium	3	0	3 (0.5-1)	N/A	N/A
Calcium	3	3	0 (N/A)	27,400	25,000-28,800
Chromium	3	3	0 (N/A)	18	14-22
Cobalt	3	0	3 (1-2)	N/A	N/A
Copper	3	3	0 (N/A)	13	12-15
Lead	3	3	0 (N/A)	44	11-70
Mercury	3	1	2 (0.1)	0.1[c]	N/A
Nickel	3	3	0 (N/A)	13	7-18
Potassium	3	3	0 (N/A)	1563	1190-2000
Selenium	3	0	3 (0.5-1)	N/A	N/A
Silver	3	0	3 (1-2)	N/A	N/A
Sodium	3	2	1 (1000[c])	1510	1100-1920
Thallium	3	0	3 (1-2)	N/A	N/A
Tin	3	0	3 (5-11)	N/A	N/A
Vanadium	3	3	0 (N/A)	9	8-12
Zinc	3	3	0 (N/A)	127	36-280

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

The results from the RCRA Characteristics testing showed a pH range from 9.9 to 10.7, with reactive sulfide detected in one of the five samples. Reactive cyanide was not detected. Toluene was detected in the TCLP leachate in one of three samples analyzed; no TCLP semi-volatile organic compounds were found. Barium was detected in the TCLP leachate of the four samples analyzed, while chromium and lead showed up in one sample. The inorganic chloride analyses, EPA Method 300.0, show low salinity in the cuttings. Flash points for all samples were >160°F; however, the ignitability test is not reliable for produced water or other aqueous fluids or solid wastes.

Discussion

All of the oil-based mud cutting samples were collected below the screen separator, immediately after separation from the mud fluid or from the interior of a cuttings pile. Generally, oily mud cuttings are exposed to weathering or washing to remove oil. Because the sampling procedures were intended to collect the highest expected level of constituents of potential environmental concern, the samples were not exposed to common procedures or conditions. Therefore, it is expected that the levels of constituents found in these samples are elevated relative to oily mud cuttings commonly managed on E&P sites.

PIGGING MATERIALS

Pigging wastes in E&P operations are generated when cleaning pipelines used for gathering crude oil and/or natural gas. Crude oil and natural gas gathering lines become partially filled (loaded) with liquids or solids that inhibit flow. These obstacles are removed by using a ball (pig) - inserted into the pipeline and pumped through the constricted or blocked section. The pig pushes the liquids and solids to a receiving vessel or sump. This waste may consist of produced water, condensed water, crude oil, and natural gas liquids and may also contain small amounts of solids, including paraffin, mineral scale, sand, and clay.

Sampling and Analysis

Five pigging samples were taken from East Texas (2), West Texas (1), and Michigan (2) during Phase II. The samples were collected from four different facilities. Samples were collected from either lined sumps, settling tanks or separators, or ball (pig) receivers. Four of the samples were from crude oil lines; one sample was obtained from a valve of a three phase separator at a natural gas plant.

One sample was analyzed for oil/water/solids, and five samples were analyzed for total Appendix IX volatile organic compounds. All five samples were analyzed for RCRA ignitability, corrosivity and reactivity, TCLP volatile organic compounds and TCLP metals.

Results

The pigging sample analyzed for oil, water and solids content, contained 30.4 percent oil, 11.5 percent water, and 58.1 percent solids. Four total Appendix IX volatile organic compounds were found at measurable levels: benzene, ethyl benzene, toluene, and xylene (Table 3-31).

Acetone was also detected; however, these results may be qualitatively unreliable due to the occurrence of this compound as a laboratory contaminant.

The results from the RCRA Characteristics showed a pH range from 3.2 to 7.7; reactive sulfide was detected in three of five samples; no reactive cyanide was detected.

Two of the five samples exhibited a flash point <140°F; however, results from ignitability testing on samples with high solids content are deemed unreliable. Benzene and toluene were the two volatile organic compounds detected in the TCLP leachate of all five samples. Metals detected in the TCLP leachate were: barium and chromium, each detected in 3 of 5 samples; and cadmium and mercury, each found in 2 of 5 samples. RCRA Characteristic results are found in Appendix C.

Table 3-31. Total Appendix IX Volatile Components Detected in Pigging Samples

Compound	Number of Samples Analyzed	Number of Detections	Number of Non-Detections [Range of Reporting Limits for Non-Detections (mg/kg)][a]	Mean Concentration of Detected Constituents[b] (mg/kg)	Range of Detected Concentrations (mg/kg)
Acetone	5	3	2 (67-2000)	234	0.16-700
Benzene	5	4	1 (250[c])	915	0.51-3500
Carbon Disulfide	5	0	5 (0.03-1000)	N/A	N/A
Dichloro Methane	5	0	5 (0.03-1000)	N/A	N/A
Ethyl Benzene	5	3	2 (0.25-34)	1487	0.076-3900
Methyl Ethyl Ketone	5	0	5 (0.06-2000)	N/A	N/A
Toluene	5	5	0	4121	0.59-19,000
Xylenes	5	5	0	4074	0.28-18,000

[a] The "Range of Reporting Limits for Non-Detections" qualitatively reflects the bias associated with the reported mean, due to excluding non-detected concentrations.

[b] Non-detected concentrations were not used in calculating the mean.

[c] Represents one value.

N/A Not Applicable

Discussion

Three samples were collected at the inlet of natural gas plants from natural gas gathering operations. Two were removed from valves on inlet receiving vessels so that minimum exposure to atmosphere occurred. The other sample was collected as the door of the receiver was opened. The final two samples (013200-0001 and 013200-0002) were collected from the same sump at a crude oil and natural gas production facility - the difference being that one sample was liquid and the other was solids. Both samples were collected from the waste receiving receptacles. The sampling procedures employed intended to collect the highest expected level of constituents of potential environmental concern. In all cases, the wastes should be considered typical of the generated wastes at those type facilities.

OVERALL DATA DISCUSSION

The results of this study support previously summarized information on the constituents present in crude oil and its byproducts. While samples were analyzed for a broad range of constituents (Appendix B), very few were detected. The data indicate that there are varying types and concentrations of total Appendix IX metals, a number of total Appendix IX volatile organic compounds at various concentrations, and few to no Petroleum Refinery List semi-volatile organic compounds.

Volatile Organic Compounds

Fourteen waste categories and a total of 120 samples were analyzed for total Appendix IX volatile organic compounds. The categories included used oil (12) and oil-based mud cuttings (5), along with the following associated wastes: crude oil impacted soil (32), workover materials (21), tank bottoms (18), waste glycol (8), pigging materials (5), rigwash (5), pit and sump materials (4), molecular sieve (3), dehydration water (3), iron sponge (2), produced sand (1), and amine (1). Five total Appendix IX volatile organic compounds were detected (Table 3-32). While acetone, dichloromethane, and methyl ethyl ketone were also detected, the results may be qualitatively unreliable due to the common occurrence of these compounds as laboratory contaminants (see Appendix B).

Table 3-32. Summary of Total Appendix IX Volatile Organic Compounds Found

Volatile Organic	Percent Detections	Range of Detected Concentrations (ppm)
Acetone	30%	0.04 - 700
Benzene	54%	0.01 - 6700
Carbon Disulfide	2%	5.2 - 54
Dichloromethane	11%	0.005 - 500
Ethyl Benzene	61%	0.007 - 7,400
Methyl Ethyl Ketone	3%	0.064 - 2.5
Toluene	73%	0.015 - 32,000
Xylene	85%	0.013 - 52,000

It is well known that crude oil contains volatile organic compounds. Concentrations of the volatile organic compounds in E&P wastes are dependent on the waste characteristics and on the crude oil or gas being extracted and processed. The data collected in this study cover a broad cross section of material types, analytical procedures, and sampling locations/procedures. Although the 120 samples analyzed begin to characterize the constituents present in the wastes associated with oil and gas production, they represent a small database relative to the diversity of the "associated wastes." In addition, many of the samples in this study were intended to capture the highest concentration of constituents of possible environmental concern and were not true wastes. In order to understand the components present in oil and gas wastes, more data must be collected. Further, a majority of the samples analyzed for total volatile organic compounds in this study indicated a matrix interference problem with at least one constituent analyzed. The effects of this are described in the Matrix Interferences section and in Appendix B.

Semi-Volatile Organic Compounds

Eight waste types and a total of thirty-one samples were analyzed for Petroleum Refinery List semi-volatile compounds. The categories included used oil (6) and oil-based mud cuttings (3), along with the following associated wastes: tank bottoms (10), crude oil impacted soil (4), waste glycol (4), pit and sump materials (2), produced sand (1), and amine (1). Only four Petroleum Refinery List semi-volatile organic compounds were detected: 1-methyl naphthalene (detected in 35 percent of the samples); chrysene (detected in 3 percent of the samples); napthalene (detected in 26 percent of samples); and phenanthrene (detected in 16 percent of the samples). Phthalate results were not reported because they are considered unreliable and of limited use, and because phthalate esters are common lab contaminants (see Appendix B). Oil-based mud cuttings had detected concentrations far above the other samples at 500-910 ppm for 1-methyl naphthalene and 180-230 ppm for phenanthrene. Without oil-based mud cuttings, the detected concentrations for 1-methyl naphthalene and phenanthrene were much lower, (21-240 ppm) and (10-71 ppm), respectively. Because crude oil is comprised of a wide range of organic compounds, it was expected that semi-volatile organic compounds might be present in the materials that were sampled. Diesel oil is used to make oil-based drilling muds and can contain higher concentrations of semi-volatile organic compounds due to refining. It is likely that this caused the elevated levels in the oil-based drilling mud cutting samples.

Metals

Eight waste categories and a total of 33 samples were analyzed for total Appendix IX metal components. The categories included used oil (6) and oil-based mud cuttings (3), along with the following associated wastes: tank bottoms (10), crude oil impacted soil (4), waste glycol (4), pit and sump materials (4), produced sand (1), and amine (1). Sixteen metals were detected (Table 3-33). Only two samples exceeded API's risk-based criteria (API, 1995) for metals in soil/waste mixtures.

Table 3-33. Summary of Total Appendix IX Metals Found in Associated Wastes

Metal	Percent Detects	Range of Detected Concentrations (ppm)	Background Soil Concentrations[1] Average and (Range)(ppm)	API (1995) Metals Criteria (ppm)
Aluminum	58%	13 - 6,700	72,000 (700 - >100,000)	-
Arsenic	52%	0.5 - 140	7.2 (<0.1 - 97)	41
Barium	73%	2 - 10,700	580 (10 - 5,000)	180,000
Beryllium	12%	0.2 - 0.6	0.92 (<1 - 15)	-
Cadmium[2]	12%	0.5 - 3	0.27 (0.005 - 2.4)	26
Calcium	70%	208 - 273,000	24,000 (100 - 320,000)	-
Chromium	55%	2 - 54	54 (1 - 2,000)	1,500
Cobalt	18%	1 - 6	9.1 (<3 - 70)	-
Copper	73%	4 - 210	25 (<1 - 700)	750
Lead	45%	7 - 970	19 (<10 - 700)	300
Mercury	12%	0.1 - 1.4	0.09 (<0.01 - 4.6)	17
Nickel	55%	4 - 100	19 (<5 - 700)	210
Potassium	15%	500 - 2,000	15,000 (50 - 63,000)	-
Sodium	45%	760 - 17,400	12,000 (<500 - 100,000)	-
Vanadium	55%	2 - 25	80 (<7 - 500)	-
Zinc	79%	1 - 400	0 (<5 - 2,900)	1,400

[1] Shacklette, *et al.*, 1984

[2] Holmgren, *et al.*, 1986

\- No API criteria

Natural gas and crude oil are produced from geologic formations within the earth. These formations are made up of minerals which naturally contain the above metals in varying concentrations. Therefore, it is expected that the associated wastes would contain varying types and concentrations of the above metals depending on the characteristics of the formation and drilling/producing practices used.

Laboratory and Project Quality Assurance/Quality Control (QA/QC) Summary

Laboratory performance QC was monitored by the use of Laboratory Control Samples (LCS) and Surrogate Control Samples (SCS). All laboratory QC data generated for this project were within normal control limits, excluding a few cases where problems were isolated to the control sample. A full discussion of laboratory QC can be found in Appendix B.

Project-specific QC activities included trip blanks, surrogate spikes and matrix spikes. These activities are discussed in Appendix B. Trip blanks were found to be free of contaminants except for some detections of the common lab contaminants acetone and methyl ethyl ketone. Matrix spikes generally produced acceptable recoveries although some recoveries were elevated due to matrix interference. Surrogate recoveries were generally acceptable, however, in some cases recoveries were diluted out due to elevated levels of hydrocarbons in the samples. No field blanks or duplicates were collected.

Matrix Interferences

Matrix interference problems (see Table 3-34) were frequently encountered when trying to analyze certain samples by EPA analytical methods. Matrix interference describes problems created from substances in the samples that cause either a chemical or physical interference during the analysis of the sample.

Many of the samples collected during this study had two distinct phases, some samples were oily liquids and others were solids with a high oil content. These types of samples pose a significant challenge to the analytical methods that are normally used to assess environmental contamination.

For organic analyses, elevated levels of oil in some samples caused problems with the standard procedures. All of the organic tests use chromatographic columns, and there is a limit to the amount of material which can be applied to a column at one time. Samples that are high in oil content will have detection limits that are 10 to 10,000 times higher than the limits that are achieved in clean soils. Approximately 60 percent of the samples for total volatiles and 40 percent of the samples for TCLP volatiles had elevated reporting limits due to elevated levels of oil. The reporting limits were greater than TCLP regulated limits in some cases. In addition, some samples were diluted so that surrogate recoveries could not be measured.

Table 3-34. Matrix Interference

A hydrocarbon sample is analyzed for benzene using a gas chromatograph. Two peaks (and/or a large baseline interference) are detected in the chromatographic column at benzene's retention time. In order to identify the peaks or determine if benzene is present in significant concentrations, the laboratory will dilute the sample in an attempt to get better resolution of the peaks. Dilution can lead to more distinct peaks and/or reduced baseline interference which will eliminate the problem and allow the benzene concentration to be determined. However, this procedure could result in dilution of benzene to below the detection limit of the instrument without resolution of the component peaks. In this case, the benzene concentration will not be quantifiable. This is referred to as "matrix interference." The instrument detection limit will also be increased by a factor equal to the dilution amount. This can lead to a reporting of analytical results such as <500 ppm benzene, which is an inadequate description of the constituent's concentration in the sample. In the case of benzene, methylcyclopentene or similar compounds can cause such a matrix interference.

For metals analyses, elevated levels of oil can also cause some problems since standard digestion procedures may not adequately break down the oily matrix. High levels of aluminum, calcium, iron and/or sodium found in many E&P samples require dilutions to minimize the physical and chemical interferences in metal analyses. Approximately 30 percent of the sample for TCLP metals analysis had elevated reporting limits due to these types of interferences.

Laboratory Contaminants

For all trace environmental analyses, method and field blank data must be reviewed carefully. Some of the reported analytes in this study are common lab contaminants, and any reported value should be considered qualitatively unreliable. These analytes include dichloromethane (a.k.a. methylene chloride), acetone, methyl ethyl ketone, phthalate esters, and barium in TCLP blanks. Concentrations of these compounds, toluene and common phthalates at less than five times the EPA contract laboratory program (CLP) required detection limit (CRDL) should be considered laboratory contaminants (EPA, 1987). These analytes were commonly seen at levels just above the reporting limits in laboratory and field blanks. Although not as common, chromium was detected in some TCLP blanks.

COMPARISON OF API AND GRI ANALYTICAL RESULTS

In order to link separate E&P associated waste studies, API and GRI agreed to share four duplicate samples and, have them analyzed separately by their contract laboratories, Quanterra and ENSR, respectively.

Sampling and Analysis

The four samples collected are described in Table 3-35. They included spent molecular sieve from a dehydrator, spent molecular sieve from an isobutane sweetener, waste glycol, and glycol dehydrator water. The analyses performed are shown in Table 3-36.

Table 3-35. Samples Used for API/GRI Comparative Analytical Study

SAMPLE TYPE	API STUDY		GRI STUDY	
	Sample Date	Designation	Sample Date	Designation
Dehydrator Spent Mol Sieve	9-4-90*	011212-0001-SA	June 1990*	AL-02PC-08
Isobutane Sweetener Spent Mol Sieve	9-4-90*	011212-0002-SA	June 1990*	AL-02PC-27
Glycol Dehydrator Condensate Water	11-27-90	012641-001-SA	11-27-90	AX-01PC-02 Carboy bottoms from reboiler vent pipe
Glycol Dehydrator Waste Glycol	11-27-90	012641-0002-SA	11-27-90	AX-01PC-01 From valve upstream of recycle pump on line from reboiler bottom

* Spent mol sieve material removed from process service in June 1990 and stored in closed containers for subsequent disposition. For these studies, material was removed on 9-4-90 for testing.

Results

Results of the comparative data are shown in Table 3-37.

Discussion

The pH data show acceptable agreement except for the waste glycol samples where there was a one pH unit difference. There was good agreement for the ignitability data on the waste glycol samples. The disagreement on the ignitability analysis of the glycol dehydrator condensate water emphasizes the problem with applying the method to water samples, especially those that may contain trace hydrocarbon. The GRI analysis would imply the sample is ignitable, whereas the API sample implies the sample is not ignitable.

Table 3-36. Analyses Conducted on the API/GRI Comparative Samples

CONSTITUENT	Dehydrator Spent Mol Sieve		Isobutane Sweetener Spent Mol Sieve		Glycol Dehydrator Condensate Water		Glycol Dehydrator Waste Glycol	
	API	GRI	API	GRI	API	GRI	API	GRI
pH	+	+	+	+	+	+	+	+
Corrosivity	-	-	-	-	-	+	-	+
Ignitability	+	+	+	+	+	+	+	+
Reactive Sulfide	+	-	+	-	+	+	+	+
TCLP Volatile Organics	+	+	+	+	+	+	+	+
TCLP Semi-Volatile Organics	-	+	-	+	-	+	-	+
TCLP Metals	+	+	+	+	+	+	+	+
Alkalinity	-	+	-	+	-	-	-	-
Cl	-	+	-	+	-	-	-	+
NH_3	-	+	-	+	-	-	-	-
Sulfide	-	+	-	+	-	+	-	+
Sulfate	-	+	-	+	-	-	-	-
Paint Filter Test*	-	+	-	+	-	-	-	-
Misc. Organics**	-	-	-	-	-	+	-	-
Total Volatile Organics	+	-	+	-	+	-	+	-

* Presence or absence of free liquid
** Includes mercaptans, amines, glycols and methanol
\+ Analyses Conducted
\- Analyses Not Conducted

Reactivity data were in general agreement with one exception. There is a disagreement with the analysis of glycol dehydration condensate water. The GRI analysis would imply that the sample is reactive, whereas the API analysis implies that the sample is not reactive. The dissimilar results may be due to improper preservation of the API sample. It should be noted that because of the intense reactivity and volatility of hydrogen sulfide, it is extremely difficult to obtain accurate analyses on samples transported to the lab. Field measurements are generally preferred for hydrogen sulfide analyses.

There are problems comparing the TCLP volatile organics given the different detection limits. The wide range in detection limits for volatile constituents indicates problems due to matrix interference. As stated previously, analysis of samples with very high organic chemical matrices is difficult. Current test methods often do not adequately address these complex matrices. For samples with detectable concentrations, there were differences in the methyl ethyl ketone values for isobutane sweetener spent mol sieve, the benzene values for glycol dehydrator condensate water and the TCE values for waste glycol.

Agreement was found between most of the TCLP metals. It is difficult to make comparisons for As, Hg and Se in some samples because of a tenfold difference in the detection/reporting limit.

Table 3-37. Comparative API and GRI Associated Wastes Analytical Data

Constituent	Unit	DEHYDRATOR SPENT MOL SIEVE		ISOBUTANE SWEETENER SPENT MOL SIEVE		GLYCOL DEHYDRATOR CONDENSATE WATER		GLYCOL DEHYDRATOR GLYCOL WASTE	
		API	GRI	API	GRI	API	GRI	API	GRI
Corrosivity	MMPY						<6.35		<6.35
pH		9.2	9.5 9.5	7.8	7.4 7.5	8.8	8.6	11.8	10.5
Ignitability	FP°F					151	132	>160	>150
Reactivity	PPM H_2S	<0.5	<1 <1	0.55	8 8	108	1490	<0.5	4.9
TCLP									
MEK	PPB	<50	<5	120	<5 <5	<2000	<2000	<2000	
TCE	PPB	<25	<5	<25	<5 <5	<1000	$<10^3$	<1000	<310,000
Benzene	PPB	<25	8	<25	<5 <5	21,000	32,000	5,000	~6,500
As	PPM	1.2	1.6 1.2	<1	<0.005	1.5	<0.005	<5	<0.005
Ba	PPM	0.4	0.24 0.3	<0.35	<.09	1.5	<.04	<0.5	<.02
Cd	PPM	<0.05	<0.063 <0.063	<0.05	<0.063	0.068	<.04	<0.25	<.01
Cr	PPM	<0.1	<.13 <.13	<0.1	<.13	<0.1	<.04	<0.5	<0.1
Hg	PPM	<0.002	<.02 <.02	<0.002	<0.002	<0.002	<0.1	<0.002	<.02
Pb	PPM	<0.5	<.13 <.13	<0.5	<.13	<0.5	<0.1	<2.5	<0.025
Se	PPM	<0.1	<.05 <.05	<0.1	<0.005	<0.1	<.25	<1.3	<0.005

Section 4

FATE AND TRANSPORT OF ASSOCIATED WASTE CONSTITUENTS

INTRODUCTION

To understand the potential impact to groundwater from a single, onsite, land disposal of associated wastes, the composition data described in the previous section of this report were used as input for a mathematical model that simulates typical industry disposal practices.

API's VADSAT model (described later in this section) was run in a Monte Carlo mode to predict the fate and transport of selected organic compounds from typically land disposed associated wastes. The modeling scenario considered:

- eleven different hydrogeologic environments;
- four chemical species (benzene, toluene, ethylbenzene and xylene);
- six waste types (tank bottoms, oily soils, oil mud cuttings, pigging waste, pit and sump waste and produced sand);
- up to three disposal scenarios per waste type;
- two infiltration rates (one inch and five inches/year);
- aqueous biodegradation; and
- two receptors locations (500 and 1500 feet downgradient).

Using this scenario, VADSAT generated peak receptor well concentrations far below the federal drinking water standards for each compound modeled. In fact, these concentrations are well below the detection limits of current analytical techniques.

The following sections describe, in more detail, the VADSAT model, the data used to perform the associated waste simulations, the modeling results, and present conclusions based on the modeling results.

OVERVIEW OF THE VADSAT MODEL

VADSAT is based on coupled analytical solutions of the unsaturated and saturated zone transport equations. With appropriate initial and boundary conditions, the model can estimate peak concentrations of a chemical and the time to reach the peak concentration for downgradient receptors in the saturated zone. The model also computes the average concentration over a 70-year period centered about the peak concentration. Since the model is analytical, it does not require substantial computational effort. Therefore, it is well suited for conducting uncertainty analyses via Monte Carlo simulations to assess effects of soil and waste property uncertainty on the risk of groundwater contamination at land-disposal sites. A detailed description of VADSAT is presented in the VADSAT User's Guide (Environmental Systems & Technologies, 1995).

VADSAT was designed by API specifically to simulate common E&P waste disposal scenarios including land spreading, road spreading, and disposal in waste pits (burial), with the latter being distinguished by the presence of a soil cover that acts to impede evaporative losses of volatile compounds. VADSAT considers the following physical and biological processes:

- *Evaporation of volatile organic chemicals.* Organic chemicals that exhibit significant volatility will occur in the gas phase within the soil and may diffuse to the soil surface where evaporative losses occur. For land spread wastes or surface spills, such losses can be especially significant, since the waste zone is in immediate proximity with the atmosphere. For covered pits, landfilled waste or subsurface leaks, evaporation may still occur but will be impeded by the rate of diffusion through overlying soil material. To be conservative, evaporation of volatile chemicals was not considered in this study.

- *Leaching of soluble chemicals.* Soluble organic chemicals within the waste will dissolve in water passing through the waste zone. Organic components in oily wastes are assumed to dissolve into the aqueous phase in proportion to their pure component solubility times the mole fraction in the oily waste.

- *Advective transport.* In the unsaturated zone, advection of dissolved chemicals will occur in the vertical direction and at a velocity that depends on the net recharge rate and the soil water content. In the saturated zone, water flow will occur in the horizontal direction at a velocity that depends on the regional seepage rate and aquifer porosity.

- *Dispersive transport.* Dispersion will occur in the vertical flow direction in the unsaturated zone since horizontal length scales of the source are generally large compared to the depth to groundwater. In the saturated zone, dispersion is considered in the direction of flow as well as in the vertical and transverse horizontal directions. Dependence of dispersivity on travel distance in the unsaturated and saturated zones is accounted for using empirical relationships based on available field data.

- *Adsorption.* Partitioning between the aqueous and solid phases will result in retardation of species in the unsaturated and saturated zones. Adsorption of organic species is considered using a linear partitioning model based on an organic carbon normalized partition coefficient.

- *Microbial decay.* Biological decay of organic constituents can have a major impact on their environmental fate. Biological decay was modeled as a first-order reaction.

INPUT DATA USED IN ASSOCIATED WASTE MODELING

Chapter 2 of the VADSAT User Guide provides description of all input variables and Chapter 4 describes the databases (and their sources) for waste zone geometry, chemical properties, unsaturated zone soil properties and saturated zone properties for various hydrogeological environments. These databases are accessed to obtain typical parameter values for a site, however, they should be used only when site specific parameter estimates cannot be obtained economically.

In the interest of brevity, only the data relevant to the hydrogeologic environment, chemical species, source, waste type, and soil parameters needed for the associated waste simulations are discussed here.

Data specific to the hydrogeologic environment include the depth from the surface to the water table, saturated zone thickness, groundwater seepage (Darcy) velocity, and hydraulic conductivity in the saturated zone. Data for eleven groundwater hydrogeologic environments were taken from the VADSAT hydrogeologic environment database (Newell *et al.*, 1989). Table 4-1 summarizes values of the model parameters for each hydrogeologic environment.

Four different chemical species (benzene, toluene, xylene, and ethylbenzene) were simulated. The data specific to each chemical species include the molecular weight, density, solubility, Henry's constant, gas diffusion coefficient in free air, and carbon adsorption coefficient K_{oc}. Data for the chemical species were taken directly from the VADSAT chemical property database. The hydrocarbon density is also required and was obtained from the chemical property database. Table 4-2 shows the values of the model parameters specific to the chemical species.

Table 4-1. Modeling Parameters Specific to Hydrogeologic Environment*

	Depth to Water Table (m)		Saturated Zone Thickness (m)		Seepage Velocity (m/day)		Saturated Zone Hyd. Conductivity (m/day)	
Hydrogeologic Environment	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Bedded Sedimentary Rock	17.4	33.4	40.4	78.2	0.36	1.04	0.13	0.3
Till Over Sedimentary Rock	8.41	9.0	9.7	12.8	0.65	1.8	0.12	0.25
Sand and Gravel	10.3	18.3	23.4	70.5	1.2	5.06	1.03	2.97
River Valley with Overbank	6.8	7.4	9.6	7.6	1.05	3.14	1.03	2.39
River Valley without Overbank	10	13.6	26.1	54.4	0.84	1.25	1.24	2.58
Alluvial Basins, Valley and Fans	16.7	21.3	20.9	42.6	2.97	11.1	0.9	1.97
Outwash	8.9	10.2	261.	27	1.54	2.35	1.83	4.85
Till and Till over Outwash	6.2	8.7	12	12.2	0.7	2.29	0.08	0.18
Unconsolidated and Semiconsolidated	7.5	8.4	11	12.2	2.73	8.48	1.21	4.95
Coastal Beaches	2.3	1.9	38.3	79.9	0.5	1.62	1.07	2.79
All Groups	9.5	18.6	21.8	50.6	1.25	4.68	0.86	2.9

* From VADSAT hydrogeologic environment database

Table 4-2. Properties of Chemical Species*

Species Parameter	Benzene		Toluene		Xylene		Ethylbenzene	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std.
Molecular Weight of Hydrocarbon Component (g/mole)	78.1	-	92.13	-	106.2	-	106.2	-
Density of Hydrocarbon Component (g/cm^3)	0.877	-	0.867	-	0.87	-	0.867	
Average Density of Hydrocarbon (g/cm^3) (Assumed)	0.9	-	0.9	-	0.9	-	0.9	-
Solubility of Hydrocarbon Component (g/cm^3)	1780	-	515	-	178.3	-	152	
Henry's Constant for Hydrocarbon Component	0.24	-	0.28	-	0.22	-	0.37	-
Gas Diffusion Coefficient in Free Air for Hydrocarbon (m^2/day)	0.76	-	0.68	-	0.61	-	0.61	-
Partition (Adsorption) Coefficient of Hydrocarbon Component (cm^3/g)	83	8.5	300	30	894	89.4	1100	110

* From VADSAT chemical database

Of the 12 types of associated wastes characterized previously in this report, sufficient data for modeling were available for only six of the waste types. Three different methods (land spreading, road spreading and burial) were simulated for land applied associated wastes. Based on typical industry practice (as reported by API members) each of the waste types is simulated by using either one, two, or all three of the disposal methods. Table 4-3 shows the waste thickness, areas of disposal and the length to width ratio for different disposal methods. An estimated hydrocarbon molecular weight was specified for each waste type and is also included in Table 4-3. It was assumed that the standard deviations for the mean values for waste thickness, length to width ratio and the hydrocarbon molecular weight were based on professional judgement. Standard deviations for these parameters were set equal to zero.

Table 4-3. Source and Waste Type Parameters

Pit and Sump Waste	Land Spreading		Road Spreading	
	Mean	Std. Dev.	Mean	Std. Dev.
Waste Thickness (m)	0.253	0	0.101	0
Area (m^2)	3750	n/p	23,900	46,600
Length to Width Ratio	1.24	0	3135	0
Molecular Weight of Hydrocarbon (g/mole)	600	0	600	0

Produced Sand	Land Spreading		Road Spreading		Burial	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Waste Thickness (m)	0.253	0	0.101	0	1.83	0
Area (m^2)	2070	309	8.0	6.0	35.0	n/p
Length to Width Ratio	1.24	0	1.0	0	1.24	0
Molecular Weight of Hydrocarbon (g/mole)	400	0	400	0	400	0

Tank Bottoms	Land Spreading		Road Spreading		Burial	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Waste Thickness (m)	0.253	0	0.101	0	1.83	0
Area (m^2)	468	n/p	157	39,920	216	n/p
Length to Width Ratio	1.24	0	20.6	0	1.24	0
Molecular Weight of Hydrocarbon (g/mole)	400	0	400	0	400	0

n/p = information needed to compute this parameter was not available

Table 4-3. Source and Waste Type Parameters (continued)

Oily Soils	Land Spreading		Road Spreading	
	Mean	Std. Dev.	Mean	Std. Dev.
Waste Thickness (m)	0.253	0	0.101	0
Area (m^2)	457	272	1150	2803
Length to Width Ratio	1.24	0	151	0
Molecular Weight of Hydrocarbon (g/mole)	405	0	405	0

Oil Mud Cuttings	Burial	
	Mean	Std. Dev.
Waste Thickness (m)	1.83	0
Area (m^2)	7241	n/p
Length to Width Ratio	1.24	0
Molecular Weight of Hydrocarbon (g/mole)	250	0

Pigging Waste (Solids)	Land Spreading		Road Spreading	
	Mean	Std. Dev.	Mean	Std. Dev.
Waste Thickness (m)	0.253	0	0.101	0
Area (m^2)	9.0	n/p	9.0	12.5
Length to Width Ratio	1.24	0	1.17	0
Molecular Weight of Hydrocarbon (g/mole)	600	0	600	0

n/p = information needed to compute this parameter was not available

The amount of waste applied for each waste type varies with the disposal method used. The average volume of waste per disposal incident was obtained from a limited survey of API member company personnel. The average oil, water, and solids content for each waste type and concentration data for each of the chemical species being investigated were obtained from the characterization study described in the preceeding sections of this report.

Data from the sources described above were used to compute several input parameters required in VADSAT. The calculations and assumptions used are described below.

The bulk density for each waste type is required to compute the disposal area from the waste volume data supplied. The density is computed for each waste type by first computing the volumes of each phase (oil, water, and solids) in the waste as

$$V_p = \frac{M_p}{\rho_p} \tag{4:1}$$

where V_p is the volume of phase p (m^3), M_p is the mass of phase p (kg), and ρ_p is the density of the phase (kg/m^3) (900 for oil, 1000 for water, and 2650 for solids). The phase volumes are then converted to volume fractions

$$F_p = \frac{V_p}{\sum_p V_p} \tag{4.2}$$

where F_p is the volume fraction (dimensionless) for phase p. Finally, the bulk density is computed as

$$\rho_W = \sum_p (F_p \, \rho_p) \tag{4.3}$$

where ρ_W is the waste density (kg/m^3). Table 4-4 shows the data used and the results of the above calculations.

The disposal area for each waste type and disposal method is computed as

$$Area = \frac{Oil \times V_w \times \rho_w}{Criteria \times Z \times \rho_b} \tag{4.4}$$

where *Area* is the disposal area (m^2), *Oil* is the average oil content in the waste (%), V_w is the average volume of waste applied (m^3), *Criteria* is the API oil and grease criteria (1% for land spreading and burial, 2.5% was assumed for road spreading), *Z* is the thickness of the zone of incorporation (10 inches (0.25m) for land spreading, 4 inches (0.1m) for road spreading, and 6 feet (1.83m) for burial), and ρ_b is the soil bulk density computed as

$$\rho_b = \rho_s (1 - \phi) \tag{4.5}$$

Table 4-4. Volume and Density Calculations

Waste Type	Oil Mass (kg)	Water Mass (kg)	Solids Mass (kg)	Oil Volume (m^3)	Water Volume (m^3)	Solids Volume (m^3)	Oil Volume Fraction	Water Volume Fraction	Solids Volume Fraction	Waste Density (kg/m^3)
Produced Sand	0.033	0.181	0.786	0.000037	0.000181	0.000297	0.071	0.352	0.577	1945
Oily Soils	0.166	0.116	0.720	0.000184	0.000116	0.000272	0.322	0.203	0.475	1751
Oil Mud Cuttings	0.21	0.07	0.720	0.000233	0.000070	0.000272	0.406	0.122	0.472	1739
Pigging Waste, Solid	0.304	0.115	0.581	0.000338	0.000115	0.000219	0.503	0.171	0.326	1488
Pit and Sump Waste	0.399	0.341	0.268	0.000443	0.000341	0.000101	0.501	0.385	0.114	1138
Tank Bottoms	0.348	0.393	0.261	0.000387	0.000393	0.000098	0.440	0.448	0.112	1141

Calculations assume:
Oil Density = 900 kg/m^3
Water Density = 1000 kg/m^3
Solids Density = 2650 kg/m^3

Example calculations: (Produced Sand)
Oil Volume (m^3) = Oil Mass (kg) / Oil Density (kg/m^3)
0.000037 = 0.033 / 900

Oil Volume Fraction = Oil Volume / (Oil Volume + Water Volume + Solids Volume)
0.071 = 0.000037 / (0.000037 + 0.000181 + 0.000297)

Waste Density (kg/m^3) = (Oil Vol. Frac. x Oil Density + Water Vol. Frac. x Water Density + Solids Vol. Frac. x Solids Density)
1945 = (0.071 x 900 + 0.352 x 1000 + 0.577 x 2650)

where ρ_s is the particle density (assumed equal to 2650 kg/m^3), and ϕ is the porosity (assumed to be 0.42). Table 4-5 shows the data and results of the above computations.

Table 4-5. Area Calculations

Waste Type	Disposal Method	Average Volume Applied (m³)	Density of Waste (kg/m³)	Average Oil Content (%)	Oil and Grease Criteria (%)	Zone of Incorporation (m)	Disposal Area (m²)	Width of Disposal Area (m)	Length to Width Ratio
Oily Soils	Land Spreading	6.12	1751	16.6	1	0.253	457	n/a	1.24
Oily Soils	Road Spreading	15.3	1751	16.6	2.5	0.101	1150	7.6	151
Produced Sand	Land Spreading	125	1945	3.3	1	0.253	2070	n/a	1.24
Produced Sand	Road Spreading	0.459	1945	3.3	2.5	0.101	8	7.6	1.00
Produced Sand	Burial	15.3	1945	3.3	1	1.829	35	n/a	1.24
Oily Cuttings	Burial	557	1739	21	1	1.829	7241	n/a	1.24
Pigging Solids	Land Spreading	0.076	1488	30.4	1	0.253	9	n/a	1.24
Pigging Solids	Road Spreading	0.076	1488	30.4	2.5	0.101	9	7.6	1.17
Pit and Sump Waste	Land Spreading	32.1	1138	39.9	1	0.253	3750	n/a	1.24
Pit and Sump Waste	Road Spreading	203	1138	39.9	2.5	0.101	23,893	7.6	3135
Tank Bottoms	Land Spreading	4.59	1141	34.8	1	0.253	468	n/a	1.24
Tank Bottoms	Road Spreading	1.53	1141	34.8	2.5	0.101	157	7.6	20.6
Tank Bottoms	Burial	15.3	1141	34.8	1	1.829	216	n/a	1.24

Notes: n/a = not applicable, length to width ratio specified as 1.24

Example:

$$\text{Area (m}^2) = \frac{\text{Avg. Oil Cont. (\%)} \times \text{Avg. Vol. of Waste App(m}^3) \times \text{Dens of Waste(kg\textbackslash\ m}^3)}{\text{Oil and Grease Criteria} \times \text{Zone of Incorporation (m)} \times \text{Density of Soil (kg/m}^3)}$$

$$457 = (16.6 \times 6.12 \times 1751) / (1 \times 0.253 \times 1537)$$

The data obtained from API member companies on average volumes for each waste type and disposal method additionally listed maximum and minimum volumes for some of the wastes. If the maximum and minimum values were given, the standard deviation of the disposal area was computed as one-fourth of the difference between the maximum and minimum disposal areas. Where only an average volume was given, the standard deviation was assumed to be zero.

A length to width ratio of 1.24 is used for land spreading and burial scenarios. The width for the road spreading scenarios was assumed to be 25 feet (7.6m). The length for road spreading is the disposal area divided by the width. Table 4-5 lists the length to width ratios for the different waste types and disposal methods.

Initial volume fractions of each chemical species in the hydrocarbon (Table 4-4) are computed by first calculating the concentration of the chemical in the oil phase (assuming all the chemical is in the oil phase) as

$$C_o = \frac{C_w}{Oil} \times 100 \tag{4.6}$$

where C_o is the species concentration in the oil phase (mg/kg) and C_w is the concentration of the chemical in the waste (mg/kg). Then, the initial volume fraction of the species in hydrocarbon is computed

$$V_o = C_o \times \frac{\rho_o}{\rho_c} \times 10^{-6} \tag{4.7}$$

where V_o is the initial volume fraction of the species in hydrocarbon (dimensionless), ρ_o is the density of the oil (kg/m^3), and ρ_c is the density of the chemical (kg/m^3). The standard deviation of the initial volume fraction of the species in hydrocarbon was assumed to be zero.

Assumed soil parameters are typical values obtained from the Soil Conservation Service for a range of soil types. Several soil parameters are values that correspond to the "all groups" soil type and have been previously reviewed in the VADSAT User's Guide. Table 4-6 lists the values for these parameters.

Table 4-6. Transport and Soil Parameters

	Mean	Std. Dev.
Biodegradtion Coefficient (1/day) (Saturated and Unsaturated zones)	0.002	0.00285
Organic Carbon Fraction (Unsaturated and Saturated Zones)	0.003	0.003
Porosity (Saturated Zone)	0.25	0.05
Longitudinal to Transverse Dispersivity Ratio	3	1
Transverse to Vertical Dispersivity Ratio	87.5	31.3
Porosity (Unsaturated Zone) *	0.42	0.11
Van Genutchen n *	1.56	0.6
Residual Water Content *	0.072	0.035

*Values are for "All Groups" soil type

A first-order aqueous biodegradation rate of 0.002 day^{-1} was assumed. This is the rate suggested for benzene by the California Leaking Underground Storage Tanks manual (California State Water Resources Control Board, 1988) for use in the SESOIL model. This rate is conservative for BTEX.

Using the above described parameters and two infiltration rates (1 and 5 inches per year), a total of 1144 VADSAT simulations (1000 realizations each) were performed to determine the predicted chemical concentration at two receptors located 500 and 1500 feet immediately downgradient of the source at the water table. The following section presents the results of the simulations.

MODELING RESULTS AND DISCUSSION

Monte Carlo simulations for E&P associated wastes were performed with VADSAT to investigate the effects of uncertainty in input parameters on model results. The peak concentrations over time of the chemical species corresponding to 85 percent cumulative probability of nonexceedence were computed. In other words, there is a 15% probability of generating a higher peak concentration. VADSAT-generated peak concentration values are presented in Tables 4-8 through 4-33, grouped at the end of this section. The results are arranged according to disposal method, waste type and infiltration rate. For example,

Table 4-8 shows the results for land spreading of pit and sump waste at an infiltration rate of one inch per year. Concentrations are shown for each of the four chemicals at two receptors located 500 and 1500 feet downgradient.

All of the runs show insignificant groundwater contamination at the receptor locations. The highest of the predicted peak concentrations for benzene, toluene, xylene and ethylbenzene at 85 percent cumulative probability of nonexceedence are shown in Table 4-7 along with the corresponding Maximum Contaminant Level (MCL). These results are based on the 1144 Monte Carlo simulations performed in this work. The predicted maximum concentration in all cases is orders of magnitude less than the regulatory standard for each compound.

Table 4-7. Highest Predicted Concentration for 85% Probability of Nonexceedence

Chemical	Waste Type	Disposal Method	Hydrogeologic Environment	Results * (mg/l)	MCL** (mg/l)
Benzene	Tank Bottoms	Burial	Coastal Beaches	1.03E-06	0.005
Toluene	Oil Mud Cuttings	Burial	Coastal Beaches	1.05E-05	1.0
Ethylbenzene	Produced Sand	Burial	Till and Till Over Overwash	6.27E-09	0.7
Xylene	Tank Bottoms	Burial	Coastal Beaches	6.72E-06	10

* **Results are peak concentration at 85 percent cumulative probability of nonexceedence**

** **MCL = Maximum Contaminant Level**

The results in Table 4-7 show that the benzene, toluene and xylene concentrations for 85 percent probability of nonexceedence are highest for the Coastal Beaches hydrogeological environment, while the highest concentration for ethybenzene is predicted for the Till and Till Over Outwash hydrogeological environment. The depths to the water table for the Coastal Beaches, and Till and Till Over Outwash hydrogeological environments are 2.3 m and 6.2 m, respectively, compared to an All Group (Table 4-1) average water table depth of 9.5 m. The higher BTEX concentrations for these hydrogeologic environments are most likely due to reduced natural attenuation in the unsaturated zone. The highest aqueous concentrations of benzene, toluene, xylene and ethylbenzene (Table 4-7) are obtained with the waste burial disposal method. The thickness of the waste zone for the burial disposal method is 1.83 m compared to 0.253 m and 0.101 m for the land spreading and road spreading methods, respectively. The time for source depletion increases with an increase in the thickness of the waste zone. The shorter the duration of the release from a source, the smaller the resulting plume size. A small plume is more likely to be diluted and dispersed when it reaches a receptor well. As water infiltrating the waste zone reaches the water table, it mixes with a larger body of groundwater and becomes diluted. Further dilution occurs due to the longitudinal and transverse dispersion resulting from pore scale and field scale heterogeneities. Simulated BTEX concentrations at groundwater receptors could be affected by retardation and biodecay. Retardation delays the arrival of the plume and the peak concentration at receptors; however, if the source depletion time is large enough, the steady state concentrations will not be influenced by retardation. The biodecay lowers the aqueous phase peak concentations. Retardation allows more time for biodecay and dispersive processes to occur resulting in reduced aqueous phase concentrations.

Table 4-8. Peak Concentrations for Pit and Sump Waste and Land Spreading at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.78E-30	4.58E-30	4.86E-30	4.66E-30	4.54E-30	4.36E-30	4.80E-30	4.61E-30
Till Over Sedimentary Rock	4.82E-30	4.75E-30	4.89E-30	4.82E-30	4.57E-30	4.51E-30	7.42E-29	4.77E-30
Sand and Gravel	4.85E-30	4.78E-30	4.89E-30	4.82E-30	4.59E-30	4.52E-30	4.83E-30	4.76E-30
River Valley with Overbank	4.82E-30	4.79E-30	4.88E-30	4.84E-30	4.56E-30	4.53E-30	4.82E-30	4.78E-30
River Valley without Overbank	4.68E-30	4.65E-30	4.74E-30	4.71E-30	4.43E-30	4.40E-30	4.68E-30	4.65E-30
Alluvial Basins, Valleys, and Fans	4.58E-30	4.56E-30	4.66E-30	4.64E-30	4.34E-30	4.33E-30	4.68E-30	4.65E-30
Outwash	4.60E-30	4.57E-30	4.66E-30	4.64E-30	4.35E-30	4.33E-30	4.60E-30	4.58E-30
Till and Till Over Outwash	4.88E-30	4.80E-30	4.93E-30	4.85E-30	4.62E-30	4.54E-30	3.63E-21	4.88E-23
Unconsolidated and Semi-consolidated	4.72E-30	4.72E-30	4.78E-30	4.78E-30	4.46E-30	4.46E-30	4.72E-30	4.72E-30
Coastal Beaches	4.85E-30	4.67E-30	4.90E-30	4.73E-30	4.59E-30	4.44E-30	4.41E-25	1.89E-28
All Groups	4.84E-30	4.78E-30	4.87E-30	4.82E-30	4.57E-30	4.52E-30	4.81E-30	4.76E-30

Table 4-9. Peak Concentrations for Pit and Sump Waste and Land Spreading at an Infiltration Rate of 5 Inches per Year

	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
Hydrogeologic Environment	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.96E-30	4.73E-30	5.28E-19	3.52E-22	4.76E-30	4.56E-30	1.47E-10	7.06E-13
Till Over Sedimentary Rock	5.03E-30	4.95E-30	1.98E-16	1.63E-18	3.16E-28	8.36E-30	4.62E-09	9.80E-11
Sand and Gravel	4.99E-30	4.91E-30	6.67E-19	6.53E-21	4.76E-30	4.69E-30	3.57E-09	1.13E-10
River Valley with Overbank	5.03E-30	4.98E-30	2.26E-22	5.20E-24	4.80E-30	4.76E-30	1.87E-11	5.77E-13
River Valley without Overbank	4.92E-30	4.89E-30	2.71E-26	2.29E-27	4.68E-30	4.65E-30	4.23E-13	2.61E-14
Alluvial Basins, Valleys, and Fans	4.88E-30	4.87E-30	4.99E-30	4.97E-30	4.65E-30	4.64E-30	4.23E-13	2.61E-14
Outwash	4.86E-30	4.84E-30	1.55E-27	1.77E-28	4.61E-30	4.59E-30	7.61E-14	1.11E-14
Till and Till Over Outwash	5.02E-30	4.92E-30	1.87E-10	8.70E-13	1.08E-19	2.05E-22	1.06E-06	2.89E-08
Unconsolidated and Semi-consolidated	4.97E-30	4.97E-30	4.47E-21	1.89E-22	4.71E-30	4.72E-30	5.70E-11	8.84E-12
Coastal Beaches	4.98E-30	4.78E-30	4.13E-14	5.64E-17	1.05E-27	4.60E-30	3.51E-07	1.62E-09
All Groups	4.99E-30	4.92E-30	9.27E-19	3.25E-21	4.75E-30	4.69E-30	2.32E-09	4.04E-11

Table 4-10. Peak Concentrations for Pit and Sump Waste and Road Spreading at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.31E-30	4.19E-30	4.45E-30	4.33E-30	4.14E-30	4.03E-30	4.44E-30	4.32E-30
Till Over Sedimentary Rock	4.33E-30	4.31E-30	4.59E-30	4.57E-30	4.26E-30	4.24E-30	4.56E-30	4.54E-30
Sand and Gravel	4.42E-30	4.41E-30	4.53E-30	4.51E-30	4.25E-30	4.23E-30	4.47E-30	4.46E-30
River Valley with Overbank	4.44E-30	4.45E-30	4.59E-30	4.60E-30	4.28E-30	4.29E-30	4.56E-30	4.57E-30
River Valley without Overbank	4.35E-30	4.39E-30	4.49E-30	4.54E-30	4.18E-30	4.22E-30	4.45E-30	4.49E-30
Alluvial Basins, Valleys, and Fans	4.01E-30	4.05E-30	4.43E-30	4.47E-30	4.11E-30	4.15E-30	4.45E-30	4.49E-30
Outwash	4.23E-30	4.28E-30	4.42E-30	4.47E-30	4.11E-30	4.16E-30	4.38E-30	4.43E-30
Till and Till Over Outwash	4.43E-30	4.40E-30	4.55E-30	4.52E-30	4.27E-30	4.24E-30	4.53E-30	4.50E-30
Unconsolidated and Semi-consolidated	4.43E-30	4.48E-30	4.56E-30	4.61E-30	4.24E-30	4.29E-30	4.52E-30	4.56E-30
Coastal Beaches	4.38E-30	4.28E-30	4.47E-30	4.37E-30	4.19E-30	4.10E-30	4.42E-30	4.33E-30
All Groups	4.42E-30	4.42E-30	4.51E-30	4.52E-30	4.24E-30	4.24E-30	4.49E-30	4.49E-30

Table 4-11. Peak Concentrations for Pit and Sump Waste and Road Spreading at an Infiltration Rate of 5 Inches per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.38E-30	4.23E-30	4.63E-30	4.50E-30	4.30E-30	4.17E-30	9.10E-25	3.50E-28
Till Over Sedimentary Rock	4.40E-30	4.38E-30	4.72E-30	4.70E-30	4.39E-30	4.38E-30	4.19E-22	5.73E-24
Sand and Gravel	4.50E-30	4.47E-30	4.60E-30	4.84E-30	4.33E-30	4.32E-30	2.10E-27	4.93E-30
River Valley with Overbank	4.54E-30	4.55E-30	4.69E-30	4.71E-30	4.37E-30	4.39E-30	4.70E-30	4.72E-30
River Valley without Overbank	4.46E-30	4.49E-30	4.63E-30	4.67E-30	4.32E-30	4.36E-30	4.64E-30	4.68E-30
Alluvial Basins, Valleys, and Fans	4.07E-30	4.11E-30	4.66E-30	4.70E-30	4.33E-30	4.37E-30	4.64E-30	4.68E-30
Outwash	4.30E-30	4.34E-30	4.61E-30	4.67E-30	4.30E-30	4.35E-30	4.61E-30	4.67E-30
Till and Till Over Outwash	4.53E-30	4.48E-30	2.87E-28	4.84E-30	4.36E-30	4.48E-30	2.35E-14	9.97E-17
Unconsolidated and Semi-consolidated	4.53E-30	4.58E-30	4.70E-30	4.75E-30	4.37E-30	4.42E-30	2.55E-29	8.00E-30
Coastal Beaches	4.46E-30	4.34E-30	4.60E-30	4.69E-30	4.31E-30	4.21E-30	1.22E-20	1.86E-24
All Groups	4.49E-30	4.49E-30	4.65E-30	4.84E-30	4.32E-30	4.33E-30	3.10E-26	2.21E-28

Table 4-12. Peak Concentrations for Produced Sand and Land Spreading at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	3.67E-30	3.51E-30	4.56E-30	4.37E-30	3.99E-30	3.82E-30	4.50E-30	4.31E-30
Till Over Sedimentary Rock	3.64E-30	3.58E-30	4.59E-30	4.52E-30	3.95E-30	3.90E-30	4.52E-30	4.46E-30
Sand and Gravel	4.45E-30	4.38E-30	4.70E-30	4.55E-30	4.22E-30	4.15E-30	4.63E-30	4.48E-30
River Valley with Overbank	3.93E-30	3.89E-30	4.59E-30	4.55E-30	4.15E-30	4.12E-30	4.52E-30	4.48E-30
River Valley without Overbank	3.66E-30	3.64E-30	4.45E-30	4.42E-30	4.00E-30	3.97E-30	4.42E-30	4.36E-30
Alluvial Basins, Valleys, and Fans	3.08E-30	3.07E-30	4.36E-30	4.34E-30	3.55E-30	3.53E-30	4.42E-30	4.36E-30
Outwash	3.49E-30	3.47E-30	4.37E-30	4.35E-30	3.78E-30	3.76E-30	4.31E-30	4.29E-30
Till and Till Over Outwash	4.47E-30	4.38E-30	4.65E-30	4.57E-30	4.24E-30	4.16E-30	1.95E-22	2.07E-25
Unconsolidated and Semi-consolidated	3.74E-30	3.74E-30	4.49E-30	4.49E-30	4.06E-30	4.06E-30	4.42E-30	4.42E-30
Coastal Beaches	4.44E-30	4.26E-30	4.63E-30	4.46E-30	4.22E-30	4.06E-30	3.43E-29	4.39E-30
All Groups	4.45E-30	4.38E-30	4.61E-30	4.55E-30	4.21E-30	4.15E-30	4.53E-30	4.48E-30

Table 4-13. Peak Concentrations for Produced Sand and Land Spreading at an Infiltration Rate of 5 Inches per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	3.79E-30	3.54E-30	2.05E-19	7.33E-22	4.21E-30	4.21E-30	5.72E-12	1.25E-14
Till Over Sedimentary Rock	3.71E-30	3.64E-30	3.53E-16	2.00E-18	4.20E-30	4.21E-30	1.57E-10	4.37E-12
Sand and Gravel	4.53E-30	4.44E-30	2.36E-18	7.38E-21	4.33E-30	4.25E-30	6.10E-11	1.96E-12
River Valley with Overbank	4.01E-30	3.97E-30	8.79E-23	1.72E-24	4.34E-30	4.30E-30	2.85E-13	2.33E-15
River Valley without Overbank	3.78E-30	3.74E-30	4.07E-26	1.77E-27	4.14E-30	4.12E-30	1.71E-15	5.65E-17
Alluvial Basins, Valleys, and Fans	3.19E-30	3.17E-30	4.66E-30	4.64E-30	3.68E-30	3.67E-30	1.71E-15	5.65E-17
Outwash	3.62E-30	3.60E-30	4.58E-27	7.47E-28	3.94E-30	3.91E-30	4.91E-16	2.78E-17
Till and Till Over Outwash	4.54E-30	4.44E-30	1.36E-10	1.25E-12	6.77E-27	5.09E-29	1.25E-07	2.05E-09
Unconsolidated and Semi-consolidated	3.86E-30	3.86E-30	9.88E-21	2.31E-22	4.25E-30	4.25E-30	1.07E-12	1.29E-13
Coastal Beaches	4.49E-30	4.30E-30	1.54E-14	3.94E-17	4.33E-30	4.13E-30	2.23E-08	5.61E-11
All Groups	4.53E-30	4.45E-30	1.54E-18	4.37E-21	4.33E-30	4.26E-30	8.88E-11	1.09E-12

Table 4-14. Peak Concentrations for Produced Sand and Road Spreading at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	2.35E-30	2.24E-30	3.83E-30	3.67E-30	2.80E-30	2.67E-30	3.80E-30	3.64E-30
Till Over Sedimentary Rock	2.33E-30	2.28E-30	3.85E-30	3.80E-30	2.76E-30	2.72E-30	3.81E-30	3.76E-30
Sand and Gravel	3.72E-30	3.65E-30	3.95E-30	3.84E-30	3.54E-30	3.48E-30	3.91E-30	3.80E-30
River Valley with Overbank	2.43E-30	2.40E-30	3.86E-30	3.83E-30	2.98E-30	2.96E-30	3.82E-30	3.78E-30
River Valley without Overbank	2.32E-30	2.31E-30	3.75E-30	3.72E-30	2.79E-30	2.77E-30	3.71E-30	3.68E-30
Alluvial Basins, Valleys, and Fans	1.77E-30	1.76E-30	3.62E-30	3.61E-30	2.31E-30	2.30E-30	3.71E-30	3.68E-30
Outwash	2.25E-30	2.24E-30	3.68E-30	3.65E-30	2.67E-30	2.65E-30	3.64E-30	3.61E-30
Till and Till Over Outwash	3.74E-30	3.65E-30	3.93E-30	3.85E-30	3.56E-30	3.48E-30	3.88E-30	3.81E-30
Unconsolidated and Semi-consolidated	2.36E-30	2.36E-30	3.78E-30	3.77E-30	2.84E-30	2.84E-30	3.73E-30	3.73E-30
Coastal Beaches	3.70E-30	3.55E-30	3.91E-30	3.76E-30	3.54E-30	3.40E-30	3.92E-30	3.72E-30
All Groups	3.72E-30	3.66E-30	3.89E-30	3.84E-30	3.53E-30	3.48E-30	3.84E-30	3.79E-30

Table 4-15. Peak Concentrations for Produced Sand and Road Spreading at an Infiltration Rate of 5 Inches per Year

	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
Hydrogeologic Environment	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	2.38E-30	2.26E-30	4.01E-30	4.00E-30	2.83E-30	2.69E-30	4.03E-30	3.98E-30
Till Over Sedimentary Rock	2.36E-30	2.32E-30	4.03E-30	3.99E-30	2.82E-30	2.76E-30	1.35E-26	9.89E-29
Sand and Gravel	3.77E-30	3.69E-30	4.12E-30	3.94E-30	3.62E-30	3.54E-30	4.08E-30	3.94E-30
River Valley with Overbank	2.47E-30	2.44E-30	4.03E-30	3.99E-30	3.06E-30	3.02E-30	4.04E-30	3.97E-30
River Valley without Overbank	2.39E-30	2.36E-30	3.95E-30	3.91E-30	2.88E-30	2.85E-30	3.96E-30	3.88E-30
Alluvial Basins, Valleys, and Fans	1.83E-30	1.82E-30	3.77E-30	3.75E-30	2.39E-30	2.38E-30	3.96E-30	3.88E-30
Outwash	2.33E-30	2.30E-30	3.89E-30	3.86E-30	2.77E-30	2.74E-30	3.93E-30	3.82E-30
Till and Till Over Outwash	3.79E-30	3.70E-30	2.06E-29	4.05E-30	3.63E-30	3.54E-30	1.30E-18	4.04E-21
Unconsolidated and Semi-consolidated	2.43E-30	2.42E-30	3.98E-30	3.97E-30	2.93E-30	2.93E-30	3.96E-30	3.96E-30
Coastal Beaches	3.74E-30	3.58E-30	4.22E-30	3.86E-30	3.59E-30	3.44E-30	3.00E-26	3.90E-30
All Groups	3.78E-30	3.71E-30	4.02E-30	3.95E-30	3.62E-30	3.55E-30	3.99E-30	3.99E-30

Table 4-16. Peak Concentrations for Produced Sand and Burial at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	2.39E-27	3.94E-30	1.20E-13	1.15E-15	1.57E-23	2.54E-26	6.85E-12	1.19E-13
Till Over Sedimentary Rock	2.10E-24	1.56E-26	1.51E-12	5.67E-14	1.23E-20	2.13E-22	7.43E-11	4.42E-12
Sand and Gravel	2.90E-24	4.20E-27	7.84E-11	2.93E-12	4.48E-20	2.38E-22	1.25E-09	1.16E-10
River Valley with Overbank	1.54E-28	4.11E-30	1.23E-12	5.77E-14	1.07E-23	1.84E-25	6.32E-11	6.04E-12
River Valley without Overbank	4.02E-30	3.99E-30	1.10E-13	1.30E-14	1.50E-26	1.34E-27	1.25E-11	1.40E-12
Alluvial Basins, Valleys, and Fans	3.93E-30	3.91E-30	6.91E-18	5.91E-19	3.69E-30	3.67E-30	1.25E-11	1.40E-12
Outwash	3.95E-30	3.92E-30	2.02E-14	2.70E-15	2.78E-27	6.71E-28	4.30E-12	7.35E-13
Till and Till Over Outwash	7.68E-18	3.46E-20	3.29E-10	1.39E-11	4.80E-16	6.78E-18	1.56E-09	1.15E-10
Unconsolidated and Semi-consolidated	2.08E-27	6.64E-29	8.34E-13	1.09E-13	9.76E-23	5.63E-24	4.96E-11	6.38E-12
Coastal Beaches	4.43E-20	1.64E-22	1.32E-09	2.58E-11	9.38E-17	3.96E-19	6.87E-09	3.27E-10
All Groups	5.96E-25	1.27E-26	2.58E-11	6.34E-13	2.05E-20	4.98E-23	3.30E-10	3.49E-11

Table 4-17. Peak Concentrations for Produced Sand and Burial at an Infiltration Rate of 5 Inches per Year

	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
Hydrogeologic Environment	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.58E-12	1.21E-14	1.55E-07	5.77E-09	4.10E-11	3.76E-13	1.65E-07	1.12E-08
Till Over Sedimentary Rock	4.63E-11	1.27E-12	5.70E-07	4.48E-08	4.59E-10	1.27E-11	6.36E-07	7.08E-08
Sand and Gravel	1.43E-09	2.68E-11	1.30E-06	1.08E-07	1.74E-09	5.36E-11	1.23E-06	1.38E-07
River Valley with Overbank	4.63E-12	1.56E-13	4.13E-07	4.56E-08	7.80E-11	4.01E-12	5.68E-07	6.94E-08
River Valley without Overbank	1.85E-13	1.13E-14	2.27E-07	2.30E-08	1.71E-11	7.22E-13	3.47E-07	4.60E-08
Alluvial Basins, Valleys, and Fans	1.21E-17	5.59E-19	1.34E-08	2.16E-09	3.63E-14	1.12E-15	3.47E-07	4.60E-08
Outwash	3.81E-14	2.32E-15	1.22E-07	1.50E-08	4.57E-12	5.40E-13	1.65E-07	2.46E-08
Till and Till Over Outwash	1.61E-08	3.83E-10	1.59E-06	1.46E-07	6.27E-09	2.99E-10	1.24E-06	1.25E-07
Unconsolidated and Semi-consolidated	3.30E-12	5.46E-13	3.05E-07	4.99E-08	1.39E-10	1.18E-11	3.77E-07	7.50E-08
Coastal Beaches	2.10E-08	2.47E-10	2.08E-06	1.24E-07	5.71E-09	1.52E-10	1.74E-06	1.35E-07
All Groups	2.29E-10	1.30E-11	8.86E-07	7.65E-08	7.45E-10	3.64E-11	9.14E-07	9.31E-08

Table 4-18. Peak Concentrations for Tank Bottoms and Land Spreading at an Infiltration Rate of 1 Inch per Year

	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
Hydrogeologic Environment	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.57E-30	4.38E-30	4.60E-30	4.41E-30	4.30E-30	4.12E-30	4.50E-30	4.31E-30
Till Over Sedimentary Rock	4.60E-30	4.53E-30	4.62E-30	4.56E-30	4.32E-30	4.26E-30	4.52E-30	4.46E-30
Sand and Gravel	4.61E-30	4.54E-30	4.62E-30	4.55E-30	4.32E-30	4.26E-30	4.52E-30	4.45E-30
River Valley with Overbank	4.59E-30	4.55E-30	4.61E-30	4.57E-30	4.31E-30	4.27E-30	4.50E-30	4.47E-30
River Valley without Overbank	4.46E-30	4.43E-30	4.48E-30	4.44E-30	4.19E-30	4.16E-30	4.38E-30	4.35E-30
Alluvial Basins, Valleys, and Fans	4.37E-30	4.36E-30	4.40E-30	4.39E-30	4.11E-30	4.10E-30	4.38E-30	4.35E-30
Outwash	4.38E-30	4.36E-30	4.40E-30	4.38E-30	4.12E-30	4.09E-30	4.31E-30	4.28E-30
Till and Till Over Outwash	4.64E-30	4.56E-30	4.65E-30	4.57E-30	4.35E-30	4.28E-30	2.45E-22	4.50E-25
Unconsolidated and Semi-consolidated	4.49E-30	4.49E-30	4.51E-30	4.50E-30	4.22E-30	4.21E-30	4.41E-30	4.41E-30
Coastal Beaches	4.62E-30	4.45E-30	4.62E-30	4.46E-30	4.33E-30	4.18E-30	1.77E-25	2.11E-29
All Groups	4.59E-30	4.54E-30	4.60E-30	4.54E-30	4.31E-30	4.26E-30	4.50E-30	4.44E-30

Table 4-19. Peak Concentrations for Tank Bottoms and Land Spreading at an Infiltration Rate of 5 Inches per Year

	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
Hydrogeologic Environment	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.77E-30	4.56E-30	2.59E-17	2.37E-20	4.30E-30	4.12E-30	3.79E-12	1.80E-14
Till Over Sedimentary Rock	4.83E-30	4.75E-30	5.05E-15	1.37E-16	1.98E-27	1.06E-29	2.15E-10	3.04E-12
Sand and Gravel	4.78E-30	4.70E-30	7.46E-16	4.15E-18	4.49E-30	4.45E-30	3.66E-10	7.46E-12
River Valley with Overbank	4.81E-30	4.77E-30	7.27E-19	9.75E-21	4.54E-30	4.51E-30	1.52E-12	3.92E-14
River Valley without Overbank	4.70E-30	4.67E-30	4.85E-22	1.92E-23	4.43E-30	4.40E-30	2.63E-14	1.49E-15
Alluvial Basins, Valleys, and Fans	4.68E-30	4.66E-30	1.62E-29	4.70E-30	4.41E-30	4.39E-30	2.63E-14	1.49E-15
Outwash	4.64E-30	4.61E-30	3.71E-23	4.02E-24	4.37E-30	4.34E-30	4.04E-15	5.22E-16
Till and Till Over Outwash	1.07E-26	2.23E-29	4.00E-10	3.74E-12	2.40E-19	2.20E-21	3.81E-08	9.23E-10
Unconsolidated and Semi-consolidated	4.74E-30	4.74E-30	4.69E-18	4.75E-19	4.46E-30	4.46E-30	2.89E-12	3.49E-13
Coastal Beaches	4.78E-30	4.60E-30	1.03E-12	1.01E-15	1.12E-25	6.11E-29	1.11E-08	4.14E-11
All Groups	4.77E-30	4.70E-30	3.53E-16	2.09E-18	4.48E-30	4.43E-30	9.92E-11	1.58E-12

Table 4-20. Peak Concentrations for Tank Bottoms and Road Spreading at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	2.94E-30	1.00E-30	3.00E-30	2.40E-30	2.80E-30	1.33E-30	3.43E-30	3.42E-30
Till Over Sedimentary Rock	2.91E-30	1.21E-30	2.96E-30	2.52E-30	2.75E-30	1.58E-30	3.39E-30	3.39E-30
Sand and Gravel	2.97E-30	1.60E-30	2.99E-30	2.39E-30	2.80E-30	1.68E-30	2.93E-30	3.07E-30
River Valley with Overbank	2.91E-30	1.42E-30	2.95E-30	2.01E-30	2.76E-30	1.34E-30	2.86E-30	2.86E-30
River Valley without Overbank	2.86E-30	1.25E-30	2.90E-30	1.78E-30	2.68E-30	1.18E-30	2.84E-30	2.70E-30
Alluvial Basins, Valleys, and Fans	2.78E-30	1.00E-30	2.85E-30	1.30E-30	2.63E-30	1.00E-30	2.84E-30	2.70E-30
Outwash	2.82E-30	1.26E-30	2.81E-30	1.66E-30	2.64E-30	1.20E-30	2.78E-30	2.57E-30
Till and Till Over Outwash	2.97E-30	1.53E-30	3.29E-30	3.46E-30	2.81E-30	2.09E-30	3.48E-30	3.49E-30
Unconsolidated and Semi-consolidated	2.83E-30	1.39E-30	2.90E-30	1.94E-30	2.70E-30	1.32E-30	2.79E-30	2.79E-30
Coastal Beaches	2.99E-30	1.74E-30	3.02E-30	2.56E-30	2.83E-30	1.81E-30	3.24E-30	3.21E-30
All Groups	2.96E-30	1.49E-30	2.98E-30	2.23E-30	2.78E-30	1.52E-30	3.11E-30	3.28E-30

Table 4-21. Peak Concentrations for Tank Bottoms and Road Spreading at an Infiltration Rate of 5 Inches per Year

	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
Hydrogeologic Environment	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	3.17E-30	3.02E-30	4.05E-30	4.09E-30	3.73E-30	3.73E-30	5.70E-30	4.05E-30
Till Over Sedimentary Rock	3.02E-30	3.03E-30	4.03E-30	4.11E-30	3.72E-30	3.72E-30	6.46E-27	4.07E-30
Sand and Gravel	3.01E-30	2.46E-30	4.06E-30	4.27E-30	3.19E-30	3.37E-30	4.39E-30	4.23E-30
River Valley with Overbank	3.01E-30	1.75E-30	3.92E-30	3.94E-30	3.01E-30	2.90E-30	4.06E-30	3.97E-30
River Valley without Overbank	3.01E-30	1.58E-30	3.91E-30	3.94E-30	2.99E-30	2.88E-30	3.91E-30	3.97E-30
Alluvial Basins, Valleys, and Fans	2.98E-30	1.09E-30	3.79E-30	3.84E-30	2.82E-30	2.19E-30	3.91E-30	3.97E-30
Outwash	2.97E-30	1.61E-30	3.86E-30	3.90E-30	2.99E-30	2.88E-30	3.84E-30	3.86E-30
Till and Till Over Outwash	3.95E-30	4.17E-30	8.77E-29	4.27E-30	3.75E-30	3.94E-30	2.54E-19	8.74E-27
Unconsolidated and Semi-consolidated	2.99E-30	1.93E-30	3.85E-30	3.94E-30	3.04E-30	2.95E-30	4.21E-30	4.03E-30
Coastal Beaches	3.05E-30	2.30E-30	4.31E-30	4.21E-30	3.71E-30	3.47E-30	7.58E-26	4.17E-30
All Groups	3.02E-30	3.10E-30	4.04E-30	4.25E-30	3.69E-30	3.89E-30	4.34E-30	4.19E-30

Table 4-22. Peak Concentrations for Tank Bottoms and Burial at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	1.07E-20	4.74E-24	2.56E-30	2.44E-30	1.93E-17	2.77E-20	2.15E-11	3.03E-13
Till Over Sedimentary Rock	3.24E-18	9.84E-20	2.53E-30	2.49E-30	1.05E-15	2.09E-17	2.06E-10	1.09E-11
Sand and Gravel	2.57E-16	1.34E-18	4.01E-30	3.94E-30	3.07E-14	7.62E-16	4.81E-09	4.09E-10
River Valley with Overbank	1.05E-19	1.57E-21	2.66E-30	2.64E-30	1.25E-16	9.46E-18	2.74E-10	2.70E-11
River Valley without Overbank	3.79E-22	4.98E-23	2.53E-30	2.52E-30	2.30E-18	2.51E-19	1.18E-10	8.91E-12
Alluvial Basins, Valleys, and Fans	4.34E-30	4.32E-30	1.95E-30	1.94E-30	1.83E-24	4.37E-25	1.18E-10	8.91E-12
Outwash	3.63E-23	6.31E-24	2.45E-30	2.44E-30	2.69E-19	3.01E-20	3.01E-11	4.98E-12
Till and Till Over Outwash	7.36E-14	8.10E-16	4.02E-30	3.95E-30	1.56E-12	2.66E-14	4.95E-09	3.86E-10
Unconsolidated and Semi-consolidated	7.78E-20	1.47E-20	2.58E-30	2.58E-30	2.29E-16	2.00E-17	2.62E-10	4.65E-11
Coastal Beaches	1.35E-13	5.28E-16	3.99E-30	3.84E-30	5.40E-12	5.68E-14	2.90E-08	1.30E-09
All Groups	2.46E-17	9.36E-19	3.99E-30	3.95E-30	1.07E-14	1.97E-16	4.42E-30	4.36E-30

Table 4-23. Peak Concentrations for Tank Bottoms and Burial at an Infiltration Rate of 5 Inches per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	5.87E-09	3.59E-11	6.24E-09	6.13E-11	3.15E-30	2.90E-30	6.07E-07	3.14E-08
Till Over Sedimentary Rock	4.78E-08	1.49E-09	3.42E-08	2.26E-09	2.65E-30	2.54E-30	1.87E-06	2.52E-07
Sand and Gravel	3.56E-07	1.15E-08	1.17E-07	5.78E-09	4.08E-30	4.00E-30	5.09E-06	4.50E-07
River Valley with Overbank	1.43E-08	6.71E-10	1.68E-08	1.25E-09	2.72E-30	2.67E-30	1.49E-06	2.60E-07
River Valley without Overbank	2.79E-09	1.66E-10	5.92E-09	5.42E-10	2.61E-30	2.58E-30	1.11E-06	2.03E-07
Alluvial Basins, Valleys, and Fans	4.59E-12	2.76E-13	9.16E-11	1.14E-11	2.00E-30	1.99E-30	1.11E-06	2.03E-07
Outwash	9.42E-10	8.72E-11	3.02E-09	3.60E-10	2.53E-30	2.51E-30	4.68E-07	1.17E-07
Till and Till Over Outwash	8.38E-07	4.81E-08	1.69E-07	1.42E-08	4.09E-30	4.00E-30	3.19E-06	5.33E-07
Unconsolidated and Semi-consolidated	1.66E-08	1.98E-09	1.73E-08	2.68E-09	2.86E-30	2.79E-30	1.15E-06	3.11E-07
Coastal Beaches	1.03E-06	2.83E-08	2.41E-07	8.03E-09	4.04E-30	3.88E-30	6.72E-06	6.13E-07
All Groups	1.52E-07	6.08E-09	6.71E-08	3.63E-09	4.08E-30	4.01E-30	5.78E-11	7.74E-13

Table 4-24. Peak Concentrations for Oily Soils and Land Spreading at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.20E-30	4.01E-30	4.23E-30	4.05E-30	4.06E-30	3.90E-30	4.16E-30	3.99E-30
Till Over Sedimentary Rock	4.22E-30	4.16E-30	4.25E-30	4.19E-30	4.08E-30	4.02E-30	4.18E-30	4.12E-30
Sand and Gravel	4.28E-30	4.20E-30	4.27E-30	4.20E-30	4.11E-30	4.04E-30	4.40E-30	4.33E-30
River Valley with Overbank	4.23E-30	4.20E-30	4.25E-30	4.21E-30	4.08E-30	4.04E-30	4.17E-30	4.14E-30
River Valley without Overbank	4.11E-30	4.08E-30	4.12E-30	4.09E-30	3.96E-30	3.93E-30	4.05E-30	4.03E-30
Alluvial Basins, Valleys, and Fans	3.91E-30	3.89E-30	4.04E-30	4.02E-30	3.88E-30	3.87E-30	4.05E-30	4.03E-30
Outwash	4.03E-30	4.01E-30	4.05E-30	4.03E-30	3.89E-30	3.87E-30	3.99E-30	3.96E-30
Till and Till Over Outwash	4.30E-30	4.22E-30	4.30E-30	4.22E-30	4.14E-30	4.06E-30	4.23E-30	4.15E-30
Unconsolidated and Semi-consolidated	4.14E-30	4.14E-30	4.15E-30	4.15E-30	3.99E-30	3.99E-30	4.08E-30	4.08E-30
Coastal Beaches	4.27E-30	4.11E-30	4.28E-30	4.12E-30	4.11E-30	3.96E-30	4.21E-30	4.06E-30
All Groups	4.27E-30	4.21E-30	4.25E-30	4.20E-30	4.09E-30	4.04E-30	4.18E-30	4.13E-30

Table 4-25. Peak Concentrations for Oily Soils and Land Spreading at an Infiltration Rate of 5 Inches per Year

	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
Hydrogeologic Environment	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.33E-30	4.12E-30	4.42E-30	4.23E-30	4.26E-30	4.07E-30	4.37E-30	4.20E-30
Till Over Sedimentary Rock	4.39E-30	4.31E-30	4.46E-30	4.40E-30	4.30E-30	4.24E-30	2.03E-26	1.98E-28
Sand and Gravel	4.38E-30	4.29E-30	4.42E-30	4.36E-30	4.26E-30	4.20E-30	4.58E-30	4.52E-30
River Valley with Overbank	4.40E-30	4.36E-30	4.45E-30	4.42E-30	4.28E-30	4.25E-30	4.39E-30	4.36E-30
River Valley without Overbank	4.32E-30	4.28E-30	4.36E-30	4.32E-30	4.19E-30	4.16E-30	4.28E-30	4.25E-30
Alluvial Basins, Valleys, and Fans	4.07E-30	4.05E-30	4.32E-30	4.31E-30	4.15E-30	4.14E-30	4.28E-30	4.25E-30
Outwash	4.24E-30	4.21E-30	4.29E-30	4.26E-30	4.12E-30	4.10E-30	4.22E-30	4.20E-30
Till and Till Over Outwash	4.40E-30	4.30E-30	6.48E-30	4.38E-30	4.29E-30	4.22E-30	1.57E-18	6.67E-21
Unconsolidated and Semi-consolidated	4.35E-30	4.35E-30	4.39E-30	4.38E-30	4.21E-30	4.21E-30	4.32E-30	4.31E-30
Coastal Beaches	4.35E-30	4.17E-30	4.43E-30	4.30E-30	4.26E-30	4.11E-30	1.39E-24	1.44E-27
All Groups	4.38E-30	4.30E-30	4.42E-30	4.36E-30	4.25E-30	4.20E-30	2.16E-29	4.31E-30

Table 4-26. Peak Concentrations for Oily Soils and Road Spreading at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	3.55E-30	3.40E-30	4.06E-30	3.90E-30	3.90E-30	3.75E-30	4.00E-30	3.85E-30
Till Over Sedimentary Rock	3.53E-30	3.48E-30	4.09E-30	4.04E-30	3.93E-30	3.88E-30	4.03E-30	3.98E-30
Sand and Gravel	4.09E-30	4.02E-30	4.12E-30	4.06E-30	3.97E-30	3.92E-30	4.26E-30	4.20E-30
River Valley with Overbank	3.83E-30	3.80E-30	4.09E-30	4.06E-30	3.93E-30	3.91E-30	4.03E-30	4.00E-30
River Valley without Overbank	3.55E-30	3.53E-30	3.97E-30	3.95E-30	3.56E-30	3.54E-30	3.91E-30	3.89E-30
Alluvial Basins, Valleys, and Fans	3.05E-30	3.04E-30	3.88E-30	3.87E-30	3.73E-30	3.72E-30	3.91E-30	3.89E-30
Outwash	3.38E-30	3.37E-30	3.90E-30	3.88E-30	3.75E-30	3.73E-30	3.84E-30	3.83E-30
Till and Till Over Outwash	4.11E-30	4.03E-30	4.14E-30	4.08E-30	4.00E-30	3.93E-30	4.09E-30	4.02E-30
Unconsolidated and Semi-consolidated	3.63E-30	3.64E-30	4.01E-30	4.01E-30	3.85E-30	3.85E-30	3.95E-30	3.95E-30
Coastal Beaches	4.08E-30	3.92E-30	4.13E-30	3.98E-30	3.97E-30	3.83E-30	4.06E-30	3.92E-30
All Groups	4.08E-30	4.03E-30	4.11E-30	4.07E-30	3.96E-30	3.91E-30	4.05E-30	4.00E-30

Table 4-27. Peak Concentrations for Oily Soils and Road Spreading at an Infiltration Rate of 5 Inches per Year

	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
Hydrogeologic Environment	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	3.60E-30	3.43E-30	4.22E-30	4.04E-30	4.07E-30	3.89E-30	4.18E-30	4.11E-30
Till Over Sedimentary Rock	3.60E-30	3.54E-30	4.28E-30	4.22E-30	4.12E-30	4.07E-30	4.24E-30	4.18E-30
Sand and Gravel	4.16E-30	4.08E-30	4.25E-30	4.19E-30	4.10E-30	4.03E-30	4.39E-30	4.33E-30
River Valley with Overbank	3.92E-30	3.88E-30	4.28E-30	4.25E-30	4.12E-30	4.09E-30	4.22E-30	4.20E-30
River Valley without Overbank	3.67E-30	3.64E-30	4.18E-30	4.16E-30	3.75E-30	3.74E-30	4.13E-30	4.11E-30
Alluvial Basins, Valleys, and Fans	3.16E-30	3.15E-30	4.15E-30	4.14E-30	3.98E-30	3.98E-30	4.13E-30	4.11E-30
Outwash	3.51E-30	3.49E-30	4.13E-30	4.11E-30	3.96E-30	3.95E-30	4.07E-30	4.05E-30
Till and Till Over Outwash	4.18E-30	4.09E-30	4.27E-30	4.34E-30	4.12E-30	4.05E-30	4.23E-30	4.32E-30
Unconsolidated and Semi-consolidated	3.76E-30	3.76E-30	4.22E-30	4.23E-30	4.06E-30	4.06E-30	4.16E-30	4.17E-30
Coastal Beaches	4.13E-30	3.97E-30	4.24E-30	4.08E-30	4.09E-30	3.94E-30	4.19E-30	4.04E-30
All Groups	4.16E-30	4.10E-30	4.24E-30	4.19E-30	4.09E-30	4.04E-30	4.20E-30	4.15E-30

Table 4-28. Peak Concentrations for Oily Mud Cuttings and Burial at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	NA	NA	9.36E-12	1.24E-13	4.07E-30	3.91E-30	2.05E-22	1.84E-25
Till Over Sedimentary Rock	NA	NA	1.39E-10	5.84E-12	4.10E-30	4.05E-30	1.71E-19	3.44E-21
Sand and Gravel	NA	NA	4.18E-09	2.29E-10	4.15E-30	4.09E-30	2.91E-17	9.72E-20
River Valley with Overbank	NA	NA	1.53E-10	1.07E-11	4.11E-30	4.08E-30	4.84E-22	1.73E-23
River Valley without Overbank	NA	NA	3.68E-11	2.61E-12	3.98E-30	3.96E-30	8.70E-25	6.83E-26
Alluvial Basins, Valleys, and Fans	NA	NA	2.01E-14	1.37E-15	3.89E-30	3.88E-30	8.70E-25	6.83E-26
Outwash	NA	NA	9.69E-12	1.14E-12	3.91E-30	3.89E-30	1.47E-25	2.70E-26
Till and Till Over Outwash	NA	NA	4.70E-09	3.23E-10	4.17E-30	4.10E-30	7.89E-15	1.38E-16
Unconsolidated and Semi-consolidated	NA	NA	1.06E-10	1.30E-11	4.02E-30	4.02E-30	2.22E-21	1.97E-22
Coastal Beaches	NA	NA	2.64E-08	8.59E-10	4.15E-30	4.00E-30	2.18E-15	1.42E-17
All Groups	NA	NA	1.25E-09	7.03E-11	4.13E-30	4.09E-30	4.22E-30	4.17E-30

NA = Not Applicable, chemical not found in waste

Table 4-29. Peak Concentrations for Oily Mud Cuttings and Burial at an Infiltration Rate of 5 Inches per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	NA	NA	7.87E-07	3.05E-08	2.21E-21	6.89E-24	3.63E-10	2.63E-12
Till Over Sedimentary Rock	NA	NA	2.27E-06	2.96E-07	1.58E-19	8.40E-21	4.72E-09	2.07E-10
Sand and Gravel	NA	NA	6.29E-06	5.15E-07	6.76E-19	9.77E-21	6.62E-07	2.43E-08
River Valley with Overbank	NA	NA	1.75E-06	3.05E-07	4.22E-22	1.68E-23	1.07E-09	4.43E-11
River Valley without Overbank	NA	NA	1.33E-06	2.30E-07	7.19E-25	1.67E-26	3.60E-10	2.00E-11
Alluvial Basins, Valleys, and Fans	NA	NA	1.43E-07	2.16E-08	4.16E-30	4.15E-30	3.60E-10	2.00E-11
Outwash	NA	NA	5.26E-07	1.25E-07	6.46E-26	5.71E-27	5.67E-11	7.11E-12
Till and Till Over Outwash	NA	NA	4.27E-06	6.99E-07	9.71E-14	8.92E-16	1.97E-07	8.06E-09
Unconsolidated and Semi-consolidated	NA	NA	1.40E-06	3.86E-07	7.45E-21	5.48E-22	2.11E-09	2.09E-10
Coastal Beaches	NA	NA	1.05E-05	6.99E-07	7.89E-15	4.06E-17	2.10E-07	5.11E-09
All Groups	NA	NA	3.69E-06	4.31E-07	4.07E-19	1.00E-20	4.34E-30	4.28E-30

NA = Not Applicable, chemical not found in waste

Table 4-30. Peak Concentrations for Pigging Waste (Solids) and Land Spreading at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.33E-30	4.15E-30	4.36E-30	4.18E-30	4.05E-30	3.88E-30	1.46E-24	6.91E-28
Till Over Sedimentary Rock	4.35E-30	4.29E-30	5.51E-29	4.32E-30	4.07E-30	4.01E-30	2.14E-21	1.73E-23
Sand and Gravel	4.36E-30	4.30E-30	4.38E-30	4.31E-30	4.07E-30	4.01E-30	6.10E-22	3.41E-24
River Valley with Overbank	4.35E-30	4.31E-30	4.36E-30	4.33E-30	4.06E-30	4.02E-30	2.33E-25	6.47E-27
River Valley without Overbank	4.22E-30	4.19E-30	4.24E-30	4.21E-30	3.94E-30	3.91E-30	3.23E-29	5.17E-30
Alluvial Basins, Valleys, and Fans	4.14E-30	4.12E-30	4.17E-30	4.16E-30	3.87E-30	3.85E-30	3.23E-29	5.17E-30
Outwash	4.15E-30	4.12E-30	4.18E-30	4.15E-30	3.88E-30	3.85E-30	7.56E-30	4.03E-30
Till and Till Over Outwash	4.39E-30	4.32E-30	3.62E-21	7.84E-23	4.10E-30	4.03E-30	6.83E-16	9.55E-18
Unconsolidated and Semi-consolidated	4.25E-30	4.25E-30	4.27E-30	4.27E-30	3.97E-30	3.96E-30	6.43E-25	1.10E-25
Coastal Beaches	4.37E-30	4.21E-30	7.94E-24	6.58E-28	4.08E-30	3.94E-30	1.18E-17	1.16E-20
All Groups	4.35E-30	4.29E-30	4.36E-30	4.30E-30	4.06E-30	4.01E-30	5.45E-22	4.54E-24

Table 4-31. Peak Concentrations for Pigging Waste (Solids) and Land Spreading at an Infiltration Rate of 5 Inches per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	2.54E-26	9.00E-30	3.57E-11	8.16E-14	2.08E-21	5.24E-24	5.63E-10	3.01E-12
Till Over Sedimentary Rock	2.42E-23	2.81E-25	5.12E-10	1.55E-11	2.33E-18	2.56E-20	6.01E-09	1.06E-10
Sand and Gravel	6.68E-26	1.35E-28	4.88E-10	2.07E-11	2.58E-21	1.60E-23	3.08E-09	9.20E-11
River Valley with Overbank	4.56E-30	4.52E-30	2.96E-12	8.51E-14	1.52E-24	2.03E-26	4.52E-10	1.95E-11
River Valley without Overbank	4.46E-30	4.42E-30	5.13E-14	5.47E-15	4.45E-28	2.17E-29	9.02E-11	4.12E-12
Alluvial Basins, Valleys, and Fans	4.43E-30	4.41E-30	6.43E-18	1.05E-18	4.15E-30	4.13E-30	9.02E-11	4.12E-12
Outwash	4.40E-30	4.37E-30	2.43E-14	2.31E-15	4.15E-29	5.41E-30	2.03E-11	1.93E-12
Till and Till Over Outwash	4.13E-16	4.75E-18	5.47E-08	1.47E-09	2.45E-13	1.92E-15	8.89E-08	3.48E-09
Unconsolidated and Semi-consolidated	5.87E-29	4.48E-30	5.69E-12	1.00E-12	4.80E-23	2.91E-24	1.09E-09	1.06E-10
Coastal Beaches	4.74E-20	1.04E-22	1.94E-08	1.13E-10	2.09E-17	1.01E-19	5.64E-08	8.90E-10
All Groups	1.80E-26	8.84E-29	3.46E-10	1.26E-11	5.20E-21	6.84E-23	5.82E-09	2.49E-10

Table 4-32. Peak Concentrations for Pigging Waste (Solids) and Road Spreading at an Infiltration Rate of 1 Inch per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.09E-30	3.92E-30	4.15E-30	3.98E-30	3.84E-30	3.68E-30	4.03E-30	3.87E-30
Till Over Sedimentary Rock	4.12E-30	4.06E-30	4.17E-30	4.11E-30	3.86E-30	3.80E-30	4.05E-30	3.99E-30
Sand and Gravel	4.14E-30	4.07E-30	4.17E-30	4.10E-30	3.88E-30	3.82E-30	3.94E-30	3.88E-30
River Valley with Overbank	4.12E-30	4.08E-30	4.16E-30	4.12E-30	3.85E-30	3.82E-30	4.04E-30	4.00E-30
River Valley without Overbank	4.00E-30	3.97E-30	4.04E-30	4.01E-30	3.74E-30	3.71E-30	3.93E-30	3.90E-30
Alluvial Basins, Valleys, and Fans	3.91E-30	3.89E-30	3.97E-30	3.95E-30	3.67E-30	3.65E-30	3.93E-30	3.90E-30
Outwash	3.93E-30	3.90E-30	3.98E-30	3.95E-30	3.68E-30	3.65E-30	3.86E-30	3.84E-30
Till and Till Over Outwash	4.16E-30	4.09E-30	4.20E-30	4.12E-30	3.90E-30	3.83E-30	4.08E-30	4.01E-30
Unconsolidated and Semi-consolidated	4.03E-30	4.02E-30	4.07E-30	4.06E-30	3.77E-30	3.77E-30	3.95E-30	3.95E-30
Coastal Beaches	4.14E-30	3.99E-30	4.18E-30	4.03E-30	3.89E-30	3.75E-30	4.06E-30	3.92E-30
All Groups	4.12E-30	4.07E-30	4.16E-30	4.10E-30	3.86E-30	3.81E-30	4.04E-30	3.99E-30

Table 4-33. Peak Concentrations for Pigging Waste (Solids) and Road Spreading at an Infiltration Rate of 5 Inches per Year

Hydrogeologic Environment	Concentration (mg/l) for 85% Cumulative Probability of Nonexceedence							
	Benzene		Toluene		Ethylbenzene		Xylene	
	Receptors		Receptors		Receptors		Receptors	
	# 1	# 2	# 1	# 2	# 1	# 2	# 1	# 2
Bedded Sedimentary Rock	4.26E-30	4.21E-30	9.86E-25	1.11E-27	4.03E-30	3.95E-30	2.74E-18	6.14E-21
Till Over Sedimentary Rock	4.31E-30	4.24E-30	1.12E-21	1.04E-23	4.07E-30	4.01E-30	5.78E-16	6.27E-18
Sand and Gravel	4.28E-30	4.20E-30	5.76E-26	8.95E-29	4.03E-30	4.06E-30	6.50E-19	5.63E-21
River Valley with Overbank	4.30E-30	4.26E-30	1.17E-29	4.34E-30	4.05E-30	4.02E-30	3.42E-21	3.67E-23
River Valley without Overbank	4.21E-30	4.18E-30	4.28E-30	4.24E-30	3.96E-30	3.93E-30	1.10E-24	6.56E-26
Alluvial Basins, Valleys, and Fans	4.18E-30	4.16E-30	4.26E-30	4.24E-30	3.93E-30	3.91E-30	1.10E-24	6.56E-26
Outwash	4.16E-30	4.13E-30	4.21E-30	4.19E-30	3.90E-30	3.87E-30	1.18E-25	1.42E-26
Till and Till Over Outwash	4.30E-30	4.36E-30	2.75E-14	7.78E-17	4.06E-30	4.08E-30	2.16E-11	2.69E-13
Unconsolidated and Semi-consolidated	4.24E-30	4.24E-30	1.52E-28	8.22E-30	3.98E-30	3.98E-30	3.08E-20	2.73E-21
Coastal Beaches	4.27E-30	4.10E-30	7.90E-20	1.22E-23	4.03E-30	3.94E-30	7.52E-15	4.36E-17
All Groups	4.27E-30	4.21E-30	3.17E-26	6.40E-28	4.02E-30	4.04E-30	5.82E-18	8.60E-20

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APPENDIX A
SUMMARY OF SAMPLES COLLECTED

See attached table, 2 pages

API ASSOCIATED WASTE STUDY APPENDIX A dated 02/22/1994				STATE	SAMPLE AGE	SAMPLE COLLECTION POINT	COMMENTS
API Sample Type	Lab ID No.	Matrix	Sample Date				
Amine Solution	006299-0009-SA	Waste	24-Aug-89	Texas - West			
Contaminated Soil	006299-0007-SA	Waste	24-Aug-89	Texas - West			
Contaminated Soil	006344-0003-SA	Waste	30-Aug-89	Oklahoma			
Contaminated Soil	007531-0003-SA	Waste	15-Nov-89	West Virginia	Not recorded	Under purge valve on htr. treater	
Contaminated Soil	007862-0004-SA	Waste	14-Dec-89	California	Not recorded		Earthen pit used for tank bottom collection
Contaminated Soil	011425-0002-SA	Waste	18-Sep-90	Oklahoma	0-72 hrs.	Below load-out valve	SS trowel, 0-3 in., free oil present, sample taken from below crude oil tank bottom truck loading valve
Contaminated Soil	011425-0008-SA	Waste	19-Sep-90	Oklahoma	0 hrs.	Beneath BPU* stuffing box	SS trowel, 0-3 in., spill in progress
Contaminated Soil	011686-0004-SA	Waste	03-Oct-90	Oklahoma	4-12 hrs.	30 yds. from well	SS trowel, 0-2 in. depth, oil is from a W.O.* kick.
Contaminated Soil	012010-0001-SA	Waste	23-Oct-90	Texas - West	0 hrs.	Trench	SS trowel, 0-3 in.; collected from trench leading to W.O.* pit
Contaminated Soil	012010-0004-SA	Waste	23-Oct-90	Texas - West	0 hrs.	Below heater treater drain line	SS trowel, leak in progress, 0-3 in. depth of collection
Contaminated Soil	012010-0007-SA	Waste	24-Oct-90	Texas - West	0 hrs.	Below valve	SS trowel, 0-3 in., valve actively dripping condensate onto soil, API deg. = 60
Contaminated Soil	012010-0008-SA	Waste	24-Oct-90	Texas - West	0 hrs.	Adjacent to wellhead	SS trowel, 0-3 in., BPU* stuffing box actively dripping, API deg = 43
Contaminated Soil	012196-0003-SA	Waste	01-Nov-90	Texas - East	48 hrs.	Below man-way cover	SS trowel, 0-3 in., collected beneath leaking, bolted man-way cover on stock tank
Contaminated Soil	012196-0004-SA	Waste	01-Nov-90	Texas - East	8 hrs.	Below BPU* stuffing-box	SS trowel, 0-3 in., surface soil sample
Contaminated Soil	012196-0006-SA	Waste	01-Nov-90	Texas - East	0 hrs.	Below pump	SS trowel, 0-3 in. depth, result of leaky packing gland, API grav. = 38
Contaminated Soil	012430-0003-SA	Waste	15-Nov-90	Texas - East	1 day	Adjacent to gas-line	SS trowel, 0-1.5 ft. depth, wet w\ HC odor, gas line leak
Contaminated Soil	012430-0004-SA	Waste	15-Nov-90	Texas - East	2 days	Near flow-line	SS trowel, 0-1.5 ft. depth, visible oil w\ HC odor, flow-line leak
Contaminated Soil	012671-0003-SA	Waste	30-Nov-90	Texas - West	3 days	Below stuffing box	SS trowel, 0-3 in.
Contaminated Soil	012671-0004-SA	Waste	01-Dec-90	Texas - West	0 hrs.	Below BPU* stuffing box	SS trowel, 0-3 in., site of an active leaky stuffing box
Contaminated Soil	012671-0005-SA	Waste	01-Dec-90	Texas - West	0 hrs.	Below BPU* stuffing box	SS trowel, 0-3 in., site of an active leaky stuffing box
Contaminated Soil	012671-0006-SA	Waste	01-Dec-90	Texas - West	0 hrs.	Below BPU* stuffing box	SS trowel, 0-3 in., site of an active leaky stuffing box
Contaminated Soil	012857-0005-SA	Waste	12-Dec-90	Oklahoma	2-3 days	Below pump	SS trowel, 0-3 in., spill resulted from a leaky packing gland on transfer pump
Contaminated Soil	012857-0006-SA	Waste	12-Dec-90	Oklahoma	3-4 days	Below BPU* stuffing box	SS trowel, 0-3 in., spill is result of a leaky stuffing box, surface soil sample
Contaminated Soil	012857-0007-SA	Waste	12-Dec-90	Oklahoma	0-4 days	Adjacent to sump	SS trowel, 0-3 in., sump below LACT pump over-flowed to adjacent soil, active packing gland leaks
Contaminated Soil	012857-0008-SA	Waste	13-Dec-90	Oklahoma	Not recorded	Adjacent to BOP*	SS trowel, 0-3 in., oil spilled during W.O.* tripping operations
Contaminated Soil	013201-0003-SA	Waste	17-Jan-91	New Mexico	3 hrs.	Near wellhead	Surface soil sample, spill occured during W.O.* operations
Contaminated Soil	013384-0002-SA	Waste	29-Jan-91	Texas - West	0-2 days	Adjacent to wellhead	SS trowel, 0-3 in.,'spill occurred while dismantling flowline for W.O.* operations
Contaminated Soil	013384-0003-SA	Waste	29-Jan-91	Texas - West	0 hrs.	Below valve	SS trowel, 0-3 in., active leak from truck load-out valve of 1000 bbl stock tank
Contaminated Soil	013384-0004-SA	Waste	29-Jan-91	Texas - West	Not recorded	Below flowline	SS trowel, 0-3 in., 150 yds. NE of well, flow line had multiple clamps
Contaminated Soil	013384-0005-SA	Waste	29-Jan-91	Texas - West	0-1 hr.	Near frac tank	Spill is result of overfill of frac tank which contained flowback, lease-water comp. fluid had a layer of oil
Contaminated Soil	013384-0010-SA	Waste	30-Jan-91	Texas - West	0 hrs.	Not recorded	SS trowel, 0-3 in., spill resulted from leaky packing gland, API deg.= 34.
Contaminated Soil	013654-0001-SA	Waste	21-Feb-91	Texas - West	0-3 hrs.	Side of road	SS trowel, 0-3 in., maintainer blade hit flowline on road causing flowline leak
Contaminated Soil	013654-0002-SA	Waste	21-Feb-91	Texas - West	0-24 hrs.	Below swingjoint	SS trowel, 0-3 in., fluid is greater than 95% water, API deg.=39, leaky swing-joint in flowline
Dehy Condensate Water	011686-0006-SA	Aqueous	03-Oct-90	Oklahoma	0 hrs.	Blow case	Collected from valve of fibreglass collection vessel (blowcase)
Dehy Condensate Water	011772-0003-SA	Aqueous	09-Oct-90	Texas - West	0 hrs.	Drip pot	Bailed from drip pot through a light gas condensate layer
Dehy Condensate Water	012641-0001-SA	Aqueous	27-Nov-90	Texas - West	0 hrs.	Valve at sump	Collected from valve at sump (condensed fluid from condensing unit)
Oil Mud Cuttings	006299-0002-SA	Soil	24-Aug-89	New Mexico			Collected sample from cuttings pit - less than one week old
Oil Mud Cuttings	007915-0001-SA	Waste	19-Dec-89	Oklahoma			Collected sample from screen separator
Oil Mud Cuttings	007915-0002-SA	Waste	19-Dec-89	Oklahoma			No information on sampling - but sampled by same person, same trip, same chain of custody form as #007915-0001
Oil Mud Cuttings	011425-0009-SA	Waste	20-Sep-90	Oklahoma	0 hrs.	Screen separator	SS trowel, collected sample directly from screen separator
Oil Mud Cuttings	011772-0005-SA	Waste	09-Oct-90	Texas - West	5 days	Below screen sep.	SS trowel, collected sample 2 to 6 inches below the surface of a cuttings pile about 5 days old
Pigging Waste	012641-0003-SA	Aqueous	28-Nov-90	Texas - West	0 hrs.	Settling tank bottom valve	High stage accumulator dumps pigging liquids (mainly water) to a settling tank (to recover hydrocarbons).
Pigging Waste	012798-0001-SA	Aqueous	11-Dec-90	Texas - East	0 hrs.	Valve on low level alarm	Valve on the low water level alarm from a large, 3-phase, horizotal inlet separator at a natural gas plant
Pigging Waste	013200-0001-SA	Waste	17-Jan-91	Michigan	1-7 days	Sump with grating	SS trowel, solid paraffin-like matreial from pig catcher hand carried daily with shovel to line sump with grating.
Pigging Waste	013200-0002-SA	Waste	17-Jan-91	Michigan	1+ days	Pigging sump	Sample was bailed, pigging liquids are periodically pumped to the stock tank
Pigging Waste	013828-0001-SA	Waste	01-Mar-91	Texas - East	0 hrs.	Not recorded	No solids present when trap door opened, only liquid avail. for sampling
Pit and Sump Waste	006299-0005-SA	Waste	24-Aug-89	Texas - West			Basic sediment pit skimmings from emergency pit
Pit and Sump Waste	007862-0003-SA	Waste	14-Dec-89	California			Vessel solids collection sump (earthen pit)
Pit and Sump Waste	011686-0003-SA	Waste	03-Oct-90	Oklahoma	0 hrs.	Bailed from sump	Buried concrete sump - natural gas plant - collects natural gas condensate and runoff water
Pit and Sump Waste	012010-0006-SA	Waste	23-Oct-90	Texas - West	0 hrs.	Sump	Buried steel sump - lease operations - collects lube oil and produced watre from water injection pumps
Produced Sand	007314-0003-SA	Waste	31-Oct-89	Louisiana			Collected from sand settling tank
Rig Wash	011425-0010-SA	Waste	20-Sep-90	Oklahoma	0 hrs.	Active sump	Collected from lined sump
Rig Wash	012010-0005-SA	Aqueous	23-Oct-90	Texas - West	0 hrs.	Open sump	Rig wash falls into earthen trench that flows to earthen sump
Rig Wash	013200-0003-SA	Aqueous	18-Jan-91	Michigan	0 hrs.	Bailed, cellar	Collected liquid sample from lined sump
Rig Wash	013200-0004-SA	Aqueous	18-Jan-91	Michigan	0 hrs.	Bailed, cellar	Collected liquid sample from lined sump
Rig Wash	013200-0005-SA	Waste	18-Jan-91	Michigan	0 hrs.	Shovel, cellar	Active drilling site, used shovel to collect sediment at bottom of cellar
Spent Iron Sponge	012010-0009-SA	Waste	25-Oct-90	Texas - West	1 month	Lease burial	SS trowel, iron sponge was collected from pit where it had been buried 2 ft. deep 1 mo. prior
Spent Iron Sponge	013143-0001-SA	Waste	15-Jan-90	Texas - West	0-8 hrs.	Pile @ W. Scrub.	SS spoon, grabbed from pile at base of west scrubber

Spent Mol Sieve	011212-0001-SA	Solid	04-Sep-90	Texas - West			
Spent Mol Sieve	011212-0002-SA	Solid	04-Sep-90	Texas - West			
Spent Mol Sieve	013143-0002-SA	Waste	16-Jan-90	Texas - West	0-3 hrs.	Loader bucket	Sample collected from loader bucket as vessel was cleaned
Tank Bottoms	006299-0001-SA	Waste	24-Aug-89	Texas - West			Collected with oil thief
Tank Bottoms	006299-0003-SA	Waste	24-Aug-89	Texas - West			Collected with oil thief - produced waste tank bottom
Tank Bottoms	006299-0004-SA	Waste	24-Aug-89	Texas - West			Collected from strainer on crude oil tank transfer pipe
Tank Bottoms	006344-0001-SA	Waste	30-Aug-89	Oklahoma			Collected from discharge hose on bottom of tank. Tank collects bottoms from all vessels on lease
Tank Bottoms	006344-0002-SA	Waste	30-Aug-89	Oklahoma			Collected with oil thief
Tank Bottoms	007314-0004-SA	Waste	31-Oct-89	Louisiana			Collected with oil thief
Tank Bottoms	007531-0002-SA	Waste	15-Nov-89	West Virginia			Collected with oil thief
Tank Bottoms	007531-0004-SA	Waste	15-Nov-89	West Virginia			Collected with oil thief
Tank Bottoms	007862-0001-SA	Waste	14-Dec-89	California			Collected from tap on tank bottom
Tank Bottoms	007862-0005-SA	Waste	14-Dec-89	California			Collected from tap on tank bottom
Tank Bottoms	011425-0001-SA	Waste	18-Sep-90	Oklahoma	NA	Tank Bottom	Collected with oil thief
Tank Bottoms	011425-0003-SA	Waste	18-Sep-90	Oklahoma	0 hrs.	Top Hatch	Collected with oil thief
Tank Bottoms	011425-0004-SA	Waste	19-Sep-90	Oklahoma	Not Recorded	Bottom Hatch	SS scoop, vessel recently out of service
Tank Bottoms	011425-0005-SA	Waste	19-Sep-90	Oklahoma	Not Recorded	Bottom Hatch	SS scoop, crude recently pumped from tank
Tank Bottoms	011425-0007-SA	Waste	19-Sep-90	Oklahoma	Not Recorded	Side Hatch	SS trowel, vessel recently out of service
Tank Bottoms	011686-0001-SA	Waste	03-Oct-90	Oklahoma	0 hrs.	Top Hatch	Collected with oil thief
Tank Bottoms	011772-0001-SA	Waste	09-Oct-90	Texas - West	0 hrs.	Top hatch	Oil thief, gas condensate in tank, 55 deg. API
Tank Bottoms	012010-0003-SA	Waste	23-Oct-90	Texas - West	0 hrs.	Bttm valve of vessel	Active free water knock-out vessel
Used Glycol	006299-0008-SA	Waste	24-Aug-89	Texas - West			Used glycol, gas plant
Used Glycol	006344-0005-SA	Waste	30-Aug-89	Oklahoma			Used glycol
Used Glycol	007314-0002-SA	Waste	31-Oct-89	Louisiana			Used glycol
Used Glycol	007862-0006-SA	Waste	14-Dec-89	California			Used glycol - gas plant reboils
Used Glycol	011425-0012-SA	Waste	20-Sep-90	Oklahoma	0 hrs.		Sample collected from valve before reboiler
Used Glycol	011686-0007-SA	Waste	03-Oct-90	Oklahoma	0 hrs.		Sample collected from valve before reboiler
Used Glycol	011772-0004-SA	Aqueous	09-Oct-90	Texas - West	0 hrs.		Sample collected from valve before reboiler
Used Glycol	012641-0002-SA	Aqueous	27-Nov-90	Texas - West	0 hrs.		Sample collected from valve after reboiler
Used Oil	006299-0006-SA	Waste	24-Aug-89	New Mexico			Diesel fired engine
Used Oil	006299-0010-SA	Waste	24-Aug-89	Texas - West			Natural gas fired engine
Used Oil	006344-0004-SA	Waste	30-Aug-89	Oklahoma			Natural gas fired engine
Used Oil	007314-0001-SA	Waste	31-Oct-89	Louisiana			Natural gas fired engine
Used Oil	007531-0001-SA	Waste	15-Nov-89	West Virginia			Natural gas fired engine
Used Oil	007862-0002-SA	Waste	14-Dec-89	California			Natural gas fired engine - composite sample of 2 engines
Used Oil	011425-0006-SA	Waste	19-Sep-90	Oklahoma	0 hrs.		Natural gas fired engine - collected from valve on engine
Used Oil	011425-0011-SA	Waste	20-Sep-90	Oklahoma	0 hrs.		Natural gas fired engine - collected from valve on compressor
Used Oil	011686-0002-SA	Waste	03-Oct-90	Oklahoma	0 hrs.		Natural gas fired engine - collected from valve on engine
Used Oil	011772-0002-SA	Waste	09-Oct-90	Texas - West	0 hrs.		Natural gas fired engine - collected from valve on engine
Used Oil	012196-0007-SA	Waste	02-Nov-90	Texas - East	0 hrs.		Natural gas fired engine - collected from valve on engine
Used Oil	012196-0008-SA	Waste	02-Nov-90	Texas - East	0 hrs.		Natural gas fired engine - collected from valve on engine
Workover Fluids	012010-0002-SA	Aqueous	23-Oct-90	Texas - West	0 hrs.	Flowline to pit	Collected from flowline into bucket. Bailed through an oil layer to collect sample.
Workover Fluids	012196-0002-SA	Aqueous	31-Oct-90	Texas - East	0 hrs.	Valve on wellhead	Sample collected at wellhead after 390 Bbls fluid returned - total 1620 Bbls injected.
Workover Fluids	012228-0001-SA	Aqueous	05-Nov-90	Texas - East		Direct from unit	SS scoop, vessel recently out of service
Workover Fluids	012430-0001-SA	Aqueous	14-Nov-90	Texas - East	0 hrs.	Flowline valve	Collected from flowline after 1510 Bbls recovered - approx 6400 Bbls injected.
Workover Fluids	012671-0001-SA	Aqueous	29-Nov-90	Texas - West	0 hrs.	Discharge line	Collected from discharge line after 127 Bbls recovered - approx. 184 Bbls injected.
Workover Fluids	012671-0002-SA	Aqueous	30-Nov-90	Texas - West	0 hrs.	Swabbing tee	Collected from swabbing tee after 14.5 Bbls swabbed - 14 Bbls is the tubing volume.
Workover Fluids	012671-0007-SA	Aqueous	01-Dec-90	Texas - West	0 hrs.	Swabbing tee	Collected from swabbing tee after 15 Bbls of fluid recovered - 13.7 Bbls is tubing volume.
Workover Fluids	012857-0001-SA	Aqueous	12-Dec-90	Oklahoma	0 hrs.	Bailed, frac tank	Collected by bailing from frac tank after 1 casing volume recovered.
Workover Fluids	012857-0002-SA	Aqueous	13-Dec-90	Oklahoma	0 hrs.	Bailed, frac tank	Collected by bailing from frac tank after 1 casing volume recovered. Total injection was 3851 Bbls.
Workover Fluids	012857-0003-SA	Aqueous	13-Dec-90	Oklahoma	0 hrs.	Flowline valve	Collected from flowline after 2300 Bbls recovered - 12,000 Bbls injected.
Workover Fluids	013654-0004-SA	Aqueous	19-Feb-91	Texas - West	0 hrs.	Valve below tee	
Workover Fluids	012196-0001-SA	Waste	31-Oct-90	Texas - East	0 hrs.	Flowline valve	Collected from flowline after 360 Bbls of aqueous fluid returned - total 3400 Bbls injected.
Workover Fluids	012196-0005-SA	Waste	01-Nov-90	Texas - East	0 hrs.	Flowline ndle. valve	Collected from flowline after 1031 Bbls recovered - approx. 1336 Bbls injected.
Workover Fluids	013201-0001-SA	Waste	21-Jan-91	New Mexico	0 hrs.	Tee fitting	Sample collected after 1031 Bbls recovered. Approx. 1300 Bbl injected.
Workover Fluids	013201-0002-SA	Waste	21-Jan-91	New Mexico	0 hrs.	Frac tank	Sample collected by bailing from frac tank.
Workover Fluids	013384-0001-SA	Waste	29-Jan-91	Texas - West	0 hrs.	Valve at wellhead	Collected from valve at wellhead after 1 tubing volume recovered - 6200 gals. total injected.
Workover Fluids	013384-0006-SA	Waste	29-Jan-91	Texas - West	0 hrs.	Swabbing tee	Sample collected after 1 tubing volume swabbed. Total 1100 gals injected, 15% acid injected.
Workover Fluids	013384-0009-SA	Waste	30-Jan-91	Texas - West	Not recorded	Near pump	Near pump. Sample collected after swabbing 1 tubing volume.
Workover Fluids	013384-0011-SA	Waste	31-Jan-91	Texas - West	0 hrs.	Not recorded	Approx. 40,000 gal injected. Sample collected after 1 tubing vol. recovered. FLuid appeared gelled.
Workover Fluids	013654-0003-SA	Waste	19-Feb-91	Texas - West	0 hrs.	Flowline valve	Approx. 3000 gals 15% NEFE acid injected. Sample collected after 1 tubing vol. recovered.
Workover Fluids	014299-0001-SA	Waste	01-Apr-91	Texas - East	0 hrs.	Flowline	Sample collected after approx. 43 Bbls recovered - 2200 Bbls total fluid injection. One casing vol is 37 Bbls.

APPENDIX B

ANALYTICAL METHODS AND QUALITY CONTROL

ANALYTICAL PROCEDURES

This project involved the analysis of approximately 100 wastes associated with the oil and gas exploration and production industry. The wastes ranged from oily wastes to spent solvents to spent iron sponge. Some of the samples had two distinct phases, some samples were oily liquids and others were solids with a high oil content. These types of samples pose a significant challenge to the analytical methods that are normally used to assess environmental contamination and special techniques must be performed in order to generate useable data.

Table B-1 provides a list of the methods used in this study.

Table B-1. List of Analytical Methods Used

Total Appendix IX Volatile Organic Compounds by EPA Methods 5030/8240

Total Petroleum Refinery List Semi-Volatile Organic Compounds by EPA Methods 8270

Total Appendix IX Metals by EPA Method 6010 for TCLP Metals; except:

- Mercury by EPA 7471
- Arsenic by EPA 7060
- Selenium by EPA 7740
- Thallium by EPA 7841
- Osmium 189 by EPA/RMAL Method 6020

Chloride by Method 300.0

RCRA Characteristics by EPA Methods as follows:

- Ignitability by 1010
- Corrosivity by 9045
- Reactivity by SW846, Chapter 7, Section 7.3
- Toxicity by: 1311 for TCLP
  - 8240 for TCLP Volatile Organic Compounds
  - 8270 for TCLP Semi-Volatile Organic Compounds
  - EPA Method 6010 for TCLP Metals; except:
    - Mercury by EPA 7471
    - Arsenic by EPA 7060
    - Selenium by EPA 7740
    - Thallium by EPA 7841

Samples analyzed for oil/water/solids content underwent MODT testing (Ref. 3 in this section)

The following sections discuss the analytical groups used and provide specific details about the approach.

1. TCLP

The Toxicity Characteristic Leaching Procedure (TCLP) method listed as Appendix I to 40 CFR Part 268 was used to generate a liquid extract. Samples analyzed after September 1, 1990, used the TCLP Method 1310 as finalized in the June 29, 1990, *Federal Register* (p. 26986-26998). This version includes a requirement for bias correction; however, the results were not bias corrected. This requirement for TCLP bias correction has been removed by the USEPA (November 24, 1992 *Federal Register*).

Simply stated, the TCLP procedure is designed to generate an aqueous leachate of a waste. The leachate is prepared at a 20 to 1 ratio relative to the solid material in the sample. The leachate is then analyzed for the various target parameters; results are reported in mg/L in the leachate.

The initial leaching procedure requires two separate laboratory preparations (extractions), *one for volatile organics and one for the remaining parameters.* The preparation for volatile organics requires the use of a specially designed extractor, termed the zero headspace extractor (ZHE).

The initial step in performing a TCLP extraction is the pressure filtration (50 psi) of the sample through a 0.8 micron filter. The solid phase remaining after this filtration is then mixed with the aqueous TCLP extraction fluid in a 20 to 1 ratio. After 18 hours of "extraction," the solid/leachate mixture is again filtered. The filtered leachate from this step is then combined with any filtrate from the initial filtration. If the sample is <0.5 percent solids (<5.0 percent for ZHE), the initial filtrate becomes the TCLP leachate and the solid phase is discarded. In this case, the 18 hour extraction (and 20 to 1 dilution with extraction fluid) is not done, and the TCLP results are normally similar to the total analysis results, although some percentage of the analytes of interest may be trapped by the filter. The initial filtrate may be aqueous or oil.

For wastes containing "oil," the initial filtration and /or TCLP extraction may result in a two phase solution, oil and water. According to the TCLP procedure, the oil layer must be analyzed separately and the results mathematically combined. Analyses of the various leachate solutions were performed according to the procedures described below.

Method 8240 was used for the analysis of volatiles, and Method 8270 for semi-volatiles. (These methods are discussed further below.) The analyte lists contains the volatile and semivolatile organics listed in the June 1986, proposed toxicity characteristic. See Tables B-2 and B-4 for the analyte lists and reporting limits. Due to a laboratory oversight, some samples analyzed after September, 1990 were analyzed only for the 10 currently regulated TCLP volatile organics.

2. Ignitability

The EPA has indicated that the ignitability test is not appropriate for solid samples and recommends the use of judgement to determine whether or not a solid waste is hazardous due to ignitability. For this study, SW-846 Method 1010 was used for ignitability. This test is considered reliable only for non-aqueous liquids.

3. Corrosivity

Corrosivity was determined by the measurement of pH using SW-846 Method 9045.

4. Reactivity

Reactivity was performed using the procedures in Chapter 7 of the third edition of SW-846. The reactivity test has a number of significant problems and gives results that are biased low. Nevertheless, the procedure is recognized by the EPA and was performed exactly as stated in the method.

5. Percent Solids, Oil, & Water

A variety of procedures exists to measure oil, water, and solids content in oily solid samples. Each of these procedures has advantages and disadvantages. The most commonly used procedures are determination of BS and W using an ASTM procedure; determination of water by extraction with tetrahydrofuran and titration with Carl Fisher reagent, solids by the residue remaining after the THF extraction and oil by difference; a variety of procedures based around traditional freon extracted oil and grease procedures; and a modified oven drying technique (MODT). Of these procedures, the MODT was selected because for most oily solids, this procedure provides the most representative data. The procedure was developed by Chevron and has been used on two other API projects with success. The advantages of this procedure are:

A. The oil, water and solids content are all determined directly. There is no calculation involved.

B. The procedure generates separate numbers for both a volatile oil and a nonvolatile oil at no additional cost. These two values are sometimes useful in evaluating the characteristic of the oil present in a sample.

C. Since the procedure is nondestructive, both the volatile and nonvolatile oil fractions can be isolated and additional work may be performed on these fractions. For example, frequently boiling point distributions have been performed on the volatile oil fraction which resulted from this procedure.

This procedure determines the amount of oil (light and heavy hydrocarbons), water, and solids in an oily waste. The sample is first heated to 230-240°F under a vacuum in a closed container to drive the water and light hydrocarbons into a cold trap. Heavy oils are separated from the solids by soxhlet extraction with methylene chloride. The amounts are then determined by mass balance.

6. Volatile Organics

There are three collections of EPA methods that are frequently cited on projects such as this. These are: 1) the 600 series methods contained in 40-CFR-136, which were promulgated in the October 1984 Federal Register rulemaking cited in the RFP; 2) the procedures contained in SW-846; and, 3) the procedures contained in EPA Contract Laboratory Program (CLP) statements of work. The original (second edition) SW-846 procedures were written only for solid samples and, accordingly, many method citations indicate that the 40-CFR-136 procedure should be used for waters and SW-846 for soils. However, the 40-CFR-136 procedures specifically have statements that indicate the procedures were approved only for determination of priority pollutants in wastewater as part of Clean Water Act regulations. The third edition SW-846 procedures have been rewritten to incorporate changes so that the procedures are appropriate for the analysis of water samples.

Accordingly, Quanterra has prepared Standard Operating Procedures (SOPs) which incorporate features from all three sources of these procedures. For the purposes of this project, we believe it is more appropriate to cite the SW-846 methods for all analyses since the primary focus of this effort is the RCRA regulations. Accordingly, all samples were analyzed by Method 8240 as defined in detail in Quanterra's SOP.

A number of options were considered for the target analyte list for the volatile organics. These include the priority pollutant compounds listed in Method 624, the target analytes listed in the CLP version of the method which are also contained in Method 8240, a list of compounds commonly referred to as the refinery list, and a list of compounds contained in Appendix IX of 40-CFR Part 264. Of these lists, the Appendix IX list was selected for this project (see Table B-3). For petroleum refineries, we generally recommend the use of the petroleum refining list. The Appendix IX list is more appropriate for this study since if various solvents were used in exploration and production activities, then many compounds which are contained on the Appendix IX list but are not on the refinery list may be present.

The Appendix IX list was generated for ground water monitoring at RCRA hazardous waste facilities. However, this list has also been used in many other areas including the recent regulations associated with the land disposal of hazardous waste. We believe this list to be a fundamental monitoring list in the RCRA program today. The list has a distinct advantage in that it is directly related to the Appendix VIII list in 40-CFR Part 261, the basis of many RCRA regulations.

7. Semivolatile Organics

As in the discussion for volatile organics, a variety of method sources exist; SW-846 Method 8270 is the appropriate citation for both solids and water samples. Also, consideration must be made relative to the analyte list that must be measured. Again, the potential analyte list included the priority pollutant, CLP, refinery, and Appendix IX lists. However, there is another factor which must be considered in addition to just the list itself. This other factor has to do with the presence of interfering aliphatic hydrocarbons which are often present in oily petroleum wastes. A "clean up" procedure exists for the removal of these types of interferences. The clean up procedures are Method 3650 (Acid/Base Partition) and Method 3611 (Alumina column cleanup). Improved data reliability for selected target analytes which are not affected by the clean up is achieved by using this clean up technique. Unfortunately, many of the target analytes in the priority pollutant CLP and Appendix IX analyte lists are also removed with this clean up technique. We believe that the improved reliability of data for those compounds of most environmental concern in petroleum industry wastes (PNA and phenols) warrant the use of this clean up step at the risk of not obtaining data for other compounds (e.g., chlorinated aliphatics) which are typically not present in petroleum industry wastes. Accordingly, the target analyte list for semivolatile organics was the petroleum refinery list shown in Table B-5. The clean up procedures were applied to obtain the best possible data for this list of compounds. (The clean up procedures were not used for the analysis of TCLP leachates.)

8. Metals

Arsenic (for total analyses), selenium, and thallium were determined by graphite furnace atomic absorption (GFAA). All mercury determinations were by cold vapor atomic absorption. All other metals (including arsenic in TCLP leachates) were determined using inductively coupled plasma atomic emission spectroscopy (ICP). Tables B-6 and B-7 list methods and reporting limits for the total and TCLP metals analyses.

9. Method Detection Limit Issues

Tables contained in the following sections indicate Quanterra's nominal reporting limits achievable in samples which do not contain significant interferences. The fact is, many exploration/production wastes contain interferences which may have a definite impact on these nominal reporting limits. For example, because of the limit to the total amount of organic material that can be applied to a chromatographic column at one time, samples that are high in oil content will have detection limits that are 10 to 10,000 times higher than the detection limits that are achieved in clean soils. Approximately 60 percent of the samples for total volatiles and 40 percent of the samples for TCLP volatiles had reporting limits elevated due to elevated levels of oil. High levels of aluminum, calcium, iron and/or sodium found in many production/exploration samples require dilutions to minimize the physical and chemical interferences in metal analyses. Approximately 30 percent of the samples for TCLP metals analysis had elevated reporting limits due to these types of interference. Because of the non-homogeneous nature of these types of samples, obtaining representative subsamples in the laboratories may be very difficult. These factors may also impact the detection limits which are achievable on a given sample. The specific detection limit which was reported for a given sample was determined by multiplying the nominal reporting limit by the dilution factor which was required to obtain a usable analysis.

It is important to note that in all waste types, a non-detect does not mean the analyte is not present. The reporting limit (detection limit) varies depending on the sample matrix. For example, the reporting limit for benzene in this project ranges from 0.5 ppm to 500 ppm, depending on the level of interferences present in individual samples. Target analytes, such as benzene, may be present at levels just below the reporting limit.

10. Blank Contamination

Method blanks are analyzed with a batch of samples processed to assess the level of background interference or contamination which exists in the analytical system. Ideally, the concentration of analytes in the blank should be below the reporting limit for that analyte. In practice, some common laboratory solvents and metals are difficult to eliminate at ppb and ppm levels. For organic analyses, target analytes in the blank must be below the reporting limit, except for common laboratory contaminants (methylene chloride, acetone, 2-butanone, and phthalate esters). These may be present at up to 5 times the reporting limit and still be acceptable.

For metals and Wet Chemistry (pH, chlorides, cyanide, sulfide, etc.) analyses, where the reporting limits are typically near the Instrument Detection Limit (IDL), the target analytes in the blank must be less than two times the reporting limit. A blank containing an analyte(s) above two times the Reporting Limit is unacceptable unless the lowest concentration of the analyte in the associated sample is at least ten times the blank concentration, or the concentration of the analyte in all samples associated with the blank is below the reporting limit.

In addition, for some Wet Chemistry tests, the method SOP directs how the blank is treated. Generally, a reagent blank is used to zero the equipment and as one of the calibration standards. Some methods require that the concentration of analyte found in a preparation blank be subtracted from the concentration in the sample (this is not applicable to any of the methods performed on these samples). Thus, no reported data were "blank corrected," since blank correction is not required by any of the referenced methods.

Some of the reported analytes in this study are common lab contaminants, and any reported values should be considered qualitatively unreliable. These analytes include methylene chloride, acetone, methyl ethyl ketone (2-butanone), phthalate esters, and barium in TCLP blanks. Although not as common, chromium was detected in some TCLP blanks; the affected data were noted.

Table B-2. Volatile Organics, Reporting Limits, and Regulatory Limits for Toxicity Characteristic Leaching Procedure: API Exploration and Production Study

CAS #	Analyte	Reporting Limit, mg/L	Regulatory Limit, mg/L
Final TCLP Components (1990 rule):			
71-43-2	Benzene	0.025	0.5
0078-93-3	2-Butanone (MEK)	0.05	200
56-23-5	Carbon tetrachloride	0.025	0.5
108-90-7	Chlorobenzene	0.025	100
67-66-3	Chloroform	0.025	6
107-06-2	1,2-Dichloroethane	0.025	0.5
75-35-4	1,1-Dichloroethene	0.025	0.7
127-18-4	Tetrachloroethene	0.025	0.7
79-01-6	Trichloroethene	0.025	0.5
75-01-4	Vinyl chloride	0.05	0.2
Additional Components: *			
107-13-1	Acrylonitrile	0.5	5
75-15-0	Carbon disulfide	0.025	14.4
078-83-1	Isobutanol	1.0	36
75-09-2	Methylene chloride	0.025	8.6
630-20-6	1,1,1,2-Tetrachloroethane	0.025	10
79-34-5	1,1,2,2-Tetrachloroethane	0.025	1.3
108-88-3	Toluene	0.025	14.4
71-55-6	1,1,1-Trichloroethane	0.025	30
79-00-5	1,1,2-Trichloroethane	0.025	1.2
Surrogates:			
460-00-4	4-Bromofluorobenzene (BFB)		
17060-07-0	1,2-Dichloroethane-d4		
2037-26-5	Toluene-d8		

* The additional components are compounds included in the original TCLP list but removed in the final rule. The regulatory limits for these components are from the 1986 proposed rule. Regulatory limits for the final TCLP list are from the 1990 rule.

Note: Reporting limits are matrix dependent and are not achievable in all samples.

Table B-3a. Volatile Appendix IX Organics and Reporting Limits:
API Exploration and Production Study (Solids)

CAS #	Analyte	Medium Level Reporting Limit, mg/kg	Low Level Reporting Limit, ug/kg
67-64-1	Acetone	1.0	10
75-05-8	Acetonitrile	10	100
107-02-8	Acrolein	10	100
107-13-1	Acrylonitrile	10	100
0107-05-1	Allyl Chloride (3-Chloroprene)	0.5	5
71-43-2	Benzene	0.5	5
75-27-4	Bromodichloromethane	0.5	5
75-25-2	Bromoform	0.5	5
74-83-9	Bromomethane	1.0	10
78-93-3	2-Butanone (MEK)	1.0	10
75-15-0	Carbon Disulfide	0.5	5
56-23-5	Carbon Tetrachloride	0.5	5
108-90-7	Chlorobenzene	0.5	5
75-00-3	Chloroethane	1.0	10
67-66-3	Chloroform	0.5	5
74-87-3	Chloromethane	1.0	10
0126-99-8	Chloroprene (2-chloro-1,3 butadiene)	0.5	5
124-48-1	Dibromochloromethane	0.5	5
96-12-8	1,2-Dibromo-3-chloropropane (DBCP)	1.0	10
106-93-4	1,2-Dibromoethane (EDB)	1.0	10
74-95-3	Dibromomethane	0.5	5
110-57-6	trans-1,4-Dichloro-2-butene	0.5	5
75-71-8	Dichlorodifluoromethane (Freon 12)	1.0	10
75-34-3	1,1-Dichloroethane	0.5	5
107-06-2	1,2-Dichloroethane	0.5	5
75-35-4	1,1-Dichloroethene (-ethylene)	0.5	5
540-59-0	1,2-Dichloroethene (total)	0.5	5
78-87-5	1,2-Dichloropropane	0.5	5
10061-01-5	cis-1,3-Dichloropropene	0.5	5
10061-02-6	trans-1,3-Dichloropropene	0.5	5
123-91-1	1,4-Dioxane	10	100
100-41-4	Ethyl Benzene	0.5	5
74-88-4	Iodomethane	0.5	5
078-83-1	Isobutanol	10	100
591-78-6	2-Hexanone	1.0	10
126-98-7	Methylacrylonitrile	0.5	5
75-09-2	Methylene Chloride(dichloromethane)	0.5	5
108-10-1	4-Methyl-2-pentanone (MIBK)	1.0	10
107-12-0	Propionitrile (ethyl cyanide)	0.5	5
100-42-5	Styrene	0.5	5

Note: Reporting limits are matrix dependent and are not achievable in all samples.

Table B-3a. Volatile Appendix IX Organics and Reporting Limits: (Continued) API Exploration and Production Study (Solids)

CAS #	Analyte	Medium Level Reporting Limit, mg/kg	Low Level Reporting Limit, ug/kg
630-20-6	1,1,1,2-Tetrachloroethane	0.5	5
79-34-5	1,1,2,2-Tetrachloroethane	0.5	5
127-18-4	Tetrachloroethene	0.5	5
71-55-6	1,1,1-Trichloroethane	0.5	5
79-00-5	1,1,2-Trichloroethane	0.5	5
79-01-6	Trichloroethene	0.5	5
75-69-4	Trichlorofluoromethane (Freon 11)	0.5	5
96-18-4	1,2,3-Trichloropropane	0.5	5
108-88-3	Toluene	0.5	5
108-05-4	Vinyl Acetate	1.0	10
75-01-4	Vinyl Chloride	1.0	10
1330-20-7	Xylenes (total)	0.5	5

Surrogates:

460-00-4	4-Bromofluorobenzene (BFB)
17060-07-0	1,2-Dichloroethane-d4
2037-26-5	Toluene-d8

<vt=5>

Note: Reporting limits are matrix dependent and are not achievable in all samples.

Table B3-b. Volatile Appendix IX Organics and Reporting Limits: API Exploration and Production Study (Aqueous)

CAS #	Analyte	Low Level Reporting Limit, ug/L
67-64-1	Acetone	10
75-05-8	Acetonitrile	100
107-02-8	Acrolein	100
107-13-1	Acrylonitrile	100
0107-05-1	Allyl Chloride (3-Chloroprene)	5
71-43-2	Benzene	5
75-27-4	Bromodichloromethane	5
75-25-2	Bromoform	5
74-83-9	Bromomethane	10
78-93-3	2-Butanone (MEK)	10
75-15-0	Carbon Disulfide	5
56-23-5	Carbon Tetrachloride	5
108-90-7	Chlorobenzene	5
75-00-3	Chloroethane	10
67-66-3	Chloroform	5
74-87-3	Chloromethane	10
0126-99-8	Chloroprene (2-chloro-1,3 butadiene)	5
124-48-1	Dibromochloromethane	5
96-12-8	1,2-Dibromo-3-chloropropane (DBCP)	10
106-93-4	1,2-Dibromoethane (EDB)	10
74-95-3	Dibromomethane	5
110-57-6	trans-1,4-Dichloro-2-butene	5
75-71-8	Dichlorodifluoromethane (Freon 12)	10
75-34-3	1,1-Dichloroethane	5
107-06-2	1,2-Dichloroethane	5
75-35-4	1,1-Dichloroethene (-ethylene)	5
540-59-0	1,2-Dichloroethene (total)	5
78-87-5	1,2-Dichloropropane	5
10061-01-5	cis-1,3-Dichloropropene	5
10061-02-6	trans-1,3-Dichloropropene	5
123-91-1	1,4-Dioxane	100
100-41-4	Ethyl Benzene	5
74-88-4	Iodomethane	5
078-83-1	Isobutanol	100
591-78-6	2-Hexanone	10
126-98-7	Methylacrylonitrile	5
75-09-2	Methylene Chloride(dichloromethane)	5
108-10-1	4-Methyl-2-pentanone (MIBK)	10
107-12-0	Propionitrile (ethyl cyanide)	5
100-42-5	Styrene	5

Note: Reporting limits are matrix dependent and are not achievable in all samples.

Table B-3b. Volatile Appendix IX Organics and Reporting Limits: (Continued) API Exploration and Production Study (Aqueous)

CAS #	Analyte	Low Level Reporting Limit, ug/kg
630-20-6	1,1,1,2-Tetrachloroethane	5
79-34-5	1,1,2,2-Tetrachloroethane	5
127-18-4	Tetrachloroethene	5
71-55-6	1,1,1-Trichloroethane	5
79-00-5	1,1,2-Trichloroethane	5
79-01-6	Trichloroethene	5
75-69-4	Trichlorofluoromethane (Freon 11)	5
96-18-4	1,2,3-Trichloropropane	5
108-88-3	Toluene	5
108-05-4	Vinyl Acetate	10
75-01-4	Vinyl Chloride	10
1330-20-7	Xylenes (total)	5

Surrogates:

460-00-4	4-Bromofluorobenzene (BFB)
17060-07-0	1,2-Dichloroethane-d4
2037-26-5	Toluene-d8

<vt=5>

Note: Reporting limits are matrix dependent and are not achievable in all samples.

Table B-4. Semi-Volatile Organics, Reporting Limits, and Regulatory Limits for Toxicity Characteristic Leaching Procedure: API Exploration and Production Study

CAS #	Analyte	Reporting Limit, mg/L	Regulatory Limit, mg/L
Final TCLP Components (1990 rule):			
106-46-7	1,4-Dichlorobenzene	0.05	7.5
121-14-2	2,4-Dinitrotoluene	0.05	0.13
118-74-1	Hexachlorobenzene	0.05	0.13
87-68-3	Hexachlorobutadiene	0.05	0.5
67-72-1	Hexachloroethane	0.05	3
95-48-7	2-Methylphenol	0.05	200
7820-600	3/4-Methylphenol	0.05	200
98-95-3	Nitrobenzene	0.05	2
87-86-5	Pentachlorophenol	0.25	100
110-86-1	Pyridine	0.1	5
95-95-4	2,4,5-Trichlorophenol	0.25	400
88-06-2	2,4,6-Trichlorophenol	0.05	2
Additional Components*			
111-44-4	bis(2-chloroethyl)ether	0.05	0.65
95-50-1	1,2-Dichlorobenzene	0.05	4.3
108-95-2	Phenol	0.05	14.4
58-90-2	2,3,4,6-Tetrachlorophenol	0.25	1.5

NOTE:

* The additional components are compounds included in the original TCLP list but removed in the final rule. The regulatory limits for these components are from the 1986 proposed rule. Regulatory limits for the final TCLP list are from the 1990 rule.

Table B-5a. Semi-volatile Petroleum Refinery List Organics and Reporting Limits: API Exploration and Production Study (Solids)

CAS#	Analyte	Medium Level Reporting Limit, mg/kg	Low Level Reporting Limit, mg/kg
120-12-7	Anthracene	10	0.33
56-55-3	Benzo(a)anthracene	10	0.33
50-32-8	Benzo(a)pyrene	10	0.33
205-99-2	Benzo(b)fluoranthene	10	0.33
207-08-9	Benzo(k)fluoranthene	10	0.33
85-68-7	Butylbenzylphthalate	10	0.33
218-01-9	Chrysene	10	0.33
84-74-2	Di-n-butylphthalate	10	0.33
117-84-0	Di-n-octylphthalate	10	0.33
53-70-3	Dibenz(a,h)anthracene	10	0.33
95-50-1	1,2-Dichlorobenzene	10	0.33
541-73-1	1,3-Dichlorobenzene	10	0.33
106-46-7	1,4-Dichlorobenzene	10	0.33
84-66-2	Diethylphthalate	10	0.33
57-97-6	7,12-Dimethylbenz(a)anthracene	10	0.33
105-67-9	2,4-Dimethylphenol	10	0.33
131-11-3	Dimethylphthalate	10	0.33
51-28-5	2,4-Dinitrophenol	50	1.67
117-81-7	bis(2-Ethylhexyl)phthalate	10	0.33
206-44-0	Fluoranthene	10	0.33
95-13-6	Indene	10	0.33
90-12-0	1-Methylnaphthalene	10	0.33
95-48-7	2-Methylphenol (o-Cresol)	10	0.33
108-39-4	3-Methylphenol (m-Cresol)*	10	0.33
106-44-5	4-Methylphenol (p-Cresol)*	10	0.33
91-20-3	Naphthalene	10	0.33
100-02-7	4-Nitrophenol	50	1.67
85-01-8	Phenanthrene	10	0.33
108-95-2	Phenol	10	0.33
129-00-0	Pyrene	10	0.33
110-86-1	Pyridine +	--	--
91-22-5	Quinoline	10	0.33
108-98-5	Benzenethiol**	--	--
Surrogates:			
4165-60-0	Nitrobenzene-d5		
321-60-8	2-Fluorobiphenyl		
1718-51-0	Terphenyl-d14		
4165-62-2	Phenol-d5 ++		
367-12-4	2-Fluorophenol		
118-79-6	2,4,6-Tribromophenol		

Note: Reporting limits are matrix dependent and are not achievable in all samples.

++ Phenol-d5 is reported for phenol-d6 as requested in CLP.

* 3-Methyl phenol and 4-methyl phenol cannot be differentiated based on their mass spectra and retention times are almost identical. These components are reported as 3/4-methylphenol.

\+ Pyridine and quinoline not consistently recovered after alumina column cleanup.

** Not consistently recoverable using standard analytical method; and consequently, method detection limits cannot be established and reporting limits are not reliable.

Table B-5b. Semi-volatile Petroleum Refinery List Organics and Reporting Limits: API Exploration and Production Study (Aqueous)

CAS#	Analyte	Reporting Limit, mg/kg
120-12-7	Anthracene	10
56-55-3	Benzo(a)anthracene	10
50-32-8	Benzo(a)pyrene	10
205-99-2	Benzo(b)fluoranthene	10
207-08-9	Benzo(k)fluoranthene	10
85-68-7	Butylbenzylphthalate	10
218-01-9	Chrysene	10
84-74-2	Di-n-butylphthalate	10
117-84-0	Di-n-octylphthalate	10
53-70-3	Dibenz(a,h)anthracene	10
95-50-1	1,2-Dichlorobenzene	10
541-73-1	1,3-Dichlorobenzene	10
106-46-7	1,4-Dichlorobenzene	10
84-66-2	Diethylphthalate	10
57-97-6	7,12-Dimethylbenz(a)anthracene	10
105-67-9	2,4-Dimethylphenol	10
131-11-3	Dimethylphthalate	10
51-28-5	2,4-Dinitrophenol	50
117-81-7	bis(2-Ethylhexyl)phthalate	10
206-44-0	Fluoranthene	10
95-13-6	Indene	10
90-12-0	1-Methylnaphthalene	10
95-48-7	2-Methylphenol (o-Cresol)	10
108-39-4	3-Methylphenol (m-Cresol)*	10
106-44-5	4-Methylphenol (p-Cresol)*	10
91-20-3	Naphthalene	10
100-02-7	4-Nitrophenol	50
85-01-8	Phenanthrene	10
108-95-2	Phenol	10
129-00-0	Pyrene	10
110-86-1	Pyridine	20
91-22-5	Quinoline	10
108-98-5	Benzenethiol**	--
Surrogates:		
4165-60-0	Nitrobenzene-d5	
321-60-8	2-Fluorobiphenyl	
1718-51-0	Terphenyl-d14	
4165-62-2	Phenol-d5 ++	
367-12-4	2-Fluorophenol	
118-79-6	2,4,6-Tribromophenol	

Note: Reporting limits are matrix dependent and are not achievable in all samples.

++ Phenol-d5 is reported for phenol-d6 as requested in CLP.

* 3-Methyl phenol and 4-methyl phenol cannot be differentiated based on their mass spectra and retention times are almost identical. These components are reported as 3/4-methylphenol.

** Not consistently recoverable using standard analytical method; consequently, method detection limits cannot be established and reporting limits are not reliable.

Table B-6. Metals and General Inorganics Methods and Reporting Limits: API Exploration and Production Study

Analyte	Method	Reporting Limit mg/kg
Aluminum	6010 (ICP)	10
Antimony	6010 (ICP)	5
Arsenic	7060 (GFAA)	0.5
Barium	6010 (ICP)	1
Beryllium	6010 (ICP)	0.2
Cadmium	6010 (ICP)	0.5
Calcium	6010 (ICP)	20
Chromium	6010 (ICP)	1
Cobalt	6010 (ICP)	1
Copper	6010 (ICP)	1
Lead	6010 (ICP)	5
Mercury	7470 (CVAA)	0.2
Nickel	6010 (ICP)	5
Potassium	6010 (ICP)	500
Selenium	7740 (GFAA)	0.5
Silver	6010 (ICP)	1
Sodium	6010 (ICP)	500
Thallium	7841 (GFAA)	0.5
Tin	6010 (ICP)	5
Vanadium	6010 (ICP)	1
Zinc	6010 (ICP)	1
Cyanide	9010	0.5
Chloride	300.0	15
Cyanide, Reactive	SW-846, Ch.7	0.1
Sulfide, Reactive	SW-846, Ch. 7	0.1

Note: Reporting limits are matrix dependent and are not achievable in all samples.

Table B-7. TCLP Metals, Methods, Reporting Limits and Regulatory Limits

CAS#	Analyte	Method	Reporting Limit, mg/L	Regulatory Limit, mg/L
7440-38-2	Arsenic	6010 (ICP)	1	5
7440-39-3	Barium	6010 (ICP)	0.1	100
7440-43-9	Cadmium	6010 (ICP)	0.05	1
7440-47-3	Chromium	6010 (ICP)	0.1	5
7439-92-1	Lead	6010 (ICP)	0.5	5
7439-97-6	Mercury	7470 (CVAA)	0.002	0.2
7782-49-2	Selenium	7740 (GFAA)	0.05	1
7440-22-4	Silver	6010 (ICP)	0.1	5

Note: Reporting limits are matrix dependent and are not achievable in all samples.

QUALITY ASSURANCE/QUALITY CONTROL

Laboratory Controls

The laboratory QA/QC program separates the evaluation of daily laboratory performance of a method from the determination of the effect of the sample matrix on the performance of the method. Laboratory performance was judged by the laboratory controls described below and matrix effects were evaluated by Matrix Project Specific QC activities.

Laboratory Performance QC relies on the use of control samples, named Laboratory Control Samples (LCS) and Surrogate Control Samples (SCS), to monitor the day-to-day performance of the laboratory. LCS and SCS, which consist of a standard control matrix spiked with compounds representative of the method analytes, were established for every routine method. At least one control sample was analyzed with every batch of samples and the results of the control samples were compared to established control limits. Data generated with LCS or SCS which were within established control limits are judged to be generated when the laboratory was "in control." Data generated with LCS or SCS which were outside of established control limits are considered suspect due to a possible "out of control" situation in the laboratory, and were repeated or reported with qualifiers. The results of the associated control samples were reported with the analytical data.

All laboratory QC generated for this project was within normal control limits, excluding a few cases where problems were isolated to the control sample.

Project Specific Quality Control

Project specific quality control activities are dependent on the test and the data quality objectives of the project. Project specific activities for this project included trip blanks, surrogate spikes and matrix spikes. Each of the activities are discussed below:

Trip Blank - a sample of analyte-free media taken from the laboratory to the sampling site and returned to the laboratory unopened. A trip blank is used to document contamination attributable to shipping and field handling procedures. This type of blank is useful in documenting contamination of volatile organics samples.

Matrix Spike - A split sample spiked with representative target analyte(s). The spiking occurs prior to sample preparation and analysis. A matrix spike is used to document the bias of a method in a given sample matrix. Matrix spike duplicates are used to document the precision of a method in a given sample matrix.

Surrogate - an organic compound which is similar to the target analyte(s) in chemical composition and behavior in the analytical process, but which is not normally found in environmental samples. Measuring the recovery of the surrogates provides an estimate of the overall efficiency of the method for each sample and matrix type.

In general, trip blanks were free of contaminants; however, some detections for common lab contaminants like acetone and methyl ethyl ketone were observed. Matrix spikes generally produced acceptable recoveries, although some recoveries were elevated due to matrix interference. Surrogate recoveries were also generally acceptable. In some cases, surrogate recoveries were diluted out due to elevated levels of hydrocarbons in the samples. No field blanks or duplicates were collected during this project.

REFERENCES

1. "Test Methods for Evaluating Solid Waste, Physical Chemical Methods," EPA Publication SW-846, 2nd Edition, 1982 as amended by Update I (April 1984) and Update II (April 1985). 3rd Edition, November, 1986. Office of Solid Waste and Emergency Response.

2. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under the Clean Water Act" 40 CFR 136; Federal Register, Vol. 49, No. 209 (1984).

3. "The Modified Oven Drying Technique: A New Method to Determine Oil, Water, and Solids in Oily Waste", Chevron Research Company, 1986.

4. EPA/600/9-87/030, "Availability, Adequacy, and Comparability of Testing Procedures for the Analysis of Pollutants Established Under Section 304 (h) of the Federal Water Pollution Control Act," September, 1988.

5. "Appendix I-Toxicity Characteristic Leaching Procedure (TCLP)" 40 CFR 268, July 1, 1989.

6. "Appendix II-Method 1311 Toxicity Characteristic Leaching Procedure (TCLP)" 40 CFR Part 261 et al.; Federal Register, Vol. 55, No. 61 (March 29, 1990).

7. "Appendix II-Method 1311 Toxicity Characteristic Leaching Procedure (TCLP)" 40 CFR Par 261, 264, 265, 268, 271, and 302; Federal Register; Vol. 55, No. 126 (June 29, 1990).

APPENDIX C

ANALYTICAL RESULTS

API ASSOCIATED WASTE STUDY										TOTAL VOLATILE ORGANICS											PETROLEUM REFINERY LIST TOTAL						
Appendix C Revised 02/22/94																					SEMI-VOLATILE ORGANICS						
API Sample type	Lab ID No.	Matrix	Sample Date		Acetone		MEK		Benzene		Carbon Disulfide		Dichloro Methane		Ethyl Benzene		Toluene		Xylenes		Chrysene		1-Methyl Napthalene		Napthalene		Phenathrene
Amine Solution	006299-0009-SA	Waste	24-Aug-89	<	1	<	1		3.7	<	0.5	<	0.5	<	0.5		1.5	<	0.5	<	0.01	<	0.01	<	0.01	<	0.01
Contaminated Soil	006299-0007-SA	Waste	24-Aug-89	<	2	<	2	<	1	<	1	<	1		10		2.5		150	<	5		21	<	5		10
Contaminated Soil	006344-0003-SA	Waste	30-Aug-89	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	5	<	5	<	6	<	5
Contaminated Soil	007531-0003-SA	Waste	15-Nov-89	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5		0.58	<	100	<	100	<	100	<	100
Contaminated Soil	007862-0004-SA	Waste	14-Dec-89	<	1	<	1		2.8	<	0.5	<	0.5	<	0.5		1.2	<	0.5	<	30		45	<	30	<	30
Contaminated Soil	011425-0002-SA	Waste	18-Sep-90	<	5	<	5	<	2.5	<	2.5	<	2.5	<	2.5	<	2.5	<	2.5								
Contaminated Soil	011425-0008-SA	Waste	19-Sep-90	<	25	<	25	<	12	<	12	<	12		36		43		130								
Contaminated Soil	011686-0004-SA	Waste	03-Oct-90	<	10	<	10	<	5	<	5	<	5	<	5	<	5		20								
Contaminated Soil	012010-0001-SA	Waste	23-Oct-90		68	<	50		41	<	25	<	25		130		120		170								
Contaminated Soil	012010-0004-SA	Waste	23-Oct-90	<	20	<	20	<	10	<	10	<	10	<	10	<	10		12								
Contaminated Soil	012010-0007-SA	Waste	24-Oct-90	<	10	<	10	<	5	<	5	<	5		6.7		8.2		85								
Contaminated Soil	012010-0008-SA	Waste	24-Oct-90	<	50	<	50	<	25	<	25	<	25		47		45		120								
Contaminated Soil	012196-0003 SA	Waste	01-Nov-90	<	5	<	5	<	2.5	<	2.5	<	2.5		3.5		2.8		32								
Contaminated Soil	012196-0004-SA	Waste	01-Nov-90	<	5	<	5		13	<	2.5	<	2.5		43		110		300								
Contaminated Soil	012196-0006-SA	Waste	01-Nov-90	<	5	<	5		8.4	<	2.5	<	2.5		16		49		120								
Contaminated Soil	012430-0003-SA	Waste	15-Nov-90	<	4	<	4	<	2	<	2	<	2	<	2	<	2		9.2								
Contaminated Soil	012430-0004-SA	Waste	15-Nov-90	<	6.7	<	6.7	<	3.4	<	3.4	<	3.4	<	3.4	<	3.4		24								
Contaminated Soil	012671-0003-SA	Waste	30-Nov-90	<	20	<	20	<	10	<	10	<	10		15		11		53								
Contaminated Soil	012671-0004-SA	Waste	01-Dec-90	<	20	<	20		22	<	10	<	10		27		79		110								
Contaminated Soil	012671-0005-SA	Waste	01-Dec-90		260	<	200	<	100	<	100		120	<	100	<	100		200								
Contaminated Soil	012671-0006 SA	Waste	01-Dec-90	<	100	<	100	<	50	<	50	<	50		130		220		340								
Contaminated Soil	012857-0005-SA	Waste	12-Dec-90	<	10	<	10	<	5	<	5	<	5	<	5	<	5		18								
Contaminated Soil	012857-0006-SA	Waste	12-Dec-90	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5								
Contaminated Soil	012857-0007-SA	Waste	12-Dec-90	<	4	<	4	<	2	<	2	<	2	<	2	<	2	<	2								
Contaminated Soil	012857-0008-SA	Waste	13-Dec-90	<	1000	<	1000	<	500	<	500	<	500	<	500	<	500		660								
Contaminated Soil	013201-0003-SA	Waste	17-Jan-91	<	100	<	100		270		54	<	50		930		1200		1100								
Contaminated Soil	013384-0002-SA	Waste	29-Jan-91		18a	<	10a	<	5	<	5	<	5	<	5	<	5		6.2								
Contaminated Soil	013384-0003 SA	Waste	29-Jan-91		3a	<	2a	<	1	<	1	<	1	<	1	<	1		1.5								
Contaminated Soil	013384-0004-SA	Waste	29-Jan-91		14a	<	10a	<	5	<	5	<	5	<	5	<	5		6.5								
Contaminated Soil	013384-0005-SA	Waste	29-Jan-91		55a	<	40a	<	20	<	20	<	20		22		58		200								
Contaminated Soil	013384-0010-SA	Waste	30-Jan-91		38a	<	30a	<	15	<	15	<	15		160		84		180								
Contaminated Soil	013654-0001-SA	Waste	21-Feb-91	<	40a	<	40a	<	20	<	20	<	20		110		54		150								
Contaminated Soil	013654-0002-SA	Waste	21-Feb-91	<	100a	<	100a	<	50	<	50	<	50		60		280		680								
Dehy Condensate Water	011686-0006-SA	Aqueous	03-Oct-90	<	10	<	10		49	<	5	<	5	<	5		96		20								
Dehy Condensate Water	011772-0003 SA	Aqueous	09-Oct-90	<	50	<	50		630	<	25	<	25	<	25		170		32								
Dehy Condensate Water	012641-0001-SA	Aqueous	27-Nov-90		2.5	<	2		26	<	1	<	1		2.5		24		18								
Oil Mud Cuttings	006299-0002-SA	Soil	24-Aug-89	<	20	<	20	<	10	<	10	<	10		18	<	10		47	<	85		650		230		230
Oil Mud Cuttings	007915-0001-SA	Waste	19-Dec-89	<	5	<	5	<	2.5	<	2.5	<	2.5		6.2		3.2		27	<	180		500		180		180
Oil Mud Cuttings	007915-0002 SA	Waste	19-Dec-89	<	5	<	5	<	2.5	<	2.5	<	2.5		9.5		3.7		44	<	390		910	<	390	<	390
Oil Mud Cuttings	011425-0009-SA	Waste	20-Sep-90	<	500	<	500	<	250	<	250		250	<	250	<	250	<	250								
Oil Mud Cuttings	011772-0005 SA	Waste	09-Oct-90	<	200	<	200	<	100	<	100	<	100	<	100	<	100	<	100								
Pigging Waste	012641-0003-SA	Aqueous	28-Nov-90		2.4	<	0.5		8.3	<	0.25		0.25	<	0.25		3.5		0.6								
Pigging Waste	012798-0001-SA	Aqueous	11-Dec-90	<	67	<	67		150	<	34		34	<	34		400		170								
Pigging Waste	013200-0001-SA	Waste	17-Jan-91		700a	<	500	<	250	<	250	<	250		560		1200		2200								
Pigging Waste	013200-0002 SA	Waste	17-Jan-91		0.16a	<	0.06		0.51	<	0.03	<	0.03		0.076		0.59		0.28								
Pigging Waste	013828-0001-SA	Waste	01-Mar-91	<	2000a	<	2000		3500	<	1000	<	1000		3900		19000		18000								
Pit and Sump Waste	006299-0005-SA	Waste	24-Aug-89	<	10	<	10		13	<	5		5		88		11		26	<	40	<	40	<	40		71
Pit and Sump Waste	007862-0003-SA	Waste	14-Dec-89	<	1	<	1	<	0.5	<	0.5		0.5	<	0.5	<	0.5	<	0.5		16	<	15	<	15	<	15
Pit and Sump Waste	011686-0003-SA	Waste	03-Oct-90	<	1000	<	1000		1200	<	500		500		1900		6600		12000								
Pit and Sump Waste	012010-0006-SA	Waste	23-Oct-90		53	<	50	<	25	<	25		25		220		150		250								
Produced Sand	007314-0003 SA	Waste	31-Oct-89	<	20	<	20		20	<	10	<	10		17		93		130	<	28	<	28	<	28	<	28
Rig Wash	011425-0010-SA	Waste	20-Sep-90		1.4	<	0.02	<	0.01	<	0.01	<	0.01	<	0.01		0.016		0.06								
Rig Wash	012010-0005-SA	Aqueous	23-Oct-90		0.22		0.064		0.045	<	0.005		0.005		0.03		0.054		0.03								
Rig Wash	013200-0003-SA	Aqueous	18-Jan-91		0.041a		0.071	<	0.005	<	0.005	<	0.005		0.0074	<	0.005		0.034								
Rig Wash	013200-0004-SA	Aqueous	18-Jan-91		0.059a	<	0.005		0.032	<	0.005	<	0.005		0.0074		0.066		0.048								
Rig Wash	013200-0005-SA	Waste	18-Jan-91	<	2.5	<	2.5	<	1.2	<	1.2	<	1.2	<	1.2		3.2		6.4								
Spent Iron Sponge	012010-0009-SA	Waste	25-Oct-90		5.6	<	2	<	1	<	1		1	<	1	<	1	<	1								
Spent Iron Sponge	013143-0001-SA	Waste	16-Jan-90	<	2a	<	2a		16	<	1	<	1		1.7		25		4.6								
Spent Mol Sieve	011212-0001-SA	Solid	04-Sep-90	<	1	<	1	<	0.5	<	0.5		0.5	<	0.5		0.72		1.8								
Spent Mol Sieve	011212-0002-SA	Solid	04-Sep-90		80		2.5	<	0.5	<	0.5		0.5	<	0.5	<	0.5	<	0.5								
Spent Mol Sieve	013143-0002-SA	Waste	16-Jan-90	<	6.7a	<	6.7a		40	<	3.3	<	3.3		14		130		94								
Tank Bottoms	006299-0001-SA	Waste	24-Aug-89	<	100	<	100		280	<	50	<	50		240		470		570	<	40		180		110		42
Tank Bottoms	006299-0003-SA	Waste	24-Aug-89	<	200	<	200		270	<	100	<	100		600		630		790	<	40		110		83	<	40
Tank Bottoms	006299-0004-SA	Waste	24-Aug-89	<	200	<	200		110	<	100	<	100		510		520		710	<	13		59		47		14
Tank Bottoms	006344-0001-SA	Waste	30-Aug-89	<	20	<	20		67	<	10	<	10		67		210		320	<	30		170		78	<	30
Tank Bottoms	006344-0002-SA	Waste	30-Aug-89	<	20	<	20		180	<	10	<	10		220		630		610	<	40		140		40	<	40
Tank Bottoms	007314-0004-SA	Waste	31-Oct-89	<	100	<	100		100	<	50	<	50		94		350		460	<	37		240		270	<	37

API ASSOCIATED WASTE STUDY

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					TOTAL VOLATILE ORGANICS																PETROLEUM REFINERY LIST TOTAL SEMI-VOLATILE ORGANICS						
API Sample Type	Lab ID No.	Matrix	Sample Date		Acetone		MEK		Benzene		Carbon Disulfide		Dichloro Methane		Ethyl Benzene		Toluene		Xylenes		Chrysene		1-Methyl Napthalene		Napthalene		Phenanthrene
Tank Bottoms	007531-0002-SA	Waste	15-Nov-89	<	1000	<	1000	<	500i	<	500	<	500	<	500		1500		2100	<	200	<	200	<	200	<	200
Tank Bottoms	007531-0004-SA	Waste	15-Nov-89	<	200	<	200		290i	<	100	<	100		110		810		1200	<	70	<	70	<	70	<	70
Tank Bottoms	007862-0001-SA	Waste	14-Dec-89	<	2	<	2		6.3	<	1	<	1		13	<	1		11	<	20	<	20	<	20		21
Tank Bottoms	007862-0005-SA	Waste	14-Dec-89	<	1	<	1	<	0.5	<	0.5	<	0.5		0.91		0.68		8.8	<	40	<	40	<	40		49
Tank Bottoms	011425-0001-SA	Waste	18-Sep-90	<	500	<	500		360	<	250	<	250		490		2400		4300								
Tank Bottoms	011425-0003-SA	Waste	18-Sep-90	<	5000	<	5000		5500	<	2500	<	2500		7400		32000		62000								
Tank Bottoms	011425-0004-SA	Waste	19-Sep-90	<	50	<	50	<	25	<	25	<	25	<	25		35		88								
Tank Bottoms	011425-0005-SA	Waste	19-Sep-90	<	100	<	100	<	50	<	50	<	50		260		490		1200								
Tank Bottoms	011425-0007-SA	Waste	19-Sep-90	<	250	<	250		140	<	120	<	120		320		690		1000								
Tank Bottoms	011686-0001-SA	Waste	03-Oct-90	<	330	<	330		720	<	160	<	160		620		2900		310								
Tank Bottoms	011772-0001-SA	Waste	09-Oct-90	<	100	<	100		1200	<	50	<	50		350		1500		1600								
Tank Bottoms	012010-0003-SA	Waste	23-Oct-90		60	<	50		190	<	25	<	25		270		200		280								
Used Glycol	006299-0008-SA	Waste	24-Aug-89	<	100	<	100		590	<	50	<	50		140		620		160	<	100	<	100	<	100	<	100
Used Glycol	006344-0005-SA	Waste	30-Aug-89		4	<	1		4.5	<	0.5	<	0.5		1.7		8.9		4.4	<	10	<	10	<	10	<	10
Used Glycol	007314-0002-SA	Waste	31-Oct-89	<	1	<	1		12	<	0.5	<	0.5		7.4		39		47	<	50	<	50	<	50	<	50
Used Glycol	007862-0006-SA	Waste	14-Dec-89	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	10	<	10	<	10	<	10
Used Glycol	011425-0012-SA	Waste	20-Sep-90	<	20	<	20		17	<	10	<	10		14		100		130								
Used Glycol	011686-0007-SA	Waste	03-Oct-90	<	170	<	170		300	<	85	<	85		100		1300		820								
Used Glycol	011772-0004-SA	Aqueous	09-Oct-90	<	330	<	330		6700	<	160	<	160		470		4000		2000								
Used Glycol	012641-0002-SA	Aqueous	27-Nov-90	<	2	<	2		9.2	<	1	<	1		5.7		23		38								
Used Oil	006299-0006-SA	Waste	24-Aug-89	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	40	<	40	<	40		57
Used Oil	006299-0010-SA	Waste	24-Aug-89	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	40	<	40	<	40	<	40
Used Oil	006344-0004-SA	Waste	30-Aug-89	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	200	<	200	<	200	<	200
Used Oil	007314-0001-SA	Waste	31-Oct-89	<	1	<	1		1.6	<	0.5		0.56		0.58		4.5		3.5	<	50	<	50	<	50	<	50
Used Oil	007531-0001-SA	Waste	15-Nov-89	<	100	<	100		120	<	50	<	50	<	50		240		310	<	40	<	40	<	40	<	40
Used Oil	007862-0002-SA	Waste	14-Dec-89	<	1	<	1		1.4	<	0.5	<	0.5	<	0.5		2.6		1.7	<	50	<	50	<	50	<	50
Used Oil	011425-0006-SA	Waste	19-Sep-90	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5								
Used Oil	011425-0011-SA	Waste	20-Sep-90	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5	<	0.5								
Used Oil	011686-0002-SA	Waste	03-Oct-90	<	1	<	1	<	0.5	<	0.5	<	0.5	<	0.5	<	0.6	<	0.5								
Used Oil	011772-0002-SA	Waste	09-Oct-90	<	1	<	1		4.9	<	0.5	<	0.5	<	0.5		3.6		1.9								
Used Oil	012196-0007-SA	Waste	02-Nov-90		3	<	2		20	<	1	<	1		1		11		7.5								
Used Oil	012196-0008-SA	Waste	02-Nov-90	<	0.5	<	0.5		3.6	<	0.25	<	0.25	<	0.25		2.1		1.6								
Workover Fluids	012010-0002-SA	Aqueous	23-Oct-90		3	<	1		13	<	0.5	<	0.5		2		6.1		2.5								
Workover Fluids	012196-0001-SA	Waste	31-Oct-90	<	250	<	250		540	<	130	<	12000		500		1900		2600								
Workover Fluids	012196-0002-SA	Aqueous	31-Oct-90		0.7	<	0.5		0.99	<	0.25	<	0.25	<	0.25		1.1		0.3								
Workover Fluids	012196-0005-SA	Waste	01-Nov-90	<	0.01	<	0.01		0.01	<	0.005	<	0.005	<	0.005		0.015		0.013								
Workover Fluids	012228-0001-SA	Aqueous	05-Nov-90		0.25	<	0.06		0.18	<	0.025	<	0.025		0.041		0.32		0.35								
Workover Fluids	012430-0001-SA	Aqueous	14-Nov-90		5.2	<	0.5		7.6	<	0.25	<	0.25		0.64		7.4		5.0								
Workover Fluids	012671-0001-SA	Aqueous	29-Nov-90		1.1	<	0.42		1.4	<	0.21	<	0.21		0.4		2.7		1.8								
Workover Fluids	012671-0002-SA	Aqueous	30-Nov-90		0.66	<	0.42		0.76	<	0.21	<	0.21		0.4		1.6		1.4								
Workover Fluids	012671-0007-SA	Aqueous	01-Dec-90	<	10	<	10		6.4	<	5	<	5		51		36		340								
Workover Fluids	012857-0001-SA	Aqueous	12-Dec-90		0.69	<	0.06		0.53	<	0.025	<	0.025		0.032		0.41		0.2								
Workover Fluids	012857-0002-SA	Aqueous	13-Dec-90	<	2	<	2		2.1	<	1	<	1		2.0		7.8		14								
Workover Fluids	012857-0003-SA	Aqueous	13-Dec-90		0.96	<	0.1		0.84	<	0.05	<	0.05	<	0.05		0.75		0.36								
Workover Fluids	013201-0001-SA	Waste	21-Jan-91	<	20	<	20	<	10	<	10	<	10		24		54		18								
Workover Fluids	013201-0002-SA	Waste	21-Jan-91	<	1	<	1		7.4	<	0.5	<	0.5		1.4		9.6		5.4								
Workover Fluids	013384-0001-SA	Waste	29-Jan-91		1.8a	<	0.1a	<	0.06	<	0.06	<	0.06	<	0.05		0.085		0.12								
Workover Fluids	013384-0006-SA	Waste	29-Jan-91		1.7a	<	1a	<	0.5	<	0.5	<	0.5		0.58		1.1		3.3								
Workover Fluids	013384-0009-SA	Waste	30-Jan-91		3.5a	<	2.5a		1.5		5.2	<	1.2		19	<	1.2		58								
Workover Fluids	013384-0011-SA	Waste	31-Jan-91		3.3a	<	2.5a	<	1.2	<	1.2	<	1.2	<	1.2	<	1.2		1.2								
Workover Fluids	013654-0003-SA	Waste	19-Feb-91		2.8a	<	1a		6	<	0.5	<	0.5		1.4		6.2		2.1								
Workover Fluids	013654-0004-SA	Aqueous	19-Feb-91		0.61a	<	0.5a		3.9	<	0.25	<	0.25		1.2		3.3		1.5								
Workover Fluids	014299-0001-SA	Waste	01-Apr-91		0.5		0.18		1.1	<	0.05	<	0.05		0.1		0.81		0.92								

a= Analyte present in method or field blank, results qualitative

i= Analyte is present in TCLP method or equipment blank, results qualitative

l= Hold time exceeded, results qualitative

j= Surrogates 0% - delivered out, results qualitative

m= Reporting Limit exceeds or equals TCLP Regulatory Limit due to matrix interference

API ASSOCIATED WASTE STUDY						GENERAL INORGANICS										
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API Sample Type	Lab ID No.	Matrix	Sample Date		Cyanide Reactive	Ignitability	Volatile Oil		Volatile Oil	% Oil	% Water	% Solids	pH		Sulfide Reactive	Sample Chloride
Amine Solution	006299-0009-SA	Waste	24-Aug-89	<	0.1								9.2		4.4	
Contaminated Soil	006299-0007-SA	Waste	24-Aug-89	<	0.1	>160	11.4	<	0.1	11.4	3.9	84.7	7.5	<	0.5	
Contaminated Soil	006344-0003-SA	Waste	30-Aug-89	<	0.1	>160	15.8		0.1	15.9	3.2	82.6	8.5	<	0.50	
Contaminated Soil	007531-0003-SA	Waste	15-Nov-89	<	0.1	>160	27.1	<	0.1	27.1	11.4	61.4	7.2	<	0.50	
Contaminated Soil	007862-0004-SA	Waste	14-Dec-89	<	0.1	>160	28.4	<	0.1	28.4	3.8	69.3	7.4		23	
Contaminated Soil	011425-0002-SA	Waste	18-Sep-90	<	0.1	>160	12.9		3.0	15.9	5.4	78.7	8.8	<	0.50	
Contaminated Soil	011425-0008-SA	Waste	19-Sep-90	<	0.1	>160	19.5		4.5	24.0	8.0	68.0	7.4	<	0.50	
Contaminated Soil	011686-0004-SA	Waste	03-Oct-90	<	0.1	>160	2.0	<	0.3	2.0	14.2	83.8	7.0	<	0.50	
Contaminated Soil	012010-0001-SA	Waste	23-Oct-90	<	0.1	>160	10.8		4.5	15.3	9.7	75.0	6.4	<	0.50	
Contaminated Soil	012010-0004-SA	Waste	23-Oct-90	<	0.1	>160	15.3		4.5	19.8	6.6	73.6	7.1	<	0.50	
Contaminated Soil	012010-0007-SA	Waste	24-Oct-90	<	0.1	>160	1.7		6.0	7.7	8.3	84.0	7.4	<	0.50	
Contaminated Soil	012010-0008-SA	Waste	24-Oct-90	<	0.1	>160	11.8		2.2	14.0	20.4	65.6	7.2	<	0.50	
Contaminated Soil	012196-0003-SA	Waste	01-Nov-90	<	0.5	>200	28.2		4.5	32.7	5.7	61.6	5.7	<	1.0	
Contaminated Soil	012196-0004-SA	Waste	01-Nov-90	<	0.5	80	7.5		12.0	19.5	9.3	71.2	5.5	<	1.0	
Contaminated Soil	012196-0006-SA	Waste	01-Nov-90	<	0.5	103	16.4		1.5	17.9	22.5	59.8	6.2	<	1.0	
Contaminated Soil	012430-0003-SA	Waste	15-Nov-90	<	0.1	>160							4.1	<	0.50	
Contaminated Soil	012430-0004-SA	Waste	15-Nov-90	<	0.1	>160							5.0	<	0.50	
Contaminated Soil	012671-0003-SA	Waste	30-Nov-90	<	0.1	90	10.1		0.8	10.8	10.1	79.1	7.7	<	0.50	
Contaminated Soil	012671-0004-SA	Waste	01-Dec-90	<	0.1	>160	6.8		3.0	9.8	15.0	75.2	7.4		1.0	
Contaminated Soil	012671-0005-SA	Waste	01-Dec-90		0.37	>160	4.2		6.0	10.2	14.0	75.9	7.2		1.2	
Contaminated Soil	012671-0006-SA	Waste	01-Dec-90	<	0.1	>160	5.7		3.0	8.7	12.7	78.6	7.4	<	0.50	
Contaminated Soil	012857-0005-SA	Waste	12-Dec-90	<	0.1	>160	19.3		6.0	25.3	1.5	73.2	7.6	<	0.50	
Contaminated Soil	012857-0006-SA	Waste	12-Dec-90	<	0.1	>160	3.5		1.5	5.0	17.9	77.1	7.3	<	0.50	
Contaminated Soil	012857-0007-SA	Waste	12-Dec-90	<	0.1	>160	7.6		0.8	8.3	9.8	81.9	7.6	<	0.50	
Contaminated Soil	012857-0008-SA	Waste	13-Dec-90	<	0.1	>160	7.1		3.0	10.1	14.8	75.1	6.8	<	0.50	
Contaminated Soil	013201-0003-SA	Waste	17-Jan-91	<	0.1	100							7.1	<	0.50	
Contaminated Soil	013384-0002-SA	Waste	29-Jan-91	<	0.1	>160	10.6		3.0	13.6	8.5	77.9	7.7	<	0.50	
Contaminated Soil	013384-0003-SA	Waste	29-Jan-91	<	0.1	>160	16.7		3.0	19.7	8.6	71.7	7.8	<	0.50	
Contaminated Soil	013384-0004-SA	Waste	29-Jan-91	<	0.1	>160	49.6		6.0	55.6	15.4	29.0	7.3		0.79	
Contaminated Soil	013384-0005-SA	Waste	29-Jan-91	<	0.1	>160	8.7		0.8	9.5	19.2	71.4	7.7	<	0.50	
Contaminated Soil	013384-0010-SA	Waste	30-Jan-91	<	0.1	106	10.6		7.5	18.1	8.5	73.4	7.8	<	0.50	
Contaminated Soil	013654-0001-SA	Waste	21-Feb-91	<	0.1	160	3.3		9.0	12.3	21.9	65.8	8.1	<	0.50	
Contaminated Soil	013654-0002-SA	Waste	21-Feb-91	<	0.1	97	6.3		6.0	12.3	25.4	62.3	6.8	<	0.50	
Dehy Condensate Water	011686-0006-SA	Aqueous	03-Oct-90	<	0.1	>160							6.0	<	0.50	
Dehy Condensate Water	011772-0003-SA	Aqueous	09-Oct-90	<	0.1	156							5.6	<	0.50	
Dehy Condensate Water	012641-0001-SA	Aqueous	27-Nov-90	<	0.1	151							8.8		108	
Oil Mud Cuttings	006299-0002-SA	Soil	24-Aug-89	<	0.1	>160	17.5		4.1	21.6	10.9	69.3	10.7	<	0.5	3640
Oil Mud Cuttings	007915-0001-SA	Waste	19-Dec-89	<	0.1	>160	19.2		5.0	24.2	8.1	67.0	9.9	<	0.50	18600
Oil Mud Cuttings	007915-0002-SA	Waste	19-Dec-89	<	0.1		28.7		6.0	34.7	8.2	57.2	RNR	<	0.50	29200
Oil Mud Cuttings	011425-0009-SA	Waste	20-Sep-90	<	0.1	>160	1.4		13.5	14.9	6.8	78.3	10.7		5.60	
Oil Mud Cuttings	011772-0005-SA	Waste	09-Oct-90	<	0.1	>160	3.8		6.0	9.8	1.9	88.3	10.7	<	0.50	
Pigging Waste	012641-0003-SA	Aqueous	28-Nov-90	<	0.1	>160							6.6	<	0.50	
Pigging Waste	012798-0001-SA	Aqueous	11-Dec-90	<	0.1	126							6.8	<	0.50	
Pigging Waste	013200-0001-SA	Waste	17-Jan-91	<	0.1	73	12.4		18.0	30.4	11.5	58.1	7.7		7.0	
Pigging Waste	013200-0002-SA	Waste	17-Jan-91	<	0.1	>160							6.9		1.2	
Pigging Waste	013828-0001-SA	Waste	01-Mar-91	<	0.1	>160							3.2		5.3	
Pit and Sump Waste	006299-0005-SA	Waste	24-Aug-89	<	0.1	>160	68.2		0.1	68.3	22.5	8.7	7.1		1.2	
Pit and Sump Waste	007862-0003-SA	Waste	14-Dec-89	<	0.1	153	11.5	<	0.1	11.5	45.7	44.8	9.6		3.4	10500
Pit and Sump Waste	011686-0003-SA	Waste	03-Oct-90	<	0.1	>160							4.6	<	0.50	
Pit and Sump Waste	012010-0006-SA	Waste	23-Oct-90	<	0.1	>160							7.4	<	0.50	
Produced Sand	007314-0003-SA	Waste	31-Oct-89	<	0.1	>160	3.3	<	0.1	3.3	18.1	78.6	5.0	<	0.50	13600
Rig Wash	011425-0010-SA	Waste	20-Sep-90	<	0.1	>160							7.7	<	0.50	
Rig Wash	012010-0005-SA	Aqueous	23-Oct-90	<	0.1	>160							7.6	<	0.50	
Rig Wash	013200-0003-SA	Aqueous	18-Jan-91	<	0.1	63							6.8		6.2	
Rig Wash	013200-0004-SA	Aqueous	18-Jan-91		0.27	>160							9.0		1.8	
Rig Wash	013200-0005-SA	Waste	18-Jan-91	<	0.1	>160	0.3		0.8	1.0	44.2	54.8	11.8	<	0.50	
Spent Iron Sponge	012010-0009-SA	Waste	25-Oct-90	<	0.1	>160	3.0		3.0	6.0	28.3	65.7	7.5	<	0.50	
Spent Iron Sponge	013143-0001-SA	Waste	15-Jan-90	<	0.1	>160							8.4		230	
Spent Mol Sieve	011212-0001-SA	Solid	04-Sep-90	<	0.1	>160					13.6	86.4	9.2	<	0.50	
Spent Mol Sieve	011212-0002-SA	Solid	04-Sep-90	<	0.1	>160					12.0	88.0	7.8		0.55	
Spent Mol Sieve	013143-0002-SA	Waste	16-Jan-90	<	0.1	142							8.2	<	0.50	
Tank Bottoms	006299-0001-SA	Waste	24-Aug-89	<	0.1	72	27		8.3	35.3	48.1	18	8		1.2	6590
Tank Bottoms	006299-0003-SA	Waste	24-Aug-89	<	0.1	68	22.1		4.1	26.2	33	45.7	8.3		34	8510
Tank Bottoms	006299-0004-SA	Waste	24-Aug-89	<	0.1	127	19.7		0.5	20.2	25.9	54.8	8.4		50	25100
Tank Bottoms	006344-0001-SA	Waste	30-Aug-89	<	0.1	55	16.8		2.3	19.1	71.1	9.0	6.9		1.90	21600
Tank Bottoms	006344-0002-SA	Waste	30-Aug-89	<	0.1	66	17.7		1.5	19.2	71.4	10.8	6.9	<	0.50	14900
Tank Bottoms	007314-0004-SA	Waste	31-Oct-89	<	0.1	82	19.6		0.5	20.1	20.8	57.6	8.6	<	0.50	8500

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GENERAL INORGANICS

API Sample Type	Lab ID No.	Matrix	Sample Date		Cyanide Reactive	Ignitability		Volatile Oil		Volatile Oil		% Oil		% Water	% Solids	pH		Sulfide Reactive	Sample Chloride
Tank Bottoms	007531-0002-SA	Waste	15-Nov-89	<	0.1	66		24.1		7.9		32.0		42.9	24.9	7.3	<	0.50	8080
Tank Bottoms	007531-0004-SA	Waste	15-Nov-89	<	0.1	66		27.2		8.8		36.0		20.3	40.1	7.2		0.70	10900
Tank Bottoms	007862-0001-SA	Waste	14-Dec-89	<	0.1	>160		34.1	<	0.1		34.1		29.2	37.7	8.3	<	0.50	350
Tank Bottoms	007862-0005-SA	Waste	14-Dec-89	<	0.1	>160		38.7	<	0.1		38.7		42.5	18.8	7.6		10	1240
Tank Bottoms	011425-0001-SA	Waste	18-Sep-90	<	0.1	79		29.0		63.0		92.0		4.8	3.2	6.7	<	0.50	
Tank Bottoms	011425-0003-SA	Waste	18-Sep-90	<	0.1	64		22.5		36.0		58.5		33.7	7.8	8.4		0.63	
Tank Bottoms	011425-0004-SA	Waste	19-Sep-90	<	0.1	>160		21.3		18.0		39.3		45.5	15.2	7.8	<	0.50	
Tank Bottoms	011425-0005-SA	Waste	19-Sep-90	<	0.1	81		15.2		13.5		28.7		45.9	25.4	6.1	<	0.50	
Tank Bottoms	011425-0007-SA	Waste	19-Sep-90	<	0.1	77		58.2		13.5		71.7		14.4	13.9	8.9	<	0.50	
Tank Bottoms	011686-0001-SA	Waste	03-Oct-90	<	0.1	102		6.2		22.5		28.7		37.7	33.6	6.3	<	0.50	
Tank Bottoms	011772-0001-SA	Waste	09-Oct-90	<	0.1	66		2.5		18.0		20.5		73.7	5.8	6.4		5.50	
Tank Bottoms	012010-0003-SA	Waste	23-Oct-90	<	0.1	126		4.0		2.2		6.2		45.8	48.0	8.2		35.6	
Used Glycol	006299-0008-SA	Waste	24-Aug-89	<	0.1											9.9	<	0.5	
Used Glycol	006344-0005-SA	Waste	30-Aug-89	<	0.1											8.9	<	0.50	
Used Glycol	007314-0002-SA	Waste	31-Oct-89	<	0.1											7.7	<	0.50	
Used Glycol	007862-0006-SA	Waste	14-Dec-89	<	0.1											9.0	<	0.50	
Used Glycol	011425-0012-SA	Waste	20-Sep-90		0.76	>160										8.5	<	0.50	
Used Glycol	011686-0007-SA	Waste	03-Oct-90	<	0.1	>160										4.2	<	0.50	
Used Glycol	011772-0004-SA	Aqueous	09-Oct-90	<	0.1	124										8.1	<	0.50	
Used Glycol	012641-0002-SA	Aqueous	27-Nov-90	<	0.1	>160										11.8	<	0.50	
Used Oil	006299-0006-SA	Waste	24-Aug-89	<	0.1	154										7.1	<	0.5	
Used Oil	006299-0010-SA	Waste	24-Aug-89	<	0.1	>160										9.3	<	0.5	
Used Oil	006344-0004-SA	Waste	30-Aug-89	<	0.1	>160										7.2		1.5	
Used Oil	007314-0001-SA	Waste	31-Oct-89	<	0.1	>160										7.8	<	0.50	
Used Oil	007531-0001-SA	Waste	15-Nov-89	<	0.1	72										9.2	<	0.50	
Used Oil	007862-0002-SA	Waste	14-Dec-89		1.6	>160										8.4		12	
Used Oil	011425-0006-SA	Waste	19-Sep-90	<	0.1	>160										7.8	<	0.50	
Used Oil	011425-0011-SA	Waste	20-Sep-90	<	0.1	>160										9.1		2.10	
Used Oil	011686-0002-SA	Waste	03-Oct-90	<	0.1	>160										6.0	<	0.50	
Used Oil	011772-0002-SA	Waste	09-Oct-90	<	0.1	>160										6.6	<	0.50	
Used Oil	012196-0007-SA	Waste	02-Nov-90	<	0.5	>200		98.2	<	0.9		98.2		1.8	0.5	5.8	<	1	
Used Oil	012196-0008-SA	Waste	02-Nov-90	<	0.5	>200		100.0	<	0.9		100.0	<	0.9	0.4	4.2	<	1	
Workover Fluids	012010-0002-SA	Aqueous	23-Oct-90	<	0.1	>160										7.3		358	
Workover Fluids	012196-0001-SA	Waste	31-Oct-90	<	0.5	100										6.7	<	1	
Workover Fluids	012196-0002-SA	Aqueous	31-Oct-90	<	0.01	>200										6.4		0.12	
Workover Fluids	012196-0005-SA	Waste	01-Nov-90	<	0.01	120										6.4	<	0.1	
Workover Fluids	012228-0001-SA	Aqueous	05-Nov-90	<	0.1	>160										6.3	<	0.50	
Workover Fluids	012430-0001-SA	Aqueous	14-Nov-90	<	0.1	75										6.0	<	0.50	
Workover Fluids	012671-0001-SA	Aqueous	29-Nov-90	<	0.1	>160										2.2	<	0.50	
Workover Fluids	012671-0002-SA	Aqueous	30-Nov-90	<	0.1	>160										0.058	<	0.50	
Workover Fluids	012671-0007-SA	Aqueous	01-Dec-90	<	0.1	81										4.1	<	0.50	
Workover Fluids	012857-0001-SA	Aqueous	12-Dec-90	<	0.1	>160										6.3	<	0.50	
Workover Fluids	012857-0002-SA	Aqueous	13-Dec-90	<	0.1	>160										7.8	<	0.5	
Workover Fluids	012857-0003-SA	Aqueous	13-Dec-90	<	0.1	>160										7.5	<	0.50	
Workover Fluids	013201-0001-SA	Waste	21-Jan-91	<	0.1	90		16.8		36.0		52.8		42.7	4.5	5.0	<	0.5	
Workover Fluids	013201-0002-SA	Waste	21-Jan-91	<	0.1	75		3.7		2.2		6.0		86.4	7.7	6.5	<	0.5	
Workover Fluids	013384-0001-SA	Waste	29-Jan-91	<	0.1	>160										7.0		0.56	
Workover Fluids	013384-0006-SA	Waste	29-Jan-91	<	0.1	>160										6.6	<	0.5	
Workover Fluids	013384-0009-SA	Waste	30-Jan-91		0.8	>160										2.6		96.1	
Workover Fluids	013384-0011-SA	Waste	31-Jan-91		0.51	>160										0.9		1.8	
Workover Fluids	013654-0003-SA	Waste	19-Feb-91	<	0.1	126										3.1	<	0.5	
Workover Fluids	013654-0004-SA	Aqueous	19-Feb-91	<	0.1	>160										6.8		70.4	
Workover Fluids	014299-0001-SA	Waste	01-Apr-91	<	0.1	>160	<	0.1	<	0.9	<	0.9		96.0	4.0	7.7	<	0.5	

a= Analyte present in method or field blank, results qualitative

f= Analyte is present in TCLP method or equipment blank, results qualitative

i= Hold time exceeded, results qualitative

j= Surrogates 0% - diluted out, results qualitative

m= Reporting Limit exceeds or equals TCLP Regulatory Limit due to matrix interference

API ASSOCIATED WASTE STUDY

Appendix C Revised 02/22/94

							TOTAL	METALS						
API Sample Type	**Lab ID No.**	**Matrix**	**Sample Date**	**Al**	**Sb**	**As**	**Ba**	**Be**	**Cd**	**Ca**	**Cr**	**Co**	**Cu**	**Pb**
Amine Solution	006299-0009-SA	Waste	24-Aug-89	< 10	< 5	< 5	2	< 0.2	< 0.5	< 30	< 1	< 1	< 1	< 5
Contaminated Soil	006299-0007-SA	Waste	24-Aug-89	1100	< 5	< 0.5	26	< 0.2	0.5	1300	2	< 1	4	7
Contaminated Soil	006344-0003-SA	Waste	30-Aug-89	480	< 50	< 0.8	12	< 2	< 5	273000	< 10	< 10	< 10	< 50
Contaminated Soil	007531-0003-SA	Waste	15-Nov-89	5400	< 5	4.2	160	0.4	2	750	11	6	16	81
Contaminated Soil	007862-0004-SA	Waste	14-Dec-89	1800	< 10	140	940	0.6	3	86700	8	< 2	23	26
Contaminated Soil	011425-0002-SA	Waste	18-Sep-90											
Contaminated Soil	011425-0008-SA	Waste	19-Sep-90											
Contaminated Soil	011686-0004-SA	Waste	03-Oct-90											
Contaminated Soil	012010-0001-SA	Waste	23-Oct-90											
Contaminated Soil	012010-0004-SA	Waste	23-Oct-90											
Contaminated Soil	012010-0007-SA	Waste	24-Oct-90											
Contaminated Soil	012010-0008-SA	Waste	24-Oct-90											
Contaminated Soil	012196-0003-SA	Waste	01-Nov-90											
Contaminated Soil	012196-0004-SA	Waste	01-Nov-90											
Contaminated Soil	012196-0006-SA	Waste	01-Nov-90											
Contaminated Soil	012430-0003-SA	Waste	15-Nov-90											
Contaminated Soil	012430-0004-SA	Waste	15-Nov-90											
Contaminated Soil	012671-0003-SA	Waste	30-Nov-90											
Contaminated Soil	012671-0004-SA	Waste	01-Dec-90											
Contaminated Soil	012671-0005-SA	Waste	01-Dec-90											
Contaminated Soil	012671-0006-SA	Waste	01-Dec-90											
Contaminated Soil	012857-0005-SA	Waste	12-Dec-90											
Contaminated Soil	012857-0006-SA	Waste	12-Dec-90											
Contaminated Soil	012857-0007-SA	Waste	12-Dec-90											
Contaminated Soil	012857-0008-SA	Waste	13-Dec-90											
Contaminated Soil	013201-0003-SA	Waste	17-Jan-91											
Contaminated Soil	013384-0002-SA	Waste	29-Jan-91											
Contaminated Soil	013384-0003-SA	Waste	29-Jan-91											
Contaminated Soil	013384-0004-SA	Waste	29-Jan-91											
Contaminated Soil	013384-0005-SA	Waste	29-Jan-91											
Contaminated Soil	013384-0010-SA	Waste	30-Jan-91											
Contaminated Soil	013654-0001-SA	Waste	21-Feb-91											
Contaminated Soil	013654-0002-SA	Waste	21-Feb-91											
Dehy Condensate Water	011686-0006-SA	Aqueous	03-Oct-90											
Dehy Condensate Water	011772-0003-SA	Aqueous	09-Oct-90											
Dehy Condensate Water	012641-0001-SA	Aqueous	27-Nov-90											
Oil Mud Cuttings	006299-0002-SA	Soil	24-Aug-89	4120	< 5	1.4	3600	0.2	< 0.5	28800	14	< 1	12	11
Oil Mud Cuttings	007915-0001-SA	Waste	19-Dec-89	6700	< 10	2.8	10700	< 0.4	< 1	25000	22	< 2	15	70
Oil Mud Cuttings	007915-0002-SA	Waste	19-Dec-89	4000	< 5	3	9900	0.3	< 0.5	28400	17	< 1	12	50
Oil Mud Cuttings	011425-0009-SA	Waste	20-Sep-90											
Oil Mud Cuttings	011772-0005-SA	Waste	09-Oct-90											
Pigging Waste	012641-0003-SA	Aqueous	28-Nov-90											
Pigging Waste	012798-0001-SA	Aqueous	11-Dec-90											
Pigging Waste	013200-0001-SA	Waste	17-Jan-91											
Pigging Waste	013200-0002-SA	Waste	17-Jan-91											
Pigging Waste	013828-0001-SA	Waste	01-Mar-91											
Pit and Sump Waste	006299-0005-SA	Waste	24-Aug-89	85	< 5	1.1	4	< 0.2	< 0.5	2130	3	< 1	10	44
Pit and Sump Waste	007862-0003-SA	Waste	14-Dec-89	4600	< 5	0.5	2600	< 0.2	< 0.5	20600	14	< 1	9	< 5
Pit and Sump Waste	011686-0003-SA	Waste	03-Oct-90											
Pit and Sump Waste	012010-0006-SA	Waste	23-Oct-90											
Produced Sand	007314-0003-SA	Waste	31-Oct-89	977	< 5	< 1	140	< 0.2	< 0.5	4130	5	< 1	9	16
Rig Wash	011425-0010-SA	Waste	20-Sep-90											
Rig Wash	012010-0005-SA	Aqueous	23-Oct-90											
Rig Wash	013200-0003-SA	Aqueous	18-Jan-91											
Rig Wash	013200-0004-SA	Aqueous	18-Jan-91											
Rig Wash	013200-0005-SA	Waste	18-Jan-91											
Spent Iron Sponge	012010-0009-SA	Waste	25-Oct-90											
Spent Iron Sponge	013143-0001-SA	Waste	15-Jan-90											
Spent Mol Sieve	011212-0001-SA	Solid	04-Sep-90											
Spent Mol Sieve	011212-0002-SA	Solid	04-Sep-90											
Spent Mol Sieve	013143-0002-SA	Waste	16-Jan-90											
Tank Bottoms	006299-0001-SA	Waste	24-Aug-89	35	< 5	2	23	< 0.2	< 0.5	1230	5	< 1	14	27
Tank Bottoms	006299-0003-SA	Waste	24-Aug-89	974	< 10	10	180	< 0.4	3	35500	54	4	190	970
Tank Bottoms	006299-0004-SA	Waste	24-Aug-89	329	< 30	6.2	58	< 1	< 3	114000	48	5	54	320
Tank Bottoms	006344-0001-SA	Waste	30-Aug-89	< 10	< 5	< 0.5	3	< 0.2	< 0.5	< 30	< 1	< 1	< 1	< 5
Tank Bottoms	006344-0002-SA	Waste	30-Aug-89	13	< 5	0.7	70	< 0.2	< 0.5	1340	5	< 1	33	140
Tank Bottoms	007314-0004-SA	Waste	31-Oct-89	1180	< 5	3	5400	< 0.2	< 0.5	4420	35	< 1	28	54

API ASSOCIATED WASTE STUDY
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TOTAL METALS

API Sample Type	Lab ID No.	Matrix	Sample Date	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Pb
Tank Bottoms	007531-0002-SA	Waste	15-Nov-89	200	< 5	22	36a	< 0.2	< 0.5	2600	6a	1	100	140
Tank Bottoms	007531-0004-SA	Waste	15-Nov-89	300	< 5	32	430	< 0.2	2.3	3400	10	< 1	210	940
Tank Bottoms	007862-0001-SA	Waste	14-Dec-89	1200	< 5	2.7	26	< 0.2	< 0.5	2800	5	1	4	< 5
Tank Bottoms	007862-0005-SA	Waste	14-Dec-89	310	< 5	2.8	56	< 0.2	< 0.5	350	5	2	24	12
Tank Bottoms	011425-0001-SA	Waste	18-Sep-90											
Tank Bottoms	011425-0003-SA	Waste	18-Sep-90											
Tank Bottoms	011425-0004-SA	Waste	19-Sep-90											
Tank Bottoms	011425-0005-SA	Waste	19-Sep-90											
Tank Bottoms	011425-0007-SA	Waste	19-Sep-90											
Tank Bottoms	011686-0001-SA	Waste	03-Oct-90											
Tank Bottoms	011772-0001-SA	Waste	09-Oct-90											
Tank Bottoms	012010-0003-SA	Waste	23-Oct-90											
Used Glycol	006299-0008-SA	Waste	24-Aug-89	< 10	< 5	< 1	< 1	< 0.2	< 0.5	< 30	< 1	< 1	< 1	< 5
Used Glycol	006344-0005-SA	Waste	30-Aug-89	< 10	< 5	< 1	< 1	< 0.2	< 0.5	< 30	< 1	< 1	1	< 5
Used Glycol	007314-0002-SA	Waste	31-Oct-89	< 10	< 5	< 1	2	< 0.2	< 0.5	394	< 1	< 1	1	< 5
Used Glycol	007862-0006-SA	Waste	14-Dec-89	< 10	< 5	< 0.5	< 1	< 0.2	< 0.5	21	1	< 1	< 1	< 5
Used Glycol	011425-0012-SA	Waste	20-Sep-90											
Used Glycol	011686-0007-SA	Waste	03-Oct-90											
Used Glycol	011772-0004-SA	Aqueous	09-Oct-90											
Used Glycol	012641-0002-SA	Aqueous	27-Nov-90											
Used Oil	006299-0006-SA	Waste	24-Aug-89	< 10	< 5	< 0.5	< 1	< 0.2	< 0.5	578	< 5	< 1	5	< 5
Used Oil	006299-0010-SA	Waste	24-Aug-89	< 10	< 5	< 0.5	730	< 0.2	< 0.5	503	< 5	< 1	3	< 5
Used Oil	006344-0004-SA	Waste	30-Aug-89	< 10	< 5	< 0.5	< 1	< 0.2	< 0.5	< 30	< 1	< 1	< 1	< 5
Used Oil	007314-0001-SA	Waste	31-Oct-89	< 10	< 5	< 1	370	< 0.2	< 0.5	82	< 1	< 1	7	< 5
Used Oil	007531-0001-SA	Waste	15-Nov-89	< 10	< 5	< 0.5	< 1	< 0.2	< 0.5	< 20	< 1a	< 1	3	< 5
Used Oil	007862-0002-SA	Waste	14-Dec-89	< 10	< 5	< 0.5	< 1	< 0.2	< 0.5	< 20	< 1	< 1	1	< 5
Used Oil	011425-0006-SA	Waste	19-Sep-90											
Used Oil	011425-0011-SA	Waste	20-Sep-90											
Used Oil	011686-0002-SA	Waste	03-Oct-90											
Used Oil	011772-0002-SA	Waste	09-Oct-90											
Used Oil	012196-0007-SA	Waste	02-Nov-90											
Used Oil	012196-0008-SA	Waste	02-Nov-90											
Workover Fluids	012010-0002-SA	Aqueous	23-Oct-90											
Workover Fluids	012196-0001-SA	Waste	31-Oct-90											
Workover Fluids	012196-0002-SA	Aqueous	31-Oct-90											
Workover Fluids	012196-0005-SA	Waste	01-Nov-90											
Workover Fluids	012228-0001-SA	Aqueous	05-Nov-90											
Workover Fluids	012430-0001-SA	Aqueous	14-Nov-90											
Workover Fluids	012671-0001-SA	Aqueous	29-Nov-90											
Workover Fluids	012671-0002-SA	Aqueous	30-Nov-90											
Workover Fluids	012671-0007-SA	Aqueous	01-Dec-90											
Workover Fluids	012857-0001-SA	Aqueous	12-Dec-90											
Workover Fluids	012857-0002-SA	Aqueous	13-Dec-90											
Workover Fluids	012857-0003-SA	Aqueous	13-Dec-90											
Workover Fluids	013201-0001-SA	Waste	21-Jan-91											
Workover Fluids	013201-0002-SA	Waste	21-Jan-91											
Workover Fluids	013384-0001-SA	Waste	29-Jan-91											
Workover Fluids	013384-0006-SA	Waste	29-Jan-91											
Workover Fluids	013384-0009-SA	Waste	30-Jan-91											
Workover Fluids	013384-0011-SA	Waste	31-Jan-91											
Workover Fluids	013654-0003-SA	Waste	19-Feb-91											
Workover Fluids	013654-0004-SA	Aqueous	19-Feb-91											
Workover Fluids	014299-0001-SA	Waste	01-Apr-91											

a= Analyte present in method or field blank, results qualitative
h= Analyte is present in TCLP method or equipment blank, results qualitative
i= Hold time exceeded, results qualitative
j= Surrogates 0% - delivered out, results qualitative
m= Reporting Limit exceeds or equals TCLP Regulatory Limit due to matrix interference

API ASSOCIATED WASTE STUDY							TOTAL	METALS						
Appendix C Revised 02/22/94														
			Sample											Osmium
API Sample Type	Lab ID No.	Matrix	Date	Hg	Ni	K	Se	Ag	Na	Tl	Sn	V	Zn	Os
Amine Solution	006299-0009-SA	Waste	24-Aug-89	< 0.1	< 4	< 500	< 0.5	< 1	< 500	< 1	< 11	< 1	1	< 0.1
Contaminated Soil	006299-0007-SA	Waste	24-Aug-89	< 0.1	9	< 500	< 0.5	< 1	< 500	< 1	< 11	3	13	< 0.1
Contaminated Soil	006344-0003-SA	Waste	30-Aug-89	< 0.1	< 40	< 5000	< 1	< 10	< 5000	< 10	< 50	< 10	19	< 0.1
Contaminated Soil	007531-0003-SA	Waste	15-Nov-89	< 0.1	10	500	< 0.5	< 1	< 500	< 0.5	< 8a	12	47a	< 0.4
Contaminated Soil	007862-0004-SA	Waste	14-Dec-89	0.1	24	< 1000	< 5	< 2	1000	< 1	< 10	< 13	250	< 0.4
Contaminated Soil	011425-0002-SA	Waste	18-Sep-90											
Contaminated Soil	011425-0008-SA	Waste	19-Sep-90											
Contaminated Soil	011686-0004-SA	Waste	03-Oct-90											
Contaminated Soil	012010-0001-SA	Waste	23-Oct-90											
Contaminated Soil	012010-0004-SA	Waste	23-Oct-90											
Contaminated Soil	012010-0007-SA	Waste	24-Oct-90											
Contaminated Soil	012010-0008-SA	Waste	24-Oct-90											
Contaminated Soil	012196-0003-SA	Waste	01-Nov-90											
Contaminated Soil	012196-0004-SA	Waste	01-Nov-90											
Contaminated Soil	012196-0006-SA	Waste	01-Nov-90											
Contaminated Soil	012430-0003-SA	Waste	15-Nov-90											
Contaminated Soil	012430-0004-SA	Waste	15-Nov-90											
Contaminated Soil	012671-0003-SA	Waste	30-Nov-90											
Contaminated Soil	012671-0004-SA	Waste	01-Dec-90											
Contaminated Soil	012671-0005-SA	Waste	01-Dec-90											
Contaminated Soil	012671-0006-SA	Waste	01-Dec-90											
Contaminated Soil	012857-0005-SA	Waste	12-Dec-90											
Contaminated Soil	012857-0006-SA	Waste	12-Dec-90											
Contaminated Soil	012857-0007-SA	Waste	12-Dec-90											
Contaminated Soil	012857-0008-SA	Waste	13-Dec-90											
Contaminated Soil	013201-0003-SA	Waste	17-Jan-91											
Contaminated Soil	013384-0002-SA	Waste	29-Jan-91											
Contaminated Soil	013384-0003-SA	Waste	29-Jan-91											
Contaminated Soil	013384-0004-SA	Waste	29-Jan-91											
Contaminated Soil	013384-0005-SA	Waste	29-Jan-91											
Contaminated Soil	013384-0010-SA	Waste	30-Jan-91											
Contaminated Soil	013654-0001-SA	Waste	21-Feb-91											
Contaminated Soil	013654-0002-SA	Waste	21-Feb-91											
Dehy Condensate Water	011686-0006-SA	Aqueous	03-Oct-90											
Dehy Condensate Water	011772-0003-SA	Aqueous	09-Oct-90											
Dehy Condensate Water	012641-0001-SA	Aqueous	27-Nov-90											
Oil Mud Cuttings	006299-0002-SA	Soil	24-Aug-89	< 0.1	7	1190	< 1	1	1920	< 2	11	8	36	< 0.1
Oil Mud Cuttings	007915-0001-SA	Waste	19-Dec-89	0.1	18	2000	< 0.5	< 2	< 1000	< 1	< 10	12	280a	< 0.4
Oil Mud Cuttings	007915-0002-SA	Waste	19-Dec-89	< 0.1	13	1500	< 1	< 1	1100	< 1	< 5	8	65a	< 0.4
Oil Mud Cuttings	011425-0009-SA	Waste	20-Sep-90											
Oil Mud Cuttings	011772-0005-SA	Waste	09-Oct-90											
Pigging Waste	012641-0003-SA	Aqueous	28-Nov-90											
Pigging Waste	012798-0001-SA	Aqueous	11-Dec-90											
Pigging Waste	013200-0001-SA	Waste	17-Jan-91											
Pigging Waste	013200-0002-SA	Waste	17-Jan-91											
Pigging Waste	013828-0001-SA	Waste	01-Mar-91											
Pit and Sump Waste	006299-0005-SA	Waste	24-Aug-89	< 0.1	9	< 500	< 0.5	< 1	800	< 10	< 11	2	22	< 0.1
Pit and Sump Waste	007862-0003-SA	Waste	14-Dec-89	< 0.1	24	1300	< 1	< 1	17400	< 1	< 5	13	25	< 0.4
Pit and Sump Waste	011686-0003-SA	Waste	03-Oct-90											
Pit and Sump Waste	012010-0006-SA	Waste	23-Oct-90											
Produced Sand	007314-0003-SA	Waste	31-Oct-89	< 0.1	4	< 500	< 0.5	< 1	10100	< 0.5	< 5	2	44	< 2
Rig Wash	011425-0010-SA	Waste	20-Sep-90											
Rig Wash	012010-0005-SA	Aqueous	23-Oct-90											
Rig Wash	013200-0003-SA	Aqueous	18-Jan-91											
Rig Wash	013200-0004-SA	Aqueous	18-Jan-91											
Rig Wash	013200-0005-SA	Waste	18-Jan-91											
Spent Iron Sponge	012010-0009-SA	Waste	25-Oct-90											
Spent Iron Sponge	013143-0001-SA	Waste	15-Jan-90											
Spent Mol Sieve	011212-0001-SA	Solid	04-Sep-90											
Spent Mol Sieve	011212-0002-SA	Solid	04-Sep-90											
Spent Mol Sieve	013143-0002-SA	Waste	16-Jan-90											
Tank Bottoms	006299-0001-SA	Waste	24-Aug-89	< 0.1	16	< 500	< 0.5	< 1	2040	< 10	< 11	3	34	< 0.1
Tank Bottoms	006299-0003-SA	Waste	24-Aug-89	< 0.1	61	< 1000	< 5	< 2	9420	< 10	< 11	5	370	< 0.1
Tank Bottoms	006299-0004-SA	Waste	24-Aug-89	< 0.1	100	< 3000	< 5	< 5	12000	< 50	< 30	< 5	54	< 0.1
Tank Bottoms	006344-0001-SA	Waste	30-Aug-89	< 0.1	5	< 500	< 0.5	< 1	< 500	< 1	< 11	25	< 1	< 0.1
Tank Bottoms	006344-0002-SA	Waste	30-Aug-89	< 0.1	5	< 500	< 0.5	< 1	9510	< 1	< 11	4	63	< 0.1
Tank Bottoms	007314-0004-SA	Waste	31-Oct-89	1.4	7	< 500	< 0.5	< 1	6100	< 0.5	< 5	2	400	< 2

API ASSOCIATED WASTE STUDY

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TOTAL METALS

API Sample Type	Lab ID No.	Matrix	Sample Date		Hg		Ni		K		Se		Ag		Na		Tl		Sn		V		Zn		Osmium Os
Tank Bottoms	007531-0002-SA	Waste	15-Nov-89	<	0.1		6	<	500	<	1	<	1		3900	<	1		9a	<	1		120a	<	0.4
Tank Bottoms	007531-0004-SA	Waste	15-Nov-89	<	0.1		9	<	500	<	1	<	1		4500		0.7	<	8a		2		190a	<	0.4
Tank Bottoms	007862-0001-SA	Waste	14-Dec-89	<	0.1		25	<	500	<	1	<	1		760	<	0.5	<	5		6		10	<	0.4
Tank Bottoms	007862-0005-SA	Waste	14-Dec-89		0.1		30	<	500	<	1	<	1		1200	<	0.5	<	5		11		100	<	0.4
Tank Bottoms	011425-0001-SA	Waste	18-Sep-90																						
Tank Bottoms	011425-0003-SA	Waste	18-Sep-90																						
Tank Bottoms	011425-0004-SA	Waste	19-Sep-90																						
Tank Bottoms	011425-0005-SA	Waste	19-Sep-90																						
Tank Bottoms	011425-0007-SA	Waste	19-Sep-90																						
Tank Bottoms	011686-0001-SA	Waste	03-Oct-90																						
Tank Bottoms	011772-0001-SA	Waste	09-Oct-90																						
Tank Bottoms	012010-0003-SA	Waste	23-Oct-90																						
Used Glycol	006299-0008-SA	Waste	24-Aug-89	<	0.1	<	4	<	500	<	5	<	1	<	500	<	1	<	11	<	1	<	1	<	0.1
Used Glycol	006344-0005-SA	Waste	30-Aug-89	<	0.1	<	4	<	500	<	0.5	<	1	<	500	<	0.5		13	<	1	<	1	<	0.1
Used Glycol	007314-0002-SA	Waste	31-Oct-89	<	0.1	<	4	<	500	<	0.5	<	1		1730	<	1	<	5	<	1		5	<	2
Used Glycol	007862-0006-SA	Waste	14-Dec-89	<	0.1	<	4	<	500	<	0.5	<	1	<	500	<	0.5	<	5	<	1	<	2	<	0.4
Used Glycol	011425-0012-SA	Waste	20-Sep-90																						
Used Glycol	011686-0007-SA	Waste	03-Oct-90																						
Used Glycol	011772-0004-SA	Aqueous	09-Oct-90																						
Used Glycol	012641-0002-SA	Aqueous	27-Nov-90																						
Used Oil	006299-0006-SA	Waste	24-Aug-89	<	0.1	<	4	<	500	<	0.5	<	1	<	500	<	0.5	<	21	<	1		390	<	0.1
Used Oil	006299-0010-SA	Waste	24-Aug-89	<	0.1	<	4	<	500	<	0.5	<	1	<	500	<	1	<	21	<	1		8	<	0.1
Used Oil	006344-0004-SA	Waste	30-Aug-89	<	0.1	<	4	<	500		1.4	<	1	<	500	<	1	<	11	<	1		130	<	0.1
Used Oil	007314-0001-SA	Waste	31-Oct-89	<	0.1	<	4	<	500	<	0.5	<	1	<	500	<	0.5	<	5	<	1		150	<	2
Used Oil	007531-0001-SA	Waste	15-Nov-89	<	0.1	<	4	<	500	<	0.5	<	1	<	500	<	0.5	<	8a	<	1	<	4a	<	0.4
Used Oil	007862-0002-SA	Waste	14-Dec-89	<	0.1	<	4	<	500	<	0.5	<	1	<	500	<	0.5	<	5	<	1		4	<	0.4
Used Oil	011425-0006-SA	Waste	19-Sep-90																						
Used Oil	011425-0011-SA	Waste	20-Sep-90																						
Used Oil	011686-0002-SA	Waste	03-Oct-90																						
Used Oil	011772-0002-SA	Waste	09-Oct-90																						
Used Oil	012196-0007-SA	Waste	02-Nov-90																						
Used Oil	012196-0008-SA	Waste	02-Nov-90																						
Workover Fluids	012010-0002-SA	Aqueous	23-Oct-90																						
Workover Fluids	012196-0001-SA	Waste	31-Oct-90																						
Workover Fluids	012196-0002-SA	Aqueous	31-Oct-90																						
Workover Fluids	012196-0005-SA	Waste	01-Nov-90																						
Workover Fluids	012228-0001-SA	Aqueous	05-Nov-90																						
Workover Fluids	012430-0001-SA	Aqueous	14-Nov-90																						
Workover Fluids	012671-0001-SA	Aqueous	29-Nov-90																						
Workover Fluids	012671-0002-SA	Aqueous	30-Nov-90																						
Workover Fluids	012671-0007-SA	Aqueous	01-Dec-90																						
Workover Fluids	012857-0001-SA	Aqueous	12-Dec-90																						
Workover Fluids	012857-0002-SA	Aqueous	13-Dec-90																						
Workover Fluids	012857-0003-SA	Aqueous	13-Dec-90																						
Workover Fluids	013201-0001-SA	Waste	21-Jan-91																						
Workover Fluids	013201-0002-SA	Waste	21-Jan-91																						
Workover Fluids	013384-0001-SA	Waste	29-Jan-91																						
Workover Fluids	013384-0006-SA	Waste	29-Jan-91																						
Workover Fluids	013384-0009-SA	Waste	30-Jan-91																						
Workover Fluids	013384-0011-SA	Waste	31-Jan-91																						
Workover Fluids	013654-0003-SA	Waste	19-Feb-91																						
Workover Fluids	013654-0004-SA	Aqueous	19-Feb-91																						
Workover Fluids	014299-0001-SA	Waste	01-Apr-91																						

a- Analyte present in method or field blank, results qualitative

f- Analyte is present in TCLP method or equipment blank, results qualitative

i- Hold time exceeded, results qualitative

j- Surrogates 0% - delivered out, results qualitative

m- Reporting Limit exceeds or equals TCLP Regulatory Limit due to matrix interference

API ASSOCIATED WASTE STUDY

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								TCLP VOLATILE		ORGANICS						TCLP SEMI-VOLATILE ORGANICS					
API Sample Type	Lab ID No.	Matrix	Sample Date		MEK		Methylene Chloride		Carbon Disulfide		Trichloro ethene		Benzene		Toluene		Phenol		o-Cresol		Sample p Cresol
Amine Solution	006299-0009-SA	Waste	24-Aug-89																		
Contaminated Soil	006299-0007-SA	Waste	24-Aug-89	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	006344-0003-SA	Waste	30-Aug-89	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	007531-0003-SA	Waste	15-Nov-89	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	007862-0004-SA	Waste	14-Dec-89	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	011425-0002-SA	Waste	18-Sep-90	<	0.05					<	0.025	<	0.025								
Contaminated Soil	011425-0008-SA	Waste	19-Sep-90	<	0.05					<	0.025		0.041								
Contaminated Soil	011686-0004-SA	Waste	03-Oct-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025		0.26						
Contaminated Soil	012010-0001-SA	Waste	23-Oct-90	<	0.20	<	0.10	<	0.10	<	0.10		1		1.4						
Contaminated Soil	012010-0004-SA	Waste	23-Oct-90	<	0.05	<	0.025	<	0.025		0.099	<	0.025		0.044						
Contaminated Soil	012010-0007-SA	Waste	24-Oct-90	<	0.20	<	0.10	<	0.10	<	0.10	<	0.10		0.29						
Contaminated Soil	012010-0008-SA	Waste	24-Oct-90	<	0.05	<	0.025	<	0.025	<	0.025		0.085		0.17						
Contaminated Soil	012196-0003-SA	Waste	01-Nov-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025		0.03						
Contaminated Soil	012196-0004-SA	Waste	01-Nov-90	<	0.05	<	0.025	<	0.025	<	0.025		0.48		12						
Contaminated Soil	012196-0006-SA	Waste	01-Nov-90	<	0.05	<	0.025	<	0.025	<	0.025		0.22		0.52						
Contaminated Soil	012430-0003-SA	Waste	15-Nov-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	012430-0004-SA	Waste	15-Nov-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025		0.16						
Contaminated Soil	012671-0003-SA	Waste	30-Nov-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025		0.14						
Contaminated Soil	012671-0004-SA	Waste	01-Dec-90	<	0.05	<	0.025	<	0.025	<	0.025		0.28		0.42						
Contaminated Soil	012671-0005-SA	Waste	01-Dec-90	<	0.05	<	0.025	<	0.025	<	0.025		0.13		0.42						
Contaminated Soil	012671-0006-SA	Waste	01-Dec-90	<	0.20	<	0.10	<	0.10	<	0.10		1		1.7						
Contaminated Soil	012857-0005-SA	Waste	12-Dec-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025		0.089						
Contaminated Soil	012857-0006-SA	Waste	12-Dec-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	012857-0007-SA	Waste	12-Dec-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	012857-0008-SA	Waste	13-Dec-90	<	0.10	<	0.05	<	0.05	<	0.05		0.094		0.41						
Contaminated Soil	013201-0003-SA	Waste	17-Jan-91	<	0.05	<	0.025	<	0.025	<	0.025		1.8		3.5						
Contaminated Soil	013384-0002-SA	Waste	29-Jan-91	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	013384-0003-SA	Waste	29-Jan-91	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	013384-0004-SA	Waste	29-Jan-91	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Contaminated Soil	013384-0005-SA	Waste	29-Jan-91	<	0.10	<	0.05	<	0.05	<	0.05	<	0.05		0.6						
Contaminated Soil	013384-0010-SA	Waste	30-Jan-91	<	0.10	<	0.05	<	0.05	<	0.05		0.16		0.78						
Contaminated Soil	013654-0001-SA	Waste	21-Feb-91	<	0.05	<	0.025	<	0.025	<	0.025		0.086		0.35						
Contaminated Soil	013654-0002-SA	Waste	21-Feb-91	<	0.10	<	0.05	<	0.05	<	0.05		0.29		0.84						
Dehy Condensate Water	011686-0006-SA	Aqueous	03-Oct-90	<	5.0	<	2.5	<	2.5	<	2.5		34		72						
Dehy Condensate Water	011772-0003-SA	Aqueous	09-Oct-90	<	50	<	25	<	25	<	25		480		130						
Dehy Condensate Water	012641-0001-SA	Aqueous	27-Nov-90	<	2.0	<	1.0	<	1.0	<	1.0		21		23						
Oil Mud Cuttings	006299-0002-SA	Soil	24-Aug-89	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025		0.053	<	0.4	<	0.4	<	0.4
Oil Mud Cuttings	007915-0001-SA	Waste	19-Dec-89	<	0.20	<	0.10	<	0.10	<	0.10	<	0.10	<	0.10	<	0.02	<	0.02	<	0.02
Oil Mud Cuttings	007915-0002-SA	Waste	19-Dec-89	<	5.0																
Oil Mud Cuttings	011425-0009-SA	Waste	20-Sep-90	<	0.05					<	0.025	<	0.025								
Oil Mud Cuttings	011772-0005-SA	Waste	09-Oct-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Pigging Waste	012641-0003-SA	Aqueous	28-Nov-90	<	1.0	<	0.5	<	0.5	<	0.5		8.4		3.7						
Pigging Waste	012798-0001-SA	Aqueous	11-Dec-90	<	10	<	5	<	5	<	5		33		45						
Pigging Waste	013200-0001-SA	Waste	17-Jan-91	<	0.50	<	0.25	<	0.25	<	0.25		1.9		4.8						
Pigging Waste	013200-0002-SA	Waste	17-Jan-91	<	0.05	<	0.025	<	0.025	<	0.025		0.23		0.31						
Pigging Waste	013828-0001-SA	Waste	01-Mar-91	<	700	<	350	<	350	<	350		800		5100						
Pit and Sump Waste	006299-0005-SA	Waste	24-Aug-89	<	0.05	<	0.025	<	0.025	<	0.025		0.083		0.033	<	0.02	<	0.02	<	0.02
Pit and Sump Waste	007862-0003-SA	Waste	14-Dec-89	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025	<	0.020	<	0.020	<	0.020
Pit and Sump Waste	011686-0003-SA	Waste	03-Oct-90	<	3900	<	2000	<	2000	<	2000m	<	2000m		6300						
Pit and Sump Waste	012010-0006-SA	Waste	23-Oct-90	<	1.80		2.4	<	0.9	<	0.9m	<	0.9m		2.8						
Produced Sand	007314-0003-SA	Waste	31-Oct-89	<	0.20	<	0.1	<	0.1	<	0.1		0.28		0.81	<	0.067	<	0.067	<	0.067
Rig Wash	011425-0010-SA	Waste	20-Sep-90	<	0.20					<	0.1	<	0.1								
Rig Wash	012010-0005-SA	Aqueous	23-Oct-90	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Rig Wash	013200-0003-SA	Aqueous	18-Jan-91		0.089	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Rig Wash	013200-0004-SA	Aqueous	18-Jan-91	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025		0.026						
Rig Wash	013200-0005-SA	Waste	18-Jan-91	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025		0.039						
Spent Iron Sponge	012010-0009-SA	Waste	25-Oct-90	<	0.05		0.086	<	0.025	<	0.025	<	0.025	<	0.025						
Spent Iron Sponge	013143-0001-SA	Waste	15-Jan-90	<	0.05	<	0.025	<	0.025	<	0.025		0.46		0.69						
Spent Mol Sieve	011212-0001-SA	Solid	04-Sep-90	<	0.05					<	0.025	<	0.025								
Spent Mol Sieve	011212-0002-SA	Solid	04-Sep-90	<	0.12					<	0.025	<	0.025								
Spent Mol Sieve	013143-0002-SA	Waste	16-Jan-90	<	0.34	<	0.17	<	0.17	<	0.17		1.4		2.9						
Tank Bottoms	006299-0001-SA	Waste	24-Aug-89	<	4.2		3.2	<	2.1	<	2.1		20		37		0.035		0.04		0.075
Tank Bottoms	006299-0003-SA	Waste	24-Aug-89	<	3.2	<	1.6	<	1.6	<	1.6		12		20	<	0.049	<	0.049	<	0.049
Tank Bottoms	006299-0004-SA	Waste	24-Aug-89	<	0.25	<	0.12	<	0.12	<	0.12		2.2		3.7	<	0.04	<	0.04	<	0.04
Tank Bottoms	006344-0001-SA	Waste	30-Aug-89	<	4.4	<	2.2	<	2.2	<	2.2		7.7		27	<	0.22	<	0.22	<	0.22
Tank Bottoms	006344-0002-SA	Waste	30-Aug-89	<	4.2	<	2.1	<	2.1	<	2.1		4.6		13	<	2	<	2	<	2
Tank Bottoms	007314-0004-SA	Waste	31-Oct-89	<	0.5	<	0.25	<	0.25	<	0.25		5.2		4.8	<	0.4	<	0.4	<	0.4

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					TCLP VOLATILE ORGANICS											TCLP SEMI-VOLATILE ORGANICS					
API Sample Type	Lab ID No.	Matrix	Sample Date		MEK		Methylene Chloride		Carbon Disulfide		Trichloro ethene		Benzene		Toluene		Phenol		o-Cresol		p Cresol
Tank Bottoms	007531-0002-SA	Waste	15-Nov-89	<	1.5	<	0.75	<	0.75	<	0.75		4.6		7	<	0.85	<	0.85	<	0.85
Tank Bottoms	007531-0004-SA	Waste	15-Nov-89	<	0.94	<	0.47	<	0.47	<	0.47		7.1		8.9	<	4.4i	<	4.4	<	4.4
Tank Bottoms	007862-0001-SA	Waste	14-Dec-89	<	0.05	<	0.025	<	0.025	<	0.025		0.092	<	0.025	<	0.02	<	0.02	<	0.02
Tank Bottoms	007862-0005-SA	Waste	14-Dec-89	<	0.05	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025	<	0.02	<	0.02	<	0.02
Tank Bottoms	011425-0001-SA	Waste	18-Sep-90	<	26					<	13		27								
Tank Bottoms	011425-0003-SA	Waste	18-Sep-90	<	1.0					<	0.5		3								
Tank Bottoms	011425-0004-SA	Waste	19-Sep-90	<	0.1					<	0.05		0.21								
Tank Bottoms	011425-0005-SA	Waste	19-Sep-90	<	0.5					<	0.25		0.37								
Tank Bottoms	011425-0007-SA	Waste	19-Sep-90	<	0.5					<	0.25		0.94								
Tank Bottoms	011686-0001-SA	Waste	03-Oct-90	<	2.5	<	1.2	<	1.2	<	1.2		3.7		5.2						
Tank Bottoms	011772-0001-SA	Waste	09-Oct-90	<	310	<	150	<	150	<	150		420		560						
Tank Bottoms	012010-0003-SA	Waste	23-Oct-90	<	0.5	<	0.25	<	0.25	<	0.25		3.8		2.2						
Used Glycol	006299-0008-SA	Waste	24-Aug-89																		
Used Glycol	006344-0005-SA	Waste	30-Aug-89																		
Used Glycol	007314-0002-SA	Waste	31-Oct-89																		
Used Glycol	007862-0006-SA	Waste	14-Dec-89	<	1.0																
Used Glycol	011425-0012-SA	Waste	20-Sep-90	<	1.2					<	0.58		9								
Used Glycol	011686-0007-SA	Waste	03-Oct-90	<	280	<	140	<	140	<	140		380		1900						
Used Glycol	011772-0004-SA	Aqueous	09-Oct-90	<	500	<	250	<	250	<	250		7900		4300						
Used Glycol	012641-0002-SA	Aqueous	27-Nov-90	<	2	<	1	<	1	<	1		5		15						
Used Oil	006299-0006-SA	Waste	24-Aug-89	<	0.092	<	0.046	<	0.046	<	0.046	<	0.046	<	0.046	<	1	<	1	<	1
Used Oil	006299-0010-SA	Waste	24-Aug-89	<	0.84	<	0.42	<	0.42	<	0.42	<	0.42	<	0.42	<	0.57	<	0.57	<	0.57
Used Oil	006344-0004-SA	Waste	30-Aug-89	<	1.00	<	0.5	<	0.5	<	0.5	<	0.5m	<	0.5	<	0.54	<	0.54	<	0.54
Used Oil	007314-0001-SA	Waste	31-Oct-89	<	0.85	<	0.42	<	0.42	<	0.42		2.3		5.1	<	1.1	<	1.1	<	1.1
Used Oil	007531-0001-SA	Waste	15-Nov-89	<	130	<	65	<	65	<	65		180		350	<	1300j	<	1300j	<	1300j
Used Oil	007862-0002-SA	Waste	14-Dec-89	<	0.90	<	0.45	<	0.45	<	0.45		0.092		1.4	<	200j	<	200j	<	200j
Used Oil	011425-0006-SA	Waste	19-Sep-90	<	0.95					<	0.48	<	0.48								
Used Oil	011425-0011-SA	Waste	20-Sep-90	<	0.95					<	0.48	<	0.48								
Used Oil	011686-0002-SA	Waste	03-Oct-90	<	0.88	<	0.44	<	0.44	<	0.44	<	0.44	<	0.44						
Used Oil	011772-0002-SA	Waste	09-Oct-90	<	0.92	<	0.46	<	0.46	<	0.46		2.1		1.7						
Used Oil	012196-0007-SA	Waste	02-Nov-90																		
Used Oil	012196-0008-SA	Waste	02-Nov-90																		
Workover Fluids	012010-0002-SA	Aqueous	23-Oct-90	<	1.0	<	0.5	<	0.5	<	0.5		8.1		4.5						
Workover Fluids	012196-0001-SA	Waste	31-Oct-90																		
Workover Fluids	012196-0002-SA	Aqueous	31-Oct-90	<	0.10	<	0.05	<	0.05	<	0.05		1.8		1.7						
Workover Fluids	012196-0005-SA	Waste	01-Nov-90	<	0.50	<	0.025	<	0.025	<	0.025		6.2		4.6						
Workover Fluids	012228-0001-SA	Aqueous	05-Nov-90		0.07	<	0.025	<	0.025	<	0.025		0.1		0.18						
Workover Fluids	012430-0001-SA	Aqueous	14-Nov-90	<	0.50	<	0.25	<	0.25	<	0.25		4.9		3.9						
Workover Fluids	012671-0001-SA	Aqueous	29-Nov-90	<	0.20	<	0.1	<	0.1	<	0.1		1		1.8						
Workover Fluids	012671-0002-SA	Aqueous	30-Nov-90	<	0.10	<	0.05	<	0.05	<	0.05		0.3		0.72						
Workover Fluids	012671-0007-SA	Aqueous	01-Dec-90	<	2.0	<	1	<	1	<	1		2		3.7						
Workover Fluids	012857-0001-SA	Aqueous	12-Dec-90		0.05	<	0.025	<	0.025	<	0.025		0.43		0.32						
Workover Fluids	012857-0002-SA	Aqueous	13-Dec-90	<	0.20	<	0.1	<	0.1	<	0.1		0.99		2.1						
Workover Fluids	012857-0003-SA	Aqueous	13-Dec-90	<	0.10	<	0.05	<	0.05	<	0.05		0.69		0.56						
Workover Fluids	013201-0001-SA	Waste	21-Jan-91	<	2.50	<	1.2	<	1.2	<	1.2	<	1.2m		14						
Workover Fluids	013201-0002-SA	Waste	21-Jan-91	<	1.00	<	0.5	<	0.5	<	0.5		3.4		4.6						
Workover Fluids	013384-0001-SA	Waste	29-Jan-91		0.07	<	0.025	<	0.025	<	0.025	<	0.025		0.043						
Workover Fluids	013384-0006-SA	Waste	29-Jan-91	<	0.10	<	0.05	<	0.05	<	0.05		0.11		0.3						
Workover Fluids	013384-0009-SA	Waste	30-Jan-91	<	2.0	<	1		3.2	<	1	<	1m	<	1						
Workover Fluids	013384-0011-SA	Waste	31-Jan-91		0.18	<	0.025	<	0.025	<	0.025	<	0.025	<	0.025						
Workover Fluids	013654-0003-SA	Waste	19-Feb-91	<	1.00	<	0.5	<	0.5	<	0.5		6		6.1						
Workover Fluids	013654-0004-SA	Aqueous	19-Feb-91	<	0.34	<	0.17	<	0.17	<	0.17		3.5		2.2						
Workover Fluids	014299-0001-SA	Waste	01-Apr-91		0.21	<	0.082	<	0.082	<	0.082		0.77		0.46						

a= Analyte present in method or field blank, results qualitative
f= Analyte is present in TCLP method or equipment blank, results qualitative
i= Hold time exceeded, results qualitative
j= Surrogates 0% - delivered out, results qualitative
m= Reporting Limit exceeds or equals TCLP Regulatory Limit due to matrix interference

API ASSOCIATED WASTE STUDY

Appendix C Revised 02/22/94

TCLP LEACHATE - METALS

API Sample Type	Lab ID No.	Matrix	Sample Date		Arsenic		Barium		Cadmium		Chromium		Lead		Mercury		Selenium	Sample
Amine Solution	006299-0009-SA	Waste	24-Aug-89															
Contaminated Soil	006299-0007-SA	Waste	24-Aug-89															
Contaminated Soil	006344-0003-SA	Waste	30-Aug-89															
Contaminated Soil	007531-0003-SA	Waste	15-Nov-89															
Contaminated Soil	007862-0004-SA	Waste	14-Dec-89	<	0.20		2.6		0.05	<	0.02	<	0.10	<	0.002	<	0.05	
Contaminated Soil	011425-0002-SA	Waste	18-Sep-90	<	1.0		1.7	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	011425-0008-SA	Waste	19-Sep-90	<	1.0		1.3	<	0.05	<	0.10		0.94	<	0.002	<	0.05	
Contaminated Soil	011686-0004-SA	Waste	03-Oct-90	<	1.0		1.9	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	012010-0001-SA	Waste	23-Oct-90	<	1.0		0.78	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	012010-0004-SA	Waste	23-Oct-90	<	1.0		0.98	<	0.05	<	0.10	<	0.50	<	0.002	<	0.10	
Contaminated Soil	012010-0007-SA	Waste	24-Oct-90	<	1.0		0.79	<	0.05	<	0.21	<	0.50	<	0.002	<	0.05	
Contaminated Soil	012010-0008-SA	Waste	24-Oct-90	<	1.0		0.62	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	012196-0003-SA	Waste	01-Nov-90	<	1.0		0.83	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	012196-0004-SA	Waste	01-Nov-90	<	1.0		1.1	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	012196-0006-SA	Waste	01-Nov-90	<	1.0		1.3	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	012430-0003-SA	Waste	15-Nov-90	<	1.0		0.57	<	0.05	<	0.10	<	0.50	<	0.002	<	0.10	
Contaminated Soil	012430-0004-SA	Waste	15-Nov-90	<	1.0		1.1	<	0.05	<	0.10	<	0.50	<	0.002	<	0.10	
Contaminated Soil	012671-0003-SA	Waste	30-Nov-90	<	1.0		1.2	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	012671-0004-SA	Waste	01-Dec-90	<	1.0		1.6	<	0.05	<	0.10		1.30	<	0.002	<	0.05	
Contaminated Soil	012671-0005-SA	Waste	01-Dec-90	<	1.0		1.4	<	0.05	<	0.10		0.67	<	0.002	<	0.10	
Contaminated Soil	012671-0006-SA	Waste	01-Dec-90	<	1.0	<	0.39	<	0.05	<	0.10	<	0.50	<	0.002	<	0.10	
Contaminated Soil	012857-0005-SA	Waste	12-Dec-90	<	1.0		2.2	<	0.05	<	0.10	<	0.50	<	0.002	<	0.10	
Contaminated Soil	012857-0006-SA	Waste	12-Dec-90	<	1.0		1.6	<	0.05	<	0.10	<	0.50	<	0.002	<	0.10	
Contaminated Soil	012857-0007-SA	Waste	12-Dec-90	<	1.0		1.5	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	012857-0008-SA	Waste	13-Dec-90	<	1.0		4.3	<	0.05	<	0.10		0.89	<	0.002	<	0.10	
Contaminated Soil	013201-0003-SA	Waste	17-Jan-91	<	5m		1.2	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	013384-0002-SA	Waste	29-Jan-91	<	1.0		1.5	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	013384-0003-SA	Waste	29-Jan-91	<	1.0		1.4	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	013384-0004-SA	Waste	29-Jan-91	<	1.0		1.1	<	0.05	<	0.10	<	0.50	<	0.002	<	0.10	
Contaminated Soil	013384-0005-SA	Waste	29-Jan-91	<	1.0		1.5	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	013384-0010-SA	Waste	30-Jan-91	<	1.0		1.4	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Contaminated Soil	013654-0001-SA	Waste	21-Feb-91	<	1.0		1.4	<	0.05	<	0.10	<	0.50	<	0.002	<	0.10	
Contaminated Soil	013654-0002-SA	Waste	21-Feb-91	<	1.0		3.5	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Dehy Condensate Water	011686-0006-SA	Aqueous	03-Oct-90	<	1.0		1.6f	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Dehy Condensate Water	011772-0003-SA	Aqueous	09-Oct-90	<	1.0		2.5f	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Dehy Condensate Water	012641-0001-SA	Aqueous	27-Nov-90		1.5		1.5		0.068	<	0.10	<	0.50	<	0.002	<	0.10	
Oil Mud Cuttings	006299-0002-SA	Soil	24-Aug-89	<	0.5		1.4	<	0.03	<	0.05	<	0.30	<	0.002	<	0.05	
Oil Mud Cuttings	007915-0001-SA	Waste	19-Dec-89	<	0.2		1.4f	<	0.01		0.04		0.30	<	0.002	<	0.05	
Oil Mud Cuttings	007915-0002-SA	Waste	19-Dec-89															
Oil Mud Cuttings	011425-0009-SA	Waste	20-Sep-90	<	1.0		4.2	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Oil Mud Cuttings	011772-0005-SA	Waste	09-Oct-90	<	1.0		4.1f	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Pigging Waste	012641-0003-SA	Aqueous	28-Nov-90	<	1.0		0.88		0.12		0.92	<	0.50	<	0.002	<	0.1	
Pigging Waste	012798-0001-SA	Aqueous	11-Dec-90	<	1.0		1.4	<	0.05		0.2	<	0.50		0.0057	<	0.05	
Pigging Waste	013200-0001-SA	Waste	17-Jan-91	<	1.0	<	0.1	<	0.05	<	2f	<	0.50	<	0.002	<	0.05	
Pigging Waste	013200-0002-SA	Waste	17-Jan-91	<	4	<	2	<	1m	<	2f	<	2.00		0.016	<	0.1	
Pigging Waste	013828-0001-SA	Waste	01-Mar-91	<	1.4		0.81f		0.068		0.2f	<	0.68	<	0.038	<	0.18	
Pit and Sump Waste	006299-0005-SA	Waste	24-Aug-89	<	0.2		0.17	<	0.01	<	0.02	<	0.10	<	0.002	<	0.05	
Pit and Sump Waste	007862-0003-SA	Waste	14-Dec-89	<	0.2		88	<	0.01	<	0.02	<	0.10	<	0.002	<	0.05	
Pit and Sump Waste	011686-0003-SA	Waste	03-Oct-90	<	3.5		0.89f	<	0.18	<	0.35	<	1.80	<	0.062	<	2.2m	
Pit and Sump Waste	012010-0006-SA	Waste	23-Oct-90	<	1		0.41	<	0.05	<	0.1	<	0.50	<	0.002	<	0.05	
Produced Sand	007314-0003-SA	Waste	31-Oct-89	<	0.1		3.7	<	0.005		0.03		0.82	<	0.002	<	0.05	
Rig Wash	011425-0010-SA	Waste	20-Sep-90	<	1		0.74	<	0.05	<	0.10	<	0.50	<	0.002	<	0.05	
Rig Wash	012010-0005-SA	Aqueous	23-Oct-90	<	10m		1.2	<	0.50	<	1	<	5.00	<	0.002	<	0.1	
Rig Wash	013200-0003-SA	Aqueous	18-Jan-91	<	1		0.89	<	0.05	<	0.10f	<	0.50	<	0.002	<	0.05	
Rig Wash	013200-0004-SA	Aqueous	18-Jan-91	<	2		2.1	<	0.50	<	1f	<	1.00		0.0075	<	0.1	
Rig Wash	013200-0005-SA	Waste	18-Jan-91	<	1	<	0.1		0.058	<	0.11f	<	0.50	<	0.002	<	0.1	
Spent Iron Sponge	012010-0009-SA	Waste	25-Oct-90	<	1		2.6	<	0.05	<	0.1	<	0.50	<	0.002	<	0.05	
Spent Iron Sponge	013143-0001-SA	Waste	15-Jan-90	<	1		0.92	<	0.05	<	0.1	<	0.50	<	0.002	<	0.05	
Spent Mol Sieve	011212-0001-SA	Solid	04-Sep-90		1.2		0.4f	<	0.05	<	0.1	<	0.50	<	0.002	<	0.1	
Spent Mol Sieve	011212-0002-SA	Solid	04-Sep-90	<	1	<	0.35f	<	0.05	<	0.1	<	0.50	<	0.002	<	0.1	
Spent Mol Sieve	013143-0002-SA	Waste	16-Jan-90	<	1	<	0.1	<	0.05	<	0.1	<	0.50	<	0.002	<	0.1	
Tank Bottoms	006299-0001-SA	Waste	24-Aug-89	<	0.6		0.99		0.03		0.06		4.20	<	0.004	<	0.07	
Tank Bottoms	006299-0003-SA	Waste	24-Aug-89	<	0.6		0.51	<	0.03	<	0.06	<	0.30	<	0.004	<	0.07	
Tank Bottoms	006299-0004-SA	Waste	24-Aug-89	<	0.5		0.33	<	0.03	<	0.05	<	0.30	<	0.002	<	0.05	
Tank Bottoms	006344-0001-SA	Waste	30-Aug-89	<	0.6		7.5	<	0.03		0.08	<	0.30	<	0.003	<	0.06	
Tank Bottoms	006344-0002-SA	Waste	30-Aug-89	<	2		24	<	0.1	<	0.2		2.00	<	0.008	<	0.08	
Tank Bottoms	007314-0004-SA	Waste	31-Oct-89	<	0.5		3.7f	<	0.03	<	0.05	<	0.30	<	0.002	<	0.05	

API ASSOCIATED WASTE STUDY

APPENDIX C REVISED 02/22/94

TCLP LEACHATE - METALS

API Sample Type	Lab ID No.	Matrix	Sample Date		Arsenic		Barium		Cadmium		Chromium		Lead		Mercury		Selenium	Sample
Tank Bottoms	007531-0002-SA	Waste	15-Nov-89	<	0.5		1.4f	<	0.03	<	0.05i		0.80	<	0.003	<	0.05	
Tank Bottoms	007531-0004-SA	Waste	15-Nov-89		1.1		4.1f		0.055		0.07i		9.20	<	0.003	<	0.06	
Tank Bottoms	007862-0001-SA	Waste	14-Dec-89	<	0.5	<	0.3	<	0.03	<	0.05	<	0.30	<	0.002	<	0.05	
Tank Bottoms	007862-0005-SA	Waste	14-Dec-89	<	0.2		0.6	<	0.01	<	0.02	<	0.10	<	0.002	<	0.05	
Tank Bottoms	011425-0001-SA	Waste	18-Sep-90	<	1.3		1.6		0.32	<	0.13	<	0.62	<	0.0075	<	0.062	
Tank Bottoms	011425-0003-SA	Waste	18-Sep-90	<	1		2.6	<	0.05		0.47	<	0.50	<	0.002	<	0.05	
Tank Bottoms	011425-0004-SA	Waste	19-Sep-90	<	1		3.4	<	0.05	<	0.1		1.00	<	0.002	<	0.05	
Tank Bottoms	011425-0005-SA	Waste	19-Sep-90	<	1		2.3	<	0.05	<	0.1	<	0.50	<	0.002	<	0.05	
Tank Bottoms	011425-0007-SA	Waste	19-Sep-90	<	1		1.6	<	0.05		0.14		9.60	<	0.002	<	0.05	
Tank Bottoms	011686-0001-SA	Waste	03-Oct-90	<	1		5.7i	<	0.05	<	0.1	<	0.50	<	0.002	<	0.05	
Tank Bottoms	011772-0001-SA	Waste	09-Oct-90	<	1.5		45.6i		0.28		0.41	<	0.72		0.033	<	0.098	
Tank Bottoms	012010-0003-SA	Waste	23-Oct-90	<	1		0.6	<	0.05	<	0.1	<	0.50	<	0.002	<	0.05	
Used Glycol	006299-0008-SA	Waste	24-Aug-89															
Used Glycol	006344-0005-SA	Waste	30-Aug-89															
Used Glycol	007314-0002-SA	Waste	31-Oct-89															
Used Glycol	007862-0006-SA	Waste	14-Dec-89															
Used Glycol	011425-0012-SA	Waste	20-Sep-90		4.5		0.18	<	0.05	<	0.1	<	0.50		0.026	<	1m	
Used Glycol	011686-0007-SA	Waste	03-Oct-90	<	5m	<	0.5		17.9	<	0.5	<	2.50	<	0.1	<	0.5	
Used Glycol	011772-0004-SA	Aqueous	09-Oct-90		5.3	<	0.97f	<	0.05	<	0.1	<	0.50		0.011	<	1m	
Used Glycol	012641-0002-SA	Aqueous	27-Nov-90	<	5m	<	0.5	<	0.25	<	0.5	<	2.50	<	0.002	<	1.3	
Used Oil	006299-0006-SA	Waste	24-Aug-89	<	5m	<	1.1	<	0.3	<	2	<	3.00	<	0.002	<	1m	
Used Oil	006299-0010-SA	Waste	24-Aug-89	<	5m		350	<	0.3	<	2	<	3.00	<	0.002	<	1m	
Used Oil	006344-0004-SA	Waste	30-Aug-89	<	2		1.2		0.1	<	0.2		2.00	<	0.1	<	1m	
Used Oil	007314-0001-SA	Waste	31-Oct-89	<	5m		35i	<	0.3		0.7		4.00	<	0.1	<	3m	
Used Oil	007531-0001-SA	Waste	15-Nov-89	<	5m		0.5		0.4		1.1f	<	3.00	<	0.1	<	0.5	
Used Oil	007862-0002-SA	Waste	14-Dec-89	<	5m	<	0.5	<	0.3		0.5	<	3.00	<	0.002	<	3m	
Used Oil	011425-0006-SA	Waste	19-Sep-90	<	5m		0.55		2.2	<	0.2	<	2.50	<	0.002	<	0.5	
Used Oil	011425-0011-SA	Waste	20-Sep-90	<	5m		1.1		1.4	<	0.2		8.00	<	0.002	<	0.25	
Used Oil	011686-0002-SA	Waste	03-Oct-90	<	5m		3.3		7.4		2.9	<	2.50	<	0.1	<	0.25	
Used Oil	011772-0002-SA	Waste	09-Oct-90	<	5m		1.5		3.4	<	0.5	<	2.50	<	0.1	<	0.5	
Used Oil	012196-0007-SA	Waste	02-Nov-90	<	0.5		1.6	<	0.5	<	1		7.90	<	0.1	<	0.5	
Used Oil	012196-0008-SA	Waste	02-Nov-90	<	0.5		3.9	<	0.5	<	1		12.90	<	0.1	<	0.5	
Workover Fluids	012010-0002-SA	Aqueous	23-Oct-90	<	5m	<	0.5	<	0.25	<	0.5	<	2.50	<	0.002	<	0.05	
Workover Fluids	012196-0001-SA	Waste	31-Oct-90	<	0.5		1	<	0.5	<	1	<	5m	<	0.1	<	0.5	
Workover Fluids	012196-0002-SA	Aqueous	31-Oct-90	<	1		4.3	<	0.05	<	0.1	<	0.50	<	0.002	<	0.1	
Workover Fluids	012196-0005-SA	Waste	01-Nov-90	<	10m		73.7		2.1	<	1	<	5m	<	0.002	<	0.2	
Workover Fluids	012228-0001-SA	Aqueous	05-Nov-90	<	5m		181	<	0.25	<	0.5	<	2.50	<	0.002	<	0.1	
Workover Fluids	012430-0001-SA	Aqueous	14-Nov-90	<	5m		45.5	<	0.25	<	0.5	<	2.50	<	0.002	<	0.1	
Workover Fluids	012671-0001-SA	Aqueous	29-Nov-90	<	10m		7.8	<	0.5		3.3		5.40	<	0.002	<	0.05	
Workover Fluids	012671-0002-SA	Aqueous	30-Nov-90	<	10m		3.0	<	0.5		3.5		77.10	<	0.002	<	0.05	
Workover Fluids	012671-0007-SA	Aqueous	01-Dec-90	<	1		1.1		0.13		2.8		2.00	<	0.002	<	0.05	
Workover Fluids	012857-0001-SA	Aqueous	12-Dec-90	<	2		9.4	<	0.1	<	0.2	<	1.00	<	0.002	<	0.1	
Workover Fluids	012857-0002-SA	Aqueous	13-Dec-90	<	1		6.4	<	0.05	<	0.1	<	0.50	<	0.002	<	0.1	
Workover Fluids	012857-0003-SA	Aqueous	13-Dec-90	<	1		2.8	<	0.05		0.43	<	0.50	<	0.002	<	0.05	
Workover Fluids	013201-0001-SA	Waste	21-Jan-91	<	5m		2.8f	<	0.25		2.4		12.40	<	0.002	<	0.5	
Workover Fluids	013201-0002-SA	Waste	21-Jan-91	<	5m		2.4f	<	0.25	<	0.5	<	2.50	<	0.002	<	0.1	
Workover Fluids	013384-0001-SA	Waste	29-Jan-91	<	2		0.35	<	0.1	<	0.2	<	1.00	<	0.002	<	0.05	
Workover Fluids	013384-0006-SA	Waste	29-Jan-91	<	1		1.1	<	0.05	<	0.12	<	0.50		0.013	<	0.1	
Workover Fluids	013384-0009-SA	Waste	30-Jan-91	<	5m		0.65	<	0.025		0.72	<	2.50	<	0.002	<	0.05	
Workover Fluids	013384-0011-SA	Waste	31-Jan-91	<	5m		3.7	<	0.25		0.9	<	2.50	<	0.002	<	0.5	
Workover Fluids	013654-0003-SA	Waste	19-Feb-91	<	1		5.5	<	0.05		1.3		10.60	<	0.002	<	0.1	
Workover Fluids	013654-0004-SA	Aqueous	19-Feb-91	<	5m		0.58	<	0.25	<	0.1	<	0.50	<	0.002	<	0.05	
Workover Fluids	014299-0001-SA	Waste	01-Apr-91	<	5m		2.1	<	0.25	<	0.5	<	2.50	<	0.002	<	0.05	

a= Analyte present in method or field blank, results qualitative
f= Analyte is present in TCLP method or equipment blank, results qualitative
i= Hold time exceeded, results qualitative
j= Surrogates 0% - delivered out, results qualitative
m= Reporting Limit exceeds or equals TCLP Regulatory Limit due to matrix interference

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