PB83-188680

Analysis of Geothermal Wastes for Hazardous Components

Acurex Corp.
Mountain View, CA

Prepared for

Industrial Environmental Research
Lab.-Cincinnati, OH

Apr 83

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
NTIS®

600/2-83-030

PB83-188680

EPA-600/2-83-030
April 1983

ANALYSIS OF GEOTHERMAL WASTES FOR HAZARDOUS COMPONENTS

by

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CINCINNATI, OHIO 45268

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1 REPORT NO.	2	3. RECIPIENT'S ACCESSION NO.
EPA-600/2-83-030		PB83 188680

4. TITLE AND SUBTITLE	5 REPORT DATE
ANALYSIS OF GEOTHERMAL WASTES FOR HAZARDOUS COMPONENTS	April 1983
	6. PERFORMING ORGANIZATION CODE

7 AUTHOR(S)	8 PERFORMING ORGANIZATION REPORT NO
E.L. Hagmann, D.D. Minicucci, C.D. Wolbach	

9 PERFORMING ORGANIZATION NAME AND ADDRESS	10 PROGRAM ELEMENT NO
Acurex Corporation Energy & Environmental Division 485 Clyde Avenue Mountain View, CA 94042	AZJNIE
	11. CONTRACT/GRANT NO 68-03-2567

12 SPONSORING AGENCY NAME AND ADDRESS	13 TYPE OF REPORT AND PERIOD COVERED
U.S. Environmental Protection Agency Office of Research & Development Industrial Environmental Research Laboratory Cincinnati, Ohio 45268	Final
	14. SPONSORING AGENCY CODE EPA 600/12

15 SUPPLEMENTARY NOTES

16 ABSTRACT

Regulations governing the disposal of hazardous wastes led to an assessment for geothermal solid wastes for potentially hazardous properties. Samples were collected from three active geothermal sites in the western United States: The Geysers, Imperial Valley, and northwestern Nevada. Approximately 20 samples were analyzed for corrosivity, EP toxicity, radioactivity, and bioaccumulation potential. The samples were further characterized by analysis for cations, anions, moisture content, priority pollutants, and additional trace metals in the leachate. In addition, an aqueous extraction was conducted at ambient pH.

None of the samples collected at The Geysers or northwestern Nevada could be classified as hazardous as defined by the Resource Conservation and Recovery Act (RCRA) regulations published May 19, 1980 in the Federal Register. However, several samples from the Imperial Valley could be classified as hazardous. The hazardousness of these wastes appear to be related to the high salinity of geothermal fluids in that area.

This study characterized samples from a limited geographical area and results cannot be extrapolated to other geothermal resource areas (GRA).

17. KEY WORDS AND DOCUMENT ANALYSIS

a DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19 SECURITY CLASS *(This Report)*	21 NO OF PAGES
Release unlimited	Unclassified	101
	20 SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollution impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. IERL-Ci assists in assessing and developing new and improved methodologies that will meet these needs both efficiently and economically.

This report documents a recently completed project. The purpose of this work was to assess the potential hazardous properties of geothermal solid wastes. Samples from active geothermal resource areas were examined for corrosivity, EP toxicity (as determined by a specific "Extract Procedure" defined in the Hazardous Waste Regulations), radioactivity, and bioaccumulation potential. The findings documented in this report showed that several samples could be classified as hazardous. However, because of the wide variability in geothermal resources, these results cannot be broadly extrapolated to other geothermal resource areas. The information contained in this report also may serve as a foundation for detailed additional work required by the Resource Conservation and Recovery Act in defining the character of geothermal wastes. For further information, contact the Oil Shale and Energy Mining Branch, IERL, Cincinnati, Ohio.

David G. Stephan
Director
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ABSTRACT

Proposed regulations governing the disposal of hazardous wastes led to an assessment for geothermal solid wastes for potentially hazardous content. The final regulations, published May 19, 1980, exempt geothermal wastes from designation as hazardous. Samples were collected from three active geothermal areas in the western United States: The Geysers, Imperial Valley, and northwestern Nevada. Approximately 20 samples were analyzed for corrosivity, EP (Extract Procedure), toxicity, radioactivity, and bioaccumulation potential. The samples were further characterized by analysis for cations, anions, moisture content, priority pollutants, and additional trace metals in the leachate. In addition, an aqueous extraction was conducted at ambient pH.

None of the samples collected at The Geysers or northwestern Nevada could be classified as hazardous as defined by the RCRA regulations published May 19, 1980 in the Federal Register. However, several samples from the Imperial Valley could be classified as hazardous. These hazardous properties appear to be related to the high salinity of geothermal fluids.

This study characterized samples from a limited geographical area and results cannot be broadly extrapolated to other geothermal resource areas.

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Acurex gratefully acknowledges the technical support and guidance received from Mr. Robert Hartley, Project Officer, Industrial Environmental Research Laboratory in Cincinnati, Ohio, and Mr. Gerald Katz, Co-project Officer, Department of Energy in Oakland, California. Acurex also wishes to acknowledge the contributions of the individuals responsible for geothermal activities at each resource area who allowed us to collect samples from their facilities.

SECTION 1

PROJECT OVERVIEW

1.1 INTRODUCTION

Under contract to the U.S. Environmental Protection Agency (EPA), Industrial Environmental Research Laboratory in Cincinnati, Ohio, Acurex Corporation is preliminarily determining the hazardous nature of solid wastes resulting from the extraction and processing of geothermal energy resources. This project is being co-sponsored by the U.S. Department of Energy (DOE), Geothermal Energy Division in Oakland, California. The purpose of this study has been to collect information in a manner sufficient to allow the design and scoping of a comprehensive and detailed project to establish whether geothermal solid wastes pose any hazardous waste management concerns.

Our work has included the following major elements:

- Surveying geothermal development sites to identify suitable solid waste streams and obtain permission to collect samples
- Conducting field sampling trips to sites in the Imperial Valley, The Geysers, and northwestern Nevada
- Analyzing approximately 20 samples to identify potentially hazardous constituents and characterize the chemical composition of the solids

The findings of our study are documented in this report. Section 1 provides an overview of the project including this introduction and a

presentation of results. The field sampling program is described in Section 2. Analytical methods and results are presented in Section 3. A discussion of the analytical results is provided in Section 4.

1.1.1 Background

The Resource Conservation and Recovery Act of 1976 (RCRA) requires that EPA promulgate regulations for the handling and disposal of solid wastes, including those containing hazardous substances. As part of its obligations under RCRA, EPA is examining the hazardous potential of various solid wastes such as those arising from geothermal activities to determine under what sections of RCRA these should be controlled.

On December 18, 1978, EPA proposed the initial set of RCRA regulations for managing hazardous solid wastes. The cornerstone of these regulations was the Agency guidance on how to determine whether a solid waste is hazardous. Four candidate characteristics were introduced which formed the basis for identifying hazardous wastes: ignitability, corrosivity, toxicity, and reactivity. Two of these, corrosivity and toxicity, were potentially applicable to solid wastes produced by geothermal energy development operations. Two other properties, radioactivity and bioaccumulation potential, were examined. These properties were included among a set of additional criteria for listing a waste as hazardous under section 250.14 of the proposed regulations. These last two properties, radioactivity and bioaccumulation potential, and criteria for them, were not included in the final regulations published in May 1980, and were left to be considered later.

1.1.2 Objectives

The objectives of this project are:

- To sample and analyze solid wastes representing a broad spectrum of geothermal resource areas (GRA's) and types of exploration and development activities

- To preliminarily determine via the RCRA analytical protocols whether such solid wastes meet the criteria for being hazardous

1.1.3 Scope

The scope of this project was dictated by its role as a screening study to provide preliminary data and help focus the efforts of a comprehensive project to examine geothermal solid wastes. The number of samples analyzed was limited to approximately 20.

As recommended by EPA's Office of Solid Waste, the draft final report, "Field and Laboratory Sampling and Analysis Manual for the Presurvey of Solid Waste Management Practices in the Mining Industry," prepared by PEDCo Environmental for EPA/IERL-Ci, January 1980, was used for protocol guidance in the field sampling program.

The analytical protocols specified in the proposed RCRA regulations of December 18, 1978 (Title 40, Code of Federal Regulations Part 250, cited at Federal Register Volume 43, Number 243, p. 58946) were followed with the addition of an ambient pH extraction procedure (EP) using deionized water. During the course of the project, EPA promulgated final regulations for the hazardous waste identification portion of the RCRA hazardous waste management program proposed in 1978 (Title 40, Code of Federal Regulations Part 261, cited at Federal Register, Volume 45, Number 98, p. 33119, May 19, 1980). The analytical protocols employed in this study reflect the proposed regulations. These were not significantly altered by the May 19, 1980 promulgation. The results, however, are compared with the final regulations for the purpose of determining the hazardous nature of the solid wastes.

1.2 RESULTS

A summary of the results for the following major tasks of this study are presented below:

- Survey to identify sampling sites
- Field sampling program
- Analytical findings

1.2.1 Sampling Site Survey

Major geothermal resource exploration and development sites in the western United States and the Gulf Coast were preliminarily screened to locate candidate sites for obtaining solid waste samples. A telephone survey of over 20 individuals representing 15 organizations was conducted to identify the types of solid wastes generated and procedures necessary to obtain permission to sample.

As a result of the telephone discussions, follow-up letters, and several site visits, the sampling program was defined and permission granted for collecting samples in three geothermal resource areas:

- Imperial Valley -- 7 sites
- The Geysers -- 11 sites
- Northwestern Nevada -- 3 sites

1.2.2 Field Sampling Program

The geothermal sampling program consisted of three field trips:

Resource Area	Sampling Dates	No. of Samples Collected
Imperial Valley	May 20-23, 1980	16
The Geysers	June 3-5, 1980	13
Nevada	July 1-2, 1980	4
		33

The 33 samples collected were comprised of the following types:

	Total	Geysers	Imperial Val.	NV
Drilling sumps				
Mud/fluid	8	2	3	3
Mud only	3			3
Fluid only	5		5	
Preinjection treatment				
Sediment ponds (brines)	3		3	
Flash tank	1		1	
Filter press	1		1	
Cooling tower basins	3	3		
H_2S removal				
Centrifuge (iron sulfide sludge dewatering)	3	3		
Stretford process sulfur recovery stream	1	1		
Miscellaneous				
Pipe scale	2		2	
Geological surface expression	1	1		
Landfill	2		2	

1.2.3 Analytical Findings

The focus of the sample analysis program was to evaluate solid wastes in comparison to some RCRA hazardous waste characteristics and listing criteria proposed in 1978. Results of this effort are presented in Table 1-1.

Of the 20 samples collected which were selected for analysis, only five exhibited corrosivity, radioactivity, toxicity, or bioaccumulation values which exceed the proposed (for radioactivity and bioaccumulation) or the promulgated (for corrosivity and toxicity) RCRA criteria for being considered hazardous solid wastes. The two samples (G10 and G14) which exceeded the maximum concentrations for the EP toxicity metals are both geothermal brines collected at wells in the northern portion of the

Table 1-1. Comparison of Analytical Results with RCRA Criteria for Hazardous Wastes

Sample Number	Sample Type	Waste Criteria / Constituent Analyzed: / RCRA Limits:	Corrosivity pH ≤2 or ≥12.5	Radioactivity Radium-226 ≥5 pCi/g or ≥50 pCi/L[b]	EP Toxicity[a] (mg/L) As 5.0	Ba 100.0	Cd 1.0	Cr 5.0	Pb 5.0	Hg 0.2	Se 1.0	Ag 5.0	Bioaccumulation potential Log P>3 positive Peaks
G8*	Sludge			78 pCi/g									
G10*	Brine		1.6			363							
G12*	Solids												Positive
G14*	Brine			1,320 pCi/L	14		4		83		5.1		
G16*	Mud			5.9 pCi/L									
All Others **	Various		3.7 - 12	0 - 3.9 pCi/g 0 pCi/L	<0.020 0.31	<0.3 22	<0.005 0.07	<0.020 0.98	<0.020 0.70	<0.001	<0.020 0.18	<0.020	Not analyzed or zero

*Values presented only for exceedences of RCRA limits

**Ranges presented for highest and lowest values (all within RCRA limits)

[a]Acid extracts and liquid sample filtrate

[b]Radioactivity criteria proposed 12/18/78; not promulgated.

Imperial Valley. Under current regulations in force in this GRA, brines such as these are routinely disposed of in State hazardous waste disposal sites.

In addition to the eight metals cited under the RCRA EP toxicity characteristic, eight additional metals were analyzed in this study. These were included because of their suspected presence in geothermal solid wastes and their listing in the water quality standards of several western states. Analytical results for these metals are summarized in Table 1-2.

Additional organic analyses were conducted on three samples. The EP extracts were solvent extracted and the acid and base/neutral fractions analyzed for a total of 57 organic compounds by GC/MS. The solvent extracts were also tested for bioaccumulation potential using the high performance liquid chromatography (HPLC) procedure specified in the proposed RCRA regulations of December 18, 1978. One sample showed a positive bioaccumulation potential.

1.2.4 Conclusions and Recommendations

Samples of solid wastes were obtained from The Geysers geothermal powerplant in northern California, from several of the geothermal exploration and development sites in the Imperial Valley of southern California, and from a few exploration sites in northern Nevada. The conclusions and recommendations from the limited sampling and analysis effort are presented below.

Conclusions

1. This study cannot be used to broadly generalize as to the hazardous character of geothermal wastes outside the sites studied without

Table 1-2. Summary of Results for Additional Metals[a]

Metal	Range of Concentrations -- All Samples (mg/L)	Average Concentration -- All Values Above Detection Limit (mg/L)	Number of Values Above Detection Limit[b]
Antimony	<0.05 - 0.18	0.14	3
Beryllium	<0.020	--	0
Boron	<0.2 - 660	43	26
Copper	<0.05 - 60	9	12
Lithium	<0.05 - 5.8	1.1	19
Nickel	<0.2 - 0.90	0.50	11
Strontium	<0.5 - 1400	174	16
Zinc	<0.020 - 6000	203	30

[a]Includes results for both acid and ambient pH extracts
[b]Total number of possible values (analyses) equals 42

considerable qualification. Each geothermal resource must be considered unique in its chemical and physical character.

2. None of the samples of waste materials collected at the commercial powerplant operations in The Geysers geothermal steam fields and at the northern Nevada exploration sites could be classified as hazardous as defined by the criteria in the Hazardous Waste regulations published May 19, 1980 in the Federal Register.

3. Several samples including brines, drilling wastes, and settling pond solids from geothermal exploration and development sites in the Imperial Valley could be classified as hazardous waste, with properties exceeding the proposed Hazardous Waste Criteria in one or more of the categories of pH, radioactivity, EP toxicity, and bioaccumulation.

4. The principal source of the hazardous properties in the Imperial Valley is the geothermal brine itself. Imperial Valley brines generally have considerably higher salinities than do geothermal fluids elsewhere. Hazardousness of the waste appears to be directly related to salinity.

5. Since salinity is site-dependent, it can be concluded that the hazardous waste character or geothermal solid wastes will be site dependent.

6. Higher heavy metal concentrations were always associated with low ambient pH, but low pH did not guarantee high heavy metal content.

7. High radioactivity (Radium 226) values were associated with higher metals content.

8. The significance of the high bioaccumulation potential in one sample has not been determined. The bioaccumulating compounds were not identified.

Recommendations

1. Geothermal resources should be screened for radioactivity and pH. Samples with pH below 4.0 should be further screened for heavy metals. The ambient or neutral toxicity EP can be used for these low pH samples.
2. Bioaccumulating constituents should be determined and their source identified before bioaccumulation is established as a major criterion for geothermal hazardous waste characterization.
3. In view of the requirements of the RCRA amendments of 1980 for a comprehensive study of the characteristics and disposal practices for geothermal solid wastes, any further research studies should be directed toward satisfying those requirements as further defined by EPA's Office of Solid Waste.

SECTION 2

SAMPLING PROGRAM

2.1 SELECTION OF SAMPLING SITES

The process of selecting sites for sampling geothermal solid wastes involved the following activities:

- Formulating a priority listing of desired sites
- Contacting site owners/operators to identify sampling points and requesting permission to collect samples
- Finalizing the group of sites to be visited

Based on discussions held at the beginning of the project with EPA, DOE, and Acurex project management, various geothermal developments in the United States were ranked into three groups according to their perceived desirability as sampling sites:

Group 1 (Prime Interest)	Group 3 (Least Interest)
The Geysers, California	Raft River, Idaho
Imperial Valley, California	Beowawe, Nevada
	Gulf Coast, Texas and Louisiana
Group 2	Klamath Falls, Oregon
	Puna, Hawaii
Valles Caldera, New Mexico	Other sites in the western
Roosevelt Hot Springs, Utah	United States

The location of these sites is illustrated in Figure 2-1.

Ranking criteria for the sites included consideration of the types of solid waste streams expected, their potential for containing hazardous

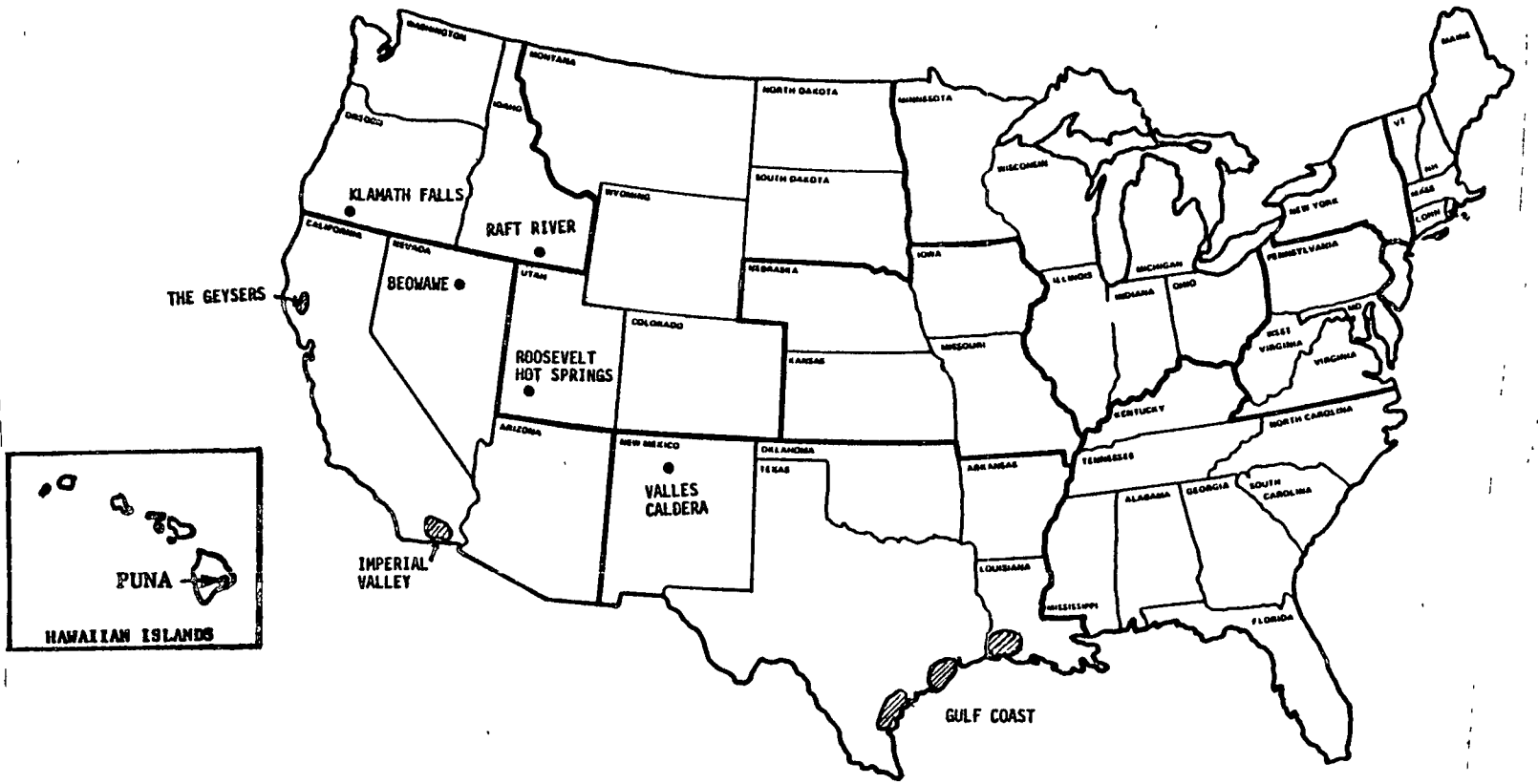


Figure 2-1. Potential Geothermal Solid Waste Sampling Sites

substances, and the extent to which the wastes may be indicative of commercial operations. It was also important to obtain samples representative of a variety of geothermal resource areas. The limit of approximately 20 samples for analysis constrained the breadth of sites considered.

Once the priority list was developed, a telephone survey of site owners/operators was begun. Over 20 individuals representing 15 organizations were contacted to determine:

- Types of solid wastes generated
- Operational status of processes producing these wastes
- Necessary procedures for obtaining permission to collect samples

As a result of the initial telephone calls to the Group 1 and 2 sites listed here, approximately 6 to 10 suitable sampling locations each were identified in The Geysers and Imperial Valley. However, due to prolonged site inactivity, no solid wastes samples were available at either Roosevelt Hot Springs, Utah or Valles Caldera, New Mexico.

Survey efforts were then redirected to focus on the Nevada and Idaho sites. After a series of telephone discussions with personnel responsible for the DOE Raft River project and Phillips Petroleum Company's three Nevada exploration sites, it was decided to request sampling permission for the following sites:

Imperial Valley

- DOE Geothermal Test Facility (GTF), East Mesa
- Republic Geothermal wells, East Mesa and near the Niland Known Geothermal Resource Area (KGRA)
- DOE Geothermal Loop Experimental Facility (GLEF), Salton Sea near Niland

- Imperial County Department of Public Works Class II-2 disposal sites, Brawley and Calexico
- MAPCO well, Westmorland

The Geysers

- Pacific Gas & Electric (PG&E) power generation facilities
- Union Oil of California wells and sedimentation pond
- Aminoil USA wells

Nevada

- Phillips Petroleum wells, Steamboat, Desert Peak, and Humbolt House

To facilitate obtaining site access permission and provide owners/operators with formal documentation of the purposes of the project, a letter of introduction and request to sample was prepared. A sample of this letter is presented in Appendix A.

A favorable response to our letter was received from each of the owners/operators contacted. In several cases, presampling site visits were conducted to discuss project objectives and sampling plans in more detail. As a result of the telephone survey, letter transmittals, and presampling meetings, final approval was obtained to collect samples at the locations identified in Table 2-1.

2.2 GENERAL SAMPLING METHODS

General methods used in the field sampling program are discussed below.

Table 2-1. Approved Sites for Collecting Samples

Geothermal Resource Area	Owner/Operator	Sampling Site	Sampling Point	Anticipated Number of Samples
The Geysers	PG&E	Units 3, 4, 5, 6	Centrifuge	1
		Unit 11	Centrifuge	1
		Unit 12	Centrifuge	1
		Units 7, 8 or 9, 10	Cooling tower basin	1
		Unit 15	Cooling tower basin	1
		Unit 13 or 15	Stretford process	1
	Aminoil USA	Drilling operations near Unit 13	Aminoil #1 well	1
			Aminoil #2 well	1
	Union Oil of California	Drilling operations near Unit 14	Abated well	?
		Adjacent to Unit 12	Sedimentation pond	
		Drilling operations near Unit 18 (planned)	Unabated well	
	California Division of Mines and Geology	Calistoga	Surface expression	1
			Ditch deposits	1
Imperial Valley	DOE/Magma Power	GLEF near Niland	Filter press	1
	DOE/Westec Services	GTF at East Mesa	Flash tank	1
			Evaporation pond	1
	Republic Geothermal	East Mesa	Sperry well mud pit	1
			Sperry well fluid pit	1
		Outside of Niland KGRA	Fee #1 well mud pit	1
			Fee #1 well fluid pit	1
	MAPCO/Republic Geothermal	Westmorland	Courier #1 well	1-2
	Imperial County Dept. of Public Works	Brawley	Class II-2 landfill	1
		Calexico	Class II-2 landfill	1
Nevada	Phillips Petroleum	Steamboat	Well sump	1
		Desert Peak	Well sump	1
		Humbolt	Well sump	1

2.2.1 Sampling Protocols

The Acurex field sampling plan was adapted from the following two sources:

- "Field and Laboratory Sampling and Analysis Manual for the Presurvey of Solid Waste Management Practices in the Mining Industry," draft report prepared by PEDCo Environmental, Inc., Cincinnati, Ohio
- "Samplers and Sampling Procedures for Hazardous Waste Streams," prepared by E. R. deVera, et al., California Department of Health Services, Berkeley, California, for the EPA/MERL-Ci, EPA-600/2-80-018, January 1980.

Preliminary Considerations

In general, sampling of solid wastes requires collecting an adequate quantity of a representative sample and maintaining its integrity through the analytical procedure.

The following steps are essential in a successful sampling program:

- Obtain permission to conduct sampling
- Research background information about the waste
- Determine sampling point
- Select proper container
- Design a sampling plan
- Observe proper sampling and handling precautions
- Deliver samples to the laboratory
- Log-in samples and set up traveller for tracking

Sampling Procedure for Dry Sumps

The surface area was divided into an imaginary grid and equal volumes of at least four subsamples (one from each corner) were obtained

to provide a composite sample representative of the entire sump. Subsamples were collected from 3 to 6 inches below the surface of the sump using a hand trowel.

Sampling Procedure for Ponds and Wet Sumps

For collecting sediment, the surface area was divided into an imaginary grid and equal volumes of at least four subsamples (one from each corner) were obtained to provide a representative composite sample. For collecting liquids, a single sample was obtained. Both types of samples were collected using a pond sampler.

Miscellaneous Procedures

Sludge from centrifuges was collected directly in the sample bottle. Samples in vats or tanks were collected by dipping. Pipe scale was removed with a hammer and chisel.

2.2.2 Field Equipment

All sampling equipment and containers were transported to and from the sites by Acurex's Mountain View, California offices. These included:

- Sample Containers -- All samples were stored in half-gallon widemouth polyethylene bottles (Nalgene)
- Sampling Equipment -- Most samples were collected using one of two basic techniques:
  - -- Pond Sampler -- A 1-liter polyethylene beaker at the end of an 8-foot extension rod
  - -- Hand Trowel -- Ordinary metal trowel
- Additional Field Equipment:
  - -- Gloves
  - -- Waders
  - -- Flashlight

-- Maps

-- Notebook

-- Labels

-- Rock hammer

-- Tape measure

-- Compass

-- Funnel

-- Safety equipment as required (i.e., goggles, hard hat, etc.)

-- Camera

2.2.3 Sample Preservation

As this study was designed to screen geothermal wastes, elaborate preservation procedures were not attempted. Samples were collected in the field and quickly returned to the Acurex Environmental Analytical Laboratory for storage at a constant temperature of $4^{o}C$.

2.3 IDENTIFICATION OF SAMPLES COLLECTED

The geothermal sampling program consisted of three field trips:

Resource Area	Sampling Dates	No. of Samples Collected
Imperial Valley	May 20-23, 1980	16
The Geysers	June 3-5, 1980	13
Nevada	July 1-2, 1980	4
		33

Trip reports for each field trip are presented in Appendix B.

Tabulation of the types of solid wastes collected is given as follows; a synopsis of the field sampling program appears in Table 2-2.

Drilling sumps	Total	Geysers	Imperial Val.	NV
Mud/fluid	8	2	3	3
Mud only	3			3
Fluid only	5		5	

Table 2-2. Results of Geothermal Field Sampling Program

Resource Area	Owner/Operator	Sampling Site	Sampling Point	No. of Samples Collected	Date Collected	Comments
Imperial Valley	DOE/Westec	GTF at East Mesa	Flash tank	1	5/20/80	Sample of wet scale from bottom of tank.
			Evaporation pond	2	5/20/80	Sampled near inlet and along perimeter.
			Pipe scale	2	5/20/80	Interior of pond inlet pipe and underground transfer pipe.
	Republic Geothermal	Sperry well at East Mesa	Mud pit	1	5/20/80	
			Fluid pit	1	5/20/80	Fluid low in suspended solids.
		Fee #1 well near Niland KGRA	Mud pit	1	5/21/80	
			Fluid pit	2	5/21/80	Two interconnected pits with fluid levels below connection point. Both samples left with Republic (proprietary data concern).
	DOE/Magma	GLEF near Niland	Filter Press	1	5/21/80	Sample previously collected (on 8/19/79). Reactor clarifier no longer in operation.
	Imperial Co. Dept. of Public Works	N. of Brawley	Class II-2 landfill	1	5/22/80	
		Calexico	Class II-2 landfill	1	5/22/80	Site last used about 2 years ago.
	MAPCO	Courier #1 well at Westmorland	Mud pit	1	5/23/80	
			Baker tanks	2	5/23/80	Flow test was in progress. Hot brine collected. Analysis begun on sample from one tank. Contents of tanks should be the same.

Table 2-2. Concluded

Resource Area	Owner/Operator	Sampling Site	Sampling Point	No. of Samples Collected	Date Collected	Comments
The Geysers	PG&E	Units 5, 6	Centrifuge	1	6/4/80	Adjoining Units 3 and 4 not in operation.
		Unit 11	Centrifuge	1	6/3/80	
		Unit 12	Centrifuge	1	6/3/80	
		Units 7, 8	Cooling tower basin	1	6/4/80	Basin cleaned last year. About 4 inches of sediment encountered.
		Units 9, 10	Cooling tower basin	1	6/3/80	Basin cleaned 2 years ago. About 8 inches of sediment. Difficulty experienced in mixing sample.
		Unit 15	Cooling tower basin	1	6/3/80	Very little sediment. Unit has not been online very long.
		Unit 15	Stretford sulfur product	1	6/3/80	Molten sulfur being transferred from storage tank to tank truck during sampling.
	Union Oil	Beigel #1 well	Sump	1	6/4/80	Steam venting and abatement (with peroxide/caustic) in progress while sampling.
		D&V #2 Unabated well	Sump	1	6/4/80	Inactive well. Rig still in place.
		Unit 12	Sedimentation pond	1	6/4/80	
	Aminoil USA	Aminoil #1 well	Sump	1	6/5/80	Well drilled to 5,249 feet. Still in mud phase.
		Aminoil #2 well	Sump	1	6/5/80	Well completed. Rig removed. Pit drying out.
	California Division of Mines and Geology	Calistoga	Surface expression	1	6/5/80	Some doubt if this is a geothermal mineral deposit. May be lava flow. Sample appears to consist of pumice.
Nevada	Phillips Petroleum	Steamboat #1 well	Sump	1	7/1/80	Flow test in progress. Sump contained liquid.
		Humbolt House well	Sump	1	7/2/80	Dry sump. Well last flow tested 11/79.
		Desert Peak well	Primary sump	1	7/2/80	Dry sump. Well last flow tested 2/79.
			Secondary sump	1	7/2/80	

	Total	Geysers	Imperial Val.	NV
Preinjection treatment				
Sediment ponds	3		3	
Flash tank	1		1	
Filter press	1		1	
Cooling tower basins	3	3		
H_2S removal				
Centrifuge (iron sulfide sludge dewatering)	3	3		
Stretford process sulfur recovery stream	1	1		
Miscellaneous				
Pipe scale	2		2	
Geological surface expression	1	1		
Landfills	2		2	

2.4 METHOD DEVELOPMENT NEEDS

Problems were encountered in sampling related to obtaining a representative sample. In some cases the samples were already homogeneous and a simple grab sample was sufficient. However, for most locations grab samples were composited onsite and then thoroughly mixed in the laboratory. Water or unstable muds prevented sampling at the middle of many ponds and sumps. In these cases, grab samples were collected at the four corners near the edge. Sampling cooling tower sediment presented special problems. Stratification was particularly obvious since layers of many colors were present. Efforts were made to mix these in the field before sample splitting, but thorough mixing in the laboratory would have been preferred. Most of the samples taken from sumps or ponds were

collected at a maximum depth of about 6 inches. A good representative sample would have required a coring device mounted on a boat or suspended from a crane. This would have permitted sampling the full depth of the pond or sump, which in some cases was 8 feet or more.

When collecting a sediment sample in contact with water, the field crew had to make a decision as to how much water to decant. Attempts were made to obtain a sample with a water content that would be representative of the waste as eventually disposed. However, standard procedures for sampling water-covered sediment should be developed.

SECTION 3

SAMPLE ANALYSIS

This section discusses the analytical scheme and how it was formulated, criteria for choosing certain samples for analysis, results of the various analyses performed, quality control procedures, and method development needs.

3.1 GENERAL ANALYTICAL APPROACH

The focus of the analytical program was to perform those hazardous waste identification tests proposed by EPA under RCRA that were potentially applicable to geothermal solid wastes. In addition, the chemical composition of the samples was to be determined by analyzing for the major cations and anions.

3.1.1 Background

EPA's proposed regulations for identifying hazardous wastes were issued on December 18, 1978 (cf 40 CFR 250, Federal Register, 43:243). Eight candidate characteristics of hazardous waste were introduced, of which four: ignitability, corrosivity, reactivity, and toxicity (via an EP) were felt by the Agency to have reliable test protocols already in place. An Advance Notice of Proposed Rulemaking was published along with the proposed regulations that sought to eventually include tests for radioactivity, unnatural genetic activity, and toxicity via chronic exposure to organic chemicals.

Consideration of the potential applicability of these proposed characteristics to geothermal solid wastes led to a decision to test for the following:

RCRA Hazardous Waste Property	Proposed Regulations Citation (Federal Register, 12/18/78)
Corrosivity	40CFR250.13(b)
Toxicity (EP)	40CFR250.13(d)
Radioactivity	40CFR250.15(a)(5), Appendix VIII
Bioaccumulation Potential*	40CFR250.15(a)(6)(ii), Appendix XI

*Only for those solid wastes for which organic additives were known or suspected to have been introduced

The EP in the toxicity test protocol was designed to simulate the leaching action of rain and groundwater in the acidic environment present in landfills or open dumps. It calls for the solid waste sample to be continuously exposed for 24 hours to an acidic solution. The extract is then analyzed for the presence of certain contaminants identified in the EPA National Interim Primary Drinking Water Standards (DWS). Only the eight inorganic elements listed under 40CFR250.13(d) were included in this study as it was not anticipated that any of the organic contaminants (all pesticides) would be found in geothermal solid wastes.

In an effort to obtain comparative data between the acidic solution EP and alternative simulations for the leaching process, an additional extraction (herein referred to as a neutral or ambient pH EP) was performed using deionized water as the extracting liquid in place of the specified acetic acid solution.

In addition to the DWS contaminants, eight elements not listed as part of the toxicity characteristic in the proposed regulations were included in the analytical plan. These were elements that were felt to be

present in geothermal solid wastes and for which various western states had adopted water quality criteria.

Because of the nature of geothermal solid wastes, only those samples known to have been contacted with anthropogenic organic compounds were analyzed for bioaccumulation potential. These samples were collected from sites downstream of points of known or suspected introduction of organic additives. Organic substances are occasionally added to drilling muds to improve their physical properties, to blowdown streams to enhance coagulation of ion hydroxides, and to process streams for scale inhibition. To provide for broader indentification of organics, a screening for the acid and base/neutral priority pollutants listed in Appendix E was performed in conjunction with the bioaccumulation potential test.

On May 19, 1980, EPA promulgated final regulations for portions of the RCRA hazardous waste management program proposed on December 18, 1978. The final regulations differed from those proposed in many respects. The key changes affecting this study were:

RCRA Hazardous Waste Characteristic	Key Changes in Final Regulations
Corrosivity	pH limits changed from ≤ 3 or ≥ 12 to ≤ 2 or ≥ 12.5
Toxicity	Maximum concentrations changed from 10 to 100 times the DWS
Radioactivity	Final regulations not promulgated
Bioaccumulation potential	Final regulations not promulgated

The analytical protocols published in the December 18, 1978 proposed regulations were followed throughout this study. However, these were not significantly changed in the final regulations. Corrosivity and

toxicity analytical results are compared in Section 3.3.4 to the May 19, 1980 final regulations rather than to the now superceded December 18, 1978 limits. As the radioactivity and bioaccumulation potential tests were not included in the final regulations, comparisons with the proposed regulations were continued.

3.1.2 Analytical Scheme

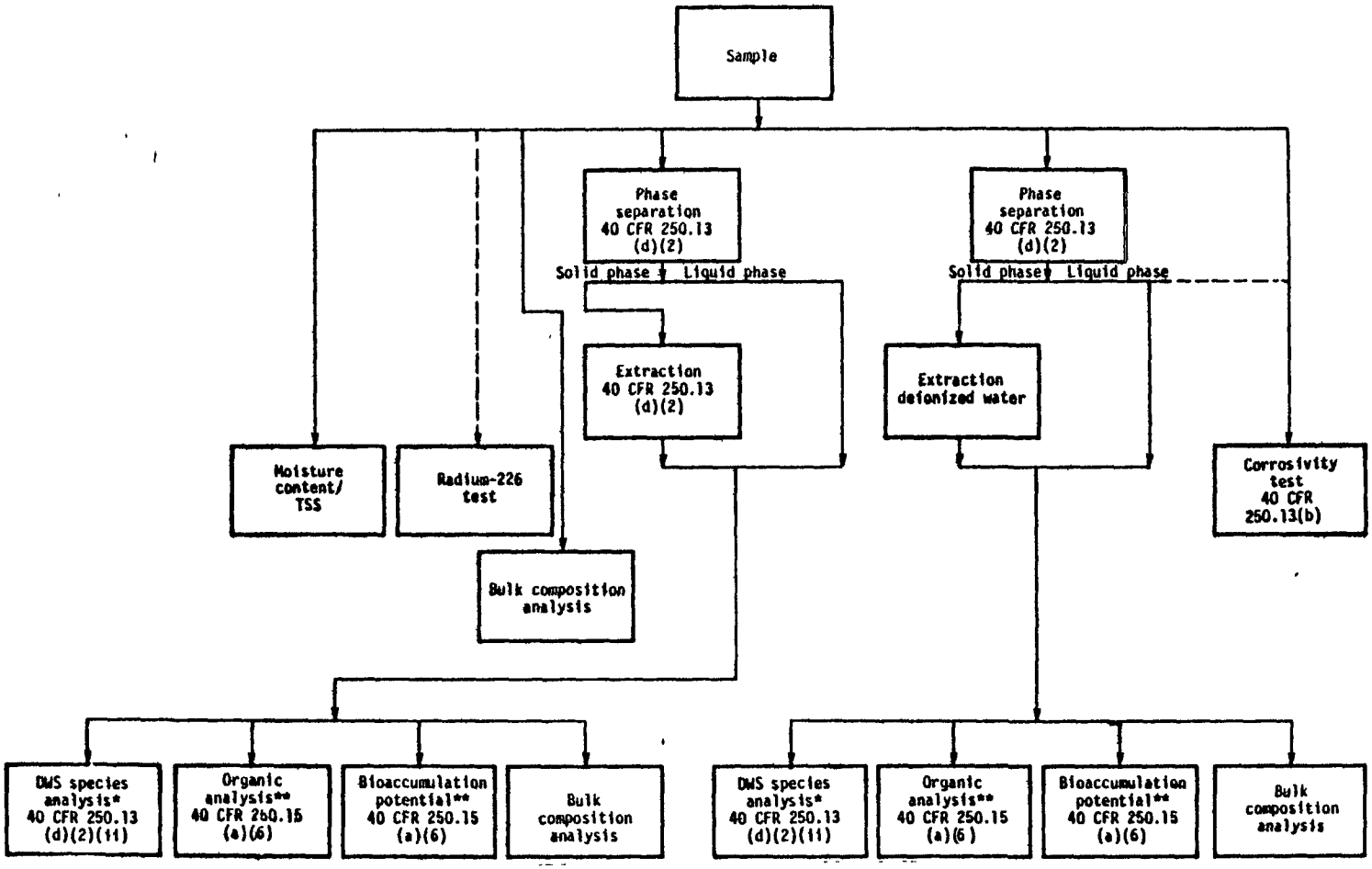
The analytical scheme employed for this study is shown in Figure 3-1. Four tests were performed on each original sample:

- Moisture content (or total suspended solids)
- Radioactivity (radium 226)
- Bulk composition (major cations and anions)
- Corrosivity

Moisture content (or total suspended solids) was determined for accurate quantitation. Total sample bulk composition analyses were performed to determine the general mineral content of the material as collected. Major cations and anions analyzed for in the bulk composition analyses included:

Anions	Cations
Chloride (Cl)	Aluminum (Al)
Fluoride (F)	Calcium (Ca)
Silica (SiO_2)	Iron (Fe)
Sulfate (SO_4)	Magnesium (Mg)
Sulfide (S)	Potassium (K)
	Sodium (Na)

Radioactivity and corrosivity are two of the properties of hazardous wastes. Under the final RCRA regulations, a solid waste is considered hazardous by reason of corrosivity if it exhibits a pH of less than or equal to 2 or greater than or equal to 12.5. According to the proposed RCRA regulations, a solid waste is hazardous by virtue of



*Plus additional water quality criteria trace elements

**For those samples with organic additives only.

40 CFR references were those published 12/18/78. These references were, in general, replaced by final regulations dated 5/19/81.

40 CFR 250.13(b) became 40 CFR 261.22
40 CFR 250.13(b)(2)(ii) became 40 CFR 261.24, Appendix II
40 CFR 250.15(a)(6) became part of 40 CFR 260.22

Figure 1. Analytical Scheme

radioactivity if it has an average radium 226 concentration equal to or greater than 5 picocuries per gram for solids or 50 picocuries per liter for liquids.

Phase separation and extraction were performed to simulate leaching as part of the EP toxicity test. The liquid phase from phase separation and the extract (either under acid pH with acetic acid or under ambient pH with deionized water) were combined for further analyses. These analyses included the RCRA EP toxicity and the bioaccumulation potential tests and the bulk composition determinations on both extracts.

The eight inorganic elements in the EP toxicity test and their maximum permissable concentrations in milligrams per liter (mg/l) are:

Element	Maximum Concentration (mg/l)*
Arsenic (As)	5.0
Barium (Ba)	100.0
Cadmium (Cd)	1.0
Chromium (Cr)	5.0
Lead (Pb)	5.0
Mercury (Hg)	0.2
Selenium (Se)	1.0
Silver (Ag)	5.0

*These values represent 100 times the DWS (cf 40CFR261.24 in Federal Register, May 19, 1980)

In addition, the following eight elements for which state water quality standards have been established were included in this study:

Element	Water Quality Standard (mg/l)	Application	State(s)
Antimony (Sb)	No standard	--	--
Beryllium (Be)	0.1	Agricultural use	Colorado
Boron (B)	0.5	All uses	Oregon
Copper (Cu)	0.005	All uses	Oregon
	0.01	Aquatic life protection	Utah
	1.0	Domestic water supply	Arizona, Colorado

Element	Water Quality Standard (mg/l)	Application	State(s)
Lithium (Li)	No standard		
Nickel (Ni)	0.05 - 0.40*	Aquatic life protection	Colorado
Strontium (Sr)	No standard		
Zinc (Zn)	0.01	All uses	Oregon
	0.05	Aquatic life protection	Utah
	5.0	Domestic water supply	Arizona, Colorado

*Standard varies as a function of stream water hardness

The bioaccumulation potential test and screening for priority pollutants were performed on the acid and ambient pH extracts for three samples known or suspected to have had organic substances added to them.

Bulk composition analyses for the major cations and anions listed above were conducted on the acid and ambient pH extracts for each sample.

3.1.3 Analytical Detection Limits

Detection limits for the analyses of the RCRA elements were determined by considering the RCRA maximum concentrations (cf Federal Register, May 19, 1980, p. 33122) and the National Interim Primary Drinking Water Standards on which they were based. These are compared below:

	RCRA Maximum Concentration (mg/L)	Drinking Water Standard (mg/L)	Analytical Detection Limit (mg/L)
Arsenic	5.0	0.05	0.02
Barium	100.0	1.0	0.3
Cadmium	1.0	0.01	0.005
Chromium	5.0	0.05	0.02
Lead	5.0	0.05	0.02
Mercury	0.2	0.002	0.001
Selenium	1.0	0.01	0.02
Silver	5.0	0.05	0.02

The detection limits chosen are significantly below the RCRA limits. For all metals except selenium, the detection limit is less than 0.5 percent of the RCRA level. For selenium, the detection limit is 2 percent of the RCRA level.

3.2 SELECTION OF SAMPLES FOR ANALYSIS

While the field sampling program yielded 33 samples, the project scope permitted only about 20 samples to be analyzed. Accordingly, a priority listing of all the samples collected was developed to facilitate the selection process. Factors considered in ranking the samples included the following:

- Sample quality -- samples taken from waste streams containing little material or from long, inactive sumps or landfills were given low rankings
- Geothermal resource variability -- a mix of samples representing the various geographic areas in the Imperial Valley and at The Geysers was desired
- Commercial operations applicability -- samples of solid wastes most closely associated with those expected of commercial operations were given high rankings

The priority listing of the samples is presented in Table 3-1. As more than one sample was collected at several of the sampling points, this list includes 33 samples obtained at 28 sites during the three field trips.

Final selection of the samples was based on a maximum for analysis of 20 (plus a duplicate of one sample); all 20 would be tested for radium 226 and 3 of the samples would be analyzed for organics (priority pollutants and bioaccumulation potential). The 20 selected samples are identified in Table 3-2.

Table 3-1. Priority Listing of Samples for Analysis

Priority	Sampling Site	Sampling Point	Date Collected
Group 1	Republic Sperry well at East Mesa	Mud pit	5/20/80
		Fluid pit	5/20/80
	North of Brawley	Class II-2 landfill	5/22/80
	MAPCO Courier #1 well at Westmorland	Mud pit	5/23/80
		Baker tank	5/23/80
Group 2	GTF at East Mesa	Flash tank	5/20/80
		Evaporation pond	5/20/80
	Geysers -- PG&E Units 5 & 6	Centrifuge	6/4/80
	Geysers -- Union abated well	Sump	6/4/80
	Geysers -- Union Unit 12	Sediment pond	6/4/80
Group 3	Republic Fee #1 well near Niland KGRA	Mud pit	5/20/80
	GLEF near Niland	Filter press	5/21/80
	Geysers -- PG&E Unit 12	Centrifuge	6/3/80
	Geysers -- PG&E Units 7 & 8	Cooling tower basin	6/4/80
	Geysers -- Aminoil #1 well	Sump	6/5/80
Group 4			
1	Nevada -- Phillips Steamboat #1 well	Sump	7/1/80
2	Nevada -- Phillips Humbolt House well	Sump	7/2/80
3	Nevada -- Phillips Desert Peak well	Primary sump	7/2/80
4 & 5	Geysers -- PG&E Unit 9[a]	Cooling tower basin	6/3/80
6	Republic Fee #1 well near Niland KGRA	Fluid pit	5/21/80

[a]To be analyzed in duplicate

Table 3-1. Concluded

Priority	Sampling Site	Sampling Point	Date Collected
7	GTF at East Mesa	Bypass pipe scale	5/20/80
8	Geysers -- Aminoil #2 well	Sump	6/5/80
9	Geysers -- Union unabated well	Sump	6/4/80
10	GTF at East Mesa	Pond inlet pipe scale	5/20/80
11	Geysers -- PG&E Unit 15	Stretford sulfur product	6/3/80
12	Geysers -- PG&E Unit 11	Centrifuge	6/3/80
13	Calistoga	Surface expression	6/5/80

Table 3-2. Final Selection of Samples for Analysis

Priority	Sampling Site	Sampling Point	Date Collected	Date Analysis Begun	Radium 226	Organics
Group 1	Republic Sperry well at East Mesa	Mud pit	5/20/80	5/29/80	X	
		Fluid pit	5/20/80	5/29/80	X	
	N. of Brawley	Class II-2 landfill	5/22/80	5/29/80	X	X
	MAPCO Courier #1 well at Westmorland	Mud pit	5/23/80	5/29/80	X	
		Baker tank	5/23/80	5/29/80	X	
Group 2	GTF at East Mesa	Flash tank	5/20/80	6/16/80	X	
		Evaporation pond	5/20/80	6/16/80	X	
	Geysers -- PG&E Units 5 & 6	Centrifuge	6/4/80	6/16/80	X	X
	Geysers -- Union abated well	Sump	6/4/80	6/16/80	X	X
	Geysers -- Union Unit 12	Sediment pond	6/4/80	6/16/80	X	
Group 3	Republic Fee #1 well near Niland KGRA	Mud pit	5/20/80	6/16/80	X	
	GLEF at Salton Sea	Filter press	5/21/80	6/16/80	X	
	Geysers -- PG&E Unit 12	Centrifuge	6/3/80	6/16/80	X	
	Geysers -- PG&E Units 7 & 8	Cooling tower basin	6/4/80	6/16/80	X	
	Geysers -- Aminoil #1 well	Sump	6/5/80	6/16/80	X	
Group 4						
1	Nevada -- Phillips Steamboat #1 well	Sump	7/1/80	7/8/80	X	
2	Nevada -- Phillips Humbolt well	Sump	7/2/80	7/8/80	X	
3	Nevada -- Phillips Desert Peak well	Primary sump	7/2/80	7/8/80	X	
4 & 5	Geysers -- PG&E Unit 9[a]	Cooling tower basin	6/3/80	7/8/80	X	
6	Republic Fee #1 well near Niland KGRA	Fluid pit	5/21/80	7/8/80	X	

[a]Duplicates to be analyzed. No bulk compositions to be performed.

X means that the sample was analyzed for Ra 226 and/or organics.

3.3 ANALYTICAL RESULTS

The analytical results are presented in this section for the following analyses:

- Corrosivity
- Radioactivity
- EP toxicity
- Organics
- Bulk composition

In each of the above, the measurement technique employed is described, the results obtained are tabulated, and any specific analytical problems encountered are identified.

Detailed discussions of the analytical methods used are provided in Appendix B. The complete set of analytical results for each sample is included in Appendix C.

To facilitate identifying the various samples in the results tables in this section, a key to the sample numbers and their descriptions is presented in Table 3-3.

3.3.1 Corrosivity

Corrosivity was determined by measuring the pH of a 5 weight percent slurry of the sample for solids. Liquids (brines) were measured directly. Results are given in Table 3-4.

3.3.2 Radioactivity

Radium 226 analyses were performed on 20 samples as a measure of radioactivity. Results are presented in Table 3-5 in pCi/g for all samples except for two liquids samples which are reported in pCi/L. Sample G10 was essentially a liquid but had high total suspended solids (TSS) and was determined on the basis of total solids and reported as

Table 3-3. Key to Identifying Samples

Sample Number		Sample Description	Location	Geothermal Resource Area (GRA)	Site Owner/Operator
Field	Lab				
G1	1428	Dowell Flash Tank	Geothermal Test Facility, East Mesa	IV	DOE/Westec Services
G3	1430	Brine Holding Pond	Geothermal Test Facility, East Mesa	IV	DOE/Westec Services
G6	1433	Mud Pit, Sperry Well	East Mesa	IV	Republic Geothermal
G7	1434	Fluid Pit, Sperry Well	East Mesa	IV	Republic Geothermal
G8	1435	Clarifier Reactor Sludge Underflow	Geothermal Loop Experimental Near Niland	IV	DOE/Magma Power
G9	1436	Mud Pit, Fee #1 Well	Near Niland	IV	Republic Geothermal
G10	1676	North Brine Pit, Fee #1 Well	Near Niland	IV	Republic Geothermal
G12	1437	Class II-2 Landfill	Brawley	IV	Imperial County Dept. of Public Works
G14	1439	East Baker Tank, Courier #1 Well	Westmorland	IV	MAPCO
G16	1441	Mud Pit, Courier #1 Well	Westmorland	IV	MAPCO
G19-2	1576	Iron Sludge from Centrifuge	Unit 12	G	PG&E
G20-1	1577A	Cooling Tower Sediment	Unit 9	G	PG&E
G20-1	1577B	Cooling Tower Sediment	Unit 9	G	PG&E
G22-1	1579	Iron Sludge from Centrifuge	Units 5 & 6	G	PG&E
G23-1	1580	Cooling Tower Sediment	Units 7 & 8	G	PG&E
G24-1	1581R	Abated Well Sump, Beigel #1 Well	Near Unit 18	G	Union Oil of California
G26-1	1585R	Sedimentation Pond	Unit 12	G	Union Oil of California
G27-1	1587	Sump in Mud Drilling Phase, Aminoil #1 Well	Near Unit 13	G	Aminoil USA
G30	1668	Sump, Steamboat #1 Well	Steamboat	N	Phillips Petroleum
G31	1669	Sump, Humbolt House Well	Humbolt	N	Phillips Petroleum
G32	1670	Primary Sump, Desert Peak Well	Desert Peak	N	Phillips Petroleum

IV = Imperial Valley
G = The Geysers
N = Nevada

Table 3-4. Corrosivity in Order of Increasing pH

Sample Number	Sample Description	Geothermal Resource Area	pH
G10	North Brine Pit (brine)	IV	1.6
G20	Cooling Tower Sediment	G	3.7
G14	East Baker Tank (brine)	IV	3.8
G26-1	Sedimentation Pond	G	4.2
G23-1	Cooling Tower Sediment	G	5.1
G8	Clarifier Sludge	IV	6.1
G19-1	Iron Sludge	G	6.2
G22-1	Iron Sludge	G	6.6
G9	Mud Pit	IV	8.4
G7	Fluid Pit (brine)	IV	8.7
G16	Mud Pit	IV	8.8
G1	Flash Tank Scale	IV	8.8
G3	Brine Holding Pond	IV	8.8
G32	Primary Sump	N	9.1
G30	Sump	N	9.3
G27	Sump	G	9.6
G31	Sump	N	9.8
G24-1	Well Sump	G	10.0
G12	Class II-2 Landfill	IV	10.0
G6	Mud Pit	IV	12.0

IV = Imperial Valley site
G = The Geysers site
N = Nevada site

Table 3-5. Radium 226 In Order of Increasing Activity
(moisture-free basis, except as noted[a])

Field Number	Sample Description	Geothermal Resource Area	pCi/g
G20-1	Cooling Tower Sediment	G	0
G26-1	Sedimentation Pond	G	0
G23-1	Cooling Tower Sediment	G	0
G19-1	Iron Sludge	G	0
G22-1	Iron Sludge	G	0
G7	Fluid Pit	IV	0 [a]
G10	North Brine Pit	IV	0.4
G27-1	Sump	G	0.4
G24-1	Sump	G	0.5
G30	Sump	N	1.0
G6	Mud Pit	IV	1.0
G12	Class II-2 Landfill	IV	1.15
G3	Brine Holding Pond	IV	1.5
G31	Sump	N	1.6
G9	Mud Pit	IV	2.1
G1	Flash Tank Scale	IV	3.0
G32	Primary Sump	N	3.8
G16	Mud Pit	IV	5.9
G8	Clarifier Sludge	IV	78
G14	East Baker Tank	IV	1320[a]

a - not moisture-free basis, shown as pCi/L

IV = Imperial Valley site
G = The Geysers site
N = Nevada site

pCi/g. All values in Table 3-5 except for samples G7 and G14 are reported on a dry basis.

3.3.3 EP Toxicity

Samples were prepared for analysis by the extraction procedures described previously. The bulk sample was filtered, the residue extracted under acid and neutral (ambient) pH conditions and filtered, and the original and final filtrate combined. Three samples (G7, G10, and G14) were geothermal brines with less than 0.5 percent TSS. These were not extracted but were filtered and the filtrate analyzed.

Analyses were performed on the acid and ambient pH extracts for a total of 16 elements: 8 RCRA regulated and 8 additional metals. Results are presented in Table 3-6 for the RCRA elements and Table 3-7 for the additional metals. All anayses except for boron were performed by atomic absorption spectroscopy (AA). Boron was measured by the Curcumin colorimetric method.

Because of high levels of colloidal material in a number of samples, problems were encountered in filtration both before and after extraction. Table 3-8 identifies alternate procedures used to circumvent these difficulties. In all cases except for the sample G12 ambient pH extract, the procedures recommended in Appendix II of the final RCRA regulations (cf Federal Register, May 19, 1980, p. 33127) were followed. Filtration after centrifugation could not be successfully performed on the sample G12 ambient pH extract.

Difficulties encountered in analyzing the extracts included the following:

- Interferences prevented quantitation of mercury in two samples: G12 (ambient pH extract) and G10

Table 3-6. RCRA Trace Elements in Order of Decreasing Total Trace Elements (mg/l) in Acid and Ambient pH Extracts

Sample Number	Sample Type		Arsenic		Barium		Cadmium		Chromium		Lead		Mercury		Selenium		Silver		Total	
		GRA	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP
G10	Brine	IV	--	ND	--	363	--	0.07	--	0.98	--	NR	--	INT	--	ND	--	NR	--	364
G14	Brine	IV	--	14	--	22	--	4	--	ND	--	83	--	ND	--	5.1	--	ND	--	128
G16	Mud	IV	0.049	0.047	13	6.8	0.020	ND	ND	ND	0.060	ND	ND	ND	0.10	0.12	ND	ND	13.2	6.9
G1	Scale	IV	0.036	0.033	10.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10.5	0.03
G8	Sludge	IV	0.23	0.23	5.0	5.4	NA	NA	ND	ND	0.20	ND	ND	ND	0.18	0.22	ND	ND	5.61	5.85
G3	Sediment	IV	0.045	0.065	3.8	0.60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.85	0.67
G9	Mud	IV	0.063	ND	1.8	ND	0.006	ND	ND	ND	ND	ND	ND	ND	0.030	0.020	ND	ND	1.90	ND
G27-1	Mud	G	ND	0.032	1.4	ND	ND	ND	0.070	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.47	0.03
G6	Mud	IV	ND	ND	1.4	ND	ND	ND	0.030	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.43	ND
G31	Mud	N	ND	0.014	0.60	0.50	0.006	0.005	ND	0.027	0.70	0.50	ND	ND	ND	ND	ND	ND	1.30	1.17
G12	Mixed Sol	IV	0.10	NA	1.0	1.4	ND	ND	0.023	0.42	ND	0.20	ND	INT	ND	NA	ND	ND	1.12	2.02
G30	Mud	N	0.06	0.26	0.60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.66	0.26
G32	Mud	N	ND	ND	0.50	ND	ND	ND	ND	0.039	ND	ND	ND	ND	0.030	ND	ND	ND	0.53	0.39
G7	Brine	IV	--	0.31	--	ND	--	ND	--	ND	--	ND	--	ND	--	ND	--	ND	--	0.31
G20-18	Sediment	G	0.087	0.068	ND	ND	0.010	0.010	0.029	0.023	0.140	0.180	ND	ND	ND	ND	ND	ND	0.27	0.28
G20-1A*	Sediment	G	0.088	0.051	ND	ND	0.013	0.014	0.051	0.020	0.100	0.130	ND	ND	ND	ND	ND	ND	0.25	0.22
G23-1	Sediment	G	0.110	0.150	ND	ND	NA	NA	ND	ND	0.070	0.050	ND	ND	ND	ND	ND	ND	0.18	0.20
G26-1	Sediment	G	0.020	0.034	ND	ND	0.008	0.007	0.053	ND	ND	ND	ND	ND	0.030	0.040	ND	ND	0.11	0.08
G22-1	Sludge	G	ND	ND	ND	ND	ND	ND	ND	ND	0.020	0.050	ND	ND	ND	ND	ND	ND	0.02	0.05
G19-1	Sludge	G	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
G24-1	Mud	G	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

AEP Acid extraction procedure
INT Interference
IV Imperial Valley
G The Geysers
NEP Ambient pH (neutral) extraction procedure
N Nevada
-- Not applicable
NR Not reported
ND Not detected
* Duplicate analysis

Table 3-7. Additional Metals in Order of Decreasing Total Trace Elements (mg/l) in Acid and Ambient pH Extracts

Sample Number	Sample Type	GRA	Antimony		Beryllium		Boron		Copper		Lithium		Nickel		Strontium		Zinc		Total	
			AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP
G14	Brine	IV	--	ND	--	ND	--	238	--	ND	--	0.24	--	ND	--	1400	--	6000	--	7630
G10	Brine	IV	--	ND	--	ND	--	660	--	7.40	--	NR	--	0.30	--	1290	--	NR	--	1960
G23-1	Sediment	G	ND	ND	ND	ND	7.70	0.88	60	33	ND	ND	ND	ND	ND	ND	7.5	6.0	67.7	39.9
G8	Sludge	IV	ND	ND	ND	ND	12.0	13.0	0.15	ND	5.8	ND	0.50	ND	12.0	15.0	6.4	4.0	37.8	39.9
G16	Mud	IV	ND	ND	ND	ND	0.25	3.10	ND	ND	3.3	3.1	ND	ND	23.0	20.0	7.0	ND	33.3	24.4
G20-1A	Sediment	G	ND	ND	ND	ND	23.0	16.0	2.2	1.8	ND	ND	0.90	0.70	ND	ND	6.20	6.00	32.3	24.5
G26-1	Sediment	G	ND	ND	ND	ND	19.0	30.0	ND	ND	ND	ND	0.40	0.40	ND	ND	9.0	14.0	28.4	34.4
G22-1	Sludge	G	ND	ND	ND	ND	28.0	27.0	ND	ND	ND	0.10	0.20	ND	ND	ND	0.06	0.03	28.2	27.1
G20-1B	Sediment	G	ND	ND	ND	ND	13.0	13.0	1.9	1.1	ND	ND	0.7	0.6	ND	ND	5.0	4.5	20.6	19.2
G3	Sediment	IV	ND	ND	ND	ND	ND	NB	ND	NB	0.17	0.13	ND	ND	8.3	ND	0.110	ND	8.60	0.13
G19-1	Sludge	G	ND	ND	ND	ND	7.6	0.52	ND	ND	ND	ND	ND	ND	ND	ND	0.20	0.05	8.10	0.57
G9	Mud	IV	ND	ND	ND	ND	ND	0.20	ND	ND	1.30	1.10	ND	ND	5.4	1.5	1.3	ND	8.0	2.8
G27	Mud	G	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.5	ND	0.08	ND	3.6	ND
G31	Mud	N	ND	ND	ND	ND	ND	ND	ND	0.10	0.05	ND	ND	ND	3.0	ND	0.42	0.28	3.5	0.34
G32	Mud	N	ND	ND	ND	ND	0.23	0.47	0.20	0.10	0.30	0.20	ND	ND	2.6	ND	0.14	0.05	3.5	0.82
G7	Brine	IV	--	ND	--	ND	--	ND	--	ND	--	2.8	--	ND	--	ND	--	0.03	--	2.8
G12	Mixed Sol	IV	ND	ND	ND	ND	ND	0.34	ND	0.23	0.13	0.34	ND	ND	2.4	ND	0.25	1.4	2.8	2.0
G6	Mud	IV	ND	ND	ND	ND	ND	ND	ND	ND	NB	ND	ND	ND	2.2	ND	0.15	ND	2.4	ND
G24-1	Mud	G	ND	ND	ND	ND	0.87	15.0	NB	ND	ND	ND	0.30	0.50	0.60	ND	0.30	ND	2.1	15.5
G30	Mud	N	ND	0.07	ND	ND	0.30	0.57	ND	ND	0.50	0.40	ND	ND	1.0	ND	0.12	ND	1.9	1.4
G1	Scale	IV	0.18	0.18	ND	ND	ND	ND	0.15	ND	0.22	0.14	ND	ND	ND	ND	0.70	ND	0.62	0.32

AEP Acid extraction procedure
IV Imperial Valley
G The Geysers
N Nevada
NEP Ambient pH (neutral) extraction procedure
-- Not applicable
NR Not reported
ND Not detected

Table 3-8. Alternate Methods Employed in the Extraction Procedure

Sample Number	Grinding Required	Acid Extraction			Neutral Extraction	
		Extended Extraction	Centri-fugation	Final pH	Centri-fugation	Final pH
G1 (1428)	X			6.0		7.0
G3 (1430)		X		5.0	X	8.3
G6 (1433)				5.0	X	11.3
G8 (1435)				4.9		5.1
G9 (1436)			X	5.2	X	6.1
G12 (1437)			X	5.0	X	9.4
G16 (1441)			X	5.2	X	8.0
G19-1 (1576)				4.5		5.7
G20-1 (1577A)				4.9		5.1
G20-1 (1577B)				4.9		5.1
G22-1 (1579)				5.0		5.5
G23-1 (1580)				3.5		3.9
G24-1 (1581)				5.0		9.4
G26-1 (1585)				4.9		5.0
G27-1 (1587)				5.2	X	6.8
G30 (1668)		X		4.9	X	9.8
G31 (1669)			X	5.1	X	9.9
G32 (1670)				5.2	X	9.1

X indicates specific alternate method employed

- The acidification of the extracts with nitric acid created interferences in the boron analysis. Also, the presence of high dissolved solids or organic compounds in some samples introduced additional interferences in boron measurement
- AA analyses were performed using the graphite furnace for arsenic, cadium, chromium, lead, selenium, and antimony. Problems developed related to inhibition signals (low recoveries, especially lead) and false positive results caused by smoke and high salt content. The samples which were filtered but not extracted (1434, 1439, 1676) and the 1437 neutral extract (high organics) tended to produce erratic results in most furnace analyses. Flame analysis produced more reliable results and were relied upon as a check or for quantitation as appropriate

3.3.4 Organics Analysis

For three samples -- G12, G22-1, G24-1 -- known or suspected to have had organic additives introduced, organics analyses were performed. Sample G12 was collected at the Class II-2 landfill in Brawley. This landfill contained a mixture of fresh solid wastes, predominately drilling muds, from the Imperial Valley. Sample G24-1 was a drilling mud sample containing significant amounts of oil. Additives known to be present in this mud were bentonite, sodium hydroxide, calcium hydroxide, sodium tetraphosphate, "Not Plug," and a polymeric material. Sample G22-1 was selected for organics analysis because cationic polyamines and anionic polyacrylamides are added to the iron sludge. These additives facilitate settling of the solids.

Bioaccumulation potential was determined using the HPLC method specified in the proposed RCRA regulations. Priority pollutants listed in Appendix E were screened by gas chromotography/mass spectroscopy (GC/MS). Results of these analyses are presented in Table 3-9.

3.3.5 Bulk Composition

Bulk composition analyses were performed on the total sample and the acid and ambient pH extracts. Metals and silica were measured by AA. Chloride, flouride, sulfate, and sulfide were measured by standard wet chemical analyses. Results are presented in Tables 3-10 and 3-11 for the total sample and extract bulk compositions, respectively.

Because the zinc acetate sample preservation technique for sulfide was not employed, it was anticipated that sulfide would not be detected. This expectation was confirmed by the results in the tables.

3.4 QUALITY CONTROL

3.4.1 General Quality Assurance/Quality Control

Program specific quality control entailed several factors. The objective of the laboratory quality assurance/quality control (QA/QC) program was to meet EPA requirements for precise and accurate results. The principal features of the laboratory QA/QC procedures are summarized below.

Upon receipt at the Acurex Environmental Analytical Laboratory, samples were assigned laboratory identification numbers and logged in. An analysis request form was filled out by the sample control center with the aid of the project chemist. Samples were then placed in the laboratory cold storage room and analysis request forms turned in to the appropriate laboratory supervisors. Thus, the samples and required analyses were clearly specified.

Table 3-9. Organics Analysis Results

Bioaccumulation Potential

Sample No.	Extract	Percent of Peak Area Log P > 3	Bioaccumulation Potential
G12	Acid extract	0	Negative
	Neutral extract	72	Positive
G22-1	Acid extract	0	Negative
	Neutral extract	0	Negative
G24-1	Acid extract	0.39	Negative
	Neutral extract	1.8	Negative

Priority Pollutants Screening

Sample No.	Extract	Compounds Identified	Concentration (μg/l)
G22-1	Acid extract	Phenol	0.4
		Benzo (k) fluoranthene	14
	Neutral extract	None detected	
G24-1	Acid extract	Phenol	3
		2-nitro phenol	2
	Neutral extract	Phenol	640
G12	Acid extract	Phenol	4
	Neutral extract	Phenol	2
		4,6-dinitro cresol	18
		anthracene/ phenanthrene	6

Table 3-10. Bulk Composition of Total Sample (Decreasing Weight % Silica) and Tentative Identification of Major Components[a]

Sample Number	Sample Type	GRA	Wt % Silica	Other Materials (Approximate % in parentheses)
G9	Mud	IV	77	Sodium, potassium, calcium salts (10%); iron, magnesium, aluminum oxides (10%)
G16	Mud	IV	61	Sodium, calcium salts (15%); iron, magnesium, aluminum oxides (20%)
G6	Mud	IV	61	Calcium salts (10%); iron, magnesium, aluminum oxides (10%)
G27	Mud	G	59	Iron, magnesium, aluminum oxides (15%)
G12	Mixed Solids	IV	49	Calcium salts (10%); iron, magnesium, aluminum oxides (15%)
G24-1	Mud	G	41	Iron, magnesium, aluminum oxides (20%)
G30	Mud	N	33	Iron, magnesium, aluminum oxides (10%)
G31	Mud	N	31	Calcium salts (10%); iron, magnesium, aluminum oxides (10%)
G32	Mud	N	30	?
G8	Sludge	IV	23	Sodium, potassium calcium salts (35%); iron oxides (10%)
G3	Sediment	IV	15	?
G23-1	Sediment	G	12	Iron oxides (50%)
G1	Scale	IV	2	Calcium carbonate (70%)
G26-1	Sediment	G	T	Iron oxides (70%)
G22-1	Sludge	G	T	Iron oxides (40%)
G19-1	Sludge	G	T	Iron oxides (60%)

IV Imperial Valley
G The Geysers
N Nevada

[a]Percentages are on dry weight basis. Oxides are proportioned at approximately 0.3 to 0.5 times element. Percentages in parentheses are on "as received" basis.

Table 3-11. Bulk Composition of Extracts in Order of Decreasing Chloride Content (mg/l)

Number	Type	GRA	Chloride		Fluoride		Dissolved Silica		Sulfate		Aluminum		Calcium		Iron		Magnesium		Potassium		Sodium	
			AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP	AEP	NEP
G10	Brine	IV	--	295,000	--	19	--	300	--	ND	--	ND	--	61,000	--	3,200	--	313	--	38,000	--	55,000
G14	Brine	IV	--	158,700	--	10	--	18	--	ND	--	1.2	--	14,800	--	2,100	--	440	--	10,000	--	60,000
G8	Sludge	IV	6,000	5,370	1.7	1.8	4	2.0	1	6.5	ND	ND	800	840	1	ND	3.5	3.7	400	400	1,900	1,900
G16	Mud	IV	2,260	2,200	0.32	0.24	11	4.0	6.6	6.7	ND	ND	1,200	330	0.8	ND	18	5	170	160	975	950
G7	Brine	IV	--	1,700	--	10	--	13	--	65	--	1.6	--	30	--	0.97	--	1.7	--	91	--	1,500
G9	Mud	IV	1,280	1,150	0.95	0.55	4	ND	80	170	ND	ND	360	120	1.2	ND	32	5.8	130	120	580	550
G32	Mud	N	487	492	0.33	0.31	ND	ND	16	40	ND	ND	790	8.1	2.6	1.0	18	0.55	28	20	350	170
G12	Mixed Solids	IV	215	227	0.29	0.56	2	160	10	85	ND	190	680	33	0.8	76	20	52	48	85	235	230
G1	Scale	IV	57	59	6.3	0.42	4	4.0	4.5	6.2	ND	ND	1,800	3.2	ND	ND	4.4	0.08	9.4	6.3	55	50
G6	Mud	IV	54	55	0.60	0.32	32	4.0	64	30	1.2	1.2	1,100	28	5.8	ND	38	ND	24	18	115	105
G31	Mud	N	53	53	0.64	0.61	9	9.0	82	78	ND	4.5	1,300	25	4.6	9.2	27	4	13	4.7	140	120
G3	Sediment	IV	49	58	1.8	0.74	8	5.0	7	5.5	ND	ND	680	6.4	1.8	ND	7.6	0.48	17	11	63	50
G30	Mud	N	23	22	0.54	0.46	14	13	39	22	ND	ND	700	8.1	1.6	ND	15	0.08	21	12	53	48
G27	Mud	G	3.0	1.0	0.13	0.14	5	4.0	ND	14	ND	ND	690	0.81	14	0.8	6	0.40	2.5	0.83	28	25
G23	Sediment	G	2.0	2.0	0.16	0.15	ND	ND	300	260	1	ND	1.7	1.7	44	50	0.36	0.30	0.23	0.23	0.9	0.9
G24	Mud	G	2.0	ND	0.34	0.28	ND	16	32	62	ND	ND	280	34	32	ND	9.6	ND	6.3	2.5	24	48
G26	Sediment	G	1.0	2.0	0.12	0.07	5	4	1,400	1,900	ND	ND	4.8	2.1	630	730	1.2	1.5	0.60	0.71	60	71
G22	Sludge	G	ND	ND	0.12	0.14	ND	ND	9.6	85	ND	ND	2.4	2.0	ND	ND	0.20	0.16	0.18	0.15	24	24
G19	Sludge	G	ND	1.0	0.11	0.11	ND	ND	1.0	55	ND	ND	2.9	2.1	0.8	ND	0.28	0.22	0.28	0.23	17	16

AEP Acid extraction procedure
IV Imperial Valley
G The Geysers
N Nevada
NEP Ambient pH (neutral) extraction procedure
-- Not applicable
NR Not reported
ND Not detected

The laboratory analysis portion of the QA/QC program involved several phases, from glassware preparation to reporting of results, each controlled by formalized procedures. Any alterations of these procedures was reviewed with the project chemist.

The analytical quality procedures included blank, duplicate, and spike analyses as well as method blanks. Reference samples and calibration standards were of primary standard grade, National Bureau of Standards (NBS) traceable, or of certified purity. Specific results for duplicates and spikes are detailed in the following section. Blank and reference sample analysis results are available, but not included in this report.

To assure the integrity of the reported results, the project chemist reviewed data with the analysts and discussed the results. Reported values were transcribed directly from the laboratory books to the laboratory reporting form. The project chemist transcribed the analytical data to the report format. The typed draft for review was then checked against the original laboratory forms. By using these specific procedures and several other integral parts of the laboratory QA/QC program, the quality of the analytical work was documented and assured.

3.4.2 Program Specific Quality Control

Quality control generally covered 10 percent of the samples analyzed. There were several areas of quality control beyond the normal QC built into each analytical method.

Extract Blank

A DI water blank was carried through the entire extraction procedure including filtration of the sample. The blank was also carried

through the priority pollutant analytical scheme. Results for these analyses are shown in Table 3-11. Trace levels of some elements were detected, but in most cases levels were below the accurate quantitation limit of the method. The amounts detected can be attributed to impurities in the DI water, laboratory contamination, or problems with the method.

Spike and Recovery Experiments

For each analysis approximately four samples were spiked with the element of interest. Average recovery results are tabulated in Table 3-12. Most of the values were very close to 100 percent and as such are a good indicator of quality results.

Duplicates

Duplicate determinations were run on about four samples for each analytical procedure. In all cases the duplicates were within 10 percent of the original. This provided a good ongoing QC check for each analyst.

Acid and Neutral Extracts

Each of the 18 solid samples was actually extracted twice: once under acid conditions and once under "neutral" conditions; i.e., without adjustment to pH 5. For many parameters the concentrations were nearly identical in both extracts. In a sense, every extract was run in duplicate and these correlations were a good QC check.

A cross check on the QC was obtained by comparing similar samples. Sample G20 was run twice and all results showed good agreement. Samples G19 and G22 were from identical but separate processes in the same GRA. They also showed excellent agreement on EP trace element and bulk analyses.

Table 3-12. Analytical Results for Extract Blank

Sample: Extract Blank

Number: GO

Bulk Composition	Extract mg/L	Trace Elements	Extract µg/L
Aluminum (Al)	1	Arsenic (As)	<20
Calcium (Ca)	0.4	Barium (Ba)	<300
Iron (Fe)	<0.2	Cadmium (Cd)	<5
Magnesium (Mg)	0.05	Chromium (Cr)	<20
Potassium (K)	0.34	Lead (Pb)	30
Sodium (Na)	1.5	Mercury (Hg)	<1
Chloride (Cl)	1.5	Selenium (Se)	<20
Fluoride (F)	0.14	Silver (Ag)	<20
Silica (SiO_2)	5	Antimony (Sb)	<50
Sulfate (SO_4)	<1.0	Beryllium (Be)	<20
Sulfide (S)	<0.1	Boron (B)	340
		Copper (Cu)	<70
		Lithium (Li)	<50
		Nickel (Ni)	<200
		Strontium (Sr)	<500
		Zinc (Zn)	30

ORGANICS

Priority Pollutants	
Acid Fraction	None detected
Base/Neutral Fraction	None detected
Bioaccumulation Potential	Negative

Table 3-13. Percent Recovery of Spiked Samples

	Average Percent Recovery
Bulk Composition	
Aluminum (Al)	102
Calcium (Ca)	96
Iron (Fe)	94
Magnesium (Mg)	114
Potassium (K)	108
Sodium (Na)	95
Chloride (Cl)	95
Fluoride (F)	102
Silica (SiO_2)	106
Sulfate (SO_4)	93
Sulfide (S)	--
Trace Elements	
Arsenic (As)	102
Barium (Ba)	95
Cadmium (Cd)	90
Chromium (Cr)	95
Lead (Pb)	55
Mercury (Hg)	90
Selenium (Se)	86
Silver (Ag)	98
Antimony (Sb)	97
Beryllium (Be)	91
Boron (B)	75
Copper (Cu)	100
Lithium (Li)	100
Nickel (Ni)	89
Strontium (Sr)	71
Zinc (Zn)	101

SECTION 4

RESULTS DISCUSSION

The results presented in Section 3.3 are discussed in this section in terms of the RCRA hazardous waste identification criteria. Additionally, the results are compared on the basis of geothermal resource area and by type of extraction procedure employed.

4.1 RCRA HAZARDOUS WASTE REGULATIONS

There are four RCRA hazardous waste criteria for which analytical protocols and maximum limits have either been promulgated or proposed by EPA and which have been considered in this study:

- Corrosivity
- Radioactivity
- EP toxicity
- Bioaccumulation potential

Comparison of the 20 samples analyzed against the hazardous waste identification criteria for these characteristics yielded the results presented in Table 4-1. Five samples exceed one or more of these criteria. Sample G8, a clarifier reactor sludge from the Imperial Valley, exceeds the proposed (December 18, 1978) radium 226 limit. Sample G10, a well brine sample from the Imperial Valley, has a pH below the lower limit for corrosivity and has a barium concentration above the maximum. Sample G12, Brawley Landfill, showed a positive bioaccumulation potential and

Table 4-1. Comparison of Analytical Results with RCRA Criteria for Hazardous Wastes

Sample Number	Sample Type	Waste Criteria / Constituent Analyzed: / RCRA Limits:	Corrosivity pH ≤2 or ≥12.5	Radioactivity Radium-226 ≥5 pCi/g or ≥50 pCi/L[b]	EP Toxicity[a] (mg/L) As 5.0	Ba 100.0	Cd 1.0	Cr 5.0	Pb 5.0	Hg 0.2	Se 1.0	Ag 5.0	Bioaccumulation potential Log P>3 positive Peaks
G8*	Sludge			78 pCi/g									
G10*	Brine		1.6			363							
G12*	Solids												Positive
G14*	Brine			1,320 pCi/L	14		4		83		5.1		
G16*	Mud			5.9 pCi/L									
All Others **	Various		3.7 - 12	0 - 3.8 pCi/g 0 pCi/L	<0.020 0.31	<0.3 22	<0.005 0.07	<0.020 0.98	<0.020 0.70	<0.001	<0.020 0.18	<0.020	Not analyzed or zero

*Values presented only for exceedences of RCRA limits

**Ranges presented for highest and lowest values (all within RCRA limits)

[a]Acid extracts and liquid sample filtrate

[b]Radioactivity criteria proposed 12/18/78; not promulgated.

further testing is recommended. Sample G14, a well brine collected while a flow test was in progress in the Imperial Valley, exceeds the radioactivity limit and the maximum concentrations for arsenic, cadmium, lead, and selenium. Sample G16, a mud sample from the same well as number G14, exceeds the radioactivity limit. The greater number of RCRA limit exceedences for sample G14 are likely due to the fact that, unlike the other brine samples collected, the salts in G14 had no opportunity to settle out since the sample was collected during a well flow test.

None of the remaining 15 samples exhibited pH, radium 226, DWS contaminant values, or log $p > 3$ outside of the nonhazardous ranges for the corrosivity, radioactivity, and EP toxicity, or bioaccumulation potential criteria, as shown in Table 4-1.

The only two samples (G10 and G14) that exceeded the maximum values for criteria for which final regulations have been promulgated (corrosivity and EP toxicity) were geothermal brine samples from wells in the Imperial Valley. Current regulations adopted by the Regional Water Quality Control Board require that brines produced by geothermal drilling operations which exceed 6,000 ppm total dissolved solids be disposed of at a state hazardous waste disposal site. Well operators in the Imperial Valley generally maintain segregated drilling mud and brine pits. Muds are disposed of at Class II-2 disposal sites for nonhazardous wastes while brines are sent to Class I hazardous waste sites. Hence, the types of geothermal solid wastes represented by the two brine samples discussed above are already managed as hazardous wastes in the Imperial Valley.

Three samples (two drilling muds and an iron sulfide sludge) were screened for the 11 acid compounds and the 46 base/neutral compounds listed as priority pollutants by EPA (Appendix D). Each sample gave two

fractions for analysis by GC/MS. Phenol and phenol derivatives were found in all three samples.

Drilling muds can either be water-based or oil-based. Oil-base muds contain diesel fuel and asphalt as well as caustic soda and organic acids to control pH. Drilling muds also contain some of the following additives:

- pH control additives
- Bactericides
- Calcium removers
- Corrosion inhibitors
- Defoamers
- Emulsifiers
- Filtrate reducers
- Flocculants
- Foaming agents
- Plugging additives
- Lubricants
- Surface active agents
- Dispersants
- Viscosifiers

Under the conditions of high temperature common in geothermal drilling operations, these materials can degrade into compounds listed as priority pollutants.

The occurrence of phenols in the drilling mud samples (G12 and G24-1) may result from direct addition of these compounds, but more likely come from the reaction of caustic soda (NaOH) with additives containing phenol groups. The alkaline nature of the muds and the final pH of the

ambient extracts (both 9.4) suggest that the phenol is present as a sodium salt. This is confirmed by the higher concentration of phenol in the ambient extract (640 μg/L) compared to the acid extract (2 μg/L) in G24-1. Polynuclear aromatic compounds (PNA's) were also detected in G-12 and G22-1. For sample G-12, these could easily have come from asphalt (known to contain PNA's) which may have been used in an oil-based drilling mud system.

The presence of a PNA's in the iron sludge (G22-1) cannot be readily explained since the only known additives were polyamines and polyacrylamides.

4.2 GEOTHERMAL RESOURCE AREA

Samples were collected from three geothermal resource areas:

- Imperial Valley
- The Geysers
- Northwestern Nevada

A comparison of the analytical results from each of these areas for the RCRA hazardous waste criteria is presented in Table 4-2. Collectively, the Imperial Valley samples demonstrated the widest range of pH values and the highest radium 226 levels and DWS contaminant concentrations. The four samples which met either proposed or promulgated RCRA criteria for hazardous wastes were all from the Imperial Valley. The Geysers and northwestern Nevada samples were overall much lower in radioactivity levels and DWS contaminant concentrations. The Nevada samples, on the whole, were much lower in all respects than the samples from the other GRA's. This may be real or due to the limited number of Nevada samples analyzed.

Table 4-2. Comparison of Geothermal Resource Areas for RCRA Hazardous Waste Criteria

Geothermal Resource Area / Number of Samples	Waste Criteria: Constituent Analyzed: RCRA Limits.	Corrosivity: pH ≤ 2 or ≥12.5	Radioactivity: Radium-226 ≥5 pCi/g or 50 pCi/L	EP Toxicity[a] (mg/L): As 5.0	Ba 100.0	Cd 1.0	Cr 5.0	Pb 5.0	Hg 0.2	Se 1.0	Ag 5.0	Bioaccumulation potential: Log P > 3 positive Peaks
Imperial Valley 10		1.6 - 12.0	1.0 - 78 pCi/g 0 - 1320 pCi/L	ND[b]-14	ND-363	ND-4	ND-0.98	ND-83	ND	ND-5.1	ND	Negative Positive
The Geysers 7	Range presented for lowest and highest values	3.7 - 10.0	0 - 0.5 pCi/g	ND-0.110	ND-1.4	ND-0.013	ND-0.070	ND-0.140	ND	ND-0.030	ND	Positive
Nevada 3		9.1 - 9.3	1.0 - 3.8 pCi/g	ND-0.06	0.50-0.60	ND-0.006	ND	ND-0.70	ND	ND-0.030	ND	Positive

[a]Acid extract (except for liquid samples)
[b]Not Detected

4.3 ACID VERSUS AMBIENT pH EXTRACTION

The proposed and final RCRA regulations specify an acidic extraction procedure as part of the toxicity analysis. In addition to performing the specified acetic acid EP, a neutral or ambient pH EP using deionized water was conducted. A comparison of the results obtained by the two procedures yields the following:

DWS Element	Average Percentage by Which Neutral EP Results Varied from Acid EP
Arsenic	+32
Barium	-64
Cadmium	-32
Chromium	+28
Lead	+10
Mercury	--
Selenium	-12
Silver	--

Correlations are difficult because in some cases the ambient pH was on the acidic side of neutral. In general, the concentrations were higher in the acid extract. This was most apparent for calcium, magnesium, strontium, and barium. All of these elements form relatively insoluble carbonate salts which are more soluble under acidic conditions.

APPENDIX A

Letter Requesting Permission to Sample

Gentlemen:

I am writing to you concerning a request to sample solid waste materials from your geothermal installations.

Acurex Corporation is currently performing a study for the U.S. Environmental Protection Agency examining the hazardous potential of solid wastes from geothermal development and operational areas. Mr. Robert P. Hartley of EPA's Office of Research and Development, Cincinnati, OH is our technical project monitor. The U.S. Department of Energy is jointly funding this effort. Mr. Gerald Katz of the San Francisco Operations Office is DOE's technical advisor to Mr. Hartley. This work is being undertaken in cooperation with EPA's Office of Solid Waste. Mr. William Kline is the contact in that office.

The Resource Conservation and Recovery Act (RCRA) requires that EPA promulgate regulations for the handling and disposal of solid wastes, including those containing hazardous substances. EPA expects, as part of its obligations under RCRA, to examine the hazardous potential of various solid wastes such as those arising from geothermal activities in order to determine under what sections of RCRA these should be controlled. Congress is considering a temporary exemption from RCRA for geothermal energy projects while studies to define the nature of the wastes are on-going. Eventually, EPA will have to promulgate regulations and/or waste management guidelines for geothermal-produced solid wastes.

The Acurex study is a screening study, the results of which will be preliminary and will help focus the efforts of an anticipated comprehensive and detailed project to define the character of potentially hazardous wastes from geothermal energy development.

Over the next 3 months, we will sample and analyze solid wastes from as representative a group of geothermal sites as access permission and time and budget permit.

While our study is directed at assisting EPA in formulating a regulatory direction, it is not intended for use in conjunction with any enforcement proceedings. EPA does not plan to publish the final report of this preliminary study although copies may be released upon request. Duplicates of all samples which we collect will be provided to the facility operator for his independent analysis, if so desired. We will withhold transmitting our analytical results for a reasonable length of time to permit comparison with any independent analysis performed. Significant differences in the results obtained which cannot be explained by procedural variations will be noted in our report.

Acurex hopes to conduct the field sampling program during the months of May and June 1980. Types of samples to be collected would include drilling muds, holding and evaporation pond tailings, conversion process waste streams, and other solids, slurries, and sludges. We would identify the specific sampling points during telephone conversations with your designated officials prior to going out in the field.

Acurex will employ sampling and analytical protocols in conformance with EPA's proposed regulations (40 CFR 250 in 43 FR 58946) as updated by discussions with EPA's Office of Solid Waste and Las Vegas Environmental Monitoring System Laboratory personnel. Due to the screening nature of our study, only grab samples will be collected.

As part of our sampling program we would like to obtain information relating to waste volumes produced over time, operational status of processes sampled, and current waste handling and disposal practices.

I hope we can reach an agreement regarding access permission and timing that will be mutually acceptable and consistent with your needs.

Your earliest response to this request would be greatly appreciated. You may reach me with any questions at 415/964-3200, extension 3383. Mr. Hartley's telephone number is 513/684-4335. Mr. Kline's telephone number is 202/755-9200.

Sincerely yours,

David D. Minicucci
Project Engineer

DDM:lw

cc: R. Hartley, EPA-Ci
G. Katz, DOE-San

ATTACHMENT

Determining the hazardous character of the samples will consist of analyzing for the following constituents:

- Inorganics listed in proposed 40 CFR 250, Section 250.13(d) regulations. This list includes arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver.
- Boron, zinc, lithium, copper, antimony, nickel, beryllium, and strontium
- Potentially hazardous materials known or suspected to have been added in conversion processes, such as:
  - -- Scale and corrosion inhibitors
  - -- Additives for H_2S removal processes
- Radium 226

APPENDIX B

SPECIFIC ANALYTICAL METHODS

Acurex used EPA approved analytical methods for this program as summarized in Table B-1. Complete descriptions of the various analyses performed are presented below.

1. Metals

Metals were determined by atomic absorption (AA) spectroscopy using a Perkin-Elmer Model 460 equipped with heated graphite analyzer, hydride system and 30 lamps. Samples were digested with nitric acid or mixed acids if required. To obtain part per billion (ppb) detection limits for some trace elements, furnace techniques were used. Mercury was determined by the cold vapor technique.

2. Chloride

For the total sample, chloride was determined by potentiometric titration with silver nitrate solution. The digested sample was titrated to an end point which gave the greatest change in potential per unit volume of silver nitrate added.

Extracts were titrated with silver nitrate using potassium chromate as an indicator.

Table B-1. Summary of Analytical Methods

Bulk Composition -- Total Sample		
Aluminum (Al)	AA, Direct Aspiration	Method 202.1 (1)
Calcium (Ca)	AA, Direct Aspiration	Method 215.1 (1)
Iron (Fe)	AA, Direct Aspiration	Method 236.1 (1)
Magnesium (Mg)	AA, Direct Aspiration	Method 242.1 (1)
Potassium (K)	AA, Direct Aspiration	Method 258.1 (1)
Sodium (Na)	AA, Direct Aspiration	Method 273.1 (1)
Chloride (Cl)	Potentiometric	Method 408.C (2)
Fluoride (F)	Electrode	Method 414.B (2)
Silica (SiO_2)	AA, Direct Aspiration	Perkin-Elmer (3)
Sulfate (SO_4)	Gravimetric	Method 427.A (2)
Sulfide (S)	Titrimetric (Iodine)	Method 428.D (2)
Bulk Composition -- Extracts		
Aluminum (Al)	AA, Direct Aspiration	Method 202.1 (1)
Calcium (Ca)	AA, Direct Aspiration	Method 215.1 (1)
Iron (Fe)	AA, Direct Aspiration	Method 236.1 (1)
Magnesium (Mg)	AA, Direct Aspiration	Method 242.1 (1)
Potassium (K)	AA, Direct Aspiration	Method 258.1 (1)
Sodium (Na)	AA, Direct Aspiration	Method 273.1 (1)
Chloride (Cl)	Argentometric	Method 408.A (2)
Fluoride (F)	Electrode	Method 414.B (2)
Silica (SiO_2)	AA, Direct Aspiration	Perkin-Elmer (3)
Sulfate (SO_4)	Turbidimetric	Method 427.C (2)
Sulfide (S)	Methylene Blue	Method 428.C (2)

Table B-1. Continued

Trace Elements -- Extracts		
Arsenic (As)	AA, Furnace	Method 206.2 (1)
Barium (Ba)	AA, Direct Aspiration	Method 208.1 (1)
Cadmium (Cd)	AA, Direct Aspiration and Furnace	Methods 213.1 and 213.2 (1)
Chromium (Cr)	AA, Direct Aspiration and Furnace	Methods 218.1 and 218.2 (1)
Lead (Pb)	AA, Direct Aspiration and Furnace	Methods 239.1 and 239.2 (1)
Mercury (Hg)	AA, Cold Vapor	Method 245.1 (1)
Selenium (Se)	AA, Furnace	Method 270.2 (1)
Silver (Ag)	AA, Direct Aspiration	Method 272.1 (1)
Antimony (Sb)	AA, Furnace	Method 204.2 (1)
Beryllium (Be)	AA, Direct Aspiration	Method 210.1 (1)
Boron (B)	Colorimetric, Curcumin	Method 405.A (2)
Copper (Cu)	AA, Direct Aspiration	Method 220.1 (1)
Lithium (Li)	AA, Direct Aspiration	Perkin-Elmer (3)
Nickel (Ni)	AA, Direct Aspiration	Method 249.1 (1)
Strontium (Sr)	AA, Direct Aspiration	Perkin-Elmer (3)
Zinc (Zn)	AA, Direct Aspiration	Method 289.1 (1)
Other Parameters		
Corrosivity	Electrode	Method 150.1 (1)
Moisture	Gravimetric	Method 208.A (2)
TSS	Gravimetric	Method 208.D (2)
Radium 226	Scintillation or Deemanation	Method 706 (2)

Priority Pollutants -- Acid and Base/Neutral Compounds

Solvent Extraction, GC/MS — Federal Register (4)

Bioaccumulation Potential

HPLC, octanol/water partition coefficient — Federal Register (5)

EP Toxicity

Extraction Procedure — Federal Register (6)

References

(1) "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020, March 1979.

(2) "Standard Methods for the Examination of Water and Wastewater," 14th Edition, 1975. APHA, AWWA, WPCF, Washington, D.C.

(3) "Standard Operating Conditions Manual," Perkin-Elmer Corporation, Norwalk, Connecticut, September 1976.

(4) Federal Register, 40CFR Part 136, Volume 44, Number 233, December 3, 1979.

(5) Federal Register, 40CFR, Part 250, Volume 43, Number 243, December 18, 1978.

(6) Federal Register, 40CFR, Part 261, Appendix II, Volume 45, Number 98, May 19, 1980.

3. Fluoride

The total sample was first distilled to separate fluoride from interferences. The resulting fluoride in the distillate was measured using a specific ion electrode. Extracts were analyzed directly using the electrode.

4. Silica

Solid samples were first digested. All digests and extracts were analyzed by flame AA. Results are reported as SiO_2.

5. Sulfate

Solid samples were digested and the sulfate precipitated with barium chloride. The resulting barium sulfate was determined gravimetrically in the extracts. Low levels of sulfate were measured turbidimetrically as barium sulfate using a nephelometer.

6. Sulfide

Samples were not preserved with zinc acetate and therefore levels were expected to be low. Aliquots of the solid samples in water were taken and treated with excess iodine. These were then back titrated with sodium thiosulfate. Extracts were determined colorimetrically as methylene blue at a wavelength of 625 mm on a Hitachi spectrophotometer.

7. Boron

Boron in the extracts was determined using the Curcumin method. Boron reacts with curcumin to form a red-colored product called rosocyanine. The color was measured photometrically.

8. Priority Pollutants

A 1-liter sample was extracted with methylene chloride using separatory funnel techniques. Because of problems with emulsions, one sample was extracted using a liquid-liquid continuous extractor. In each

case, the extract was dried over sodium sulfate and concentrated to a volume of 1 ml in a Kuderna-Danish evaporator. Each sample gave two fractions (base/neutral and acid) which were analyzed by GC/MS following Method 625 (Federal Register, Vol. 44, #233, p. 69540, December 3, 1979).

9. Bioaccumulation Potential

Specific correlations exist between octanol/water partition coefficients and bioconcentration in fish. High performance liquid chromatography is used to determine this bioaccumulation potential. First, the instrument is calibrated with a series of compounds with known partition coefficients. If the organic compounds in an extract have partition coefficients above a designated level, the sample has a positive bioaccumultion potential.

10. Corrosivity

The pH was measured using an Orion Model 701 pH Meter. Liquids were measured directly. Ten grams of solids (as received) were slurried with 200 ml of DI water for 12 hours and then the pH was measured.

11. Moisture

A portion of the sample was dried at 105^{o}C for 12 hours and the residue determined gravimetrically.

12. Total Suspended Solids (TSS)

A known volume of sample was filtered and the residue dried at 105^{o}C for 12 hours. A gravimetric determination gave the TSS.

13. Radium 226

Radium 226 in solids was determined by gamma spectroscopy using a Ge(Li) scintillation counter and the radium 226 in liquid samples was determined by deemanation techniques.

14. Toxicity Extraction Procedure

Approximately 150g of a representative sample were used in this procedure. The solid phase was extracted in an Acurex Rotary Extractor for 24 hours at pH 5 to give the acid extract. Each sample was also extracted with DI water with no adjustment of the pH. This extract became the neutral extract. In some cases the samples were difficult to filter and centrifugation was necessary.

APPENDIX C

ANALYTICAL DATA REPORTING SHEETS

A Geothermal Analytical Data form was prepared for each sample analyzed. These are presented on the following pages. Abbreviations used on the forms include:

NA -- Not applicable

Int -- Interference (reporting of results not possible)

The following notes also apply:

- Total sample bulk composition analyses reported on an "as received basis"
- mg/L = ppm
- ug/L = ppb

GEOTHERMAL ANALYTICAL DATA

Sample: Dowell Flash Tank

Number: G1 (1428) Type: Scale

Location: Geothermal Test Facility, East Mesa (Imperial Valley) Site Owner/Operator: DOE/Westec Services

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	0.29	< 1	<1
Calcium (Ca)	11.4	1,800	3.2
Iron (Fe)	5.1	< 0.2	< 0.2
Magnesium (Mg)	0.13	4.4	0.08
Potassium (K)	0.035	9.4	6.3
Sodium (Na)	0.11	55	50
Chloride (Cl)	0.080	57.0	59.0
Fluoride (F)	0.040	6.3	0.42
Silica (SiO_2)	0.9	4.0	4.0
Sulfate (SO_4)	0.01	4.5	6.2
Sulfide (S)	< 0.01	< 0.1	< 0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	36	33
Barium (Ba)	10,500	300
Cadmium (Cd)	< 5	<5
Chromium (Cr)	< 20	< 20
Lead (Pb)	< 20	< 20
Mercury (Hg)	< 1	< 1
Selenium (Se)	< 20	< 20
Silver (Ag)	< 20	< 20
Antimony (Sb)	180	180
Beryllium (Be)	<20	< 20
Boron (B)	< 200	< 200
Copper (Cu)	150	70
Lithium (Li)	220	140
Nickel (Ni)	< 200	< 200
Strontium (Sr)	< 500	< 500
Zinc (Zn)	70	< 20

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	8.8 pH
Moisture	61 %
TSS	NA
Radium 226	3.0 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Brine Holding Pond

Number: G3 (1430) Type: Sediment

Location: Geothermal Test Facility, East Mesa (Imperial Valley) Site Owner/Operator: DOE/Westect Services

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	0.22	<1	<1
Calcium (Ca)	0.73	680	6.4
Iron (Fe)	0.32	1.8	<0.2
Magnesium (Mg)	0.15	7.5	0.48
Potassium (K)	0.094	17	11
Sodium (Na)	0.087	63	50
Chloride (Cl)	0.090	49.0	58.0
Fluoride (F)	0.010	1.8	0.74
Silica (SiO_2)	9.8	8	5
Sulfate (SO_4)	0.01	7.0	5.5
Sulfide (S)	<0.0002	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	45	65
Barium (Ba)	3,800	600
Cadmium (Cd)	<5	<5
Chromium (Cr)	<20	<20
Lead (Pb)	<20	<20
Mercury (Hg)	<1	<1
Selenium (Se)	<20	<20
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<50
Beryllium (Be)	<20	<20
Boron (B)	<2,000	<200
Copper (Cu)	<70	<70
Lithium (Li)	170	130
Nickel (Ni)	<200	<200
Strontium (Sr)	8,300	<500
Zinc (Zn)	110	<20

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	8.8 pH
Moisture	34 %
TSS	NA
Radium 226	3.8 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Mud Pit, Sperry Well

Number: G6 (1433) Type: Mud

Location: East Mesa (Imperial Valley) Site Owner/Operator: Republic Geothermal

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	1.2	1.2	1.2
Calcium (Ca)	1.65	1,100	28
Iron (Fe)	0.66	5.8	0.2
Magnesium (Mg)	0.43	38	0.04
Potassium (K)	0.36	24	18
Sodium (Na)	0.24	115	105
Chloride (Cl)	0.10	54.0	55.0
Fluoride (F)	0.023	0.60	0.32
Silica (SiO_2)	24.4	32	4
Sulfate (SO_4)	0.05	64	30
Sulfide (S)	<0.1	0.1	0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	< 20	< 20
Barium (Ba)	1,400	< 300
Cadmium (Cd)	< 5	< 5
Chromium (Cr)	< 20	< 20
Lead (Pb)	30	< 20
Mercury (Hg)	< 1	< 1
Selenium (Se)	< 20	< 20
Silver (Ag)	< 20	< 20
Antimony (Sb)	< 50	< 50
Beryllium (Be)	< 20	< 20
Boron (B)	< 2,000	< 200
Copper (Cu)	< 70	< 70
Lithium (Li)	< 50	< 50
Nickel (Ni)	< 200	< 200
Strontium (Sr)	2,200	< 500
Zinc (Zn)	150	< 20

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	12.0 pH
Moisture	60 %
TSS	NA
Radium 226	1.0 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Fluid Pit, Sperry Well

Number: G7 (1434) Type: Brine

Location: East Mesa (Imperial Valley) Site Owner/Operator: Republic Geothermal

BULK COMPOSITION	Total mg/L
Aluminum (Al)	1.6
Calcium (Ca)	30.0
Iron (Fe)	0.97
Magnesium (Mg)	1.7
Potassium (K)	91
Sodium (Na)	1500
Chloride (Cl)	1700
Fluoride (F)	10
Silica (SiO_2)	13
Sulfate (SO_4)	65
Sulfide (S)	<0.1

TRACE ELEMENTS	Filtrate µg/L
Arsenic (As)	310
Barium (Ba)	< 300
Cadmium (Cd)	< 5
Chromium (Cr)	< 20
Lead (Pb)	< 20
Mercury (Hg)	< 1
Selenium (Se)	< 20
Silver (Ag)	< 20
Antimony (Sb)	< 100
Beryllium (Be)	< 20
Boron (B)	< 200
Copper (Cu)	< 70
Lithium (Li)	2,800
Nickel (Ni)	< 200
Strontium (Sr)	< 500
Zinc (Zn)	30

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	8.7 pH
Moisture	NA
TSS	54 mg/L
Radium 226	0.0 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Clarifier Reactor Sludge Underflow

Number: G8 (1435) Type: Sludge

Location: Geothermal Loop Experimental Facility, Near Niland (Imperial Valley) Site Owner/Operator: DOE/Magma Power

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	<0.01	<1	<1
Calcium (Ca)	1.5	800	840
Iron (Fe)	2.45	1.0	<0.2
Magnesium (Mg)	0.020	3.5	3.7
Potassium (K)	1.1	400	400
Sodium (Na)	4.3	1,900	1,900
Chloride (Cl)	9.3	5,000	5,370
Fluoride (F)	0.34	1.7	1.8
Silica (SiO_2)	12.4	4	2
Sulfate (SO_4)	0.007	1.0	6.5
Sulfide (S)	<0.01	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	230	230
Barium (Ba)	5,000	5,400
Cadmium (Cd)	60	60
Chromium (Cr)	<20	<20
Lead (Pb)	200	<20
Mercury (Hg)	<1	<1
Selenium (Se)	180	220
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<50
Beryllium (Be)	<20	<20
Boron (B)	12,000	13,000
Copper (Cu)	150	<70
Lithium (Li)	5,800	7,900
Nickel (Ni)	500	<200
Strontium (Sr)	12,000	15,000
Zinc (Zn)	6,400	4,000

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	6.1 pH
Moisture	46 %
TSS	NA
Radium 226	78 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Mud Pit, Fee #1 Well

Number: G9 (1436) Type: Mud

Location: Near Niland (Imperial Valley) Site Owner/Operator: Republic Geothermal

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	2.57	<1	<1
Calcium (Ca)	2.2	360	120
Iron (Fe)	1.7	1.2	<0.2
Magnesium (Mg)	1.15	32	5
Potassium (K)	1.1	130	120
Sodium (Na)	1.25	580	550
Chloride (Cl)	2.0	1,280	1,150
Fluoride (F)	0.042	0.95	0.55
Silica (SiO_2)	29.2	4	<4
Sulfate (SO_4)	0.15	80	170
Sulfide (S)	<0.02	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	63	<20
Barium (Ba)	1,800	<300
Cadmium (Cd)	6	<5
Chromium (Cr)	<20	<20
Lead (Pb)	<20	<20
Mercury (Hg)	<1	<1
Selenium (Se)	30	20
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<50
Beryllium (Be)	<20	<20
Boron (B)	<2,000	200
Copper (Cu)	<70	<70
Lithium (Li)	1,300	1,100
Nickel (Ni)	<200	<200
Strontium (Sr)	5,400	1,500
Zinc (Zn)	1,300	<20

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	8.4 pH
Moisture	62 %
TSS	NA
Radium 226	2.1 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: North Brine Pit, Fee #1 Well

Number: G10 (1676) Type: Brine

Location: Near Niland (Imperial Valley) Site Owner/Operator: Republic Geothermal

BULK COMPOSITION	Total mg/L
Aluminum (Al)	<1
Calcium (Ca)	51,000
Iron (Fe)	3,200
Magnesium (Mg)	313
Potassium (K)	38,000
Sodium (Na)	55,000
Chloride (Cl)	295,000
Fluoride (F)	19
Silica (SiO_2)	300
Sulfate (SO_4)	<0.01
Sulfide (S)	<0.1

TRACE ELEMENTS	Filtrate µg/L
Arsenic (As)	<250
Barium (Ba)	363,000
Cadmium (Cd)	70
Chromium (Cr)	980
Lead (Pb)	6,300
Mercury (Hg)	Int
Selenium (Se)	<500
Silver (Ag)	<20
Antimony (Sb)	<200
Beryllium (Be)	<20
Boron (B)	660,000
Copper (Cu)	7,400
Lithium (Li)	509,000
Nickel (Ni)	300
Strontium (Sr)	1,290,000
Zinc (Zn)	1,130,000

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	1.6 pH
Moisture	NA
TSS	5600 mg/L
Radium 226	0.4 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Class II-2 Landfill

Number: G12 (1437) Type: Mixed Solids

Location: Brawley (Imperial Valley) Site Owner/Operator: Imperial County Dept. of Public Works

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	2.3	<1	190
Calcium (Ca)	1.60	680	33
Iron (Fe)	1.2	0.8	76
Magnesium (Mg)	1.72	20	52
Potassium (K)	0.69	48	85
Sodium (Na)	0.50	235	230
Chloride (Cl)	0.40	215	227
Fluoride (F)	0.033	0.29	0.56
Silica (SiO_2)	24.2	2	160
Sulfate (SO_4)	0.06	10	85
Sulfide (S)	<0.01	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	100	<250
Barium (Ba)	1,000	1,400
Cadmium (Cd)	<5	<5
Chromium (Cr)	23	420
Lead (Pb)	<20	200
Mercury (Hg)	<1	Int
Selenium (Se)	<20	<50
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<100
Beryllium (Be)	<20	<20
Boron (B)	<200	340
Copper (Cu)	<70	230
Lithium (Li)	130	340
Nickel (Ni)	<200	<200
Strontium (Sr)	2,400	<100
Zinc (Zn)	250	1,400

ORGANICS

Priority Pollutants Detected		µg/L
Acid Extract	phenol	4
Neutral Extract	4,6-dinitro-o-creosol	18
	phenol	2
	anthracene/phenanthrene	6

Bioaccumulation Potential
Acid extract negative
Neutral extract positive

OTHER PARAMETERS

Corrosivity	10 pH
Moisture	51 %
TSS	NA
Radium 226	1.15 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: East Baker Tank, Courier #1 Well

Number: G14 (1439) Type: Brine

Location: Westmorland (Imperial Valley) Site Owner/Operator: MAPCO

BULK COMPOSITION	Total mg/L
Aluminum (Al)	1.2
Calcium (Ca)	14,800
Iron (Fe)	2,100
Magnesium (Mg)	440
Potassium (K)	10,000
Sodium (Na)	60,000
Chloride (Cl)	158,700
Fluoride (F)	10
Silica (SiO_2)	18
Sulfate (SO_4)	<1
Sulfide (S)	<0.1

TRACE ELEMENTS	Filtrate µg/L
Arsenic (As)	14,000
Barium (Ba)	22,000
Cadmium (Cd)	4,000
Chromium (Cr)	<60
Lead (Pb)	83,000
Mercury (Hg)	<1
Selenium (Se)	5,100
Silver (Ag)	<20
Antimony (Sb)	<1,000
Beryllium (Be)	<20
Boron (B)	230,000
Copper (Cu)	<100
Lithium (Li)	240
Nickel (Ni)	<200
Strontium (Sr)	1,400,000
Zinc (Zn)	6,000,000

ORGANICS	
Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS	
Corrosivity	3.8 pH
Moisture	NA
TSS	220 mg/L
Radium 226	1,320 pCi/L

GEOTHERMAL ANALYTICAL DATA

Sample: Mud Pit, Courier #1 Well

Number: G16 (1441) Type: Mud

Location: Westmorland (Imperial Valley) Site Owner/Operator: MAPCO

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	2.1	<1	<1
Calcium (Ca)	2.2	1,200	330
Iron (Fe)	1.6	0.8	<0.2
Magnesium (Mg)	0.69	18	5
Potassium (K)	0.97	170	160
Sodium (Na)	2	975	950
Chloride (Cl)	5.3	2,260	2,220
Fluoride (F)	0.029	0.32	0.24
Silica (SiO_2)	42.4	11	4
Sulfate (SO_4)	<0.001	6.5	5.7
Sulfide (S)	<0.2	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	49	41
Barium (Ba)	13,000	6,800
Cadmium (Cd)	20	<5
Chromium (Cr)	<20	<20
Lead (Pb)	60	<20
Mercury (Hg)	<1	<1
Selenium (Se)	100	120
Silver (Ag)	<20	<20
Antimony (Sb)	<50	50
Beryllium (Be)	<20	20
Boron (B)	250	1,100
Copper (Cu)	<70	70
Lithium (Li)	3,300	3,100
Nickel (Ni)	<200	<200
Strontium (Sr)	23,000	20,000
Zinc (Zn)	7,000	<20

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	8.8 pH
Moisture	31 %
TSS	NA
Radium 226	5.9 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Iron Sludge from Centrifuge

Number: G19-1 (1576) Type: Sludge

Location: Unit 12 (The Geysers) Site Owner/Operator: PG&E

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	0.01	<1	<1
Calcium (Ca)	<0.005	2.9	2.1
Iron (Fe)	9.45	0.8	<0.2
Magnesium (Mg)	<0.005	0.28	0.22
Potassium (K)	0.002	0.28	0.23
Sodium (Na)	0.041	17	16
Chloride (Cl)	0.005	<1	1
Fluoride (F)	0.003	0.11	0.11
Silica (SiO_2)	0.004	<4	<4
Sulfate (SO_4)	0.22	<1	55
Sulfide (S)	<0.2	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	<20	<20
Barium (Ba)	<300	<300
Cadmium (Cd)	<5	<5
Chromium (Cr)	<20	<20
Lead (Pb)	<20	<20
Mercury (Hg)	<1	<1
Selenium (Se)	<20	<20
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<50
Beryllium (Be)	<20	<20
Boron (B)	7,600	520
Copper (Cu)	<70	<50
Lithium (Li)	<50	<50
Nickel (Ni)	300	<200
Strontium (Sr)	<500	<500
Zinc (Zn)	200	50

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	6.2 pH
Moisture	80 %
TSS	NA
Radium 226	0 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Cooling Tower Sediment

Number: G20-1 (1577A) Type: Sediment

Location: Unit 9 (The Geysers) Site Owner/Operator: PG&E

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	NA	NA	NA
Calcium (Ca)	NA	NA	NA
Iron (Fe)	NA	NA	NA
Magnesium (Mg)	NA	NA	NA
Potassium (K)	NA	NA	NA
Sodium (Na)	NA	NA	NA
Chloride (Cl)	NA	NA	NA
Fluoride (F)	NA	NA	NA
Silica (SiO_2)	NA	NA	NA
Sulfate (SO_4)	NA	NA	NA
Sulfide (S)	NA	NA	NA

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	88	51
Barium (Ba)	< 300	< 300
Cadmium (Cd)	13	14
Chromium (Cr)	51	20
Lead (Pb)	100	130
Mercury (Hg)	< 1	< 1
Selenium (Se)	< 20	< 20
Silver (Ag)	< 20	< 20
Antimony (Sb)	< 50	< 50
Beryllium (Be)	< 20	< 20
Boron (B)	23,000	16,000
Copper (Cu)	2,200	1,800
Lithium (Li)	< 50	< 50
Nickel (Ni)	900	700
Strontium (Sr)	< 500	< 500
Zinc (Zn)	6,200	6,000

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	3.7 pH
Moisture	85 %
TSS	NA
Radium 226	0 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Cooling Tower Sediment

Number: G20-1 (1577B) Type: Sediment

Location: Unit 9 (The Geysers) Site Owner/Operator: PG&E

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	NA	NA	NA
Calcium (Ca)	NA	NA	NA
Iron (Fe)	NA	NA	NA
Magnesium (Mg)	NA	NA	NA
Potassium (K)	NA	NA	NA
Sodium (Na)	NA	NA	NA
Chloride (Cl)	NA	NA	NA
Fluoride (F)	NA	NA	NA
Silica (SiO_2)	NA	NA	NA
Sulfate (SO_4)	NA	NA	NA
Sulfide (S)	NA	NA	NA

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	87	68
Barium (Ba)	< 300	< 300
Cadmium (Cd)	10	10
Chromium (Cr)	29	23
Lead (Pb)	140	180
Mercury (Hg)	< 1	< 1
Selenium (Se)	< 20	< 20
Silver (Ag)	< 20	< 20
Antimony (Sb)	< 50	< 50
Beryllium (Be)	< 20	< 20
Boron (B)	13,000	13,000
Copper (Cu)	1,900	1,100
Lithium (Li)	< 50	< 50
Nickel (Ni)	700	600
Strontium (Sr)	< 500	< 500
Zinc (Zn)	5,000	4,500

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	3.7 pH
Moisture	84.6 %
TSS	NA
Radium 226	0 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Iron Sludge from Centrifuge

Number: G22-1 (1579) Type: Sludge

Location: Unit 5 & 6 (The Geysers) Site Owner/Operator: PG&E

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	0.01	<1	<1
Calcium (Ca)	0.005	2.4	2
Iron (Fe)	7.7	<0.2	<0.2
Magnesium (Mg)	<0.005	0.20	0.16
Potassium (K)	0.004	0.18	0.15
Sodium (Na)	0.055	24	24
Chloride (Cl)	<0.005	<1	<1
Fluoride (F)	0.001	0.12	0.14
Silica (SiO_2)	0.04	<4	<4
Sulfate (SO_4)	0.29	9.5	85
Sulfide (S)	<0.2	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	<20	<20
Barium (Ba)	<300	<300
Cadmium (Cd)	<5	<5
Chromium (Cr)	<20	<20
Lead (Pb)	20	50
Mercury (Hg)	<1	<1
Selenium (Se)	<20	<20
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<100
Beryllium (Be)	<20	<20
Boron (B)	28,000	27,000
Copper (Cu)	<70	<70
Lithium (Li)	<50	100
Nickel (Ni)	200	<200
Strontium (Sr)	<500	<500
Zinc (Zn)	60	30

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ORGANICS

Priority Pollutants Detected	µg/L
Acid Extract phenol	0.4
benzo (k) fluoranthene	14
Neutral Extract	None detected
Bioaccumulation Potential	
Acid Extract	negative
Neutral Extract	negative

OTHER PARAMETERS

Corrosivity	6.6 pH
Moisture	70 %
TSS	NA
Radium 226	0 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Cooling Tower Sediment

Number: G23-1 (1580) Type: Sediment

Location: Unit 7 & 8 (The Geysers) Site Owner/Operator: PG&E

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	0.52	1	<1
Calcium (Ca)	0.02	1.7	1.7
Iron (Fe)	11.3	44	50
Magnesium (Mg)	0.22	0.36	0.30
Potassium (K)	0.12	0.23	0.23
Sodium (Na)	0.016	0.9	0.9
Chloride (Cl)	<0.005	2	2
Fluoride (F)	0.005	0.16	0.15
Silica (SiO_2)	3.6	<4	<4
Sulfate (SO_4)	0.65	300	260
Sulfide (S)	<0.08	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	110	150
Barium (Ba)	<300	<300
Cadmium (Cd)	<60	<60
Chromium (Cr)	<20	<20
Lead (Pb)	70	50
Mercury (Hg)	<1	<1
Selenium (Se)	<20	<20
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<50
Beryllium (Be)	<20	<20
Boron (B)	7,700	880
Copper (Cu)	60,000	33,000
Lithium (Li)	<50	<50
Nickel (Ni)	<500	<500
Strontium (Sr)	<500	<500
Zinc (Zn)	7,500	6,000

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	5.1 pH
Moisture	71 %
TSS	NA
Radium 226	0 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Abated Well Sump, Beigel #1 Well

Number: G24-1 (1581R) Type: Mud

Location: Near Unit 18 (The Geysers) Site Owner/Operator: Union Oil of California

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	1.58	<1	<1
Calcium (Ca)	0.59	280	34
Iron (Fe)	3.03	32	<0.2
Magnesium (Mg)	1.65	9.6	<0.04
Potassium (K)	0.27	6.3	2.5
Sodium (Na)	0.11	24	48
Chloride (Cl)	0.014	2	<1
Fluoride (F)	0.024	0.34	0.28
Silica (SiO_2)	19.4	<4	16
Sulfate (SO_4)	0.02	32	62
Sulfide (S)	<0.02	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	< 20	32
Barium (Ba)	< 300	< 300
Cadmium (Cd)	< 5	< 5
Chromium (Cr)	< 20	< 20
Lead (Pb)	< 20	< 20
Mercury (Hg)	< 1	< 1
Selenium (Se)	< 20	< 20
Silver (Ag)	< 20	< 20
Antimony (Sb)	< 50	< 50
Beryllium (Be)	< 20	< 20
Boron (B)	870	15,000
Copper (Cu)	< 70	< 70
Lithium (Li)	< 50	< 50
Nickel (Ni)	300	500
Strontium (Sr)	600	< 500
Zinc (Zn)	300	< 20

ORGANICS		µg/L
Priority Pollutants Detected		
Acid Extract	2-nitrophenol	3
	phenol	2
Neutral Extract	phenol	640
Bioaccumulation Potential		
Acid Extract		negative
Neutral Extract		negative

OTHER PARAMETERS	
Corrosivity	10 pH
Moisture	53 %
TSS	NA
Radium 226	0.5 pCi/g

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GEOTHERMAL ANALYTICAL DATA

Sample: Sedimentation Pond

Number: G26-1 (1585R) Type: Sediment

Location: Unit 12 (The Geysers) Site Owner/Operator: Union Oil of California

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	0.01	<1	<1
Calcium (Ca)	<0.005	4.8	2.1
Iron (Fe)	6.4	630	730
Magnesium (Mg)	<0.005	1.2	1.5
Potassium (K)	0.002	0.60	0.71
Sodium (Na)	0.051	60	71
Chloride (Cl)	0.010	1	2
Fluoride (F)	0.001	0.12	0.07
Silica (SiO_2)	0.04	5	4
Sulfate (SO_4)	1.1	1,400	1,900
Sulfide (S)	<0.02	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	20	34
Barium (Ba)	<300	<300
Cadmium (Cd)	8	7
Chromium (Cr)	53	<20
Lead (Pb)	<20	<20
Mercury (Hg)	<1	<1
Selenium (Se)	30	40
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<50
Beryllium (Be)	<20	<20
Boron (B)	19,000	30,000
Copper (Cu)	<70	<70
Lithium (Li)	<50	<50
Nickel (Ni)	400	400
Strontium (Sr)	<500	<500
Zinc (Zn)	9,000	14,000

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	4.2 pH
Moisture	88 %
TSS	NA
Radium 226	0 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Sump in Mud Drilling Phase, Aminoil #1 Well

Number: G27-1 (1587) Type: Mud

Location: Near Unit 13 (The Geysers) Site Owner/Operator: Aminoil USA

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	2.45	<1	<1
Calcium (Ca)	0.93	690	0.81
Iron (Fe)	3.9	14	0.8
Magnesium (Mg)	1.78	6	0.40
Potassium (K)	0.51	2.5	0.83
Sodium (Na)	0.090	28	25
Chloride (Cl)	0.005	3	1
Fluoride (F)	0.018	0.13	0.14
Silica (SiO_2)	45.6	5	4
Sulfate (SO_4)	0.001	<1	14
Sulfide (S)	<0.0002	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	<20	20
Barium (Ba)	1,400	<300
Cadmium (Cd)	<5	<5
Chromium (Cr)	70	<20
Lead (Pb)	20	<20
Mercury (Hg)	<1	<1
Selenium (Se)	<20	<20
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<50
Beryllium (Be)	<20	<20
Boron (B)	<200	<200
Copper (Cu)	<70	<70
Lithium (Li)	<50	<50
Nickel (Ni)	<500	<500
Strontium (Sr)	3,500	<500
Zinc (Zn)	80	<20

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	9.6 pH
Moisture	23 %
TSS	NA
Radium 226	0.4 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Sump, Steamboat #1 Well

Number: G30 (1668) Type: Mud

Location: Steamboat (Nevada) Site Owner/Operator: Phillips Petroleum

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	1.63	<1	<1
Calcium (Ca)	1.8	700	8.1
Iron (Fe)	1.85	1.6	<0.2
Magnesium (Mg)	0.67	15	0.08
Potassium (K)	0.46	21	12
Sodium (Na)	0.19	53	48
Chloride (Cl)	0.039	23	22
Fluoride (F)	0.015	0.54	0.46
Silica (SiO_2)	21.6	14	13
Sulfate (SO_4)	0.05	39	22
Sulfide (S)	<0.0002	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	60	260
Barium (Ba)	600	<300
Cadmium (Cd)	<5	<5
Chromium (Cr)	<20	<20
Lead (Pb)	<20	<20
Mercury (Hg)	<1	<1
Selenium (Se)	<20	<20
Silver (Ag)	<20	<20
Antimony (Sb)	<50	70
Beryllium (Be)	<20	<20
Boron (B)	300	570
Copper (Cu)	<70	<70
Lithium (Li)	500	400
Nickel (Ni)	<300	<300
Strontium (Sr)	1,000	<500
Zinc (Zn)	120	<20

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	9.3 pH
Moisture	34 %
TSS	NA
Radium 226	1 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Sump, Humbolt House Well

Number: G31 (1669) Type: Mud

Location: Humbolt (Nevada) Site Owner/Operator: Phillips Petroleum

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	2.02	< 1	4.5
Calcium (Ca)	1.9	1,300	25
Iron (Fe)	2.35	4.6	9.2
Magnesium (Mg)	0.73	27	4
Potassium (K)	0.54	13	4.7
Sodium (Na)	0.40	140	120
Chloride (Cl)	0.10	53	53
Fluoride (F)	0.034	0.64	0.61
Silica (SiO_2)	20.2	9	9
Sulfate (SO_4)	0.22	82	78
Sulfide (S)	<0.02	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	<20	140
Barium (Ba)	600	500
Cadmium (Cd)	6	5
Chromium (Cr)	<20	27
Lead (Pb)	400	400
Mercury (Hg)	<1	<1
Selenium (Se)	<20	<20
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<50
Beryllium (Be)	<20	<20
Boron (B)	<200	<200
Copper (Cu)	<70	100
Lithium (Li)	50	<50
Nickel (Ni)	<300	<300
Strontium (Sr)	3,000	<500
Zinc (Zn)	420	280

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	9.8 pH
Moisture	36 %
TSS	NA
Radium 226	1.6 pCi/g

GEOTHERMAL ANALYTICAL DATA

Sample: Primary Sump, Desert Peak Well

Number: G32 (1670) Type: Mud

Location: Desert Peak (Nevada) Site Owner/Operator: Phillips Petroleum

BULK COMPOSITION	Total %	Acid Extract mg/L	Neutral Extract mg/L
Aluminum (Al)	1.98	<1	<1
Calcium (Ca)	0.87	790	8.1
Iron (Fe)	2.95	2.6	1
Magnesium (Mg)	0.92	18	0.55
Potassium (K)	0.59	28	20
Sodium (Na)	0.77	350	170
Chloride (Cl)	0.98	487	492
Fluoride (F)	0.024	0.33	0.31
Silica (SiO_2)	27.4	<4	<4
Sulfate (SO_4)	0.08	16	40
Sulfide (S)	<0.0002	<0.1	<0.1

TRACE ELEMENTS	Acid Extract µg/L	Neutral Extract µg/L
Arsenic (As)	<20	<20
Barium (Ba)	500	<300
Cadmium (Cd)	<5	<5
Chromium (Cr)	<20	39
Lead (Pb)	<20	<20
Mercury (Hg)	<1	<1
Selenium (Se)	30	<20
Silver (Ag)	<20	<20
Antimony (Sb)	<50	<50
Beryllium (Be)	<20	<20
Boron (B)	230	470
Copper (Cu)	200	100
Lithium (Li)	300	200
Nickel (Ni)	<300	<300
Strontium (Sr)	2,600	<500
Zinc (Zn)	140	50

ORGANICS

Priority Pollutants Detected	µg/L
NA	
Bioaccumulation Potential	NA

OTHER PARAMETERS

Corrosivity	9.1 pH
Moisture	9.9 %
TSS	NA
Radium 226	1.5 pCi/g

APPENDIX D

ACID AND BASE/NEUTRAL PRIORITY POLLUTANTS

POLLUTANT AND CAS NUMBERS	CONCENTRATION ug/L
GC/MS FRACTION - ACID COMPOUNDS	
1A 2-Chlorophenol (95-57-8)	
2A, 2,4-Dichlorophenol (120-83-2)	
3A, 2,4-Dimethylphenol (105-67-9)	
4A, 4,6-Dinitro-o-Cresol (534-52-1)	(2)
5A, 2,4-Dinitrophenol (51-28-5)	(2)
6A 2-Nitrophenol (88-75-5)	
7A, 4-Nitrophenol (100-02-7)	
8A, p-Chloro-m-Cresol (59-50-7)	
9A, Pentachlorophenol (87-86-5)	
10A, Phenol (108-95-2)	
11A, 2,4,6-Trichlorophenol (88-06-2)	
GC/MS FRACTION - BASE/NEUTRAL COMPOUNDS	
1B Acenaphthene (83-32-9)	
2B, Acenaphthylene (208-96-8)	
3B, Anthracene (120-12-7)	
4B, Benzidine (92-87-5)	(3)
5B, Benzo (a) Anthracene (56-55-3)	
6B, Benzo (a) Pyrene (50-32-8)	
7B, 3,4-Benzofluoranthene (205-99-2)	
8B, Benzo (ghi) Perylene (191-24-2)	

POLLUTANT AND CAS NUMBERS	CONCENTRATION ug/L
9B, Benzo (k) Fluoranthene (207-08-9)	
10B, Bis (2-Chloroethoxy) Methane (111-91-1)	
11B, Bis (2-Chloroethyl) Ether (111-44-4)	
12B, Bis (2-Chloroisopropyl) Ether (39638-32-9)	
13B, Bis (2-Ethylhexyl) Phthalate (117-81-7)	
14B,4-Bromophenyl Phenyl Ether (101-55-3)	
15B, Butyl Benzyl Phthalate (85-68-71)	
16B, 2-Chloronaphthalene (91-58-7)	
17B, 4-Chlorophenyl Phenyl Ether (7005-72-3)	
18B, Chrysene (218-01-9)	
19B, Dibenzo (a,h) Anthracene (53-70-3)	
20B, 1,2-Dichlorobenzene (95-50-1)	
21B, 1,3-Dichlorobenzene (541-73-1)	
22B, 1,4-Dichlorobenzene (106-46-7)	
23B, Dimethyl Phthalate (131-11-3)	
24B, Di-N-Butyl Phthalate (84-74-2)	
25B, 3,3'-Dichlorobenzidine (91-94-1)	
26B, Diethyl Phthalate (84-66-2)	
27B, 2,4-Dinitrotoluene (121-14-2)	

POLLUTANT AND CAS NUMBERS	CONCENTRATION ug/L
28B, 2,6-Dinitrotoluene (606-20-2)	
29B, Di-N-Octyl Phthalate (117-84-0)	
30B, 1,2-Diphenylhydrazine (as Azobenzene) (122-66-7)	
31B, Fluoranthene (206-44-0)	
32B, Fluorene (86-73-7)	
33B, Hexachlorobenzene (118-71-1)	
34B, Hexachlorobutadiene (87-68-3)	
35B, Hexachlorocyclopentadiene (77-47-4)	
36B, Hexachloroethane (67-72-1)	
37B, Indeno (1,2,3-cd) Pyrene (193-39-5)	(2)
38B, Isophorone (78-59-1)	
39B, Naphthalene (91-20-3)	
40B, Nitrobenzene (98-95-3)	
41B, N-Nitrosodimethylamine (62-75-9)	(2)
42B, N-Nitrosodi-N-Propylamine (621-64-7)	(2)
43B, N-Nitrosodiphenylamine (86-30-6)	
44B Phenanthrene (85-01-8)	
45B, Pyrene (129-00-0)	
46B, 1,2,4-Trichlorobenzene (120-82-1)	