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Utilization of Ash From Municipal Solid Waste Combustion

Final Report
Phase I

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EXECUTIVE SUMMARY

This ash study investigates several aspects of Municipal Waste Combustion (MWC) ash utilization in order to develop an alternative to the present disposal practice of landfilling in a lined monofill.

Two major options were investigated. These were:

Task 1 - as a daily or final cover for municipal waste in the landfill.

Task 2 - as a road construction aggregate.

Statistically valid samples of eight mixtures of ash and other materials, and one sample of soil were analyzed for chemical constituents. Biological tests on these mixtures were conducted, along with erosion tests and sieve analyses. In addition, a chemical analysis of each sieve size was conducted.

An engineering evaluation of the observable qualities of the sieve sizes was made, followed by a few engineering tests to measure geotechnical properties of the most promising materials. A test landfill cover section and a test road strip will be constructed in Phase II of the study.

Experts from the asphalt industry, State Road Division, Department of Health, and others who might properly have a role in implementation of any ash utilization program were involved from the start.

Significant findings to this point include:

1) All ash samples taken to date (over 400 samples over more than 4 years) have passed the EPA TCLP testing.

2) Chemical analysis of bottom and combined ash samples indicated less than expected variability.

3) Selected ash mixtures exhibited very low coefficients of hydraulic conductivity, less than 10^{-6} cm/sec hydraulic conductivity.

4) All but one of the ash mixtures exhibited greater erosion resistance than the currently used landfill cover material.

5) MWC combined ash chemical analysis, hydraulic conductivity, and erosion resistance indicates this ash fraction is a viable alternative for landfill cover.

6) MWC ash size fractions and chemical analysis show bottom and combined ash to be a viable alternative aggregate for road construction. Preliminary engineering test results show the H-POWER bottom and combined ash to be a promising potential product.

BACKGROUND

General

The City & County of Honolulu comprises the entire island of Oahu, where approximately 80% of the population (800,000 plus a significant tourist population) of the State reside. To prevent possible contamination of the fresh water basal lens underlying most of the island, landfills must be sited around the periphery of the island. Since this is a prime area for tourists and residents, landfills are unpopular and difficult to site. It is therefore in the best interests of all to extend the current landfill life as long as possible. The City & County of Honolulu has already made great strides toward this goal by incorporating a waste-to-energy facility (H-POWER) into their solid waste program. The City currently disposes of approximately 598,750 metric tons (660,000 tons) of municipal solid waste (MSW) annually at two sites, H-POWER and the Waipahu Incinerator. Over 90% of this annual waste stream is processed at H-POWER, where the volume is reduced to about 10% of the original MSW. The remaining ash, however, is currently being landfilled. Finding a beneficial use for the ash would mean that 90% of the island's solid waste stream is being completely recycled, and more importantly, being kept out of the landfill.

The H-POWER facility is a refuse derived fuel (RDF) plant with a nominal capacity of 544,320 metric tons (600,000 tons) of MSW per year, and generates a maximum output of 57 MW of electricity. The RDF processing facility is equipped with a ferrous metal separation system. The power block facility employs two RDF-fed boilers, each equipped with a dry scrubber and a five field electrostatic precipitator (ESP). The bottom ash is processed through a vibrating finger screen, ferrous magnet, and an eddy current separator where both ferrous and non-ferrous metals are separated from the ash. Fly ash is removed from each ESP field and from the dry scrubber cyclone tower as a dry powder, and run through a pug mill where water is added to reduce the dust. This fly ash stream is then combined with the bottom ash, placed in a trailer, and hauled to the landfill. Approximately 108,864 metric tons (120,000 tons) of wet ash is produced annually composed of approximately 60% bottom and 40% fly ash.

Also included in this study is ash from the Waipahu Incinerator. This is a two unit, 544 metric ton/day (600 ton/day) mass-burn facility located in Waipahu, Hawaii. Each unit has a water spray and a three field ESP to control ton/day) mass-burn facility located in Waipahu, Hawaii. Each unit has a water spray and a three field ESP to control particulate emissions. This incinerator does not employ any energy recovery and was included in the study so that results could be applied to mass-burn as well as RDF facilities. The Waipahu Incinerator currently operates at approximately 181 metric tons per day (200 tons per day) [approximately 54,432 metric tons/year (60,000 tons/year)]

STUDY OBJECTIVES

The objective of the study was to develop low-cost options for utilizing MWC ash in a productive and environmentally responsible manner. The options investigated were divided into two tasks:

Task 1 - using MWC ash as landfill cover -- as daily and/or final-closure cover.

Task 2 - using MWC ash as a road construction aggregate.

TASK 1

Task 1 was designed to investigate the feasibility of using various MWC ash mixtures as daily or final-closure cover. Appendix A1 outlines the regulatory requirements for materials used as landfill cover. Figure 1 below lists the mixtures used. Note that mixture 4 is the soil material currently used as a daily cover material.

ASH MIXTURES

Mixture	Mixture Contents
1	H-POWER Fly Ash
2	H-POWER Bottom Ash
3	H-POWER Combined Ash
4	Landfill Soil (control)
5	3 Parts H-POWER Fly Ash to 1 Part Sewage Sludge
6	1 Part H-POWER Fly Ash, 1 Part AES Coal Ash, 1 Part Sewage Sludge
7	1 Part H-POWER Fly Ash to 1 Part Sewage Sludge
8	2 Parts H-POWER Fly Ash, 2 Parts Sewage Sludge, 1 Part Hydrated Lime
9	1 Part H-POWER Combined Ash to 1 Part Waipahu Ash

Figure 1

Mixtures including sterile sludge from the City's wastewater treatment plant were also tried in order to ascertain the viability of mixing this material with ash. It was anticipated that mixing this ash with sludge would preclude or reduce any odors, and perhaps result in a soil-like material more suitable for plant growth.

Task 1 was divided into several subtasks. All mixtures were subjected to chemical analysis and microbiological testing. General physical and structural characteristics were observed in addition to placing each sample in a test erosion box where it was subjected to natural weathering and erosion.

Mixtures 4, 5, 6, 7, and 8 were provided to the botanical garden operated by the City Parks Department for testing of their potential to support growth of several common grasses and weeds.

TASK 2

Hawaii currently employs volcanic rock for it's aggregate use. Communications with representatives from Grace Pacific (one of two major aggregate suppliers) and with a purchaser of aggregate on Oahu indicated that aggregate smaller than the #8 sieve size are in the greatest demand. This is because these smaller sizes are costlier to produce as they require more crushing and separation steps. All aggregate supply representatives consulted agreed that an alternative aggregate source would be a welcome addition to the market. Task 2 was designed to investigate some of the numerous possible applications for MWC ash as road construction material. This investigation involved sieve analysis, chemical analysis, and mechanical testing.

Task 2 was also divided into several subtasks. The first of these was a sieve analysis, followed by chemical analysis of each sieve size. A qualitative review of the various sieve fractions was conducted by personnel knowledgeable in the asphalt road construction business, and based on their recommendations, dry density tests, unconfined compressive strength tests, sand equivalent tests, plasticity index measurements, and LA Abrasion testing were conducted. In addition, samples of the ash material were provided to Permabase, Inc. for analysis and testing in their products, as well as providing an opportunity to compare our material with that from MWC ash in Florida. The objective here was to evaluate the potential for use as a soil cement component, an application which has been tested in Florida, New Hampshire, Minnesota, and several European Countries.

TASK DETAILS

Task 1 - Landfill Cover Studies

Phase I study conducted certain chemical and physical tests on each of the mixtures shown in Figure 1. Observations were also made over a 4-month period on inclined erosion test boxes containing each of the test mixtures. These observations were made to see the effects of rain and wind erosion, to observe how easily the mixture would compact, what their lateral shear strengths were, and how easily the surface cracked after drying.

Task 1.1 - Ash Collection and Mixture Preparation

Ash Collection

The MWC ash used in the study was collected in small increments over a five day period to insure representative sampling. The date, time, quantity and storage drum destination was noted and recorded for each sample (Appendix A2 Tables 1 - 6). The 209-liter (55-gallon) steel storage drums were obtained from a local dairy and were in excellent condition. The drums were prepared by lining them with a 4-mil fitted, plastic drum liner. Once filled, the liner was sealed to keep the moisture level relatively constant and to prevent possible contamination.

Processed bottom ash samples were taken directly from the ash loadout trailer located beneath the bottom ash metal recovery unit (BAMR). Dry fly ash was collected from a 10-centimeter (4-inch) steel pipe mounted on the side of the surge bin, prior to the ash reaching the pug mill. Photographs and a description of the H-POWER ash loadout procedures are included in Appendix A2, pages 1-3.

Waipahu Incinerator ash used herein was collected at the ash monofill located directly across from the incinerator (Appendix A2, figure 3). All of the Waipahu ash was first run through BAMR at H-POWER, however, and the processed ash was then loaded into steel drums for storage. Figure 2 below shows a comparison of the Waipahu ash and H-POWER bottom ash after processing through the BAMR.

Bottom Ash Metal Recovery Operation

Separation Stream	H-POWER Bottom Ash	Waipahu Incinerator Ash
Screened Ash	66%	72%
Non-Ferrous Metals	2%	17%
Ferrous Metals	12%	10%
Other	20%	1%

Figure 2

Mixture Preparation

Preparation of the nine test mixtures was accomplished using a gas-powered cement mixer. Water was added in small amounts until a clumpy, semi-dry paste was formed with a plasticity high enough that the mixture could be easily spread out, but not such that it couldn't hold its shape. The details of mixture preparation are included in Appendix A2, page 10.

Task 1.2 - Chemical Analysis of Ash Mixtures

Sampling Methods

After the Task 1 mixtures had cured for a period of no less than 72 hours, they were individually dumped out, mixed using a hand trowel, and quartered. Duplicate samples of each mixture were taken randomly from each of the four quarters, placed in a 500 ml plastic sample bottle, labeled, and transported to Environmental Laboratory of the Pacific (E.L. Pacific).

E.L. Pacific performed acid digestion using a combination of nitric, perchloric and hydrofluoric acids to dissolve all of the solids. The solutions were then tested for the following metals content: Al, As, Ba, C, Cd, Ca, Cr, Cu, Fe, Pb, Hg, K, Se, Si, Ag, and Zn. Other chemical analyses included pH, %Cl, percent soluble SO_4, NO_3, NO_4, total nitrogen, and moisture content. Titration curves were also prepared for duplicate samples of the 9 mixtures. The EPA analysis methods used are listed by each chemical parameter in Appendix A3, page 1.

Chemical Summary

A detailed discussion of the results of the Task 1 chemical analyses is provided along with the data in Appendix A3, pages 1-12. The entire E.L. Pacific laboratory report can be found following the analysis (page A3-13). Figure 3 below provides a summary of the average concentrations of trace metals for the ash mixture major constituents.

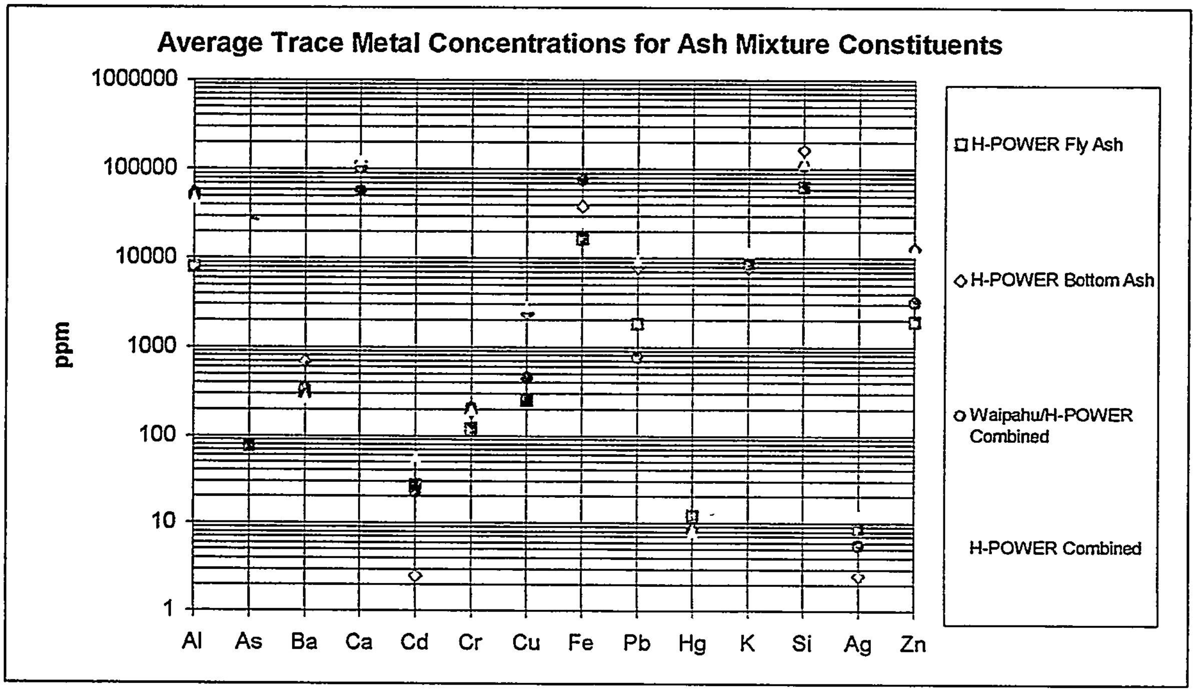

Figure 3

Bear in mind that these concentrations are **not** leachate concentrations and should not be interpreted as such.

H-POWER Ash TCLP data can be found in Appendix A8.

A few notable trends in the trace metal analysis are as follows:

1. Cadmium is only about 8 times higher in the fly ash than the bottom ash.

2. Mercury is in relatively low concentration in all ash fractions and uniformly distributed.

3. Mercury is in relatively low concentration in all ash fractions and uniformly distributed.

4. Metal concentrations are within 1 order of magnitude from one ash type to another.

In most cases the variation in chemical characteristics between the ash mixtures and the soil controls were within 1 order of magnitude of each other. The elements or chemical parameters where the ash mixtures were significantly higher than the control concentrations are illustrated in figures 4 through 6 below:

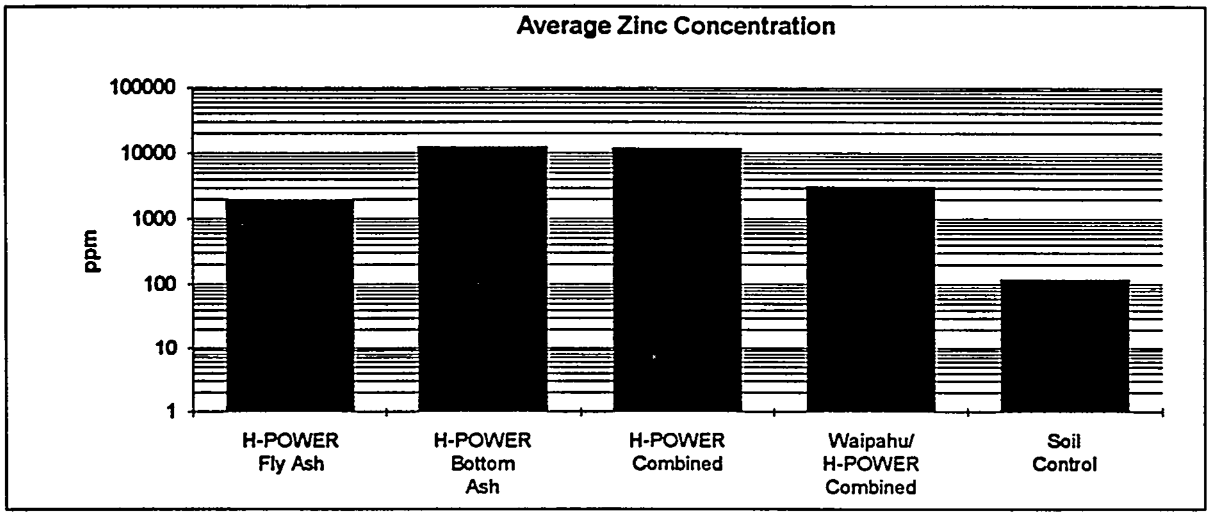

Figure 4

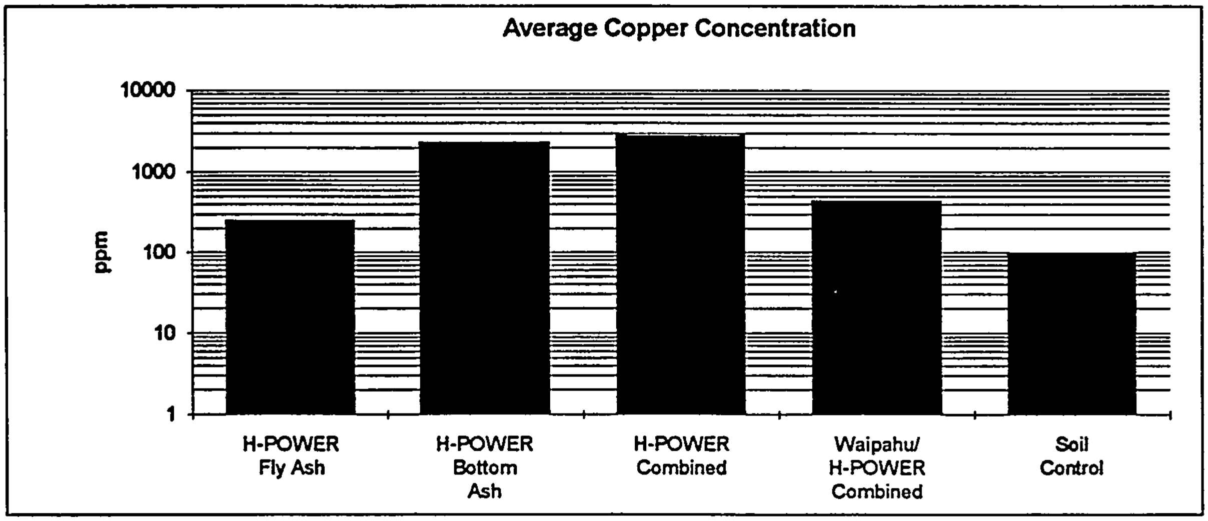

Figure 5

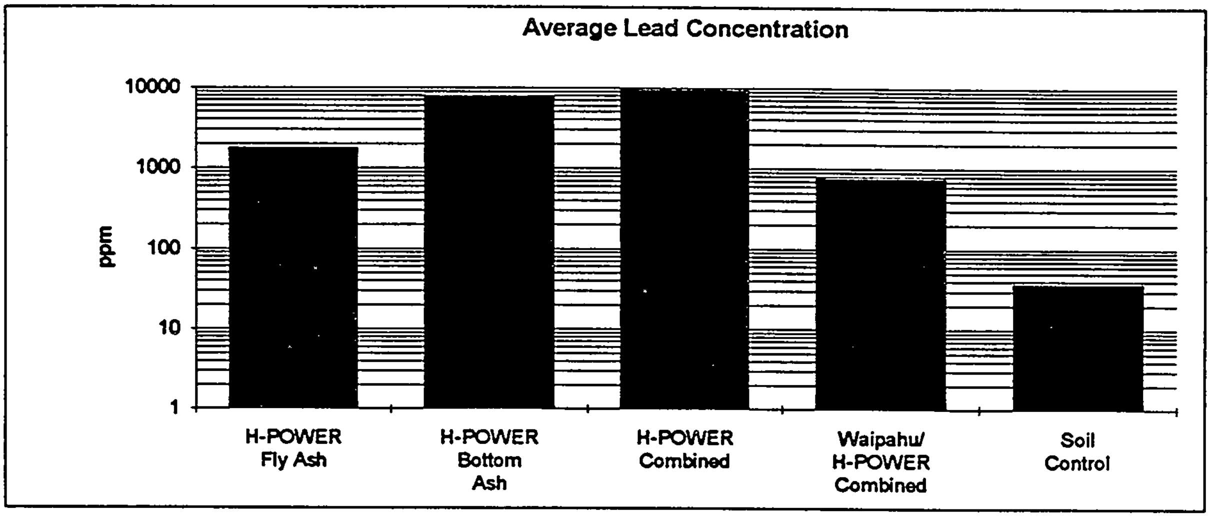

Figure 6

One other notable difference was that the pH levels in all ash mixtures averaged around 11.8 compared to 8 for the soil control.

Acid Neutralization Curves

Acid neutralization (titration) curves were run on each duplicate mixture sample. The titrations were carried out by combining 10 grams of each mixture sample with 50 ml of distilled water. While the resulting solutions were constantly being stirred, they were titrated with 1N H_2SO_4 and 1 minute pH readings were recorded. The resulting curves indicate, among other things, the buffering capacity of the various mixtures and are shown in Appendix A3, beginning on page 22.

The analysis of the data presented was accomplished by identifying the pH level corresponding to the inflection points in the curve. In general, pH 4.5 marks the point at which all of the carbonates and bicarbonates have been converted to carbonic acid. Therefore, the amount of acid required to reach this point can be reported as the total alkalinity of the ash mixture solution. The following figure presents the alkalinity of each mixture as g/L $CaCO_3$.

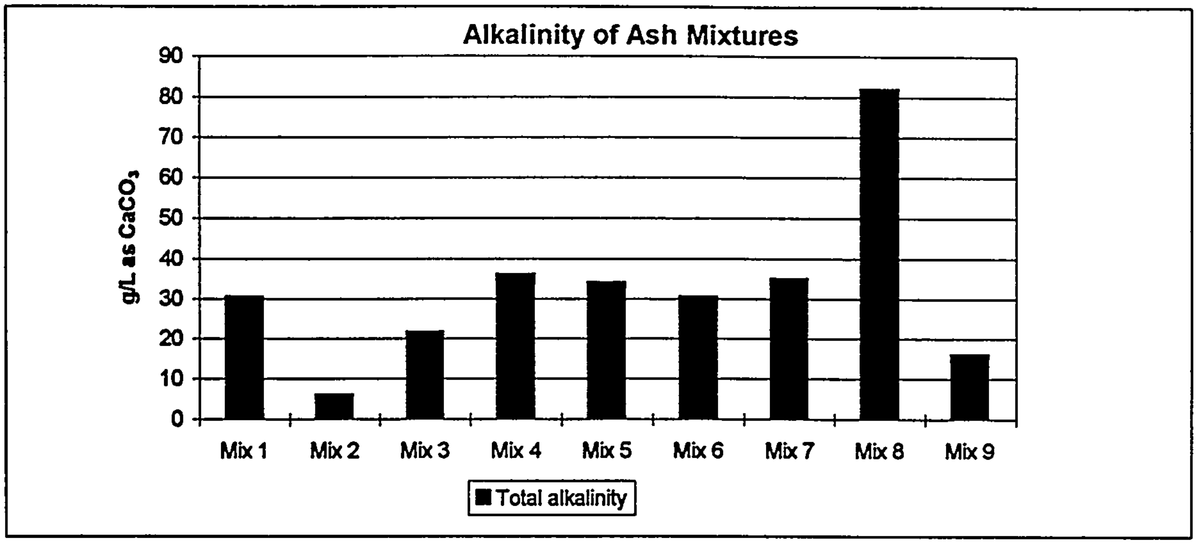

Figure 7

As the data in Figure 7 demonstrate, with only two exceptions, the total alkalinity and consequently the buffering capacity of the mixtures is relatively constant compared to the soil control (mixture 4). The extreme outliars are mixture 2 at 6 g/L, and mixture 8 at 82 g/L. This comparatively high alkalinity is a result of the additional lime added in preparation of this mixture.

Chemical Analysis Findings

Overall, there appears to be nothing from this chemical data to indicate ash mixtures would cause endangerment of human health or the environment when used as an alternative to natural soil as daily landfill cover.

Task 1.3 - Microbiological Analysis

The initial objective of the microbiological analysis was to ascertain the potential of MWC ash to reduce unpleasant odors and neutralize fecal coliform bacteria in sewage sludge. Tests were also conducted to determine the existence of Salmonella in mixtures containing sewage sludge. Salmonella test results appear on page 4 of Appendix A4, following the fecal coliform report. It was subsequently determined that the sludge from the City's wastewater treatment facility is sterile when it leaves the facility, and this was confirmed by the negative findings of the microbiological analysis. See Appendix A4 for lab findings.

Task 1.4 - Botanical Growth Potential of Ash Mixtures

Five MWC ash mixtures (4, 5, 6, 7, and 8) were tested to ascertain their potential to support botanical growth by attempting to grow grass. Appendix A5 contains a description of the test procedures and findings.

Botanical Findings Summary

After 10 weeks, all of the grass samples had died. Root growth was not substantial and it is believed that the test grass samples were able to survive for so long by living off top soil clinging to the roots prior to transplanting. Germination of the seeds was poor in all cases except for the Australian Carpet Grass which germinated better in some ash mixtures than in the botanical garden's control soil. The seedlings were also dead within 10 weeks. In both cases, the ash mixtures could not sustain long-term plant growth because of their hard, cement-like characteristics which provided insufficient water drainage and oxygen. It is likely that the low nitrogen content and high pH level were also major factors in the growth inhibiting properties of the mixtures. In Phase II, further studies are proposed to evaluate mixing combined ash with soil in a 1:4 ratio and adding nitrogen rich fertilizer.

Task 1.5 - Physical and Structural Characteristics

Erosion Resistance Test

The objective of the erosion test was to determine the MWC ash mixtures' ability to resist wind and rain erosion. Mixtures 1 through 9, (Figure 1) were placed to a depth of approximately two inches in a wooden box of approximately 1 square meter (12 sq. ft.), mounted at a 15° angle. The face of each mixture was leveled off as smoothly as possible. In the two months to follow, photographs were taken every ten days and visual observations were recorded as necessary. Some of the photographs taken are included in Appendix A6 along with a description of the findings.

At the end of the test period, each of the mixtures were examined and ranked according to the following pass/fail criteria: erosion resistance, material strength, and shrinkage. Figure 8 below shows the qualitative evaluation of the various mixtures.

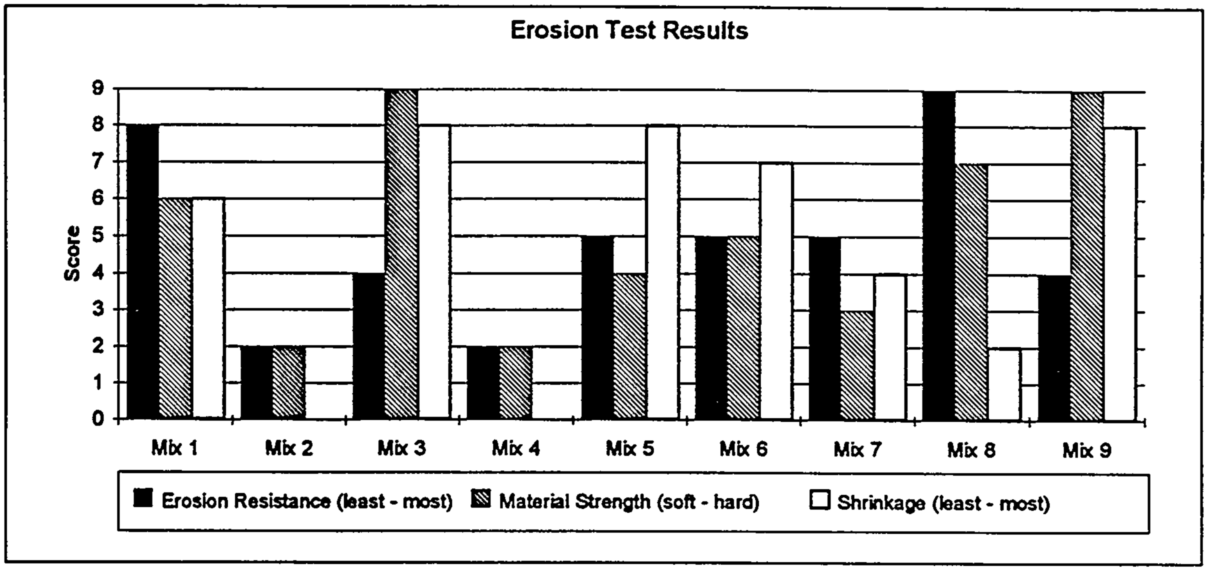

Figure 8

Note that mixture #8 was the most resistant to erosion while #2 and #4 were the least resistive as expected by their loose nature. With the exception of mixtures #2 and #4, the overall performance of the ash mixtures was essentially similar, with no single mixture clearly out-performing the others. As a result, the most economical mixture was chosen as the top performer for this subtask. Mixture #3 is clearly the most economical in that it represents the entire ash stream produced by H-POWER, requires no additional processing, no stabilizing additives, and no mixing.

Permeability Test

These tests were included in the protocol to evaluate the various mixtures with respect to permeability characteristics. The objective was to determine whether any of them could meet the Hawaii subsection 58.1-17 requirements (outlined in Appendix A1) for final landfill cover. The analysis utilizes a falling head permeameter and to insure accurate results, three specimens from each sample were subjected to a minimum of four runs each.

Laboratory findings indicate that the mixtures tested possess very low coefficients of hydraulic conductivity meeting the permeability requirements for the infiltration inhibiting layer (no greater than 10^{-5} cm/s). The results of the permeability testing along with a description of the findings are included in Appendix A7.

Task I Conclusions from Findings

The Task 1 test results indicate that MWC ash mixtures pose no apparent threat to human health or the environment. This will be further elaborated on in Phase II with the conduct of a health risk evaluation. Most of the ash mixtures have superior infiltration and erosion resistance material at the same relative buffering capacity as the presently used cover material. Although most of the ash mixtures would be deserving of large scale field testing, the decision to narrow the field down to one or two mixtures was made in the early planning stages so as to focus more intensely on each mixture. As a result, it has been decided to carry mixture #3 (H-POWER combined ash) into the second phase of the project.

TASK 2 -Evaluation of Ash as Aggregate for Road Construction

Task 2 efforts involved conducting sieve analyses on the three MWC ash types (H-POWER bottom, combined, and Waipahu combined ash) and subsequent chemical and physical analyses of the individual size fractions. Based on a qualitative review by professionals in the paving industry, certain fractions of the three MWC ash types were selected for further engineering properties testing to determine the suitability of the ash as a road construction aggregate.

Task 2.1 - Sieve Analysis

Samples of each ash type were oven-dried in preparation for sieving. After drying, the samples were analyzed using the following U.S. Standard sieve sizes: 3/4" (19.05 mm), 1/2" (12.7 mm), 3/8" (9.53 mm), #4 (4.75 mm), #8 (2.36 mm), #16 (1.18 mm), #30 (0.60 mm), #50 (0.30 mm), #100 (0.15 mm), and #200 (0.075 mm). Figure 9 below shows a summary of the sieve analysis for each ash type:

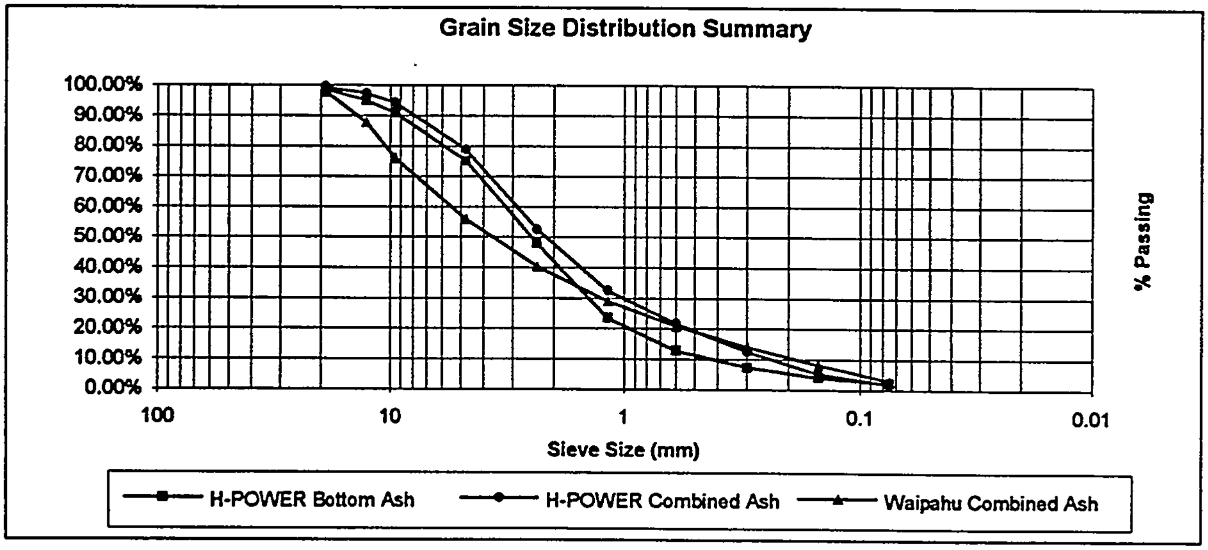

Figure 9

Results of the individual sieve analyses and an explanation of the data are found in Appendix B1.

A qualitative review of the size fractions found the H-POWER combined ash to be the most promising material. Although it was desirable to use all the material passing the #4 or 3/8" sieve, it turned out that the material larger than the #16 sieve size was simply unfit for use in asphalt as there were occasional pieces of metal wire and long flat pieces of ceramic and glass. Fortunately, the minus #16 material still accounts for over 50% of the H-POWER combined ash gradation.

One interesting point to note is that while a sieve analysis conducted on the fly ash alone indicated approximately 50% passing the #200 sieve, the gradations of the H-POWER combined ash did not reflect the same characteristic (compare Figures 2 and 5, [page 8 and 23] of Appendix B1). This anomaly is believed to be a result of pelletizing of the fly ash as it was mixed with the wet bottom ash. It is important to note in this case that the gradations of combined ash samples which were mixed in a dry state provide considerably more fine material than those mixed wet. Figure 10 below illustrates this phenomenon.

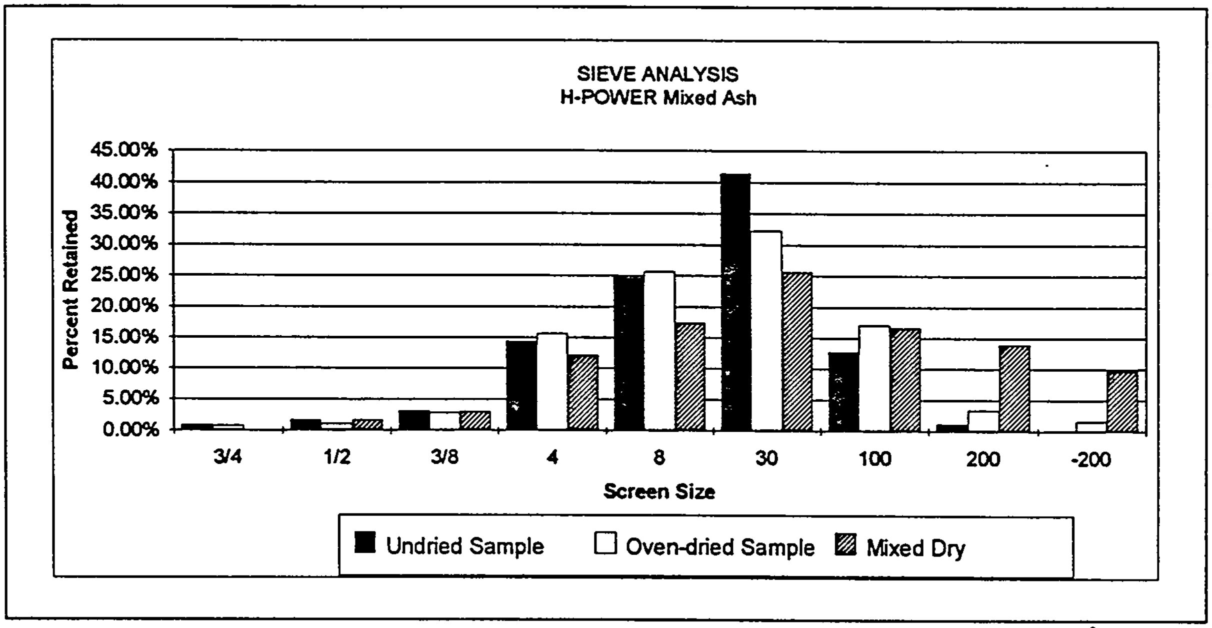

Figure 10

Task 2.2 - Chemical Analysis of Screened Ash Fractions

Sampling and Analysis Methods

Representative samples (about 5 ml each) were taken from each of the 8 size fractions from each of the three types of ash (H-POWER combined ash, H-POWER bottom ash, and Waipahu combined ash). Individual chemical analyses were carried out on each sample for: Al, Cd, Ca, Cu, Fe, Na, Pb, Zn, Hg, Si,

% chlorides, % sulfates, pH, % moisture, and density. The analytical chemistry methods used for these analyses are listed by each chemical parameter in Appendix B2.

Chemical Findings Summary

A detailed discussion of the results of the Task 2 chemical analyses is provided along with the data in Appendix B2. The entire E.L. Pacific laboratory report can be found following the analysis. Figures 11, 12, and 13 below present a summary of the trace metal concentrations for the three different ash types by sieve size. The sieve sizes indicated represent the material retained on that particular screen size.

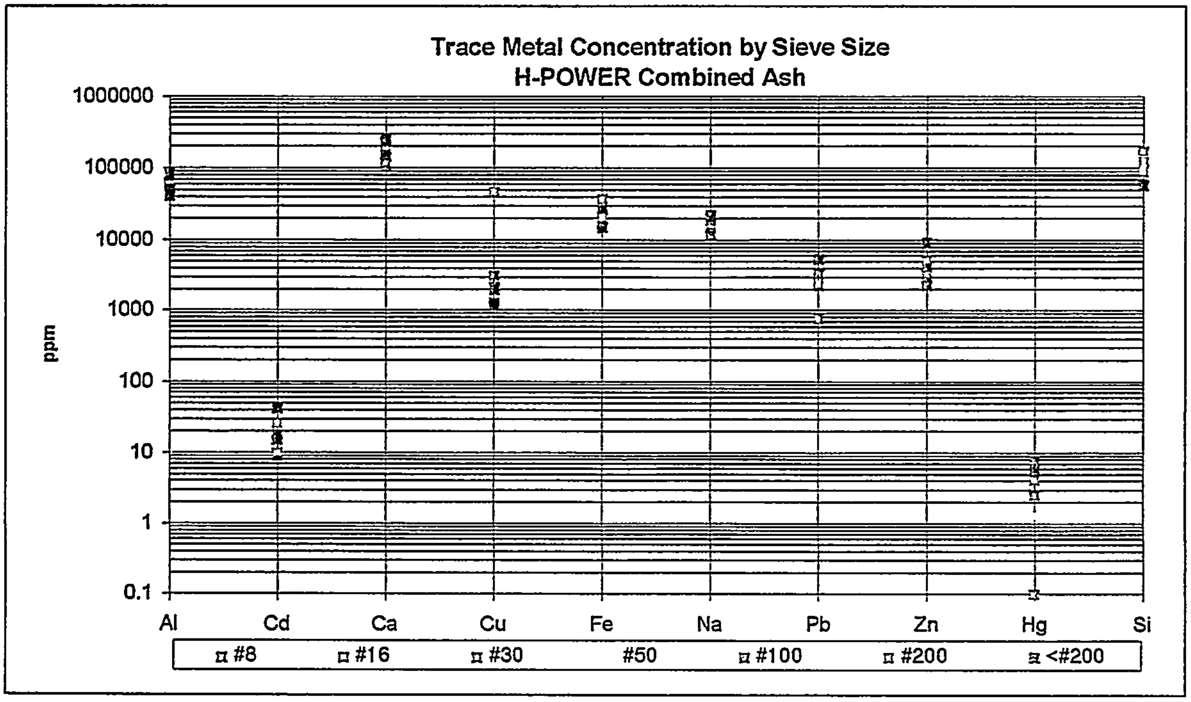

Figure 11

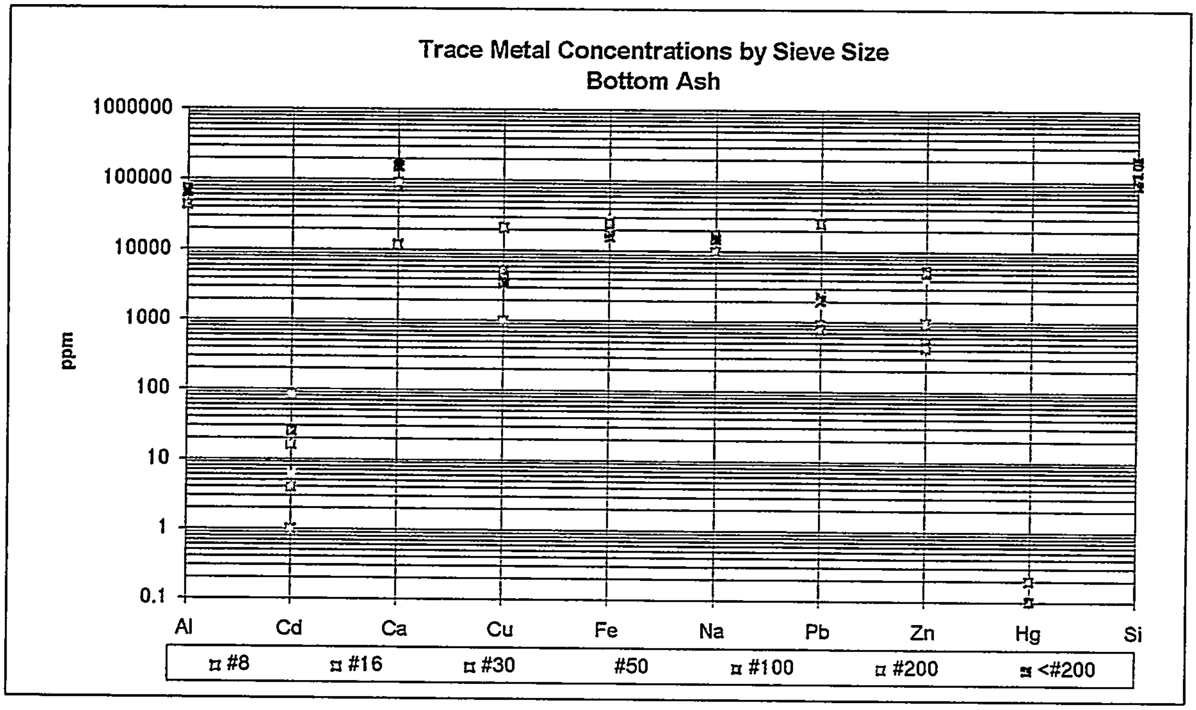

Figure 12

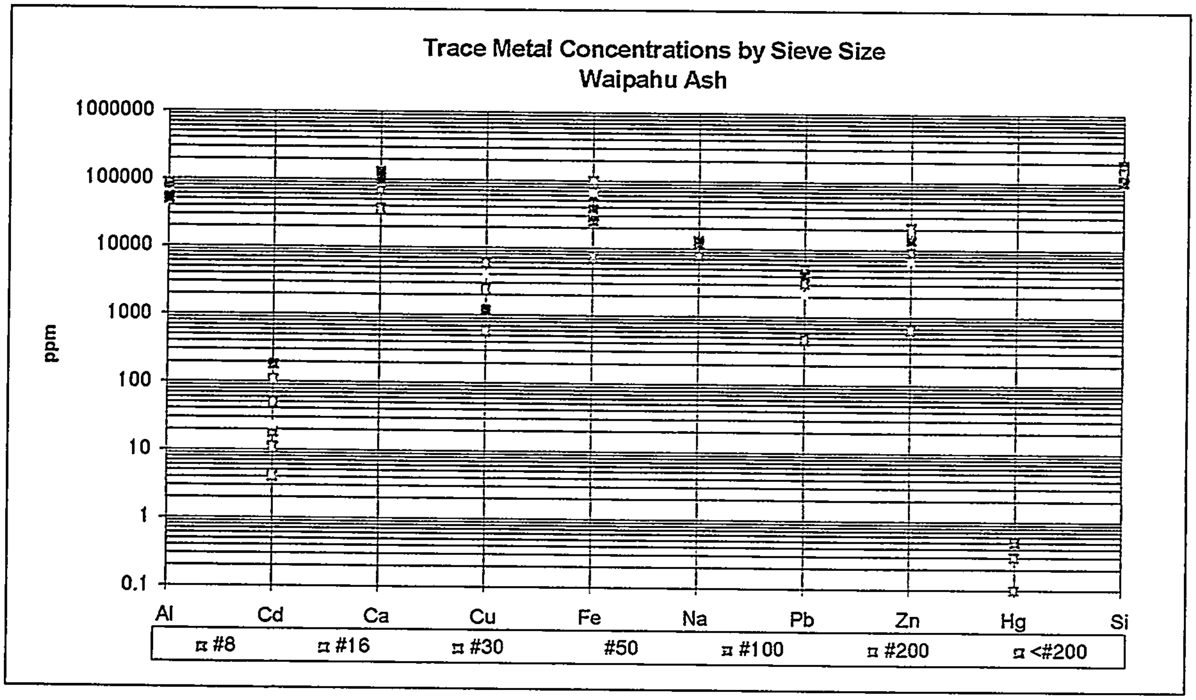

Figure 13

It is important to note that the three ash types were reasonably consistent in metal concentrations among the seven different size fractions.

Traditionally, the municipal waste combustion ash most often utilized as aggregate in road construction is bottom ash. These data show combined ash to be chemically equivalent to bottom ash, and, thus, equally relevant for aggregate use. With some modification to its BAMR unit, H-POWER could produce a screened fraction of this ash starting at sieve size #16. This could result in potential utilization of 50% of this ash fraction.

Task 2.3 - Engineering Tests for Aggregate Use

During the early stages of Phase I, a meeting with representatives of the two local paving companies and Florida-based Permabase, Inc. was held to discuss possible applications of H-POWER bottom ash as a substitute road construction aggregate. Permabase, Inc. is a roadbase material supplier interested in using H-POWER ash in their patented soil cement mixture, PERMABASE-PLUS. Permabase conducted a preliminary investigation using H-POWER ash in their soil cement product and achieved seven-day strengths which were "well above the typical strengths achieved with sand mixtures" (see Appendix B3, page 3). These positive preliminary findings moved Permabase to conduct a more thorough investigation involving H-POWER ash. Several laboratory tests were carried out on H-POWER ash and locally available Hawaiian construction materials. The purpose of these tests was to determine the suitability of H-POWER ash for use in PERMABASE-PLUS while meeting Hawaii Department of Transportation (HDOT) specifications. The complete Permabase Task 2 investigation report is found in Appendix B4.

<u>Analysis Methods and Sampling</u>

PERMABASE-PLUS is a combination of MWC ash, cement, water and locally produced aggregates. Each of these ingredients can be utilized in varying amounts depending on the quality and availability of the raw materials, and the structural and environmental specifications which apply. According to the Hawaii Department of Transportation's (HDOT) Standard Specifications for Road and Bridge Construction - Section 308, soil cement is locally known as Portland Cement Treated Base and is required to be tested by the following procedures:

soil cement is locally known as Portland Cement Treated Base and is required to be tested by the following procedures:

Los Angeles Abrasion	AASHTO T 96
Sand Equivalent	AASHTO T 176
Plasticity	AASHTO T 90
Flat or Elongated Pieces	HWY-TC 4
Grading	AASHTO T 27

H-POWER bottom and combined ash were used for these tests along with local Red Base Rock, #4 Rock, and #3 Sand; the latter three supplied by Grace Pacific Corporation (GP) from their rock quarry and processing facility on Oahu. After evaluation of the five materials received and a review of the specifications, Permabase, Inc. decided to utilize GP #4 Rock and GP #3 Sand in combination with H-POWER combined ash.

Due to the sample size and time limitations, Permabase, Inc. prepared four aggregate combinations using the following criteria: a minimum content of 25% ash as a practical level of recycling necessary for commercial viability, and a maximum of 50% ash due to HDOT specification limits. Note that if the aggregate mixtures are found to have commercial applications, the optimum aggregate combination can be determined through practice and experience. The four aggregates prepared for testing are in the concentrations shown in Figure 15:

Aggregate Mix	H-POWER Combined Ash	GP #4 Rock	GP #3 Sand	Crushed Concrete-Coarse	Crushed Concrete-Fine
1	25%	50%	25%	n/a	n/a
2	50%	50%	n/a	n/a	n/a
3	25%	n/a	n/a	50%	25%
4	50%	n/a	n/a	50%	n/a

Figure 15

NOTE: Coarse graded aggregates are larger than the #4 (4.75 mm) sieve.

Aggregate mixtures #3 and #4 utilized H-POWER combined ash and Florida crushed concrete. Although they are not within the scope of the overall project, Permabase, Inc. felt that these combinations offer an opportunity for the City and County of

Findings

Results of the HDOT testing procedures appear in Table 2, Appendix B4. Note that all of the results are within the required specifications. This clearly demonstrates that processed H-POWER ash can be successfully combined with locally available natural aggregates or recycled materials to meet all specifications as detailed in Section 308 - Portland Cement Treated Base, of the Hawaii Department of Transportation Standard Specifications for Road and Bridge Construction.

Task 2 Conclusions from Findings

Task 2 results, like those of Task 1, clearly demonstrate that MWC ash could feasibly function as a quality alternative aggregate. The test results underscore the fact that MWC ash is a chemically safe and physically appropriate material to use in aspects of road construction. With minimal processing, H-POWER combined ash could be easily combined with local aggregates to produce a reliable, economical aggregate mixture.

Conclusion

The benefits of utilizing MWC ash in landfill and road construction applications are vast.

In Task 1, the chemical analysis shows no indication that using any of the ash mixtures would cause endangerment of human health or the environment when used as an alternative daily landfill cover. A health risk assessment will be conducted in Phase II to confirm this. The strong buffering capacity coupled with the natural pozzolanic type reactions of wet combined ash should decrease the potential for metal leachability. The addition of sewage sludge to the ash mixtures provides an alternative means for its disposal and should help reduce the moisture and the odor properties of the sludge, resulting in improved public health and environmental consequences as compared to current practices for sludge disposal. Although the chemical analysis and botanical tests show mixtures containing sludge to be less than desirable final top cover material by themselves, these mixtures may still be used as infiltration and erosion layers of final landfill covers. For economic reasons, mixture #3 (combined H-POWER ash) was chosen for further study in Phase II.

In Task 2, the results of the sieve size analysis indicate that H-POWER combined ash would be best suited for use in asphalt mixtures since over 50% of its particles fall into the minus #16 size range. Actual tests on mixtures employing H-POWER ash show that it can be used successfully. Additional tests are currently being conducted by Hawaiian Bitumuls and will be reported in Phase II.

As shown, MWC ash is a safe and suitable alternative. It is readily available, and with proper processing, is the key to closing the municipal waste recycling loop. Moreover, MWC ash utilization would extend the current landfill life. Decreasing the amount of material going to the landfill would also mean lower tipping fees at waste-to-energy plants. Alternatively, money currently spent landfilling could be channeled into other areas of waste management. Large scale studies planned for Phase II will be more illustrative of the benefits that MWC ash utilization can bring to municipalities nationwide.

Acknowledgment

We would like to express our gratitude and appreciation to the following for their contribution to the project. The management and personnel of: Honolulu Resource Recovery Venture, Ogden Projects Inc., David Kawamoto and Chris Steele of Grace Pacific Corporation, Ralph Witham and David Scott of Hawaiian Bitumuls & Paving Co., Eric Shafer of Permabase Inc., Foremost Dairy, Barbers Point AES, City and County of Honolulu Department of Wastewater Management, Waipahu Incinerator and Material Testing Lab, Dr. David and Teresa Kosson, Dr. Peter Nicholson, and the Hawaii State Department of Health - Office of Solid Waste Management. Finally, we would like to thank the City's H-POWER staff for their assistance in completing this report: Mr. Nathan Yuen, Ms. Valerie Kane, and Mr. Jim Grogan.

Appendix A1

Regulatory Requirements for Landfill Cover Materials

Sections 11-58.1-15 and 11-58.1-17 of the Hawaii Administrative Rules specify the operational criteria and closure care requirements for material used for daily and final cover for landfills containing municipal solid waste. The landfill daily cover requirements as specified in subsection 58.1-15 include:

1. Cover MSW with at least 15.24 cm. (6 inches) of earthen material at the end of each working day, or more often if necessary to control disease vectors, fires, odors, blowing litter, and scavenging, or;

2. Alternative cover material may be approved if the owner or operator demonstrates that the alternative material and thickness can do the same as (1) above without endangering human health and the environment.

Subsection 58.1-17 of the Hawaii Administrative Rules specify requirements at MSW landfills where final cover material is used for final closure. Those regulations indicate that the final cover system must be designed to minimize infiltration and erosion. The infiltration and erosion inhibiting cover layer must:

1. Have a permeability no greater than 1×10^{-5} cm/sec, and

2. Minimize infiltration through the use of an infiltration layer that contains a minimum 45.72 cm. (18 inches) of earthen material, and

3. Minimize erosion by the use of an erosion layer that contains a minimum of 15.24 cm. (6 inches) of earthen material that is capable of sustaining plant growth.

Alternative final cover design to the above requirements may be approved if it is shown that the alternative achieves an equivalent degree of impermeability, and controls infiltration and erosion to a similar or improved degree.

Appendix A2

Ash Collection, Storage, and Mixture Preparation

Ash Collection and Storage

The H-POWER bottom ash after falling from the boiler grate into a quench tank, is retrieved via the submerged scraper conveyors (SSC)and is deposited onto a conveyor belt which feeds the BAMR. A photograph of the BAMR is shown appears as Figure 1 below.

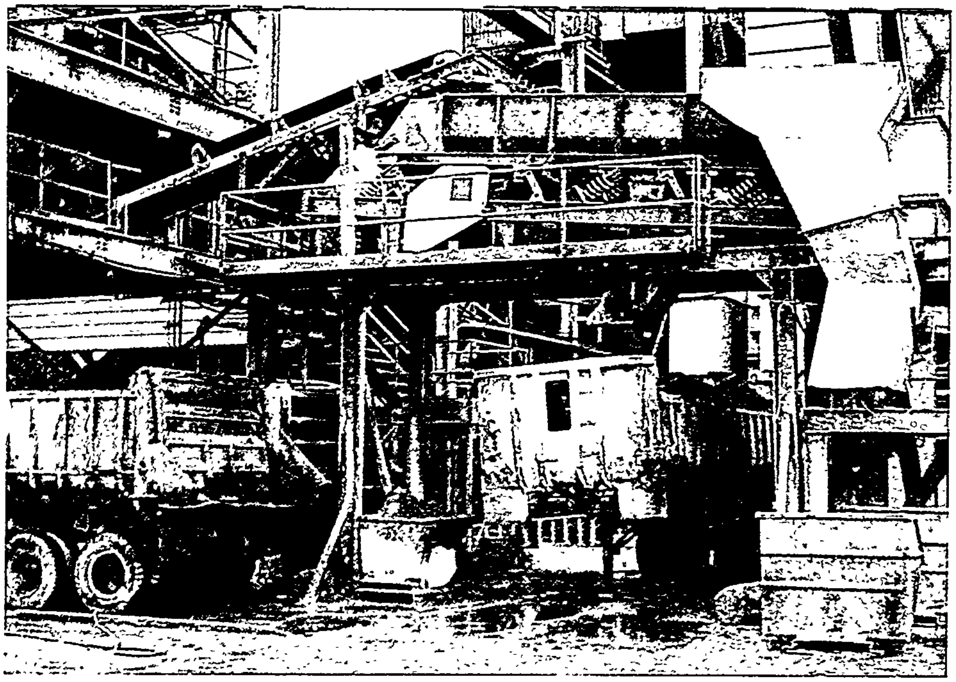

Figure 1

The BAMR is made up of 6 major components: a vibrating finger screen, rotating drum electromagnet, eddy current separator, and three hoppers. The ash stream first encounters the vibrating finger screen. The finger screen has triangular openings with a length of about 3.8 centimeters (1.5 inches) and a base width of roughly 1.6 centimeters (5/8 of an inch). Material which does not pass through the screen continues on past the rotating drum electromagnet which deflects the ferrous metals into a separate hopper. The remaining non-ferrous material is then removed using the eddy current separator which deflects the material into the appropriate hopper. The remaining material is collected in yet a third hopper. Material passing the screen falls directly into the loadout trailer, which is where the samples were collected.

Six 38-liter (10-gallon) samples were taken throughout the day at roughly 1.5 hour intervals.

The H-POWER fly ash comes from the electrostatic precipitators (ESP) and goes into a pug mill where it is sprayed with water to control dusting. The moistened fly ash is then fed into the ash loadout trailer. Since the object was to obtain dry fly ash, the ash was collected prior to reaching the pug mill. Figure 2 below shows the surge bin from which the dry ash was collected.

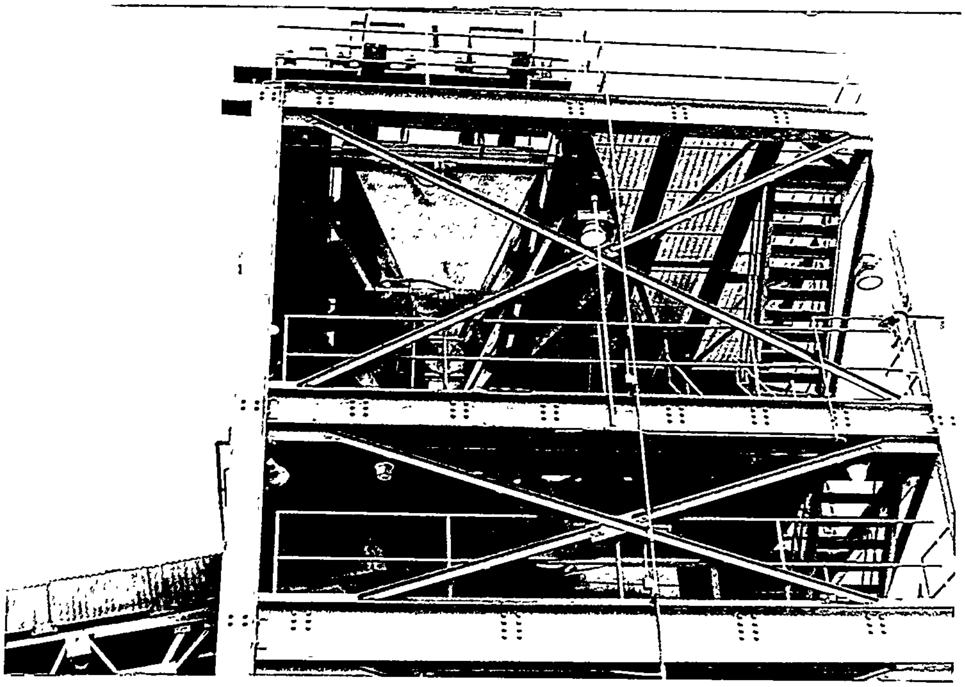

Figure 2

All of the H-POWER ash was placed in the appropriate storage drum and the particulars of collection recorded. Tables 1-5, beginning on page A2-4, show the ash collection data.

Waipahu Incinerator ash was collected from the ash monofill located near the incinerator. Twice each day over a five day period, the ash was taken to the monofill and dumped (see Figures 3 and 4, page A2-3). The pile was spread out using a Bobcat tractor and samples were taken randomly from different parts of the pile. The ash samples were then loaded from the bucket of the Bobcat into steel storage drums. Table 6 contains the Waipahu ash collection data.

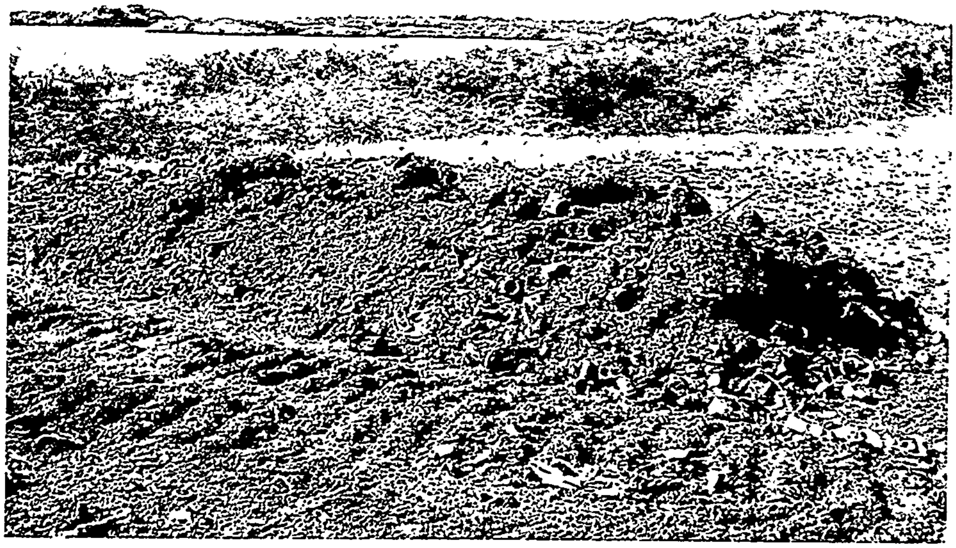

Figure 3

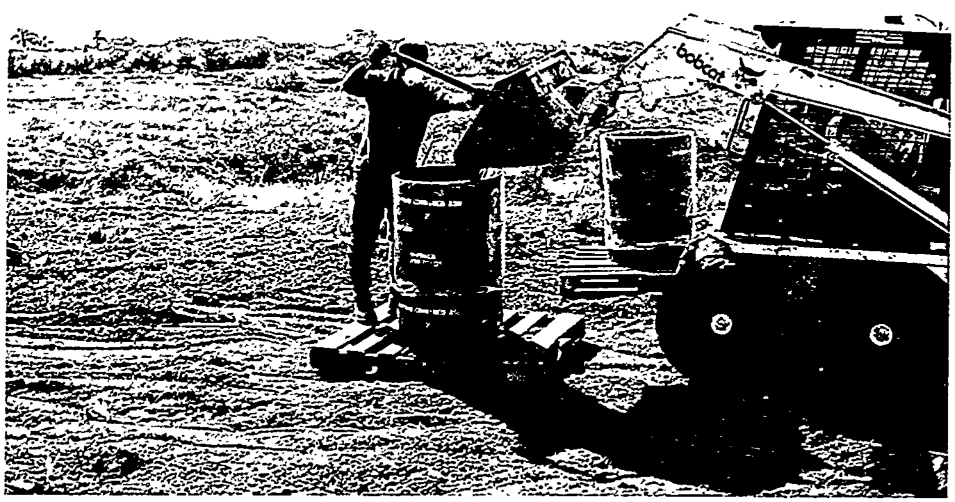

Figure 4

ASH COLLECTION DATA SHEET (H-POWER FLY ASH)

DATE	TIME	DRUM NUMBER	REMARKS
19-Oct-93	09:00 AM	F1	5 GALLONS
19-Oct-93	09:45 AM	F1	5 GALLONS
19-Oct-93	12:00 PM	F1	5 GALLONS
19-Oct-93	01:20 PM	F1	5 GALLONS
19-Oct-93	02:30 PM	F1	5 GALLONS
20-Oct-93	09:00 AM	F2	5 GALLONS
20-Oct-93	10:45 AM	F2	5 GALLONS
20-Oct-93	12:15 PM	F2	5 GALLONS
20-Oct-93	01:15 PM	F2	5 GALLONS
20-Oct-93	02:15 PM	F2	10 GALLONS
21-Oct-93	10:45 AM	F3	15 GALLONS
21-Oct-93	01:45 PM	F3	15 GALLONS
22-Oct-93	10:00 AM	F4	15 GALLONS
22-Oct-93	01:30 PM	F4	15 GALLONS
26-Oct-93	12:00 PM	F5	15 GALLONS
26-Oct-93	02:30 PM	F5	15 GALLONS

Table 1

ASH COLLECTION DATA SHEET (H-POWER BOTTOM ASH)

DATE	TIME	DRUM NUMBER	REMARKS
19-Oct-93	08:00 AM	B1	5 GALLONS
19-Oct-93	09:20 AM	B1	5 GALLONS
19-Oct-93	11:45 AM	B1	5 GALLONS
19-Oct-93	01:00 PM	B1	5 GALLONS
19-Oct-93	01:45 PM	B1	5 GALLONS
19-Oct-93	03:00 PM	B1	5 GALLONS
20-Oct-93	08:30 AM	B2	5 GALLONS
20-Oct-93	10:15 AM	B2	5 GALLONS
20-Oct-93	12:00 PM	B2	5 GALLONS
20-Oct-93	01:00 PM	B2	5 GALLONS
20-Oct-93	02:00 PM	B2	5 GALLONS
20-Oct-93	03:00 PM	B2	5 GALLONS
21-Oct-93	10:30 AM	B3	5 GALLONS
21-Oct-93	11:10 AM	B3	5 GALLONS
21-Oct-93	11:50 AM	B3	5 GALLONS
21-Oct-93	12:30 PM	B3	5 GALLONS
21-Oct-93	01:10 PM	B3	5 GALLONS
21-Oct-93	02:10 PM	B3	5 GALLONS
22-Oct-93	08:30 AM	B4	5 GALLONS
22-Oct-93	09:40 AM	B4	5 GALLONS
22-Oct-93	10:50 AM	B4	5 GALLONS
22-Oct-93	12:00 PM	B4	5 GALLONS
22-Oct-93	01:10 PM	B4	5 GALLONS
22-Oct-93	02:30 PM	B4	5 GALLONS

Table 2

ASH COLLECTION DATA SHEET (H-POWER BOTTOM ASH)

DATE	TIME	DRUM NUMBER	REMARKS
28-Oct-93	09:30 AM	B5	5 GALLONS
28-Oct-93	10:30 AM	B5	5 GALLONS
28-Oct-93	11:30 AM	B5	5 GALLONS
28-Oct-93	12:30 PM	B5	5 GALLONS
28-Oct-93	01:30 PM	B5	5 GALLONS
28-Oct-93	02:30 PM	B4	5 GALLONS

Table 3

ASH COLLECTION DATA SHEET (H-POWER MIXED ASH)

DATE	TIME	DRUM NUMBER	REMARKS
19-Oct-93	08:00 AM	M1	5 GALLONS BOTTOM
19-Oct-93	09:00 AM	M1	5 GALLONS FLY
19-Oct-93	09:20 AM	M1	5 GALLONS BOTTOM
19-Oct-93	09:45 AM	M1	5 GALLONS FLY
19-Oct-93	11:45 AM	M1	5 GALLONS BOTTOM
19-Oct-93	12:00 PM	M1	5 GALLONS FLY
19-Oct-93	01:00 PM	M1	5 GALLONS BOTTOM
19-Oct-93	01:20 PM	M1	5 GALLONS FLY
19-Oct-93	01:45 PM	M1	5 GALLONS BOTTOM
19-Oct-93	03:00 PM	M1	5 GALLONS BOTTOM
20-Oct-93	08:30 AM	M2	5 GALLONS BOTTOM
20-Oct-93	09:00 AM	M2	5 GALLONS FLY
20-Oct-93	10:15 AM	M2	5 GALLONS BOTTOM
20-Oct-93	10:45 AM	M2	5 GALLONS FLY
20-Oct-93	12:00 PM	M2	5 GALLONS BOTTOM
20-Oct-93	12:15 PM	M2	5 GALLONS FLY
20-Oct-93	01:00 PM	M2	5 GALLONS BOTTOM
20-Oct-93	01:15 PM	M2	5 GALLONS FLY
20-Oct-93	02:00 PM	M2	5 GALLONS BOTTOM
20-Oct-93	03:00 PM	M2	5 GALLONS BOTTOM
21-Oct-93	10:30 AM	M3	5 GALLONS BOTTOM
21-Oct-93	10:45 AM	M3	10 GALLONS FLY
21-Oct-93	11:10 AM	M3	5 GALLONS BOTTOM
21-Oct-93	11:50 AM	M3	5 GALLONS BOTTOM
21-Oct-93	12:30 PM	M3	5 GALLONS BOTTOM
21-Oct-93	01:10 PM	M3	5 GALLONS BOTTOM
21-Oct-93	01:45 PM	M3	10 GALLONS FLY
21-Oct-93	02:10 PM	M3	5 GALLONS BOTTOM

Table 4

ASH COLLECTION DATA SHEET (H-POWER MIXED ASH)

DATE	TIME	DRUM NUMBER	REMARKS
22-Oct-93	08:30 AM	M4	5 GALLONS BOTTOM
22-Oct-93	09:40 AM	M4	5 GALLONS BOTTOM
22-Oct-93	10:00 AM	M4	10 GALLONS FLY
22-Oct-93	10:50 AM	M4	5 GALLONS BOTTOM
22-Oct-93	12:00 PM	M4	5 GALLONS BOTTOM
22-Oct-93	01:10 PM	M4	5 GALLONS BOTTOM
22-Oct-93	01:30 PM	M4	10 GALLONS FLY
22-Oct-93	02:30 PM	M4	5 GALLONS BOTTOM
26-Oct-93	12:00 PM	M5	10 GALONS FLY
26-Oct-93	02:30 PM	M5	10 GALONS FLY
28-Oct-93	09:30 AM	M5	5 GALLONS BOTTOM
28-Oct-93	10:30 AM	M5	5 GALLONS BOTTOM
28-Oct-93	11:30 AM	M5	5 GALLONS BOTTOM
28-Oct-93	12:30 PM	M5	5 GALLONS BOTTOM
28-Oct-93	01:30 PM	M5	5 GALLONS BOTTOM

Table 5

ASH COLLECTION DATA SHEET (WAIPAHU INCINERATOR)

DATE	TIME	DRUM NUMBER	REMARKS.
18-Oct-93	09:30 AM	W1	COLLECTION FROM 7 DIFFERENT AREAS
18-Oct-93	12:30 PM	W2	COLLECTION FROM 6 DIFFERENT AREAS
19-Oct-93	09:30 AM	W3	COLLECTION FROM 5 DIFFERENT AREAS
19-Oct-93	12:30 PM	W4	COLLECTION FROM 6 DIFFERENT AREAS
20-Oct-93	09:30 AM	W5	COLLECTION FROM 6 DIFFERENT AREAS
20-Oct-93	12:30 PM	W6	COLLECTION FROM 6 DIFFERENT AREAS
21-Oct-93	09:30 AM	W7	COLLECTION FROM 6 DIFFERENT AREAS
21-Oct-93	12:30 PM	W8	COLLECTION FROM 6 DIFFERENT AREAS
22-Oct-93	09:30 AM	W9	COLLECTION FROM 7 DIFFERENT AREAS
22-Oct-93	12:30 PM	W10	COLLECTION FROM 7 DIFFERENT AREAS.

Table 6

Mixture Preparation

During the preparation of the test mixtures, water was added in small amounts to achieve a managable plasticity. Table 7 below shows the amount of water added to each of the mixtures.

Mixture	Contents	Quantity (gals)	Water added (gals)
1	Fly Ash	16	8
2	Bottom Ash	16	1
3	Mixed Ash	16	1
4	Landfill Soil	16	2 *
5	Fly Ash	12/22.5 **	6.2/12.5
	Sludge	4/7.5	
6	Coal Ash	5/7	6/7.5
	Sludge	5/7	
	Fly Ash	5/7	
7	Fly Ash	8/15	6/11.5
	Sludge	8/15	
8	Fly ash	6/10	8/15
	Sludge	6/10	
	Lime	3/5	
9	Waipahu Ash	8	0
	Mixed ash	8	

* Mixture 4 turned out too clumpy and would not spread out. An additional half gallon of water was added to help smooth the face of the erosion test sample. Moreover, an additional gallon of soil mixed with a half gallon of water was mixed to form a putty-like mixture. This putty was used to fill in the gaps in the face of the test mixture.

** Where numbers are separated by a slash, the first number refers to the quantity mixed for lab analysis and erosion testing, while the second number is the quantity mixed for the botanical cover potential.

Table 7

The mixtures were prepared in quantities large enough to satisfy requirements for each of the three laboratory analyses. This typically included 114 liters (30 gallons) for botanical cover testing, 46 liters (12 gallons) for erosion resistance tests, and

19 liters (5 gallons) from which to sample for chemical and microbiological analysis.

Appendix A3

Chemical Analysis of Ash Mixtures

Task 1 chemical analysis was carried out following the methods listed below:

Task 1 Chemical Analysis Methods

Aluminum	EPA Method 3050M
Arsenic	EPA Method 6010
Barium	EPA Method 6010
Cadmium	EPA Method 6010
Calcium	EPA Method 6010
Chromium	EPA Method 6010
Copper	EPA Method 6010
Iron	EPA Method 6010
Lead	EPA Method 6010
Mercury	EPA Method 6010
Potassium	EPA Method 6010
Selenium	EPA Method 6010
Silicon	EPA Method 6010
Silver	EPA Method 6010
Zinc	EPA Method 6010
pH	EPA Method 9045
Chloride	EPA Method 325.3
Sulfate	EPA Method 375.4
Carbon	ASTM D5291M
Nitrate/Nitrite	EPA Method 353.3
Total Nitrogen	EPA Method 351.3
Moisture	CLP ILM 2.0

Inductively coupled argon plasma analysis (ICAP) was used for all metals except Silicon where atomic absorption spectroscopy methods were used.

Summary Findings

The following is a detailed summary of the Task 1 chemical analysis findings. Please refer to the appropriate tables listed at the beginning of each section. Data appearing in the tables has been adapted from the E.L. Pacific laboratory report, which can be found beginning on page A3-13 of this appendix.

In addition to comparing the elemental chemistry data from each of these mixtures with each other, it is also useful to compare the concentrations of H-POWER fly ash only (mix 1) and H-POWER bottom ash only (mix 2) to the fly ash and bottom ash concentrations EPA found in a 1991 study it conducted at the Mid-Connecticut (MC) RDF facility (Appendix C1). That facility burns similar prepared fuel (RDF) and is nearly identical in design except in that it employs a baghouse instead of an electrostatic precipitator (ESP) for particulate control.

Aluminum through Chromium
Refer to Table 1 on page A3-4

Aluminum - Low: 7,884.5 PPM, High: 55,052.5 PPM. Except for H-POWER bottom ash, the aluminum levels were higher in the soil control mixtures than any ash mixtures. The average concentration of aluminum in the H-POWER bottom ash was much higher at 55,052 PPM than in the fly ash which averaged 7,884 PPM. The aluminum bottom ash concentrations at H-POWER are essentially the same as that which EPA found at the Mid Connecticut RDF facility (MC) in their 1991 study, but the fly ash concentrations were much lower than the 59,300 PPM at MC.

Arsenic - Low: Non-detect, High: 75.5 PPM (mix 1[1]). There was no significant difference, however, between the arsenic concentration in the control and any other mixture except mixture 1. The fly ash arsenic concentration was slightly higher than the MC fly ash which averaged 19 PPM, but the bottom ash which had no detectable concentrations (0.5 PPM detection limit) was lower than MC's 10 PPM.

Barium - Low: 128.5 PPM, High: 690 PPM (mix 2). The range of variation was very narrow and one can not conclude there was any appreciable increase in barium in the ash mixtures over the control. The barium concentrations in MC fly ash at an average 98 PPM was lower than H-POWER's average of 310 PPM. The bottom ash at H-POWER was also slightly higher (690 PPM) than at MC which averaged 403 PPM.

Cadmium -Low: Non-detect (control), High: 58 PPM. This also was a very narrow range of variation and no meaningful difference can be drawn between concentration in the ash mixtures than in the control mixture. The H-POWER fly ash concentrations which averaged 27 PPM were lower than MC

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[1] A table summarizing mixture contents appears on page A3-12 (table 9) of this appendix.

which averaged about 100 PPM. Similarly the H-POWER non-detectable concentrations (0.05 PPM detection limit) in the bottom ash were lower than MC's bottom ash concentrations (7 PPM).

Calcium - Low: 30,133 PPM (control), High: 148,901 PPM (mix 8). This 5-fold increase compared to the control mixture is not surprising. The similarity in the fly and bottom ash concentrations (each averaging around 104,000 PPM) was peculiar, however, and is so far inexplicable. Also a surprise was the higher MC concentrations (120,000 PPM). This is surprising because H-POWER, having a dry lime scrubber and an ESP, was expected to have a much higher fly ash calcium concentration (MC also burns RDF and has a dry lime scrubber, but with a baghouse fabric filter instead of an ESP). This is because an ESP requires more calcium to reduce SO_2 levels than with a baghouse. The unreacted lime that coats the bags in a baghouse allows additional time to react with the gaseous SO_2 to form calcium sulfate.

Chromium - Low: 37 PPM (mix 8), High: 280 PPM (control). The control mixture, with an average concentration of 280 PPM, was slightly higher than either the average concentrations for H-POWER fly or bottom ash (118 and 187 PPM). The MC bottom ash concentration averaged around 200 PPM and about 220 PPM in the fly ash.

Table 1 below shows the results for Al, As, Ba, Cd, Ca, and Cr for each of the duplicate mixtures. An average is calculated for each of the six chemical parameters listed above for each mixture. The control mixture, mix 4, is a sample of native soil currently used as daily cover taken from the Waimanalo Gulch landfill. At the bottom of the table, an average concentration for all mixtures excluding this control is given. The percent difference between the mixture average and the control average is then calculated according to the following formula:

$$\% \, diff = \frac{mix\ avg - control\ avg}{mix\ avg}$$

Tables 2, 3, and 4 are set up the same way for the remaining chemical parameters.

Chemical Analysis in units of PPM unless otherwise indicated						
Test Mix	Al	As	Ba	Cd	Ca	Cr
Mix 1a	10233.00	76.00	310.00	26.00	107248.00	116.00
Mix 1b	5536.00	75.00	310.00	27.00	99844.00	120.00
Mix 1 avg.	**7884.50**	**75.50**	**310.00**	**26.50**	**103546.00**	**118.00**
Mix 2a	48985.00	25*	570.00	2.5*	109122.00	160.00
Mix 2b	61120.00	25*	810.00	2.5*	101082.00	214.00
Mix 2 avg.	**55052.50**	**25.00**	**690.00**	**2.50**	**105102.00**	**187.00**
Mix 3a	46341.00	25*	5*	11.00	131156.00	206.00
Mix 3b	47469.00	87.00	537.00	105.00	118166.00	181.00
Mix 3 avg.	**46905.00**	**56.00**	**271.00**	**58.00**	**124661.00**	**193.50**
Mix 4a	55563.00	25*	184.00	2.5*	24145.00	250.00
Mix 4b	50755.00	25*	73.00	2.5*	36121.00	310.00
Mix 4 avg. [Control, (CT)]	**53159.00**	**25.00**	**128.50**	**2.50**	**30133.00**	**280.00**
Mix 5a	26877.00	73.00	405.00	23.00	112753.00	113.00
Mix 5b	26758.00	74.00	360.00	24.00	123589.00	110.00
Mix 5 avg.	**26817.50**	**73.50**	**382.50**	**23.50**	**118171.00**	**111.50**
Mix 6a	41040.00	25*	238.00	7.00	81646.00	55.00
Mix 6b	23197.00	25*	220.00	5.00	75629.00	46.00
Mix 6 avg.	**32118.50**	**25.00**	**229.00**	**6.00**	**78637.50**	**50.50**
Mix 7a	16835.00	25*	233.00	16.00	101861.00	83.00
Mix 7b	19585.00	25*	270.00	15.00	94160.00	84.00
Mix 7 avg.	**18210.00**	**25.00**	**251.50**	**15.50**	**98010.50**	**83.50**
Mix 8a	10485.00	25*	139.00	8.00	143000.00	39.00
Mix 8b	10303.00	25*	119.00	7.00	154802.00	35.00
Mix 8 avg.	**10394.00**	**25.00**	**129.00**	**7.50**	**148901.00**	**37.00**
Mix 9a	49099.00	70.00	391.00	25.00	94776.00	202.00
Mix 9b	50794.00	25*	303.00	20.00	79435.00	214.00
Mix 9 avg.	**49946.50**	**47.50**	**347.00**	**22.50**	**87105.50**	**208.00**
Avg all mix except CT	30916.06	44.06	326.25	20.25	108016.81	123.63
Avg for CT	53159.00	25.00	128.50	2.50	30133.00	280.00
Percent difference	-71.95%	43.26%	60.61%	87.65%	72.10%	-126.49%

* When results indicate non-detect, 1/2 the Method Reporting Limit is used in place of 0.00

Table 1

Copper through Selenium
Refer to Table 2 on page A3-6

Copper - Low: 79 PPM (mix 6), High: 2,842.5 PPM (mix 3). The control concentrations (98.5 PPM), appear to be at least 1 order of magnitude lower than the H-POWER bottom and combined ash which averaged about 2,000 PPM. The H-POWER bottom ash concentration is similar to the MC range of 1,000-6,000 PPM. The fly ash concentration is also similar at 200-600 PPM.

Iron - Low: 4,787.5 PPM (mix 8), High: 77,125 PPM (mix 9). The second highest average iron concentration (74,995 PPM) was found in the soil control mixture. The MC fly ash concentrations average around 550 PPM compared to H-POWER's 16,000 PPM. The MC bottom ash concentrations were also much lower at around 5000 PPM compared to 38,000 PPM for H-POWER bottom ash.

Lead - Low: .37 PPM (control), High: 9,490.5 PPM (mix 3) This concentration is at least one order of magnitude higher in all the ash mixtures--except those containing sewage sludge--than in the control mixtures. The H-POWER fly ash concentrations are slightly lower at an average 1,784 PPM than the 3,000 PPM average at MC. The H-POWER bottom ash concentrations appear slightly higher at an average 7,788 PPM compared to MC's average of around 2,000 PPM.

Mercury - Low: 8 PPM (mix 9), High: 13.5 PPM (mix 5). The MC fly ash concentrations averaged higher at 38 PPM compared to H-POWER's average of 12 PPM. The MC bottom ash levels were lower at concentrations slightly below 1 PPM compared to H-POWER's average of 9 PPM.

Potassium - Low: 1,212.5 PPM (control), High: 11,515.5 PPM (mix 3). This appears to be another case where all the ash mixtures--except those containing sewage sludge--were at least one order of magnitude higher than the soil control. There is no published data of MC potassium levels.

Selenium - There were no detectable concentrations of selenium found in any mixtures nor were any found in the MC ash samples. Thus there is nothing to indicate any comparative findings for this element.

Chemical Analysis in units of PPM unless otherwise indicated						
Test Mix	Cu	Fe	Pb	Hg	K	Se
Mix 1a	241.00	14953.00	1707.00	10.00	8640.00	25*
Mix 1b	260.00	17512.00	1861.00	14.00	8649.00	25*
Mix 1 avg.	**250.50**	**16232.50**	**1784.00**	**12.00**	**8644.50**	**25.00**
Mix 2a	3800.00	27401.00	828.00	12.00	7950.00	25*
Mix 2b	940.00	50101.00	14748.00	5.30	7565.00	25*
Mix 2 avg.	**2370.00**	**38751.00**	**7788.00**	**8.65**	**7757.50**	**25.00**
Mix 3a	5126.00	25380.00	3172.00	8.20	10800.00	25*
Mix 3b	559.00	24782.00	15809.00	7.70	12231.00	25*
Mix 3 avg.	**2842.50**	**25081.00**	**9490.50**	**7.95**	**11515.50**	**25.00**
Mix 4a	95.00	64235.00	48.00	5.20	1393.00	25*
Mix 4b	102.00	85756.00	26.00	12.00	1032.00	25*
Mix 4 avg. [Control, (CT)]	**98.50**	**74995.50**	**37.00**	**8.60**	**1212.50**	**25.00**
Mix 5a	245.00	13874.00	1437.00	14.00	8457.00	25*
Mix 5b	275.00	15150.00	1582.00	13.00	8574.00	25*
Mix 5 avg.	**260.00**	**14512.00**	**1509.50**	**13.50**	**8515.50**	**25.00**
Mix 6a	78.00	16815.00	569.00	12.00	5066.00	25*
Mix 6b	80.00	15261.00	460.00	11.00	5770.00	25*
Mix 6 avg.	**79.00**	**16038.00**	**514.50**	**11.50**	**5418.00**	**25.00**
Mix 7a	199.00	100740.00	1150.00	12.00	5811.00	25*
Mix 7b	220.00	13088.00	840.00	10.00	6111.00	25*
Mix 7 avg.	**209.50**	**56914.00**	**995.00**	**11.00**	**5961.00**	**25.00**
Mix 8a	98.00	4742.00	447.00	10.00	3511.00	25*
Mix 8b	76.00	4833.00	348.00	13.00	3298.00	25*
Mix 8 avg.	**87.00**	**4787.50**	**397.50**	**11.50**	**3404.50**	**25.00**
Mix 9a	464.00	50132.00	919.00	5.00	9716.00	25*
Mix 9b	429.00	104118.00	606.00	11.00	7717.00	25*
Mix 9 avg.	**446.50**	**77125.00**	**762.50**	**8.00**	**8716.50**	**25.00**
Avg all mix except CT	818.13	31180.13	2905.19	10.51	7491.63	25.00
Avg for CT	98.50	74995.50	37.00	8.60	1212.50	25.00
Percent difference	87.96%	-140.52%	98.73%	18.19%	83.82%	0.00%

* When results indicate non-detect, 1/2 the Method Reporting Limit is used in place of 0.00

Table 2

Silicon through Sulfates
Refer to Table 3 on page A3-8

Silicon - Low: 18,451.5 PPM (mix 8), High: 224,102 PPM (control). The H-POWER fly ash which averages about 62,000 PPM, is very similar to MC fly ash at 59,000 PPM. The H-POWER bottom ash, which averaged about 164,000 PPM was higher than the MC bottom ash which averaged about 50,000 PPM.

Silver- Low: 2.5 (mix 4), High: 12 PPM (mix 3). The soil control concentration averaged 3 PPM. MC fly ash and bottom ash concentrations were similarly low averaging around 1-2 PPM.

Zinc - Low: 119.5 PPM (control), High: 12,819.5 PPM (mix 2). It is clear that the zinc in the ash mixtures have increased by about one order of magnitude compared to the soil controls. The H-POWER fly ash concentrations, which average around 2,000 PPM, are lower than the MC fly ash zinc levels which at 7,000 PPM. The H-POWER bottom ash zinc concentrations, at an average of 12,000 PPM, are higher than MC's which are roughly 1,300 PPM.

pH - The pH levels of all the ash mixtures were in a consistent range of 11.00 to 11.96 while the control mixtures averaged 8.15. This is probably the most significant chemical difference between the ash mixtures and the control mixtures. The high pH levels in the ash mixtures can have both positive and negative effects. Since lead becomes more soluble at lower and higher pH levels, there would likely be increased solution rates of lead, accompanying the addition of water to the mixtures. On the other hand the high pH will help to kill various microorganisms and varmints which might be attracted to sanitary landfills causing bad odors and unsanitary conditions. Moreover, high pH landfill cover mixtures help guard against leaching of metals from the MSW and also provides protection against acid rain.

Chloride - The chloride concentrations, which are expressed as percent by weight, vary from a low of 0.05% (control), to a high of 2.9% (mix 1). This increase is caused by the combination of HCL in the flue gas with CaOH from the scrubber to form $CaCL_2$. Since HCL concentrations in the RDF can average around 0.5%, it is not surprising to see chloride levels increase 3 times in the fly ash compared to the RDF, and 10 times compared to the levels in the soil. These results appear consistent with the elemental or ultimate chloride analysis of RDF found at EPA's MC study.

Sulfates - The percent sulfate concentrations in the mixtures were extremely low, varying from 0.002% for mix 2, to maximum levels of only 0.12% in mix 5. No statistical significance could be determined between the soil control sulfate levels and the ash mixture levels.

TABLE 5						
Chemical Analysis in units of PPM unless otherwise indicated						
Test Mix	Si	Ag	Zn	pH	Chloride(%)	Sulfate(%
Mix 1a	62986.00	10.00	2106.00	11.69	2.90	0.01
Mix 1b	62747.00	7.00	1700.00	11.64	2.60	0.02
Mix 1 avg.	**62866.50**	**8.50**	**1903.00**	**11.67**	**2.75**	**0.01**
Mix 2a	158738.00	2.50	23600.00	11.91	0.26	0.00
Mix 2b	169682.00	2.50	2039.00	11.76	0.05	0.00
Mix 2 avg.	**164210.00**	**2.50**	**12819.50**	**11.84**	**0.16**	**0.00**
Mix 3a	116705.00	8.00	20230.00	11.88	1.00	0.01
Mix 3b	113747.00	16.00	4062.00	11.85	1.37	0.01
Mix 3 avg.	**115226.00**	**12.00**	**12146.00**	**11.87**	**1.19**	**0.01**
Mix 4a	174885.00	2.50	116.00	7.96	0.05	0.01
Mix 4b	273319.00	2.50	123.00	8.33	0.11	0.01
Mix 4 avg. [Control, (CT)]	**224102.00**	**2.50**	**119.50**	**8.15**	**0.08**	**0.01**
Mix 5a	56494.00	0.00	1992.00	11.67	2.50	0.03
Mix 5b	57485.00	9.00	2119.00	11.66	1.19	0.03
Mix 5 avg.	**56989.50**	**4.50**	**2055.50**	**11.67**	**1.85**	**0.03**
Mix 6a	62943.00	6.00	735.00	11.94	0.37	0.12
Mix 6b	52684.00	7.00	640.00	11.85	0.77	0.12
Mix 6 avg.	**57813.50**	**6.50**	**687.50**	**11.90**	**0.57**	**0.12**
Mix 7a	46204.00	11.00	1538.00	11.81	1.80	0.02
Mix 7b	43523.00	11.00	1468.00	11.85	1.80	0.04
Mix 7 avg.	**44863.50**	**11.00**	**1503.00**	**11.83**	**1.80**	**0.03**
Mix 8a	19570.00	7.00	796.00	11.00	0.87	0.01
Mix 8b	17333.00	8.00	675.00	11.92	0.98	0.01
Mix 8 avg.	**18451.50**	**7.50**	**735.50**	**11.46**	**0.93**	**0.01**
Mix 9a	90357.00	6.00	3032.00	11.94	0.61	0.01
Mix 9b	127860.00	5.00	3293.00	11.96	0.58	0.01
Mix 9 avg.	**109108.50**	**5.50**	**3162.50**	**11.95**	**0.60**	**0.01**
Avg all mix except CT	78691.13	7.25	4376.56	11.77	1.23	0.03
Avg for CT	224102.00	2.50	119.50	8.15	0.08	0.01
Percent difference	-184.79%	65.52%	97.27%	n/a	93.36%	57.42%

* When results indicate non-detect, 1/2 the Method Reporting Limit is used in place of 0.00

Table 3

Nitrate through Moisture
Refer to Tables 4 on page A3-10

Nitrate/Nitrite - Low: non-detect, High: 14.5% (control). The mixtures with sewage sludge were able to bring the nitrate/nitrite levels up to 3-4%. There is no published data from the EPA MC study to compare to the H-POWER ash data, but it is unlikely the MC would have been different.

Total Nitrogen - The total percent nitrogen levels in the mixtures varied in a similar manner to that found above for nitrate/nitrite. The ash mixtures without sewage sludge had no detectable nitrogen levels. The soil control samples averaged 0.02% and mixture 5 had the maximum total nitrogen levels of 0.16%. Nitrogen is essential to all plant and animal life. Thus for final landfill cover nitrogen in the sewage sludge component of some ash mixtures will be effective in improving the ability of the final cover to support plant growth.

Carbon - The percent carbon levels--as determined by loss on ignition--for the various mixtures ranged from a low of 0.51% for mix 2, to a high of 3.2% for mix 5. The soil control samples averaged 0.535%. This low carbon level in bottom ash is good for ash stabilization purposes because it lowers the voids produced over time from bacterial actions or when the ash is heated to high temperatures. The percent carbon in fly ash was found to be about 1.5%. These levels are very similar to what was found in the EPA MC study.

Moisture - Low: 21% (mix 3), High: 60.5% (mix 7). The moisture levels were largely a function of how much water was added to form the mixture. Water was added so that hydration of the cementitious materials would occur and cause the mixtures to harden as they dried. It was not possible to formulate an optimum water content for each mixture, and different mixtures appeared to require different amounts of water. The fly ash mixtures required more water to cause the mixture to become well mixed and pasty. The bottom ash samples required much less water to get to this state, since they were already saturated. When the same amount of water was added to the samples containing sewage sludge, the water was retained in higher levels even after curing because the pozzolanic reactions were much lower in these mixtures, and thus did not use up the water to the same degree.

Chemical Analysis in units of PPM unless otherwise indicated					
Test Mix	Nitrate/Nitrite	T. Nitrogen	Carbon	Moisture	Density
Mix 1a	1*	10*	1.63	42.00	1.79
Mix 1b	1*	10*	1.75	41.00	1.69
Mix 1 avg.	**1.00**	**10.00**	**1.69**	**41.50**	**1.74**
Mix 2a	1*	10*	0.46	23.00	1.76
Mix 2b	1*	10*	0.55	20.00	2.10
Mix 2 avg.	**1.00**	**10.00**	**0.51**	**21.50**	**1.93**
Mix 3a	1*	10*	1.53	22.00	2.35
Mix 3b	1*	10*	1.91	20.00	1.90
Mix 3 avg.	**1.00**	**10.00**	**1.72**	**21.00**	**2.13**
Mix 4a	15.00	0.02	0.57	24.00	2.05
Mix 4b	14.00	0.02	0.50	22.00	2.01
Mix 4 avg. (Control, CT)	**14.50**	**0.02**	**0.54**	**23.00**	**2.03**
Mix 5a	1*	0.05	3.05	48.00	1.80
Mix 5b	1*	0.08	3.35	49.00	2.28
Mix 5 avg.	**1.00**	**0.07**	**3.20**	**48.50**	**2.04**
Mix 6a	3.00	0.07	2.88	50.00	2.13
Mix 6b	1*	0.08	3.09	50.00	2.62
Mix 6 avg.	**2.00**	**0.08**	**2.99**	**50.00**	**2.38**
Mix 7a	4.00	0.17	7.38	60.00	1.25
Mix 7b	3.00	0.14	6.28	61.00	1.41
Mix 7 avg.	**3.50**	**0.16**	**6.83**	**60.50**	**1.33**
Mix 8a	1*	0.07	3.28	53.00	1.64
Mix 8b	1*	0.08	2.90	52.00	1.97
Mix 8 avg.	**1.00**	**0.08**	**3.09**	**52.50**	**1.81**
Mix 9a	1*	10*	1.64	29.00	2.20
Mix 9b	1*	10*	0.87	21.00	2.09
Mix 9 avg.	**1.00**	**10.00**	**1.26**	**25.00**	**2.15**
Avg all mix except CT	1.44	5.05	2.66	40.06	1.94
Avg for CT	14.50	0.02	0.54	23.00	2.03
Percent difference	-908.70%	99.60%	79.88%	42.59%	-4.84%

* When results indicate non-detect, 1/2 the Method Reporting Limit is used in place of 0.00

Table 4

Summary

In most cases the variation in chemical characteristics between the ash mixtures and the soil controls were not statistically significant. The elements or chemical parameters where the control concentrations were significantly higher than some of the ash mixtures were:

1) The soil concentration levels of **iron** averaged 75,000 PPM, while most of the ash **iron** mixtures were in the range of 14,000-50,000 PPM.

2) The **nitrate/nitrite** levels averaged 14.5% in the soil control but were at non-detect levels in the ash mixtures. On the other hand, the total nitrogen levels in the mixtures with sewage sludge were higher than the total nitrogen levels in the native soil.

The elements or chemical parameters where there were large differences between the H-POWER ash concentrations and the MC ash levels were:

1) The H-POWER bottom ash **arsenic** concentrations which had non-detect concentrations were lower than MC's bottom ash which averaged 10 PPM.

2) The H-POWER **cadmium** concentrations in the bottom ash were at non-detect levels (0.05 PPM) while MC averaged 7 PPM.

3) The H-POWER **zinc** concentrations averaged lower at 2,000 PPM than MC's (7,000 PPM) in the fly ash, but was higher at 12,000 PPM in the bottom ash than MC which averaged 1,300 PPM.

Conclusions

The chemical elemental analysis indicates most ash mixtures are not significantly different in metal concentrations from the soil control except for lead and zinc, where modest elevations are present. The natural pozzolanic reactions that will likely occur in the field with the addition of water, will tend to bind these and other metals to a crystalline matrix. This will cause the daily cover to be more stable, firm and less susceptible to erosion. Also the in situ chemical reactions will help make the metals less friable for dusting, more impermeable, and thus, less leachable.

The chemical analyses of the ash/sewage sludge mixtures indicate that the high pH and relatively low sulfur, carbon, and nitrogen levels will make these mixtures relatively poor material for landfill final top cover by themselves. However, such mixtures are shown to be ideal for use as the infiltration and erosion layers of final landfill cover.

Ash Mixture Contents

Mixture	Mixture Contents
1	H-POWER Fly Ash
2	H-POWER Bottom Ash
3	H-POWER Combined Ash (1)
4	Landfill Soil (control)
5	3 Parts H-POWER Fly Ash to 1 Part Sewage Sludge
6	1 Part H-POWER Fly Ash, 1 Part AES Coal Ash, 1 Part Sewage Sludge
7	1 Part H-POWER Fly Ash to 1 Part Sewage Sludge
8	2 Parts H-POWER Fly Ash, 2 Parts Sewage Sludge, 1 Part Hydrated Lime
9	1 Part H-POWER Combined Ash to 1 Part Waipahu Ash

Table 9

E.L. Pacific

A Full Service Laboratory ... Professional
950 Mapunapuna Street Suite 101 • Honolulu Hawaii 96819
Telephone (808) 833-5603 Facsimile (808) 833-7390

Laboratory Report

Client: NREL/ H-Power Ash Utilization
23 Rexinger Lane
Avon, CT 06001
Attention: Michael Hartman

ELP Project No.: **5347**
Report Date: 10-Feb-94

Sample Description: Samples from H-Power.
Sample Matrix: ash

Date Collected: see below
Date Received: 12-Nov-93

Client ID:		1-1	1-1dup	2-1	2-1dup
Collected:		10-Nov-93	10-Nov-93	10-Nov-93	10-Nov-93
Matrix:		ash	ash	ash	ash
Lab ID:	Method Blank	111293-22	111293-23	111293-24	111293-25

Date	Analysis	Method	Units	MRL	Results	Results	Results	Results	Results
	Total Metals in soil								
22-Dec-93	Metals Digestion (ICP)	EPA 3050M							
11-Jan-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	ND	10,223	5,536	48,985	61,120
07-Jan-94	Arsenic	EPA 6010	mg/Kg (ppm)	50	ND	76	75	ND	ND
17-Jan-94	Barium	EPA 6010	mg/Kg (ppm)	10	ND	310	310	570	810
17-Jan-94	Cadmium	EPA 6010	mg/Kg (ppm)	5	ND	26	27	ND	ND
11-Jan-94	Calcium	EPA 6010	mg/Kg (ppm)	20	ND	107,248	99,844	109,122	101,082
07-Jan-94	Chromium	EPA 6010	mg/Kg (ppm)	5	ND	116	120	160	214
07-Jan-94	Copper	EPA 6010	mg/Kg (ppm)	10	ND	241	260	3,800	940
11-Jan-94	Iron	EPA 6010	mg/Kg (ppm)	10	ND	14,953	17,512	27,401	50,101
11-Jan-94	Lead	EPA 6010	mg/Kg (ppm)	20	ND	1,707	1,861	828	14,748
14-Feb-94	Mercury	EPA 7471	mg/Kg (ppm)	0.2	ND	10	14	12	5.3
07-Jan-94	Potassium	EPA 6010	mg/Kg (ppm)	20	ND	8,640	8,649	7,950	7,565
07-Jan-94	Selenium	EPA 6010	mg/Kg (ppm)	50	ND	ND	ND	ND	ND
25-Jan-94	Silicon*	EPA 6010	mg/Kg (ppm)	10,000	ND	62,986	62,747	158,738	169,682
07-Jan-94	Silver	EPA 6010	mg/Kg (ppm)	5	ND	10	7	ND	ND
07-Jan-94	Zinc	EPA 6010	mg/Kg (ppm)	10	ND	2,106	1,700	23,800	2,039
	Wet Chemistry								
22-Nov-93	pH	EPA 9045	units	0.01	NA	11.69	11.64	11.91	11.76
19-Nov-93	Chloride	EPA 325.3	%	0.001	ND	2.9	2.6	0.26	0.053
19-Nov-93	Sulfate	EPA 375.4	%	0.005	ND	0.013	0.015	0.0018	0.0024
22-Dec-93	Nitrogen, Nitrate+Nitrite (N)**	EPA 353.3	mg/Kg (ppm)	2	ND	<2	<2	<2	<2
22-Dec-93	Nitrogen, Total Kjeldahl (N)**	EPA 351.3	mg/Kg (ppm)	20	ND	*NR*	*NR*	*NR*	*NR*
22-Nov-93	Moisture	CLP ILM 2.0	percent	NA	NA	42	41	23	20
05-Jan-94	Density, Apparent	***	g/cc	NA	NA	0.937	0.967	0.916	1.32
05-Jan-94	Density, True	***	g/cc	NA	NA	1.79	1.69	1.76	2.10
22-Nov-93	Carbon**	ASTM D5291M	percent	0.1	NA	1.63	1.75	0.46	0.55

* Perkin Elmer "Analytical Methods for AAS" Jan 1982
** Analysis performed by Huffman Laboratories, Inc.
*** Methods of Soil Analysis, American Society of Agronomy, Part 1, 1982.

Approved by: ______________________
Jeffrey Bryson, Laboratory Manager

Approved by: ______________________
Dirk Koeppenkastrop, PhD, Laboratory Director

		Client ID:			3-1	3-1 dup	4-1	4-1 dup	5-1
		Date Sampled:			10-Nov-93	10-Nov-93	12-Nov-93	12-Nov-93	12-Nov-9:
		Lab ID:			111293-26	111293-27	111293-28	111293-29	111293-3
Date	**Analysis**	**Method**	**Units**	**MRL**	**Results**	**Results**	**Results**	**Results**	**Results**
	Total Metals in soil								
22-Jan-94	Metals Digestion (ICP)	EPA 3050M							
11-Jan-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	46,341	47,469	55,563	50,755	26,877
07-Jan-94	Arsenic	EPA 6010	mg/Kg (ppm)	50	ND	87	ND	ND	73
07-Jan-94	Barium	EPA 6010	mg/Kg (ppm)	10	ND	537	184	73	405
07-Jan-94	Cadmium	EPA 6010	mg/Kg (ppm)	5	11	105	ND	ND	23
11-Jan-94	Calcium	EPA 6010	mg/Kg (ppm)	20	131,156	118,166	24,145	36,121	112,753
07-Jan-94	Chromium	EPA 6010	mg/Kg (ppm)	5	206	181	250	310	113
07-Jan-94	Copper	EPA 6010	mg/Kg (ppm)	10	5,126	559	95	102	245
11-Jan-94	Iron	EPA 6010	mg/Kg (ppm)	10	25,380	24,782	64,235	85,756	13,874
14-Jan-94	Lead	EPA 6010	mg/Kg (ppm)	20	3,172	15,809	48	26	1,437
14-Dec-93	Mercury	EPA 7471	mg/Kg (ppm)	0.2	8.2	7.7	5.2	12	14
02-Jan-94	Potassium	EPA 6010	mg/Kg (ppm)	20	10,800	12,231	1,393	1,032	8,457
02-Jan-94	Selenium	EPA 6010	mg/Kg (ppm)	50	ND	ND	ND	ND	ND
25-Jan-94	Silicon*	EPA 6010	mg/Kg (ppm)	10,000	116,705	113,747	174,885	273,319	56,494
07-Jan-94	Silver	EPA 6010	mg/Kg (ppm)	5	8	16	ND	ND	ND
07-Jan-94	Zinc	EPA 6010	mg/Kg (ppm)	10	2,230	4,062	116	123	1,992
	Wet Chemistry								
22-Nov-93	pH	EPA 9045	units	0.01	11.88	11.85	7.96	8.33	11.67
19-Nov-93	Chloride	EPA 325.3	%	0.0001	1.0	1.37	0.053	0.11	2.5
19-Nov-93	Sulfate	EPA 375.4	%	0.005	0.0065	0.011	0.011	0.012	0.026
22-Dec-93	Nitrogen, Nitrate+Nitrite (N)**	EPA 353.3	mg/Kg (ppm)	2	<2	<2	15	14	<2
22-Dec-93	Nitrogen, Total Kjeldahl (N)**	EPA 351.3	mg/Kg (ppm)	200	*NR*	*NR*	0.02	0.02	0.05
22-Nov-93	Moisture	CLP ILM 2.0	percent	NA	22	20	24	22	48
05-Jan-94	Density, Apparent	***	g/cc	NA	0.991	1.37	1.29	1.10	0.979
05-Jan-94	Density, True	***	g/cc	NA	2.35	1.90	2.05	2.01	1.80
22-Nov-93	Carbon**	ASTM D5291M	percent	0.1	1.53	1.91	0.57	0.5	3.05

* Perkin Elmer "Analytical Methods for AAS" Jan 1982

** Analysis performed by Huffman Laboratories, Inc.

*** Methods of Soil Analysis, American Society of Agronomy, Part 1, 1982.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

ELP Project No.: 5347
Report Date: 10-Feb-94

		Client ID:			5-1 dup	6-1	6-1 dup	7-1	7-1 dup
		Date Sampled:			12-Nov-93	12-Nov-93	12-Nov-93	12-Nov-93	12-Nov-93
		Lab ID:			111293-31	111293-32	111293-33	111293-34	111293-35
Date	**Analysis**	**Method**	**Units**	**MRL**	**Results**	**Results**	**Results**	**Results**	**Results**
	Total Metals in soil								
22-Jan-94	Metals Digestion (ICP)	EPA 3050M							
14-Jan-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	26,758	41,040	23,197	16,835	19,585
07-Jan-94	Arsenic	EPA 6010	mg/Kg (ppm)	50	74	ND	ND	ND	ND
07-Jan-94	Barium	EPA 6010	mg/Kg (ppm)	10	360	238	220	233	270
07-Jan-94	Cadmium	EPA 6010	mg/Kg (ppm)	5	24	7	5	16	15
14-Jan-94	Calcium	EPA 6010	mg/Kg (ppm)	20	123,589	81,646	75,629	101,861	94,160
07-Jan-94	Chromium	EPA 6010	mg/Kg (ppm)	5	110	55	46	83	84
07-Jan-94	Copper	EPA 6010	mg/Kg (ppm)	10	275	78	80	199	220
14-Jan-94	Iron	EPA 6010	mg/Kg (ppm)	10	15,150	16,815	15,261	100,740	13,088
14-Jan-94	Lead	EPA 6010	mg/Kg (ppm)	20	1,582	569	460	1,150	840
14-Dec-93	Mercury	EPA 7471	mg/Kg (ppm)	0.2	13	12	11	12	10
07-Jan-94	Potassium	EPA 6010	mg/Kg (ppm)	20	8,574	6,066	5,770	5,811	6,111
14-Jan-94	Selenium	EPA 6010	mg/Kg (ppm)	50	ND	ND	ND	ND	ND
25-Jan-94	Silicon*	EPA 6010	mg/Kg (ppm)	10,000	57,485	62,943	52,684	46,204	43,523
07-Jan-94	Silver	EPA 6010	mg/Kg (ppm)	5	9	6	7	11	11
07-Jan-94	Zinc	EPA 6010	mg/Kg (ppm)	10	2,119	735	640	1,538	1,468
	Wet Chemistry								
22-Nov-93	pH	EPA 9045	units	0.01	11.66	11.94	11.85	11.81	11.85
19-Nov-93	Chloride	EPA 325.3	%	0.0001	1.19	0.37	0.77	1.8	1.8
19-Nov-93	Sulfate	EPA 375.4	%	0.005	0.026	0.12	0.12	0.023	0.038
22-Dec-93	Nitrogen, Nitrate+Nitrite (N)**	EPA 353.3	mg/Kg (ppm)	2	<2	3	<2	4	3
22-Dec-93	Nitrogen, Total Kjeldahl (N)**	EPA 351.3	mg/Kg (ppm)	20	0.08	0.07	0.08	0.17	0.14
22-Nov-94	Moisture	CLP ILM 2.0	percent	NA	49	50	50	60	61
05-Jan-94	Density, Apparent	***	g/cc	NA	1.15	0.82	0.961	1.13	0.974
05-Jan-94	Density, True	***	g/cc	NA	2.28	2.13	2.62	1.25	1.41
22-Nov-93	Carbon**	ASTM D5291M	percent	0.1	3.35	2.88	3.09	7.38	6.28

* Perkin Elmer "Analytical Methods for AAS" Jan 1982
** Analysis performed by Huffman Laboratories, Inc.
*** Methods of Soil Analysis, American Society of Agronomy, Part 1, 1982.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

Date	Analysis	Method	Units	MRL	Results	Results	Results	Results
				Client ID:	8-1	8-1 dup	9-1	9-1 dup
				Matrix:	12-Nov-93	12-Nov-93	10-Nov-93	10-Nov-93
				Lab ID:	111293-36	111293-37	111293-38	111293-39
	Total Metals in soil							
22-Jan-94	Metals Digestion (ICP)	EPA 3050M						
14-Jan-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	10,485	10,303	49,099	50,794
07-Jan-94	Arsenic	EPA 6010	mg/Kg (ppm)	50	ND	ND	70	ND
07-Jan-94	Barium	EPA 6010	mg/Kg (ppm)	10	139	119	391	303
07-Jan-94	Cadmium	EPA 6010	mg/Kg (ppm)	5	8	7	25	20
14-Jan-94	Calcium	EPA 6010	mg/Kg (ppm)	20	143,000	154,802	94,776	79,435
07-Jan-94	Chromium	EPA 6010	mg/Kg (ppm)	5	39	35	202	214
07-Jan-94	Copper	EPA 6010	mg/Kg (ppm)	10	98	76	464	429
14-Jan-94	Iron	EPA 6010	mg/Kg (ppm)	10	4,742	4,833	50,132	104,118
14-Jan-94	Lead	EPA 6010	mg/Kg (ppm)	20	447	348	919	606
14-Dec-93	Mercury	EPA 7471	mg/Kg (ppm)	0.2	10	13	5	11
07-Jan-94	Potassium	EPA 6010	mg/Kg (ppm)	20	3,511	3,298	9,716	7,717
14-Jan-94	Selenium	EPA 6010	mg/Kg (ppm)	50	ND	ND	ND	ND
25-Jan-94	Silicon*	EPA 6010	mg/Kg (ppm)	10,000	19,570	17,333	90,357	127,880
07-Jan-94	Silver	EPA 6010	mg/Kg (ppm)	5	7	8	6	5
07-Jan-94	Zinc	EPA 6010	mg/Kg (ppm)	10	796	675	3,032	3,293
	Wet Chemistry							
22-Nov-93	pH	EPA 9045	units	0.01	11.92	11.92	11.94	11.96
19-Nov-93	Chloride	EPA 325.3	%	0.0001	0.87	0.98	0.61	0.58
19-Jan-93	Sulfate	EPA 375.4	%	0.005	0.010	0.0087	0.0071	0.0086
22-Dec-93	Nitrogen, Nitrate+Nitrite (N)**	EPA 353.3	mg/Kg (ppm)	2	<2	<2	<2	<2
22-Dec-93	Nitrogen, Total Kjeldahl (N)**	EPA 351.3	mg/Kg (ppm)	20	0.07	0.08	*NR*	*NR*
22-Nov-93	Moisture	CLP ILM 2.0	percent	NA	53	52	29	21
05-Jan-94	Density, Apparent	***	g/cc	NA	1.36	1.41	9.34	0.850
05-Jan-94	Density, True	***	g/cc	NA	1.64	1.97	2.2	2.09
22-Nov-93	Carbon**	ASTM D5291M	percent	0.1	3.28	2.90	1.64	0.87

* Perkin Elmer "Analytical Methods for AAS" Jan 1982
** Analysis performed by Huffman Laboratories, Inc.
*** Methods of Soil Analysis, American Society of Agronomy, Part 1, 1982.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

Quality Control Data

SPIKES		Lab ID: Units:	LCS1 %R	LCS2 %R	RPD	MS %R	MSD %R	RPD
Lab ID	Analysis	Method	Results	Results	Results	Results	Results	Results
	Total Metals in soil							
111293-30	Aluminum	EPA 6010	87	96	10	****	****	****
111293-30	Arsenic	EPA 6010	101	98	3	104	110	6
111293-30	Barium	EPA 6010	107	106	1	70	81	15
111293-30	Barium (PDS)	EPA 6010	NA	NA	NA	95	97	2
111293-30	Cadmium	EPA 6010	99	93	6	97	100	3
111293-30	Calcium	EPA 6010	107	96	11	****	****	****
111293-30	Chromium	EPA 6010	105	90	15	99	86	14
111293-30	Copper	EPA 6010	107	103	4	112	101	10
111293-30	Iron	EPA 6010	109	95	14	****	****	****
111293-30	Lead	EPA 6010	99	93	6	****	****	****
111293-22	Mercury	EPA 7471	123	115	7	****	****	****
111293-30	Potassium	EPA 6010	77	208	92	101	95	6
111293-30	Selenium	EPA 6010	101	98	3	102	90	13
111293-30	Silicon*	EPA 6010	112	107	5	****	****	****
111293-30	Silicon (PDS)*	EPA 6010	NA	NA	NA	108	116	7
111293-30	Silver	EPA 6010	32	63	65	101	98	3
111293-30	Silver (PDS)	EPA 6010	NA	NA	NA	102	96	6
111293-30	Zinc	EPA 6010	104	97	7	21	73	111
111293-30	Zinc (PDS)	EPA 6010	NA	NA	NA	96	113	16
	Wet Chemistry in soil							
111293-23	Chloride	EPA 325.3	101	102	1	106	111	5
111293-35	Sulfate	EPA 375.4	92	94	2	105	103	2
120193-19	Sulfate	EPA 375.4	100	101	1	103	106	3

DUPLICATES		Lab ID: Units: are mg/L unless otherwise noted	OS	D	RPD percent
Lab ID	Analysis	Method	Results	Results	Results
	Wet Chemistry in soil				
111293-39	Moisture	percent	21	14	40

* Perkin Elmer "Analytical Methods for AAS" Jan 1982

**** Native analyte greater than 4 times the spike added, therefore recovery not calculable.

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Dirk Koeppenkastrop, PhD, Laboratory Director

Definitions

D	Duplicate
LCS	Laboratory Control Sample
MS	Matrix Spike
MSD	Matrix Spike Duplicate
MRL	Method Reporting Limit
NA	Not Applicable
ND	Not Detected at the MRL
NR	Not Requested
OS	Original Sample
%R	Percent Recovery
PDS	Post Digestion Spike
RPD	Relative Percent Difference

Approved by: ______________________
Jeffrey Bryson, Laboratory Manager

Approved by: ______________________
Dirk Koeppenkastrop, PhD, Laboratory Director

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Honolulu, Hawaii 96822
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22 December 1993

Executive Summary:

A series of samples was received from Environmental Laboratory of the Pacific (ELP) to be digested by procedures that could not be feasibly performed by the client laboratory. Twenty individual samples were provided consisting of heterogenous powders/gravelly solids with variable water content. A brief summary of the visual appearance of some samples follows to provide an indication of the extent of variability amongst individual samples. Certain samples were quite wet such as 111293-32, 111293-36, and 111293-38, others quite homogenous such as 111693-21, and others quite heterogeneous such as 111293-22.

For further example the following descriptions apply to the first batch of digested samples.

111693-21	Relatively dry and homogenous sample.
111693-22	Wet and very cohesive yet heterogeneous material.
111293-22	Fine-grained material present as a wet paste.
111293-23	Wet globular, somewhat heterogenous material.
111293-24	Gravelly, heterogeneous moist material.
111293-25	Wet gravelly, heterogeneous material.
111293-26	Coarse, yet more homogenous moist material.
111293-27	Moist, coarse material with some chunks of greyish other material. This sample was quite hygroscopic and gained weight rapidly when weighed on an analytical balance.
111293-28	Very smooth, clayey rather homogenous brown material.

The samples were taken "as is" for the digestion procedure which was conducted as follows:

A mass of "as is" sample was weighed (to the nearest 0.1 mg) into 120 psi-rated CEM Teflon microwave digestion vessels. To each sample was added 5 mL of 30% H_2O_2 to oxidize organic matter. After the subsidence of the reaction with H_2O_2, as evidenced by a lack of further gas evolution, a mixture of 15 mL 2:1 concentrated HNO_3:HCl and 7 mL concentrated HF was added and the vessels sealed. Vessels were then placed in a carousel, connected via vent tubes to a $NaHCO_3$ neutralizing bath (in case of venting of acid fumes) then placed in a microwave oven. Digestion was performed as a series of repetitive low power runs ranging from 20% power for 30 minutes (per carousel of 12 vessels) to 40% power for 30 minutes. After digestion appeared to not proceed further, vessels were cooled, opened and 50 mL of 0.5 M H_3BO_3 added. The vessels were resealed and placed in the microwave oven for a further run at 50% power for 60 minutes. It should be noted that samples were cooled in between runs whenever the pressure in the vessels appeared excessive or a slight extent of sample venting was observed. This procedure was necessary owing to the volatility of SiF_4 and because of the client's desire to perform Si analysis. In general samples were very difficult to digest and residues remained even after extensive heating in the microwave oven.

Several procedural blanks were prepared by only adding acids and carrying the vessels through the procedure. Two blanks were also spiked prior to digestion as requested by ELP personnel. Three actual samples were also spiked prior to digestion as requested. Spikes consisted of the addition of 1 mL 1000 ppm Si, 2 mL QC23 100 ppm multi-element spike, and 100 μL 1000 ppm Ag.

Because residues remained in most samples after the digestion procedure a second digestion was performed with further acid additions. This procedure was employed only for the first batch of samples (111693 series and 111293-22 through 28). These samples were then filtered at the end of the procedure owing to the presence of some residues. Final masses of the first batch of samples is near 200 g. Residues were retained and their weight recorded after air-drying. Individual sample masses and final solution masses are reported on labels on the individual sample solution bottles and are not repeated here. The second and third batches of samples were only carried through a single digestion procedure, hence, their final masses are near 100 g. Because smaller masses of original sample were used in the second and third digestion procedures, residues tended to be much smaller.

Special notes regarding individual samples follow.

Samples 111693-21, 111293-22, 111293-23, 111293-27, 111293-31, 111293-36, 111293-37 all reacted strongly with H_2O_2.

Samples 111693-22, 111293-24, 111293,25 reacted vigorously with aqua-regia, whereas samples 111293-30,31,32,33,34 and 35 reacted well with aqua-regia but not as vigorously as the previous batch.

One sample (111293-29) was digested in duplicate because the first replicate was observed to contain a large chunk (relative to overall sample mass) of what appeared to be basaltic material after the H_2O_2 step, hence the second replicate of this sample, which did not contain such a chunk, is more likely to be representative.

Some samples were obviously organic-rich as evidenced by yellow-orange coloration in the final digested solutions. Several of these subsequently developed a precipitate in the solution although they were completely clear immediately after filtration. It is suspected that these precipitates may represent insoluble organic acids.

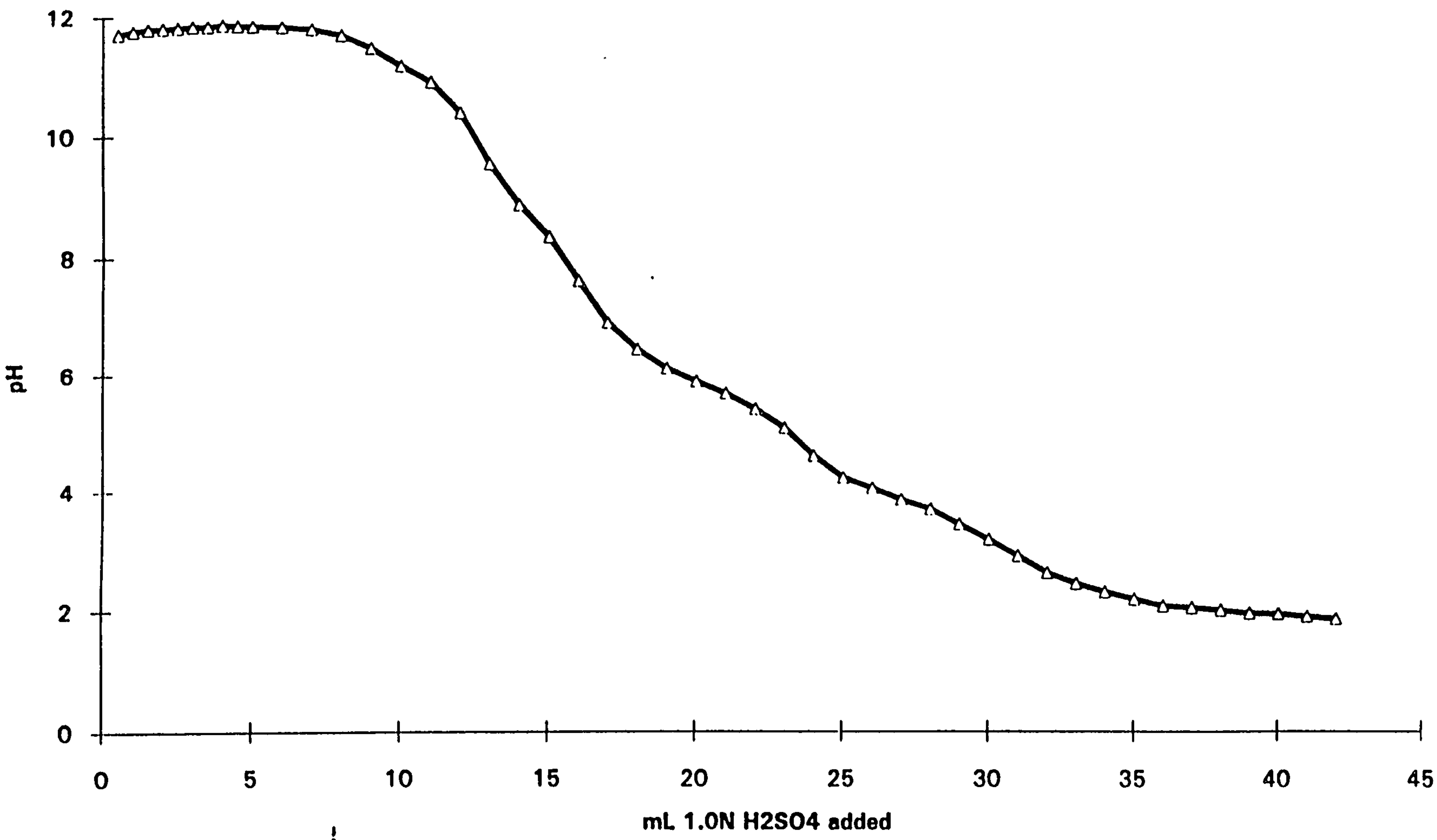
The following is a summary of residue masses and their appearance:

111693-21:	11 mg black
111693-21Spike:	11 mg black
111693-22:	131 mg grey
111293-22:	87 mg dark grey
111293-23:	101 mg dark grey
111293-24:	78 mg grey and white
111293-25:	106 mg grey and white
111293-26:	55 mg black and white
111293-27:	84 mg black and white
111293-28:	no residue
111293-29:	57 mg grey/white (chunk)
111293-30:	10 mg black
111293-30Spike:	20 mg dark grey/black
111293-31:	12 mg black
111293-32:	7 mg black
111293-33:	12 mg grey/black
111293-34:	13 mg grey/black
111293-35:	7 mg grey/black
111293-36:	59 mg grey and black specks
111293-36Spike:	45 mg grey and black specks
111293-29Repl:	9 mg slight greyish
111293-37:	30 mg light grey to black
111293-38:	11 mg very dark, black
111293-29	8 mg very dark, black

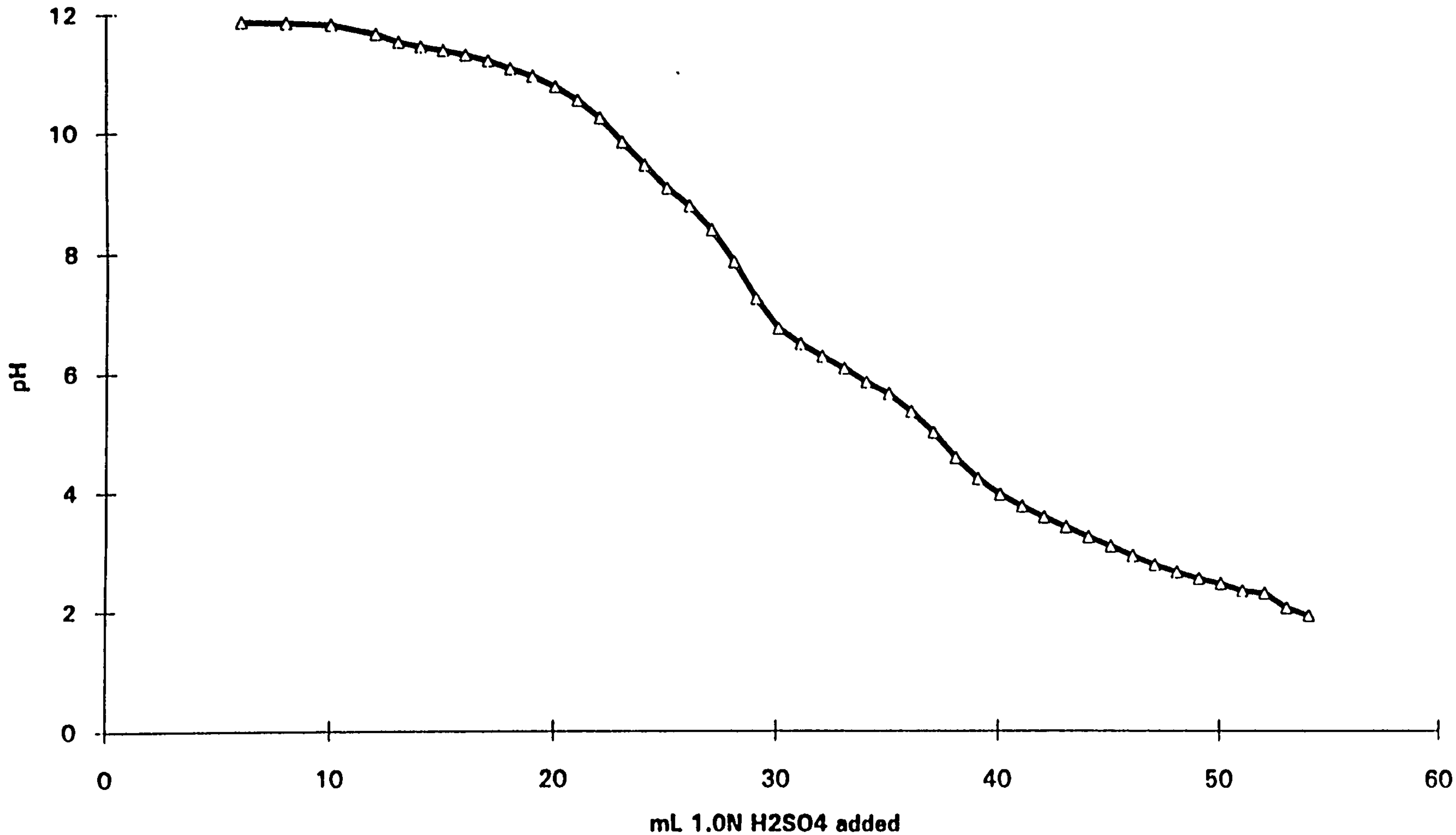
Dark grey and black residues tend to occur in samples which later displayed yellow-orange solution colors and are inferred to represent unoxidizable Carbon... Greyish-white residues are more likely to be siliceous matter.

Note that residue masses are somewhat irrepresentative of original matter because of air-drying, whereas original samples were sometimes quite wet. The mass of the residues was determined by difference using an average of masses determined for clean 0.22 μm millipore membranes, hence these are approximate but reasonably reliable.

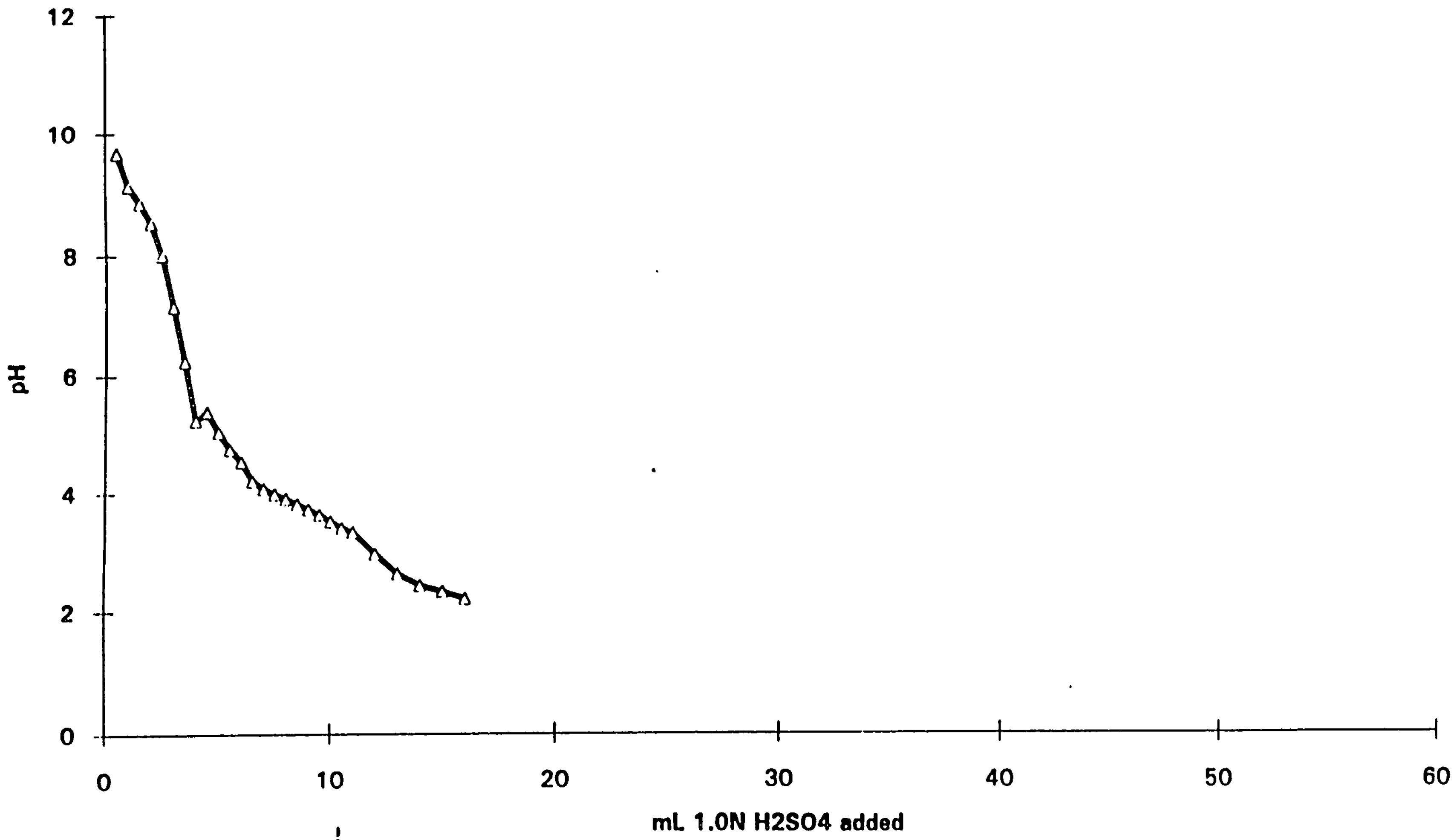
pH Titration of Sample ID 111293-22
AN, 1-8-94, 1 min/reading, 10g sample/50 mL H2O

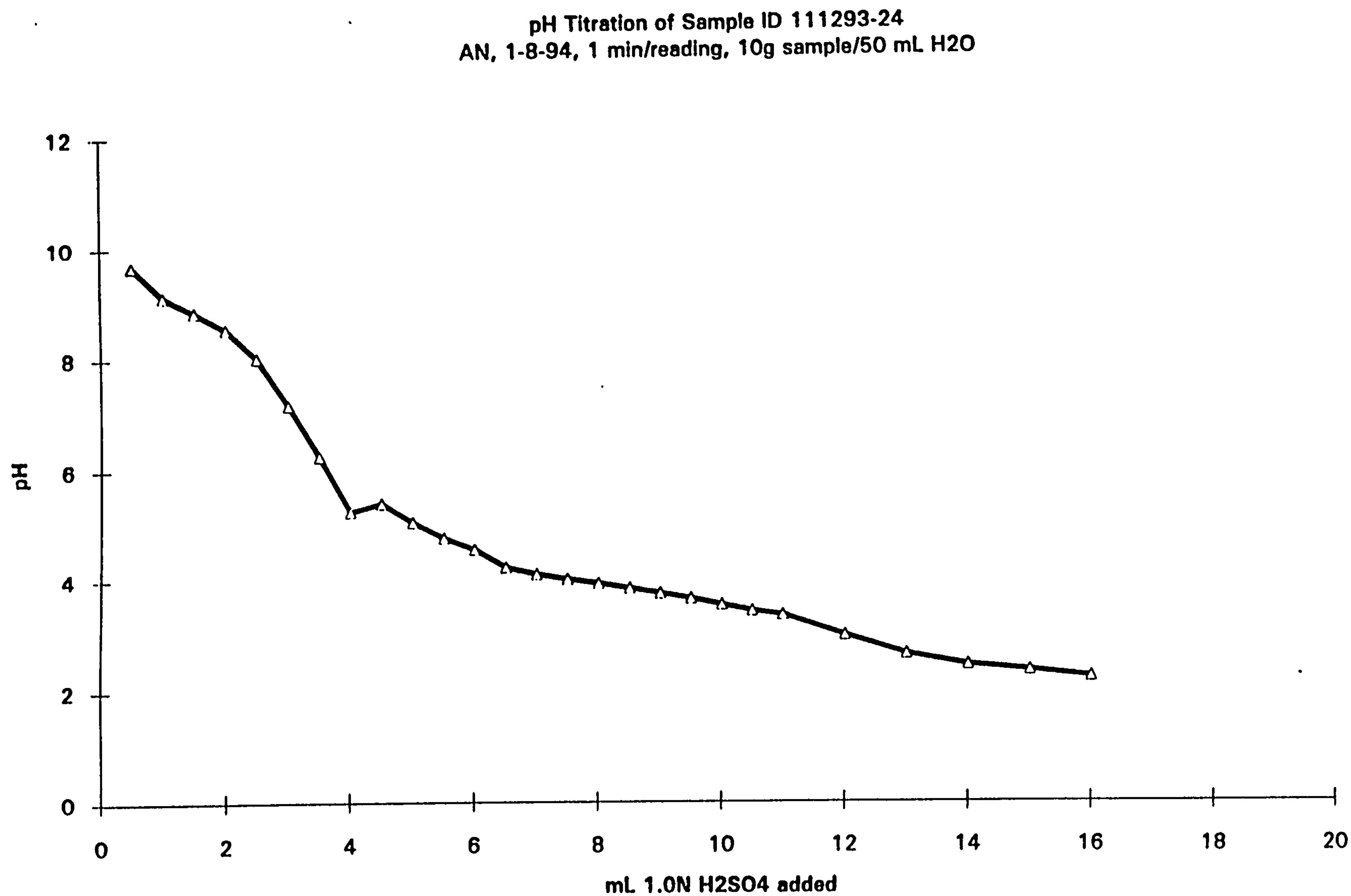


pH Titration of Sample ID 111293-23
AN, 1-8-94, 1 min/reading, 10g sample/50 mL H2O

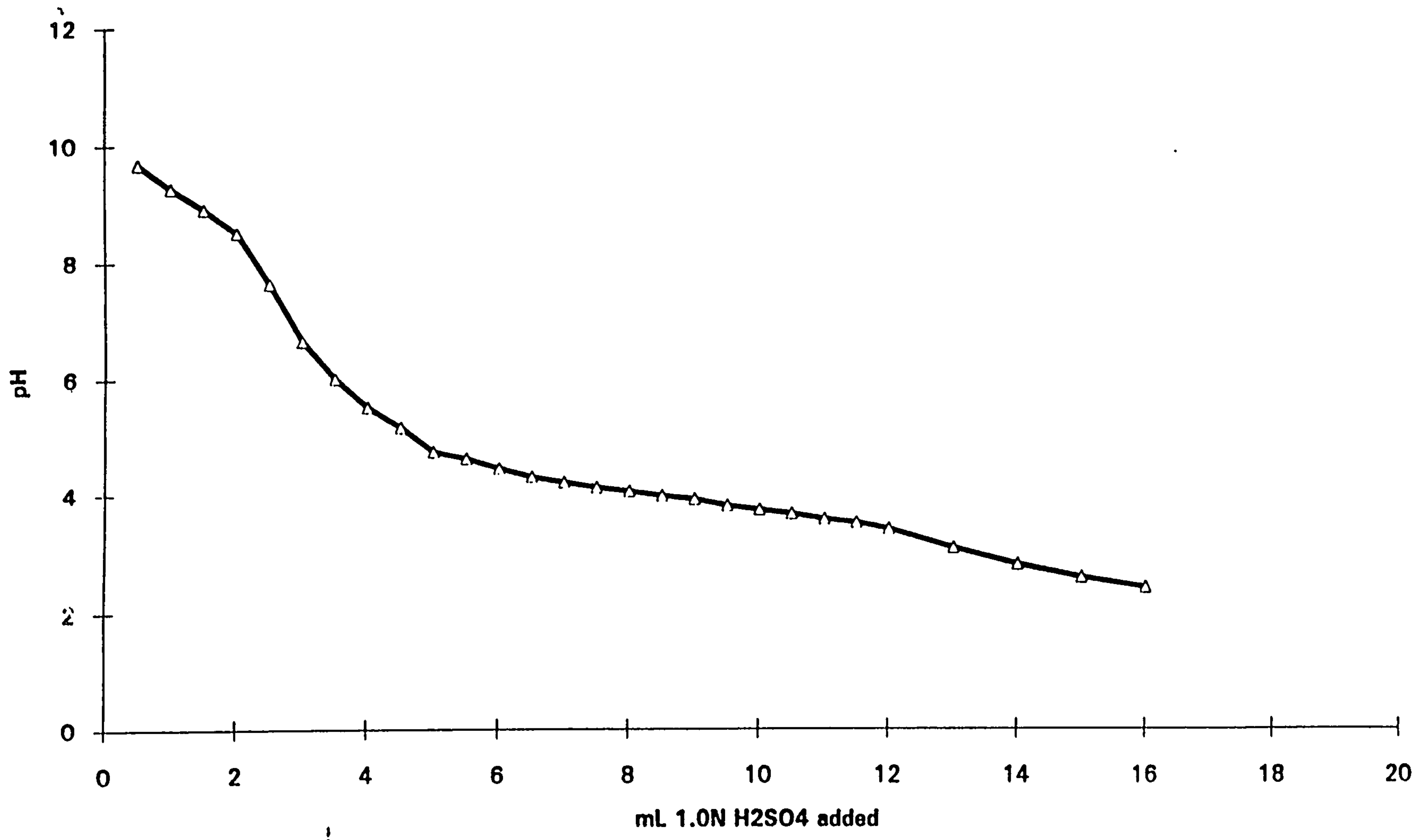


pH Titration of Sample ID 111293-24
AN, 1-8-94, 1 min/reading, 10g sample/50 mL H2O

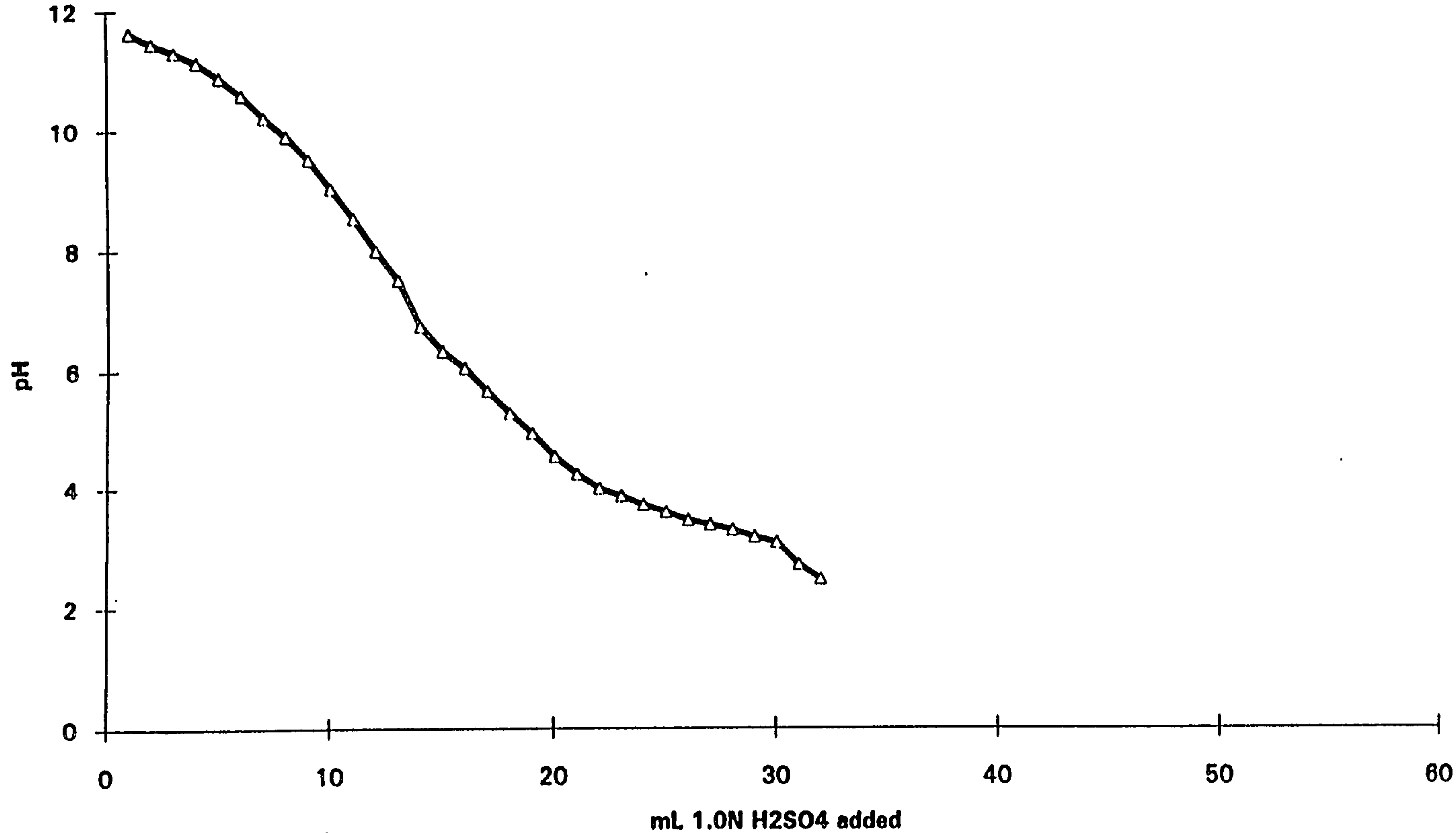



pH Titration of Sample ID 111293-24
AN, 1-8-94, 1 min/reading, 10g sample/50 mL H2O
pH
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
16
18
20
mL 1.0N H2SO4 added

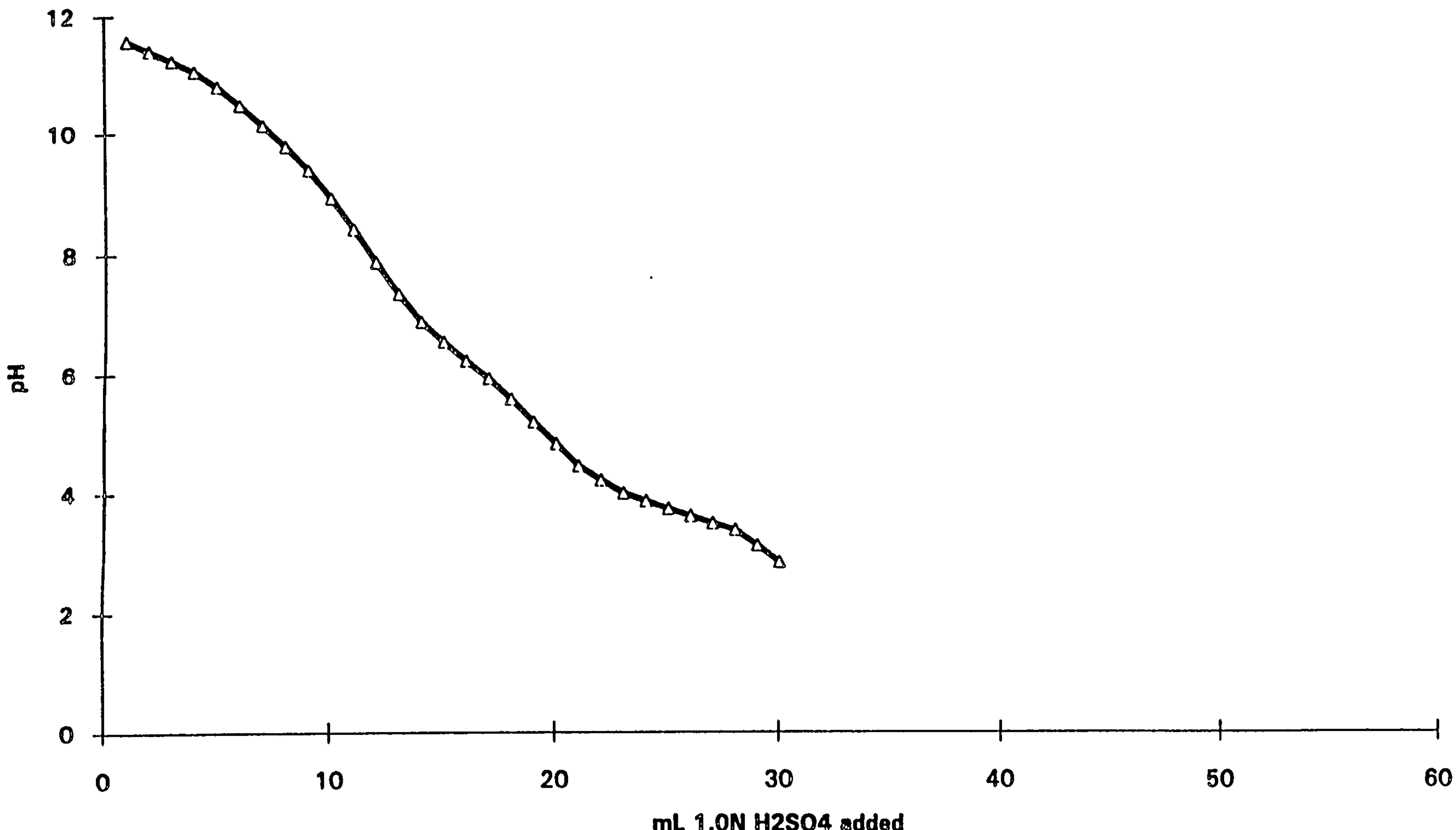
pH Titration of Sample ID 111293-25
AN, 1-8-94, 1 min/reading, 10g sample/50 mL H2O



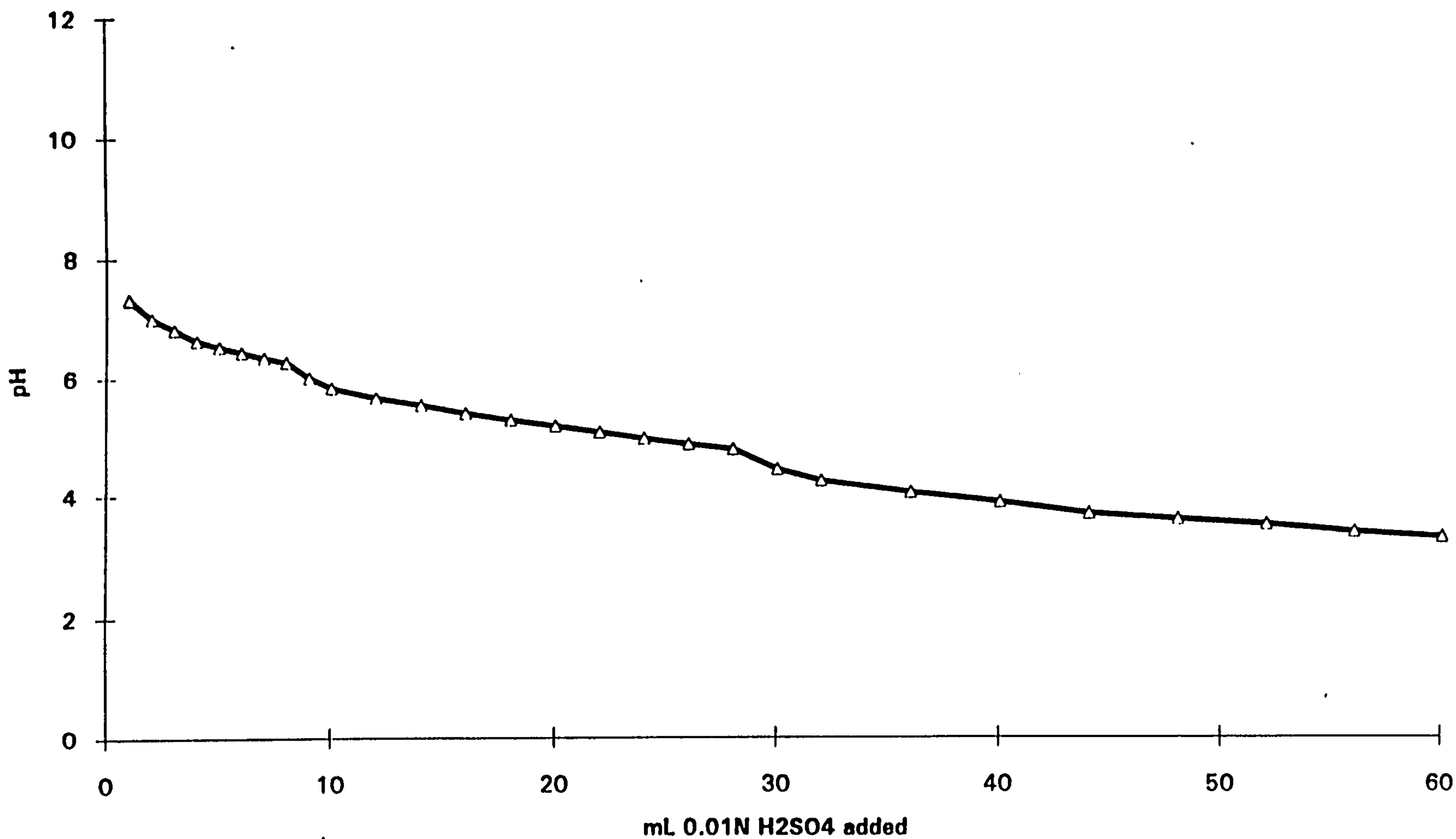
pH Titration of Sample ID 111293-26
AN, 1-8-94, 1 min/reading, 10g sample/50 mL H2O



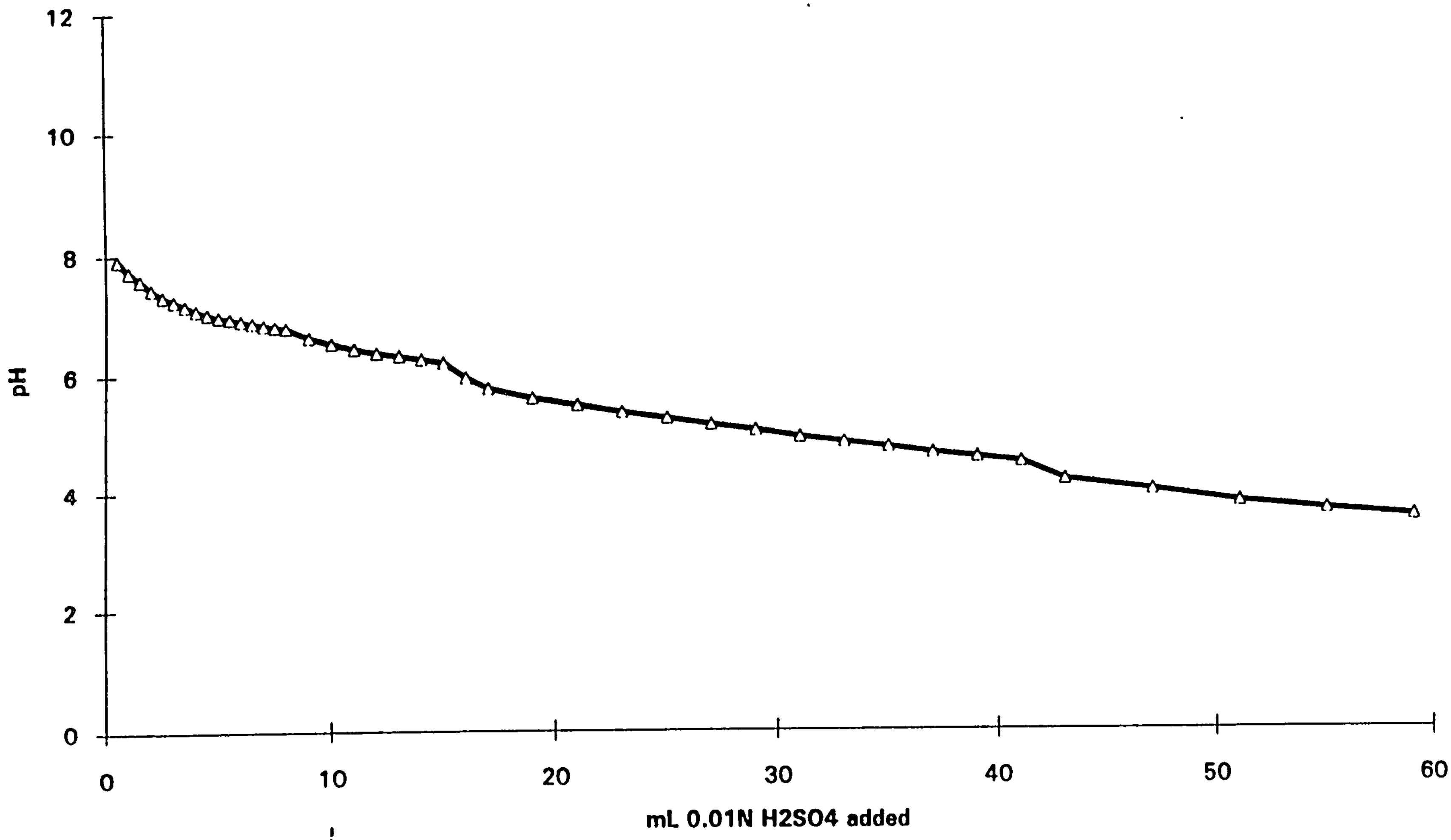
pH Titration of Sample ID 111293-27
AN, 1-8-94, 1 min/reading, 10g sample/50 mL H2O



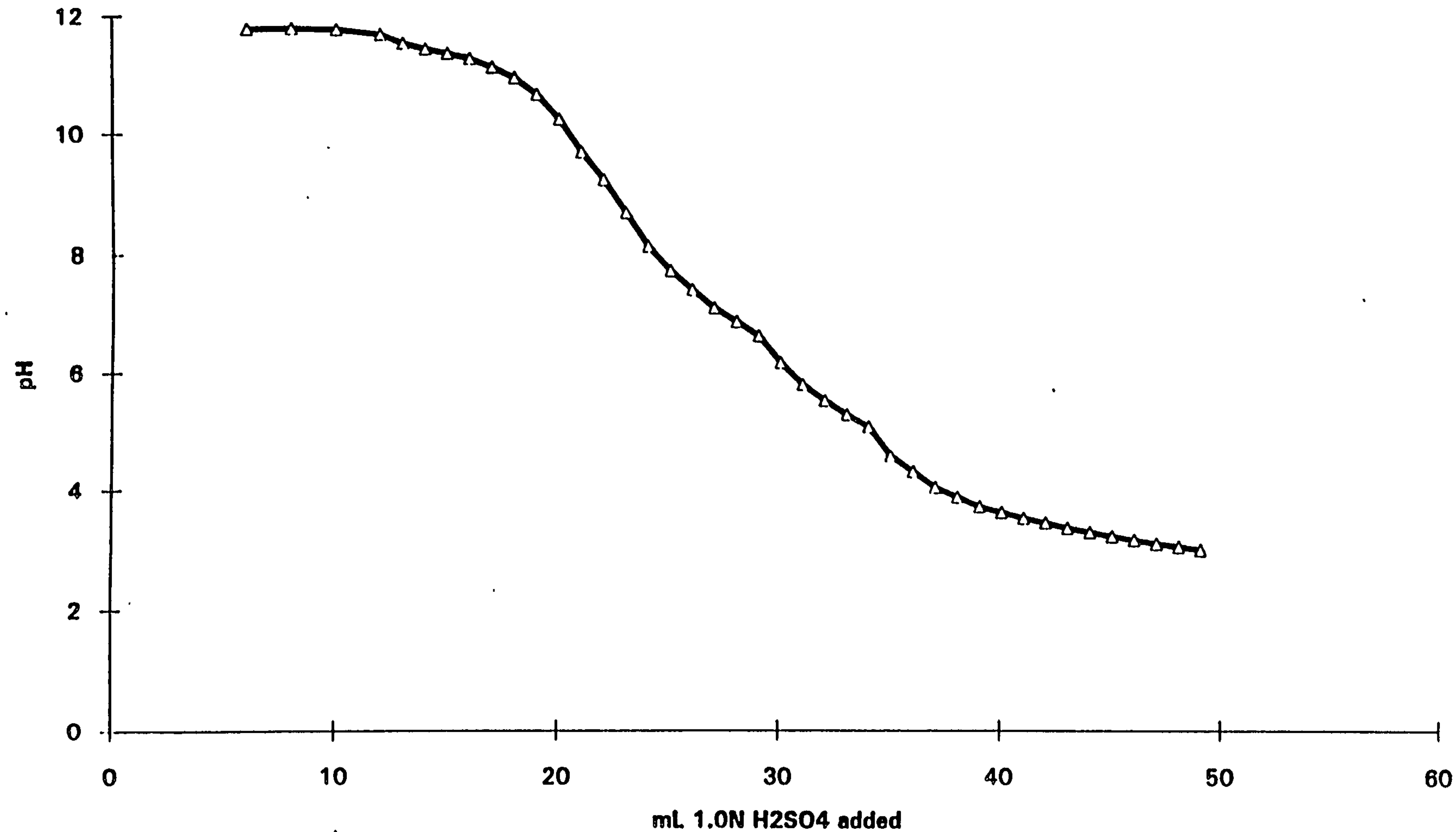
pH Titration of Sample ID 111293-28
AN, 1-12-94, 1 min/reading, 10g sample/50 mL H2O



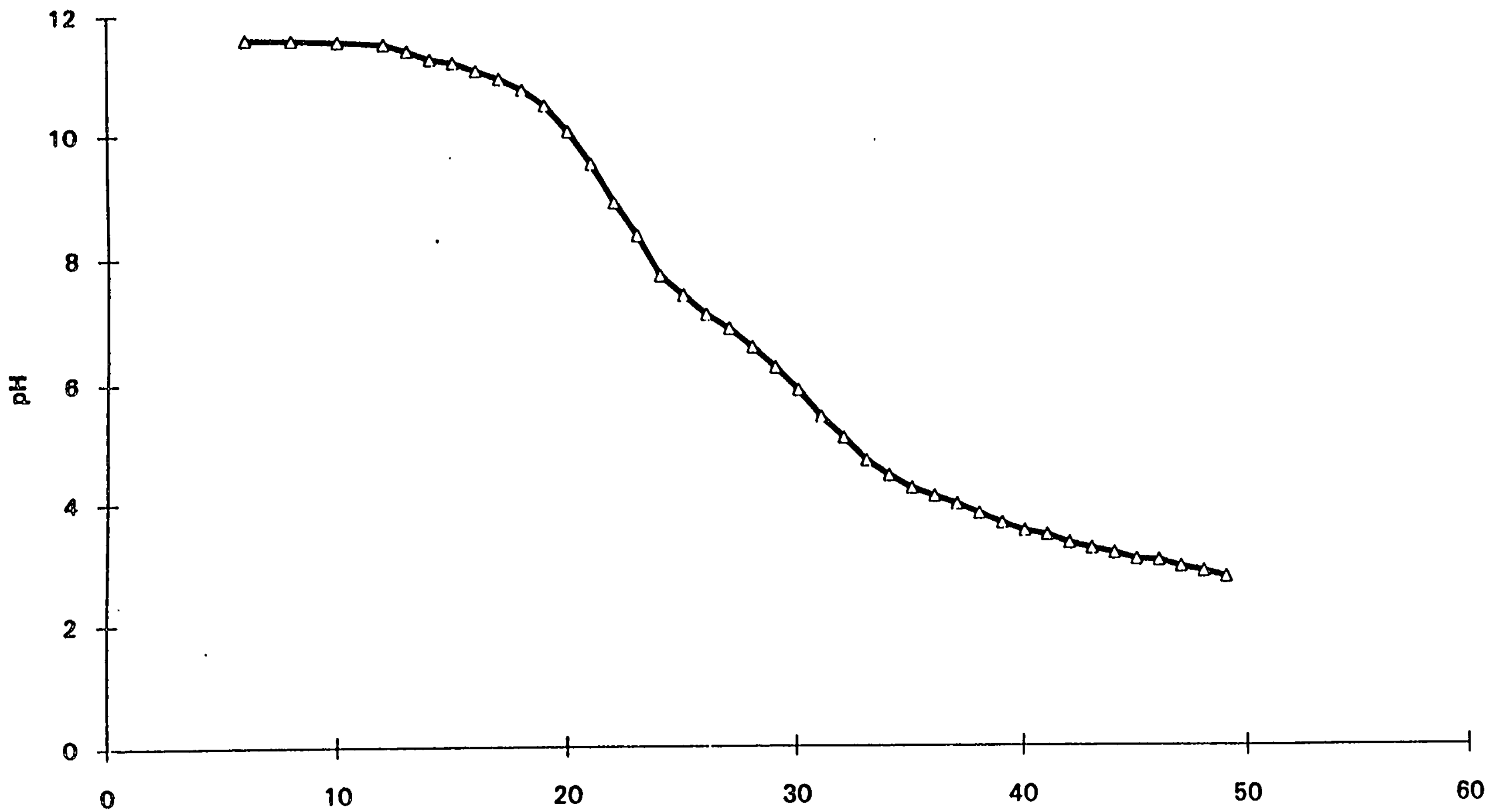
pH Titration of Sample ID 111293-29
AN, 1-11-94, 1 min/reading, 10g sample/50 mL H2O

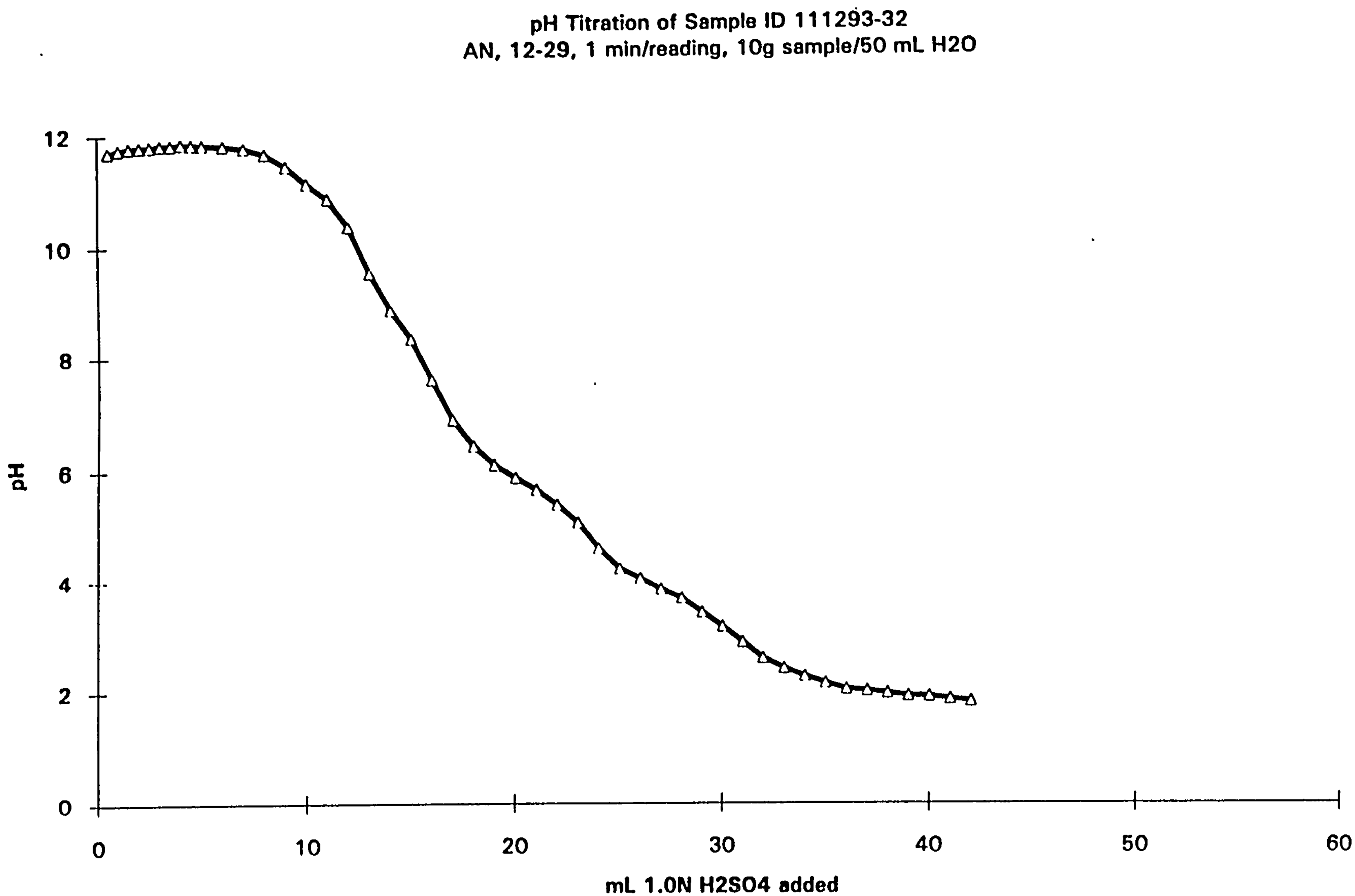


pH Titration of Sample ID 111293-30
AN, 1-11-94, 1 min/reading, 10g sample/50 mL H2O

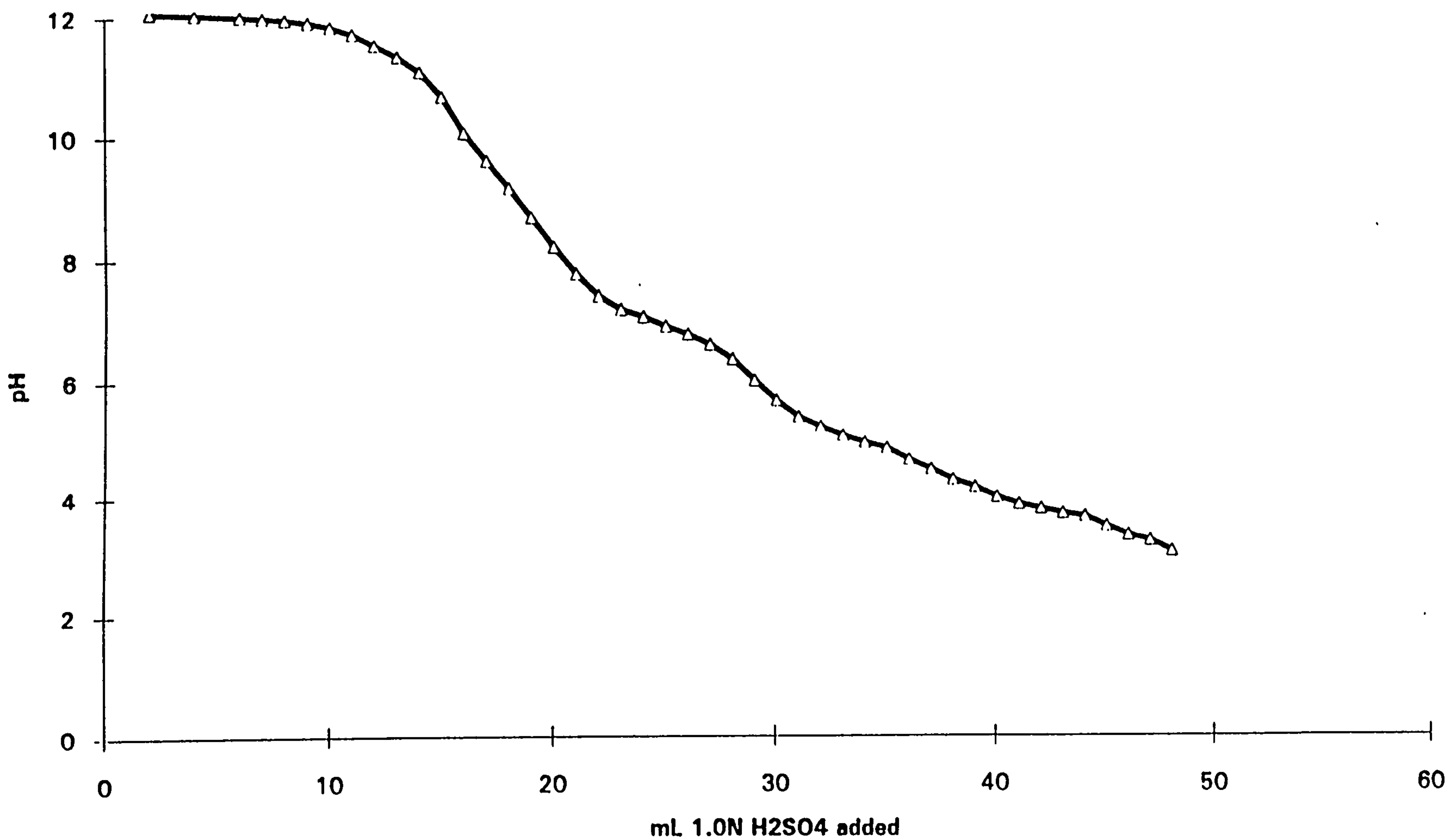


pH Titration of Sample ID 111293-31
AN, 1-11-94, 1 min/reading, 10g sample/50 mL H2O

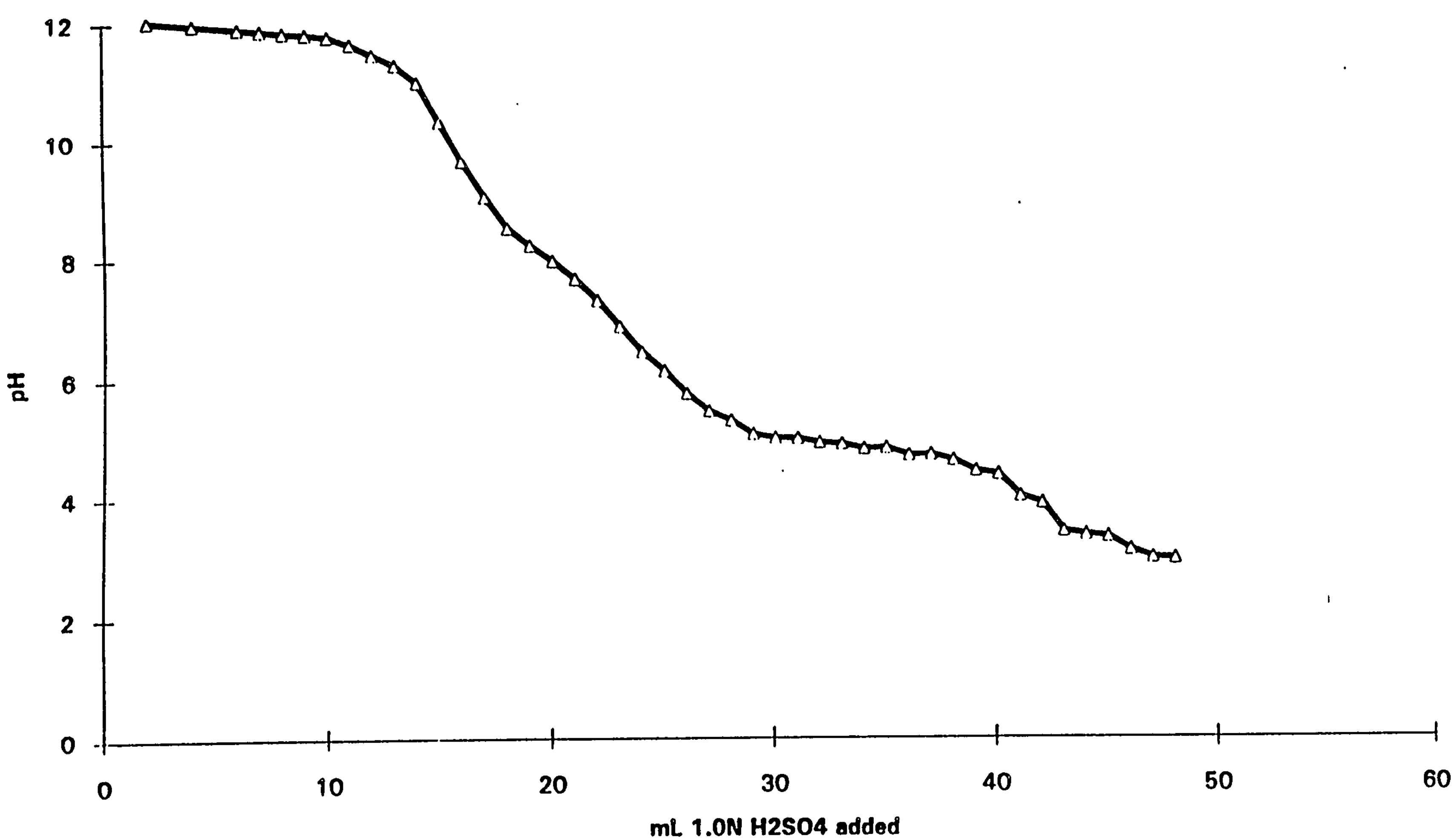



pH Titration of Sample ID 111293-32
AN, 12-29, 1 min/reading, 10g sample/50 mL H2O
pH
0
2
4
6
8
10
12
0
10
20
30
40
50
60
mL 1.0N H2SO4 added

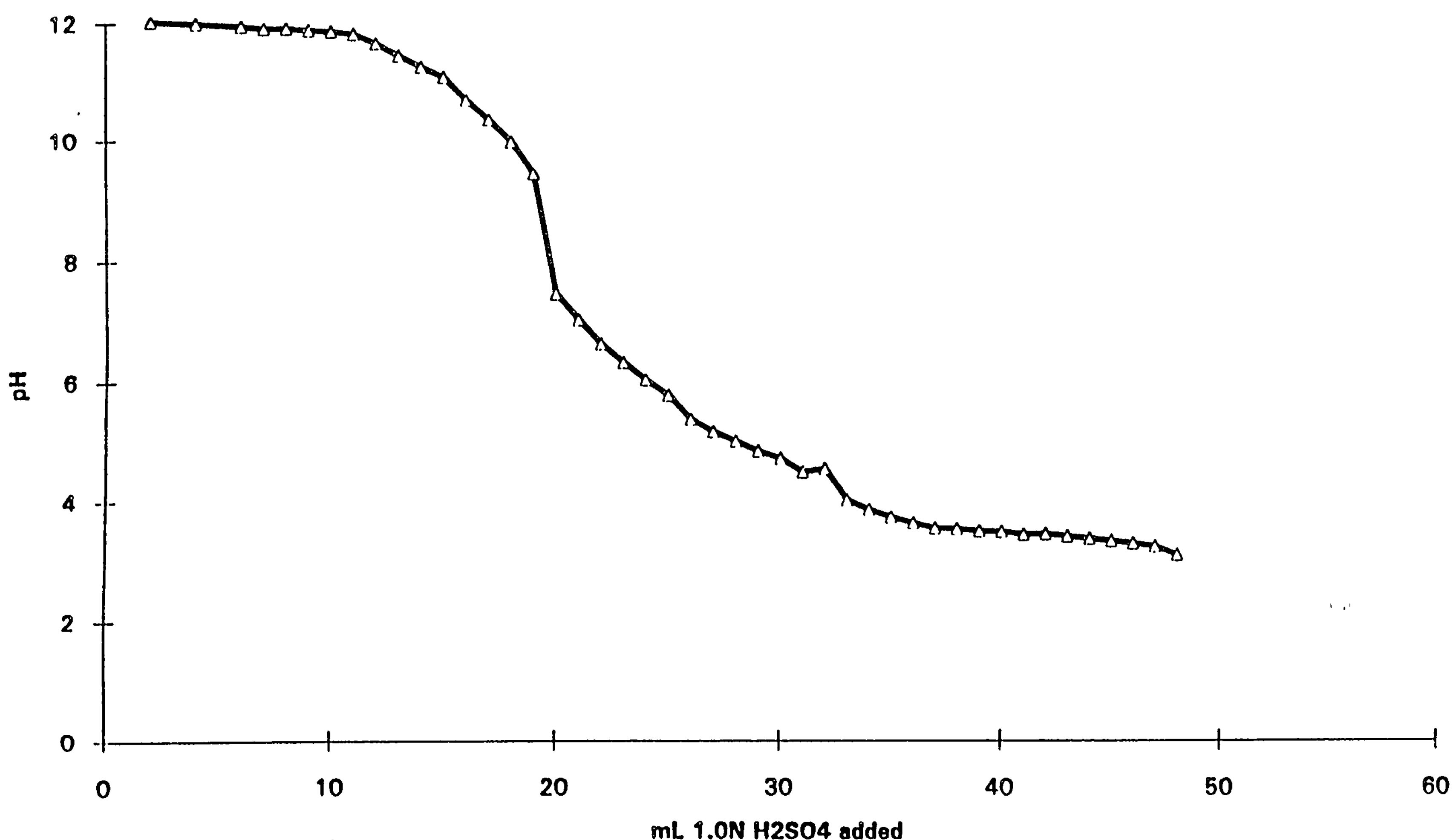
pH Titration of Sample ID 111293-33
AN, 12-29-93, 1 min/reading, 10g sample/50 mL H2O



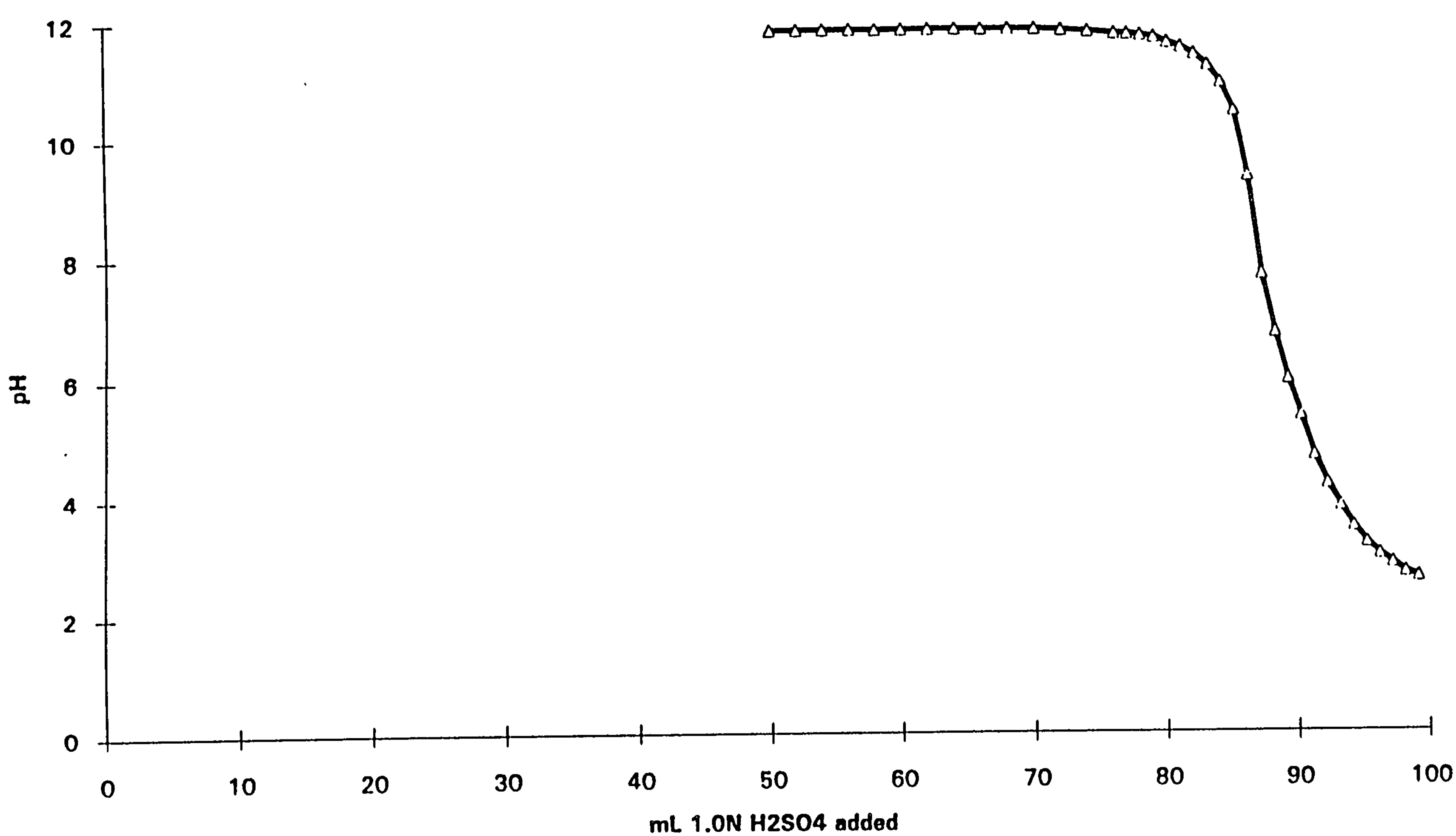
pH Titration of Sample ID 111293-34
AN, 12-29-93, 1 min/reading, 10g sample/50 mL H2O



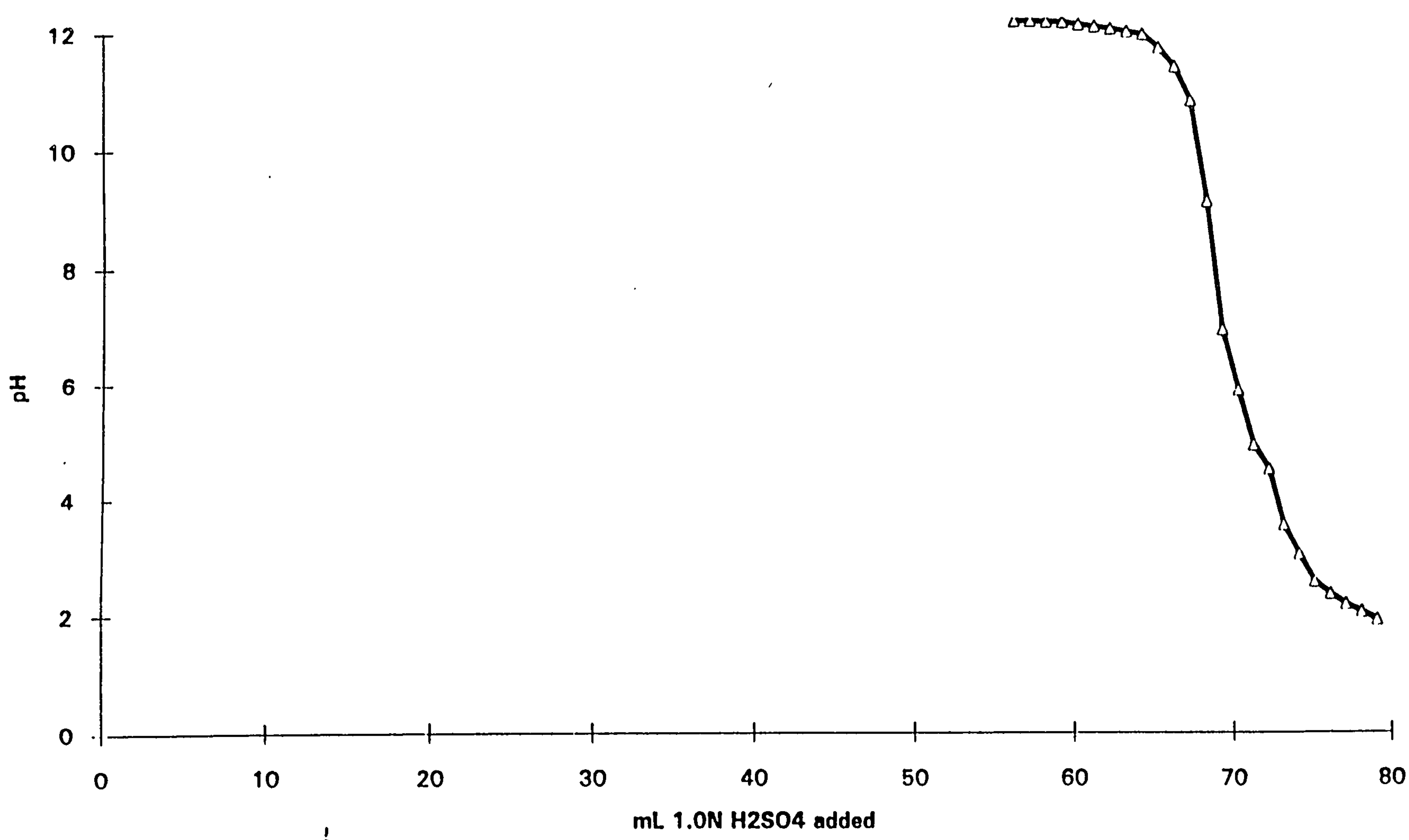
pH Titration of Sample ID 111293-35
AN, 12-30-93, 1 min/reading, 10g sample/50 mL H2O



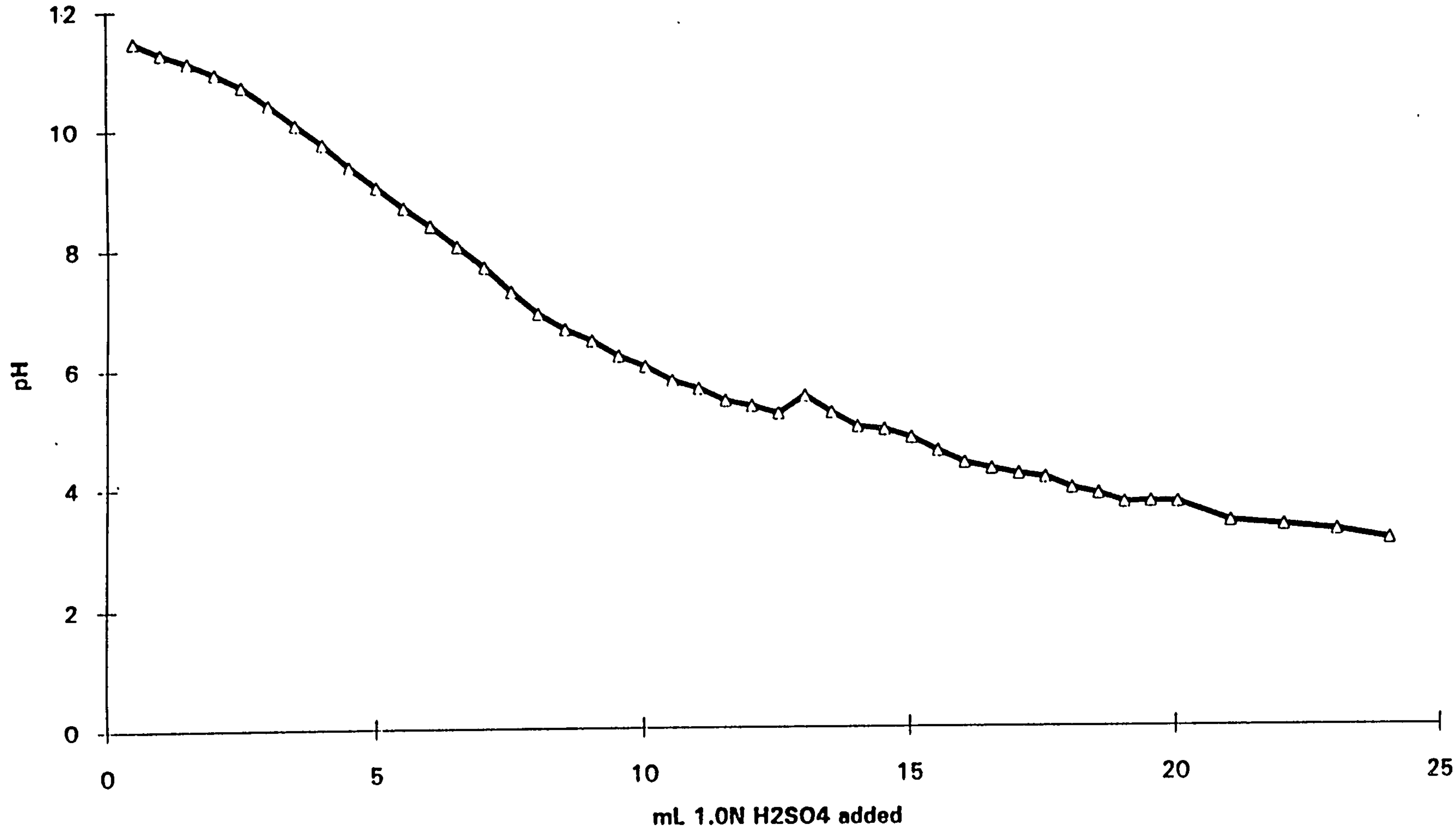
pH Titration of Sample ID 111293-36
AN, 12-30-93, 1 min/reading, 10g sample/50 mL H2O



pH Titration of Sample ID 111293-37
AN, 1-6-94, 1 min/reading, 10g sample/50 mL H2O



pH Titration of Sample ID 111293-38
AN, 1-6-94, 1 min/reading, 10g sample/50 mL H2O



Appendix A4

Enumeration of Fecal Coliform Densities in H-Power Ash and Municipal Sludge Mixtures

Water Quality Laboratory

November 19, 1993

Sample Description	MPN/gram dry weight
Sand Island Sludge	5,050
H-Power Bottom Ash	
Replicate 2.5	< 0.24
Replicate 2.6	< 0.24
Soil	
Replicate 4.5	0.66
Replicate 4.6	0.39
H-Power Fly Ash and Sludge (3:1 Mix)	
Replicate 5.5	< 0.38
Replicate 5.6	< 0.38
H-Power Bottom Ash and Sludge (3:1 Mix)	
Replicate 6.5	< 0.40
Replicate 6.6	< 0.40
H-Power Fly Ash and Sludge (2:2 Mix)	
Replicate 7.5	< 0.49
Replicate 7.6	< 0.49
H-Power Fly Ash and Sludge and Lime (2:2:1 Mix)	
Replicate 8.5	< 0.42
Replicate 8.6	< 0.42
Waipahu Combined Ash	
Replicate 9.5	< 0.26
Replicate 9.6	< 0.27

MATERIALS AND METHODS

Sample source and handling. All samples were delivered to the Water Quality Laboratory by personnel or consultants from the H-Power facility. The one (1) sludge sample received on 11-8-93 at 12:30 PM was not accompanied by a chain-of-custody form and an appropriate transport temperature of 0-10°C was not maintained. The fourteen (14) samples received on 11-12-93 at 1:28 PM were accompanied by a chain-of-custody form, but a spot check revealed that appropriate transport temperatures were not achieved for all sample containers. An unexpected sample (Mixture 9 - Waipahu ash) was received while an expected sample (Mixture 1 - H-Power fly ash) was not received. The samples received and analyzed for fecal coliform include the sludge and two replicates each of Mixtures 2, 4, 5, 6 ,7, 8, and 9.

Upon receipt, samples were immediately placed into a refrigerator at 4°C and sequentially removed for processing. All samples were analyzed within the recommended six (6) hours after collection except for samples 8.5 and 8.6 (about 6.5 hours) and samples 9.5 and 9.6 (about 9 hours after collection at H-Power).

Bacteriological analyses. The solid and semi-solid mixtures were analyzed for fecal coliform using the Most Probable Number (MPN) method according to procedures detailed in "Control of Pathogens and Vector Attraction in Sewage Sludge," EPA/625/R-92/013, December 1992, Appendix F. Briefly, a sample dilution series was prepared and inoculated into tubes of Lauryl Tryptose Broth (LTB). The 10.0 and 1.0 gram dilutions were weighed and directly added. The 0.1 gram dilution was prepared by adding 10.0 grams of sample to 90.0 mL of buffered dilution water and blending for five minutes (1.0 mL of this solution contains 0.1 gram sample). Ten-fold serial dilutions starting with this solution were also prepared as required. Positive Escherichia coli and negative Enterobacter aerogenes control cultures were inoculated into LTB tubes. All LTB tubes including uninoculated blank control tubes were incubated at 35.0°C for 24-48 hours. Growth in tubes with positive gas production was transferred to EC broth and incubated for 24 hours at 44.5°C. Positive gas production confirmed the presence of fecal coliform. Sterile supplies and media and aseptic techniques were employed. Replicate analyses of samples 2.5 and 2.6 were also performed.

pH correction. Sample mixtures with ash or lime exhibited extremely high pH while the sludge sample exhibited slightly low pH. Such pH extremes could interfere with the growth of fecal coliform under test conditions and cause erroneous results. Additional 1.0 gram dilutions into LTB were prepared for all samples and the pH determined - which ranged from pH 6.89 to pH 7.84. An additional 10.0 gram dilution of sample 8.6

(ash/sludge/lime mixture) into double-strength LTB was prepared, washing with 10.0 mL sterile distilled water, and the pH was determined at 11.05. The pH buffering capacity of the LTB solutions sufficiently corrected the high and low pH of the samples at the 1.0 gram dilution but not at the 10.0 gram dilution. Results from 10.0 gram dilutions were not used (except for soil samples 4.5 and 4.6 at pH 8 before dilution).

Percent solids. The final calculation in terms of grams of dry weight required the determination of percent solids. A 10-50 gram aliquot was dried at 104°C and weighed, then re-dried until a constant weight of less than or equal to 50 mg between each subsequent weighing was achieved. Empty dishes were weighed at the beginning and end of each series as weight control checks. Duplicate analyses for percent solids was performed for each sample and the average result used for final calculations.

Calculations. The following equation is used to calculate fecal coliform densities:

$$\text{MPN fecal coliform/gram} = \frac{10 \times \text{MPN index/100 mL}}{\text{largest volume} \times \text{\% dry solids}}$$

Sample disposal. The dried samples from the percent solids determinations and any remaining sample mixtures were consolidated and transferred to the Treatment and Disposal Division for final disposal into the municipal landfill.

B. Asato
Sanitary Chemist IV
Water Quality Laboratory

cc:KT

Food Quality Labs

1505 Dillingham Blvd., Suite 220
Honolulu, Hawaii 96817
Tel/Fax: 808-841-4484

For: H-Power Ash Utilization Study
91-714 Hanua St.
Kapolei, HI 96707

Case No. 1
Received: 11-12-93
Analyzed: 11-12-93
Completed: 11-16-93

Lab No.	Sample	Salmonella per 25 g.				
1	#2-7 11-12-93 9:00 AM	Negative				
2	#4-7 11-12-93 9:45 AM	Negative				
3	#5-7 11-12-93 10:00 AM	Negative				
4	#6-7 11-12-93 10:15 AM	Negative				
5	#7-7 11-12-93 10:30 AM	Negative				
6	#8-7 11-12-93 10:45 AM	Negative				
7	#9-7 11-12-93 9:15 AM	Negative				

Analyzed by:
Unu Jones

Food Quality Analysts, Inc.
Portland, Oregon

Appendix A5

Botanical Growth Potential of Ash Mixtures

This subtask was designed to determine the potential of the ash mixtures to support botanical growth. This was accomplished by seeding mixtures with native grasses and recording germination rates, disease, color, etc. In addition to seed, similar experiments were also carried out using transplanted turf grass. It was originally planned that the mixtures be used in three varying degrees: one at full concentration, and two at lower concentrations as soil admixtures. However, due to time constraints and insufficient resources, tests on the latter two concentrations were not conducted.

Procedure

The following six turfgrass samples were selected:

Sunturf Bermuda	Tifway 419 Bermuda
Seashore Paspalum	'El Toro' Zoysia
'Z-3' Zoysia	'Emerald' Zoysia

Each sample, approximately 58 cm^2 (9 in^2) in size, was placed in individual 10-centimeter (4-inch) pots; each containing one of the selected MWC ash mixtures. Four replicates of each sample were prepared.

The following three types of turfgrass seeds were selected:

- Zoysia Japonica
- Hulled Bermuda Grass
- Australian Carpet Grass

Each seed type was sown in a 10-centimeter (4-inch) pot containing one of the selected MWC ash mixtures. Four replicates of each sample were also prepared. All of the samples were provided with water. No fertilizers, pesticides, etc., were used or added. Observations were recorded daily and photographs taken as needed

The following report, prepared by the staff of the City & County of Honolulu's Botanical Gardens, includes the actual observation data, and the conclusions drawn therefrom by the horticulturists. Photographs of the test specimens begin on page A5-6, following the report.

INITIAL H-POWER ASH UTILIZATION STUDY
HONOLULU BOTANICAL GARDENS

MATERIALS AND METHODS USED

12-28-93 Planted 6 turfgrass samples:

Sunturf Bermuda
Tifway 419 Bermuda
Seashore Paspalum
'El Toro' Zoysia
'Z-3' Zoysia
'Emerald' Zoysia

Four samples of each turfgrass (approximately 3" square inches each) were placed in 4" pots with soil samples # 4,5,6,7,8 provided by H-Power.

Plants were only provided with water - no fertilizers, pesticides, etc. were used.

1-6-94 Three types of turfgrass seed were sown:

Zoysia japonica
Hulled Bermuda Grass
Australian Carpet Grass

Four pots (4") of each seed type were sown over soil samples #4,5,6,7,8 provided by H-Power.

Pots were only provided with water - no fertilizers, pesticides, etc. were used.

OBSERVATIONS

1-6-94 -	NO CHANGES IN TURF POTS - PLANTS ALL GREEN				
1-13-94 -	" " "				
1-13-94 -	SEED SPROUTING :	#4	HULLED BERMUDA GRASS	(4 POTS)
		#4	ZOYSIA JAPONICA	(2 POTS)
1-14-94 -	" " " :	#8	HULLED BERMUDA GRASS	(3 POTS)
		#4	ZOYSIA JAPONICA	(4 POTS)
1-18-94 -	" " " :	#4	ZOYSIA JAPONICA	(4 POTS)
		#4	AUSTRALIAN CARPET	(4 POTS)
		#8	HULLED BERMUDA	(3 POTS)
		#6	HULLED BERMUDA	(1 POT)

1-18-94 -	SEED SPROUTING :	#6 AUSTRALIAN CARPET	(1 POT)
1-19-94 -	" " " :	NO CHANGE	
1-20-94 -	" " " :	NO CHANGE	
1-21-94 -	" " " :	NO CHANGE	

NO SIGNIFICANT CHANGES NOTED UNTIL 2/15

2-15-94 -	TURFGRASS POTS :	#5	TIFWAY 419 - ALL POTS DYING OUT
		#6	" " "
		#7	" " "
		#5	SUNTURF BERMUDA - ALL POTS DYING
		#6	" " "
		#7	" " "
2-22-94 -	TURFGRASS POTS :		ALL SOILS - SEASHORE PASPALUM STILL ALIVE AND GREEN
2-28-94 -	" " :	#8	SEASHORE PASPALUM - DYING OUT ALL OTHER SOILS PALE GREEN
	" " :	#8	EMERALD ZOYSIA - 1 POT DYING
	" " :	"	N-3 ZOYSIA - " "
	" " :	#7	SEASHORE PASPALUM - ALL DYING

CONCLUSIONS

FOR COMPLETE RECORD PLEASE SEE ATTACHED DATA SHEET WITH DATES. GERMINATION FOR THE SEEDS WAS POOR IN ALL CASES EXCEPT FOR THE AUSTRALIAN CARPET GRASS WHICH GERMINATED BETTER THAN THE CONTROL SOIL. EVENTUALLY ALL SAMPLES DIED DUE EITHER TO FACTORS ASSOCIATED WITH THE MEDIA CHEMICALLY (ALKALINITY?) OR STRUCTURALLY (VERY POOR DRAINAGE). ALL SEED POTS DEAD AS OF 3/94.

THE TURFGRASS POTS HAVE ALL DIED AS OF 3/13/94. THE PLANTS WOULD BEGIN TO TURN PALE GREEN AND EVENTUALLY BURN OUT TO A YELLOW COLOR. DRAINAGE WAS SO POOR THAT ROOT GROWTH WAS NOT SUBSTANTIAL. THE PLANTS MOST LIKELY LIVED ON THE ORIGINAL TOP SOIL THAT THEY WERE PLANTED WITH AND COULD NOT SUSTAIN LONG TERM GROWTH IN THE HARDENED, CEMENT-LIKE SOIL SAMPLES DUE TO LACK OF WATER DRAINAGE, OXYGEN, AND POSSIBLY THE ALKALINE PH.

OF ALL TYPES TESTED THE AUSTRALIAN CARPET GRASS PERFORMED THE BEST, EVEN GERMINATING IN SEED TRIAL BETTER THAN THE CONTROL. HOWEVER, NONE OF THE SOILS WERE SUITABLE FOR LONG TERM GROWTH. WE CANNOT DETERMINE WHAT FACTORS ARE RESPONSIBLE, BUT THE SOIL STRUCTURE ALONE IS CAUSE FOR PLANT GROWTH FAILURE. THE SOILS TURN TO HARD, CEMENT-LIKE SUBSTANCES THAT DO NOT ALLOW ROOTS TO PENETRATE AND WATER TO DRAIN ADEQUATELY.

TURFGRASS PLANTS - TEST DATA

DATE PLANTED: 28 DEC 93

HBG SOIL - PEAT/PERLITE MIX
CONTROL

		H.B.	J.Z.	A.C.	H.B.	J.Z.	A.C.
SAMPLE 1	4	7 FEB	7 FEB	7 FEB *	7 FEB	7 FEB	7 FEB
	5	28 FEB	28 FEB	28 FEB			
	6	22 FEB	22 FEB	22 FEB			
	7	28 FEB	28 FEB	28 FEB			
	8						
SAMPLE 2	4	7 FEB	7 FEB	7 FEB	7 FEB	9 FEB	9 FEB
	5	28 FEB	28 FEB	28 FEB			
	6	22 FEB	22 FEB	22 FEB			
	7	28 FEB					
	8						
SAMPLE 3	4	7 FEB	7 FEB	7 FEB *	7 FEB	9 FEB	9 FEB
	5	28 FEB	28 FEB				
	6	22 FEB	22 FEB	22 FEB			
	7	28 FEB					
	8						
SAMPLE 4	4	7 FEB	7 FEB	7 FEB*	7 FEB	9 FEB	9 FEB
	5	28 FEB	28 FEB				
	6	22 FEB	22 FEB	22 FEB			
	7	28 FEB					
	8						

* Australian Carpet Grass #4 soil - Good growth occuring

Notes: 2/28 - Good growth - J.Z. in #4 soil
2/28 - H.B. - starting to looked burnt.

3/94 - ALL POTS DEAD - YELLOWED AND/OR BURNT

ASH UTILIZATION STUDY - H - POWER

SEEDS SOWN 4" POTS

DATE PLANTED: 6 JAN 94

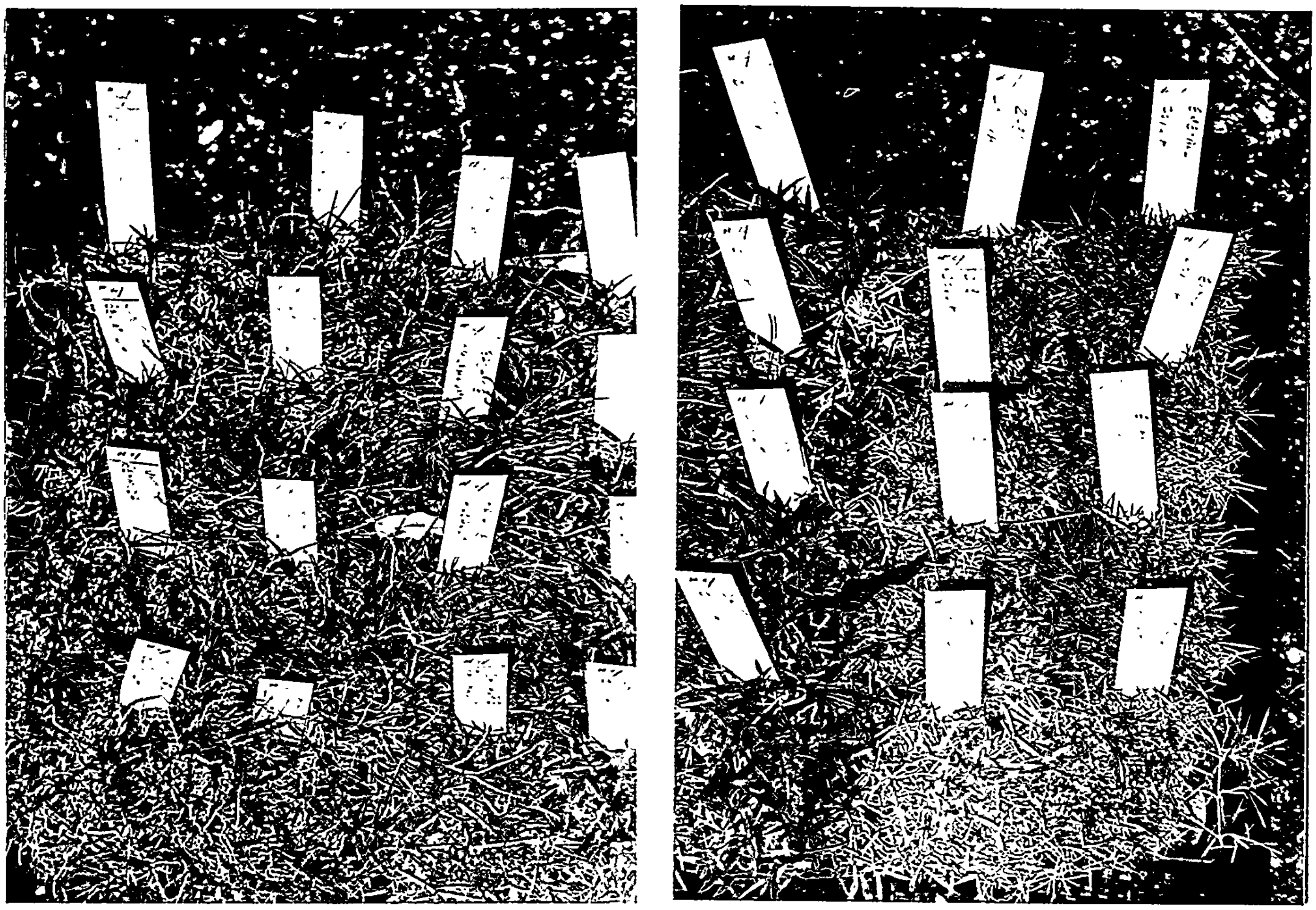
		H.B.	J.Z.	A.C.	CONTROL H.B.	CONTROL J.Z.	CONTROL A.C.
SAMPLE 1	4	13 JAN*	13 JAN	18 JAN			
	5	3 FEB	7 FEB*	3 FEB			
	6	18 JAN	24 JAN	18 JAN			
	7	1 FEB	7 FEB*	3 FEB			
	8	14 JAN	7 FEB[1]	3 FEB[1]			
SAMPLE 2	4	12 JAN	13 JAN	18 JAN			
	5	7 FEB	7 FEB*	3 FEB			
	6	24 JAN	3 FEN	1 FEB			
	7	1 FEB	7 FEB*	3 FEB			
	8	14 JAN	7 FEB[1]	7 FEB[1]			
SAMPLE 3	4	13 JAN	14 JAN	18 JAN			
	5	7 FEB	9 FEB	3 FEB			
	6	24 JAN	3 FEB	1 FEB			
	7	1 FEB	7 FEB*	3 FEB			
	8	14 JAN	7 FEB[1]	3 FEB[1]			
SAMPLE 4	4	13 JAN	14 JAN	18 JAN			
	5	16 JAN	9 FEB	16 FEB			
	6	7 FEB	3 FEB	1 FEB			
	7	1 FEB	9 FEB*	7 FEB			
	8	3 FEB	-	-			

* Sickly - FEB 28

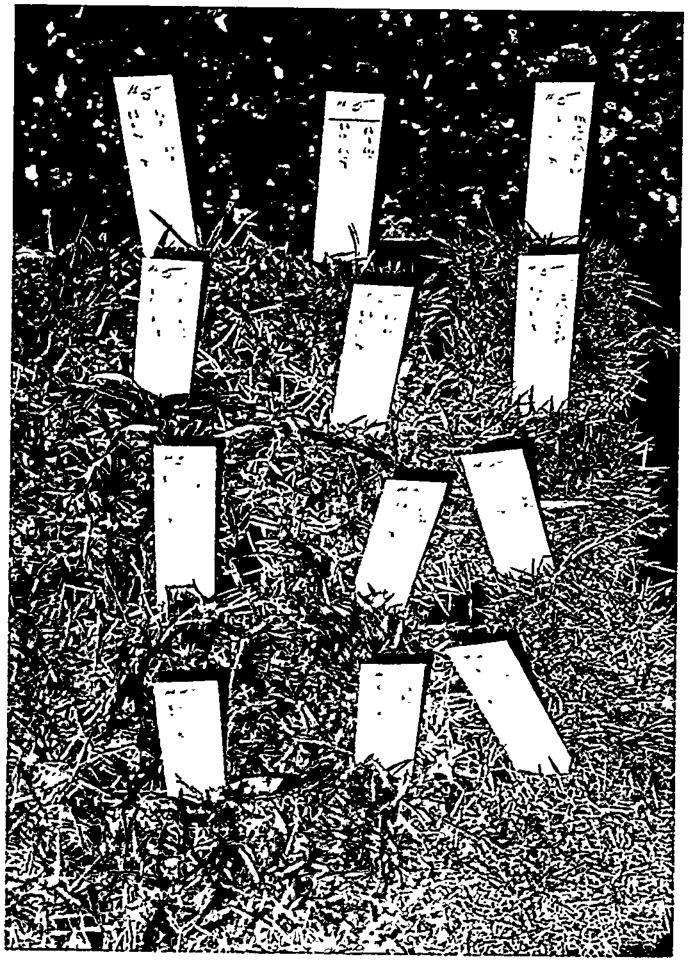
1 Dead - FEB 28

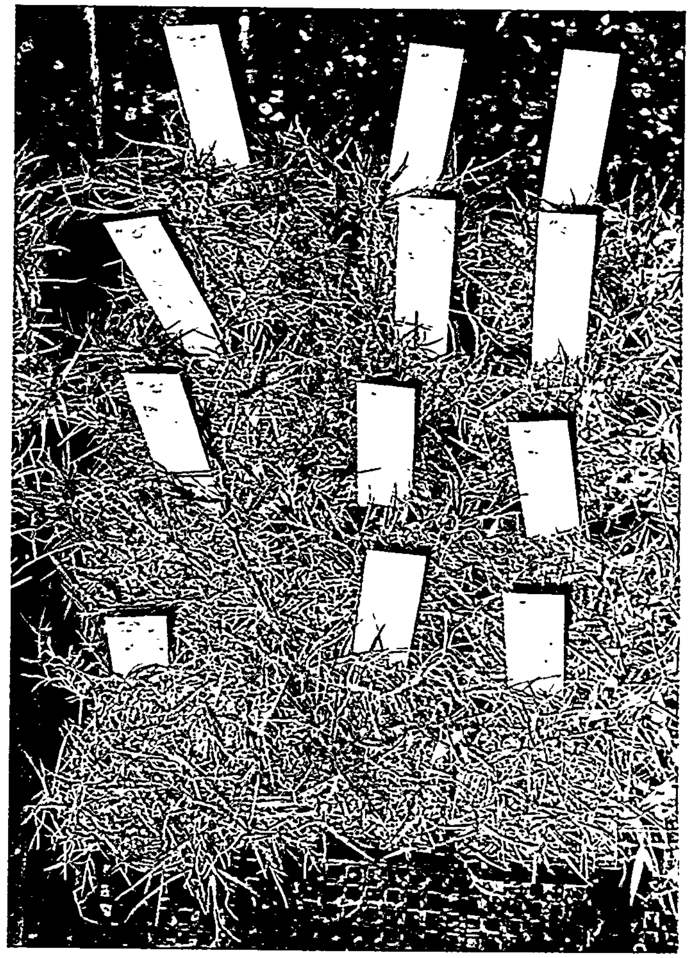
3/14/94 - All dead

Turfgrass

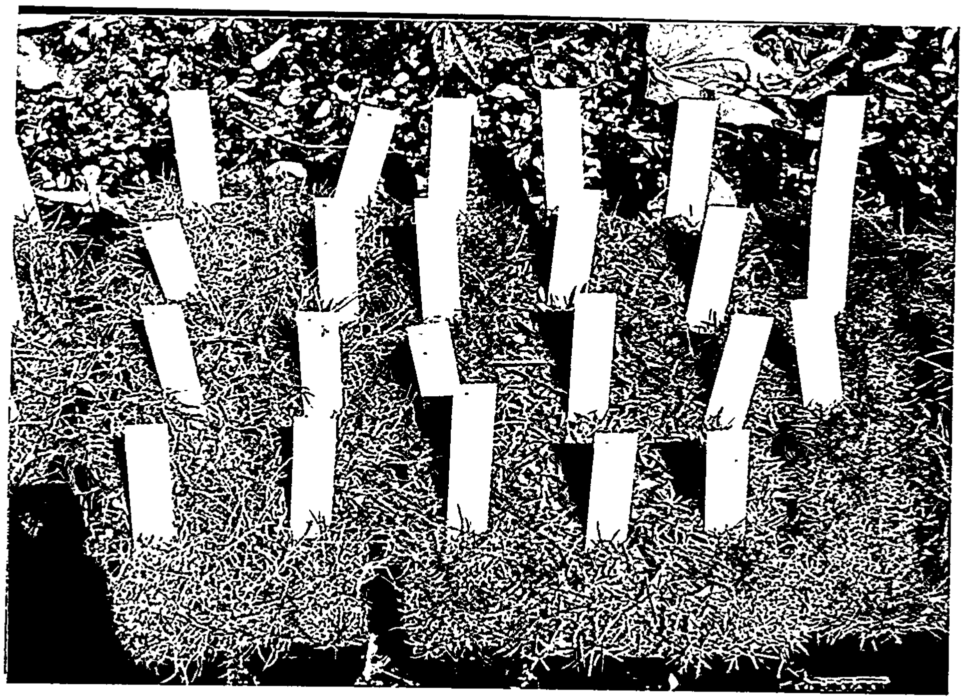


Mixture #4 Photographed January 28, 1994

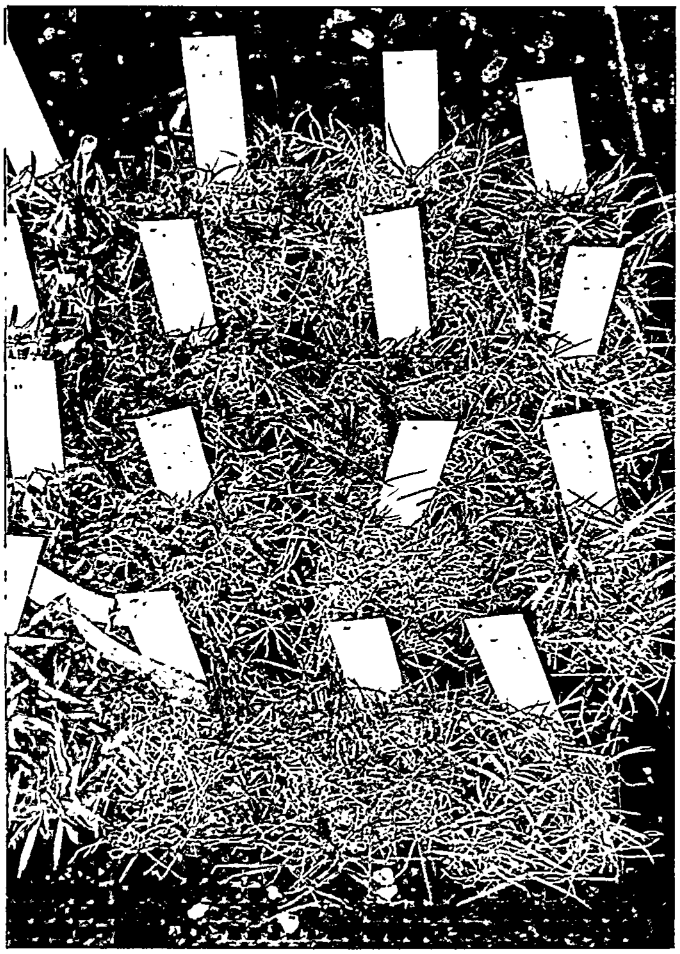


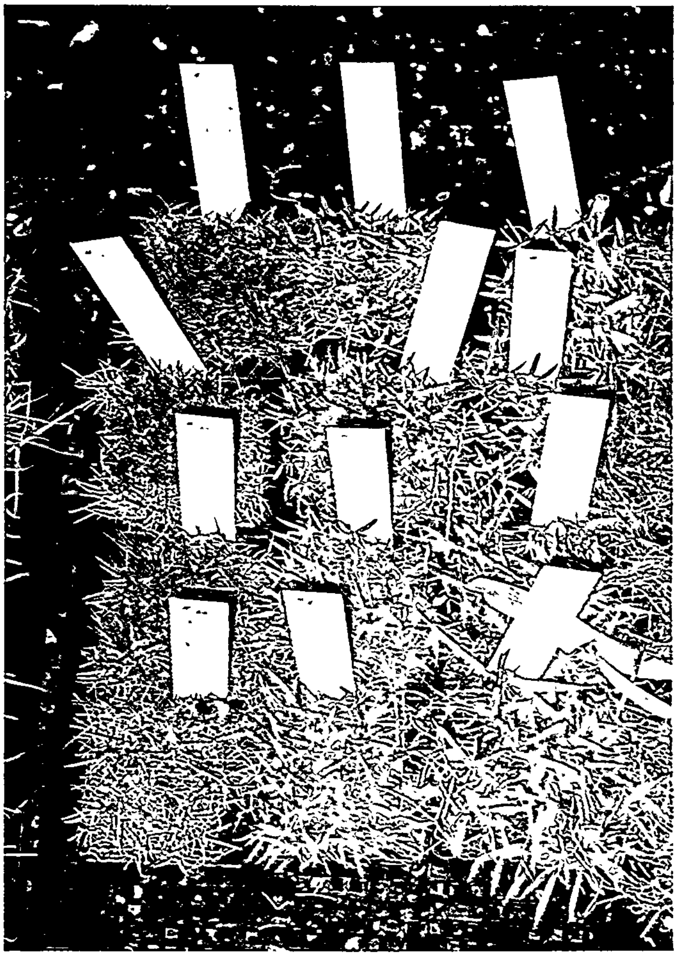


Mixture #5 Photographed January 28, 1994



Mixture #5 Photographed February 28, 1994





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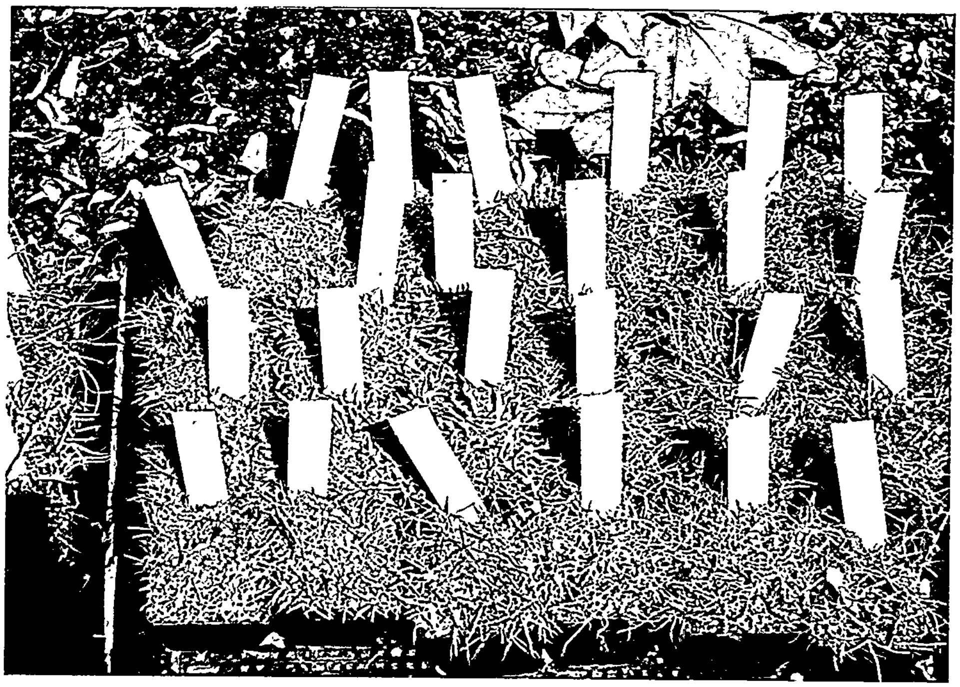

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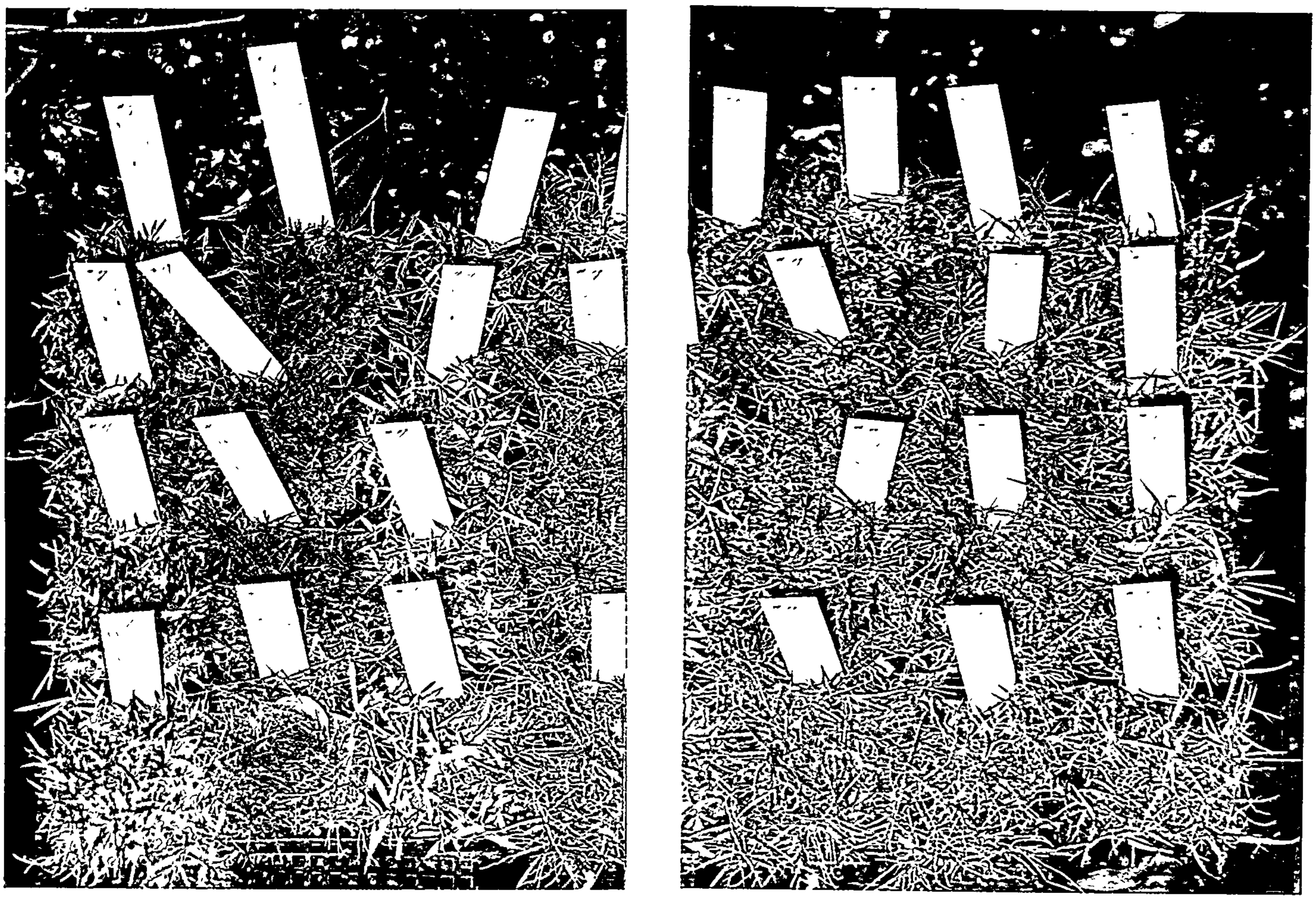
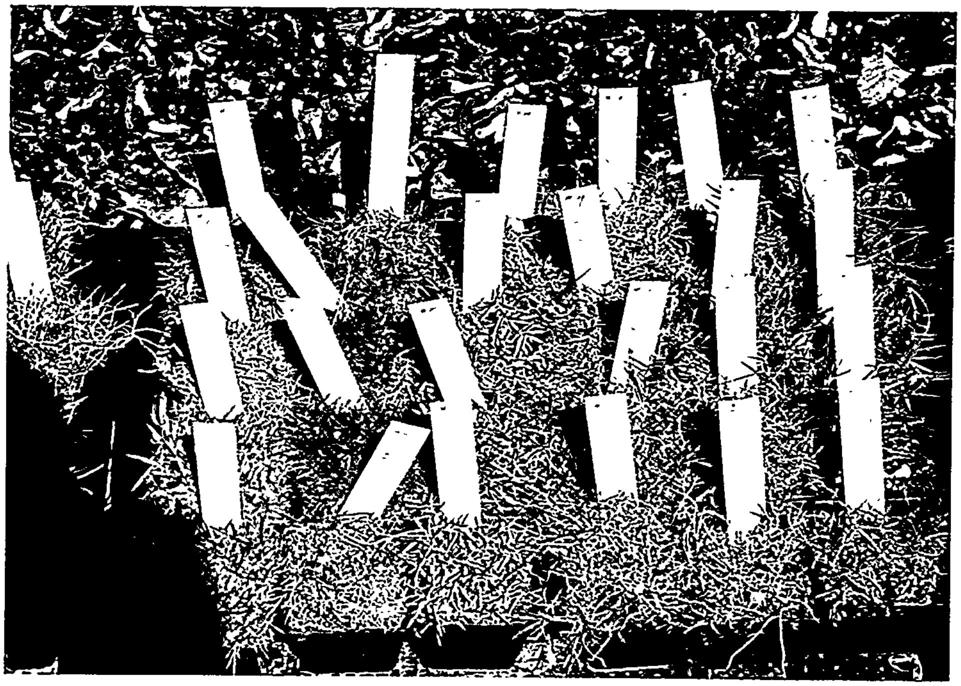


Mixture #7 Photographed January 28, 1994



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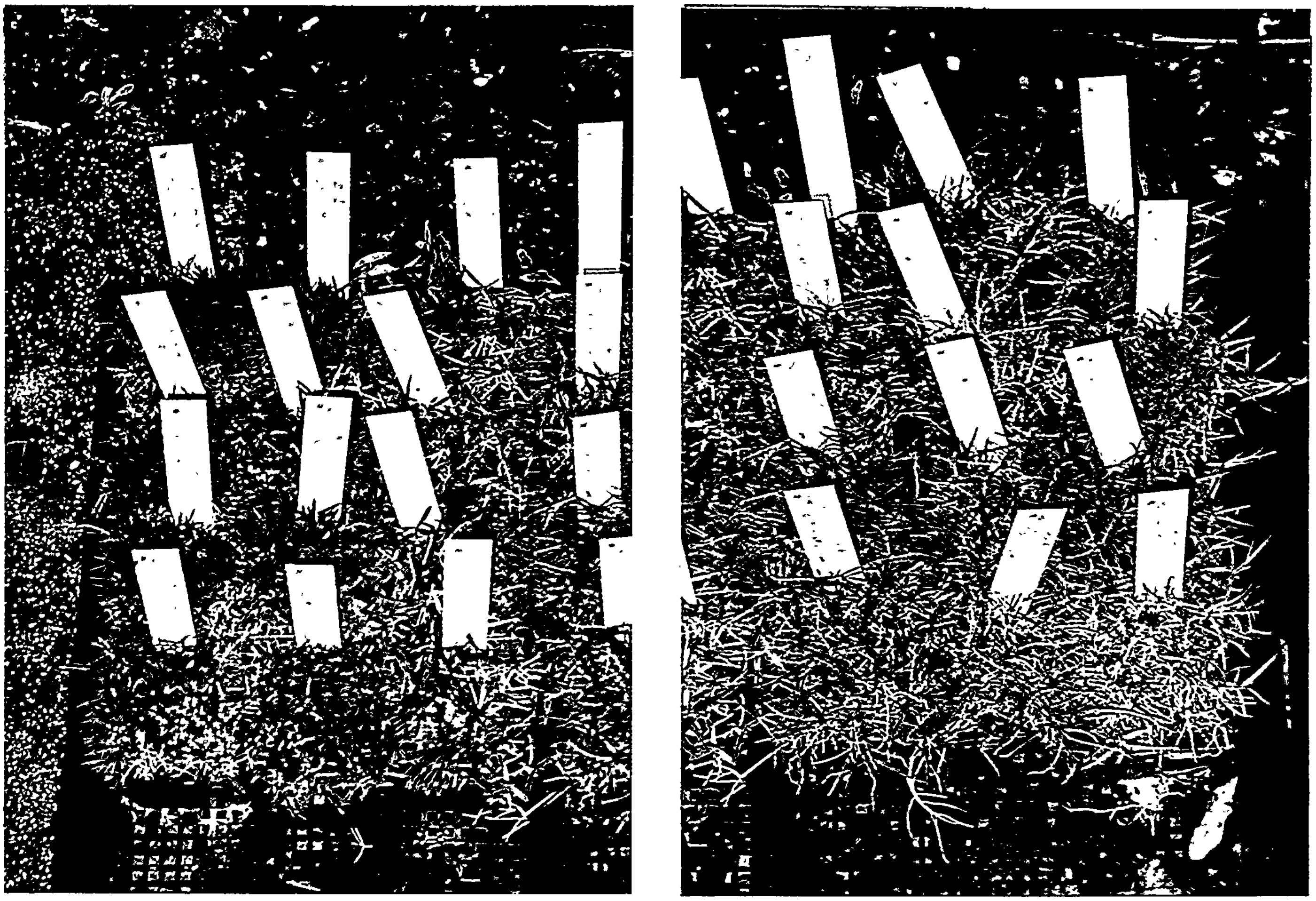
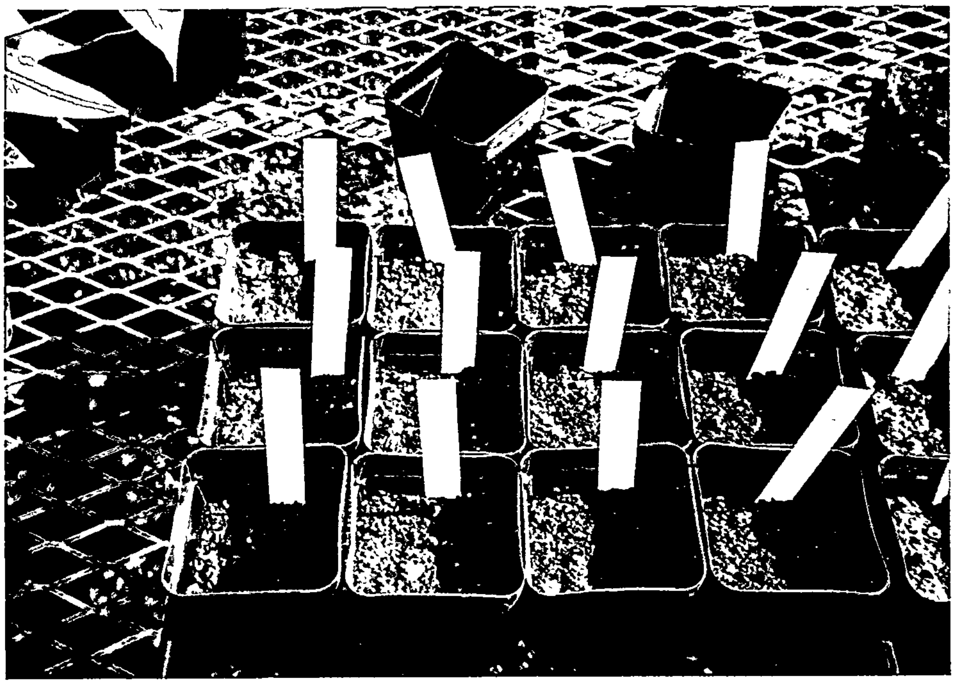


Mixture #8 Photographed January 28, 1994

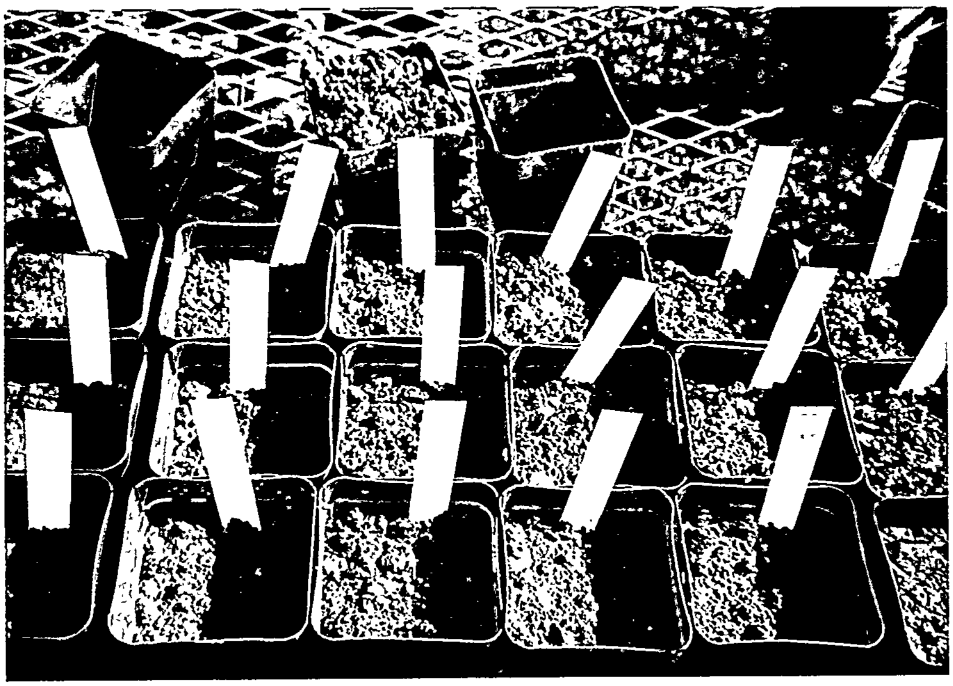
Mixture #8 Photographed February 28, 1994

Seedlings

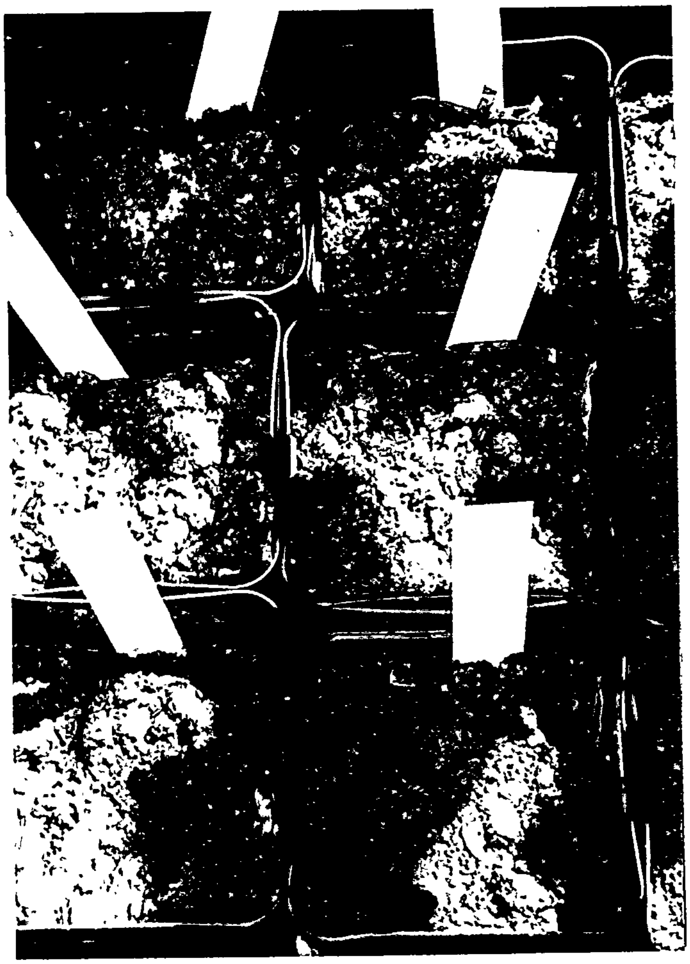


Mixture #4 Photographed January 28, 1994

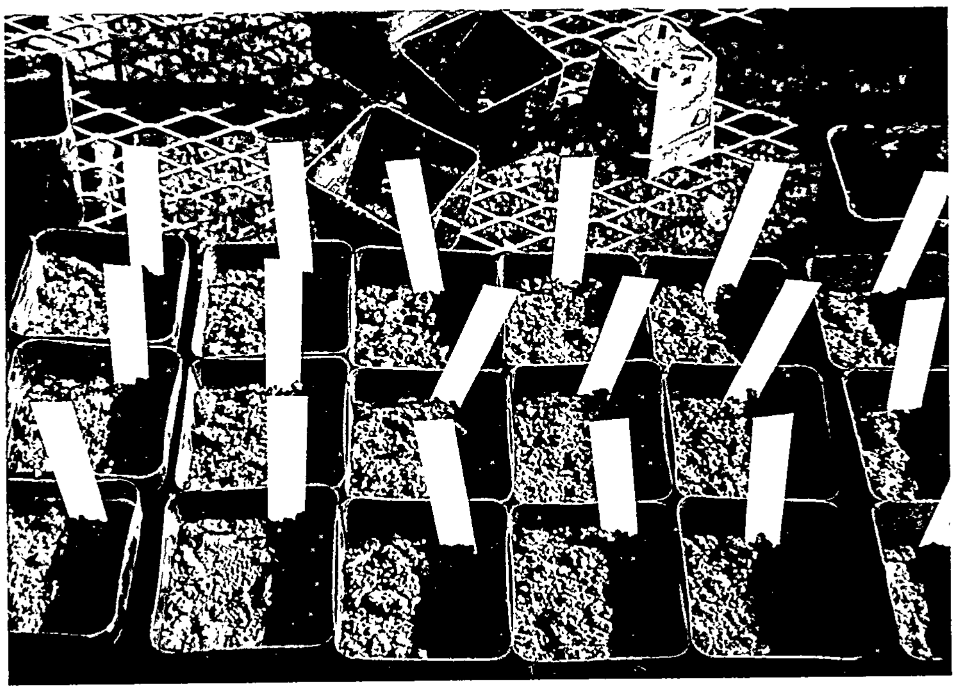
Mixture #4 Photographed February 28, 1994



Mixture #5 Photographed January 28, 1994




Mixture #5   Photographed February 28, 1994



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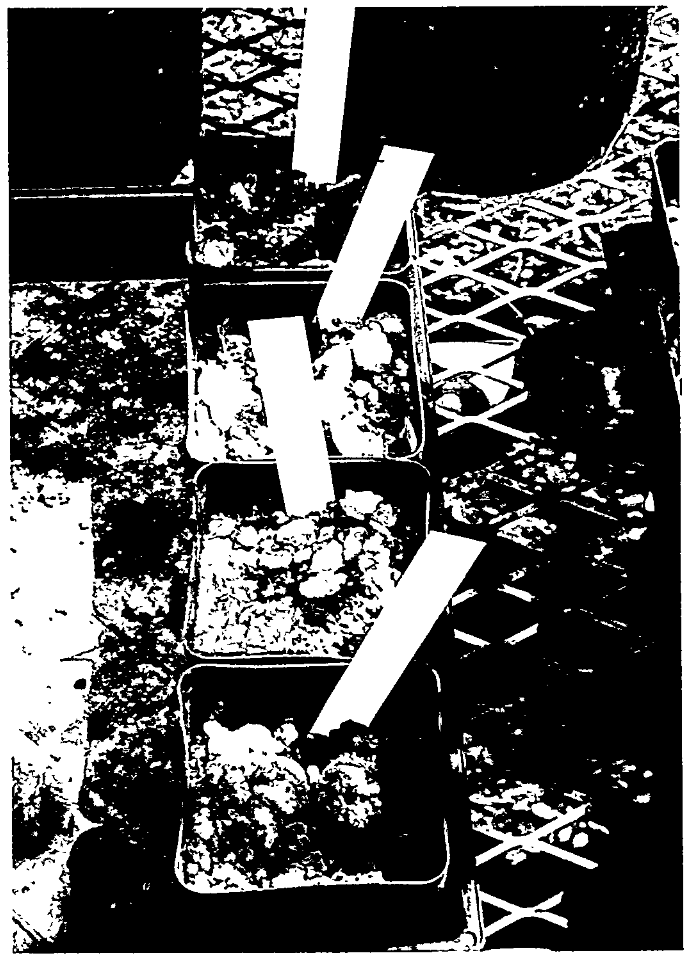
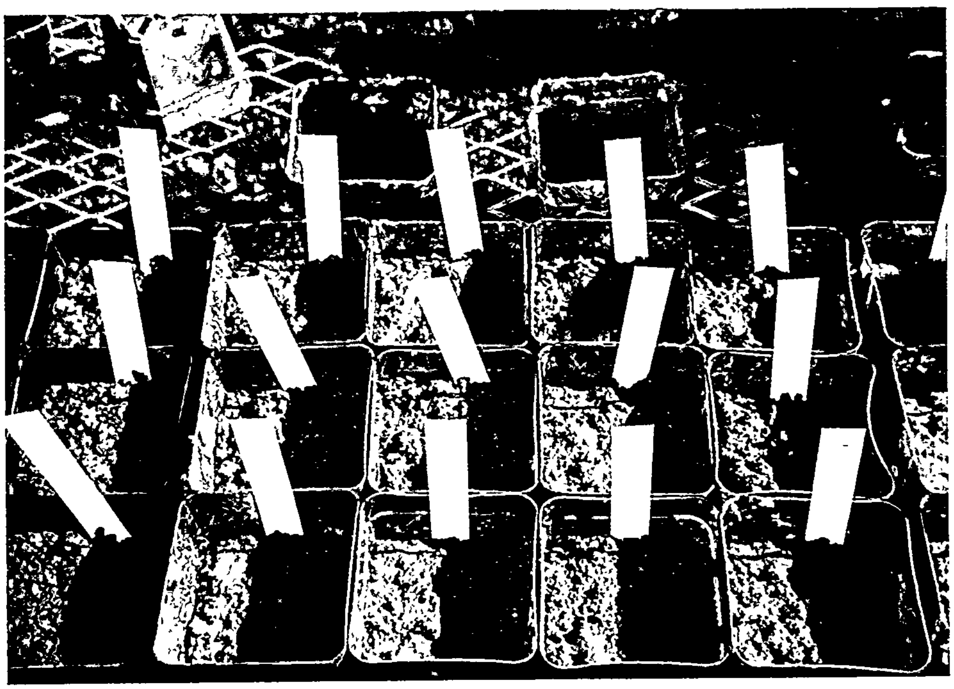
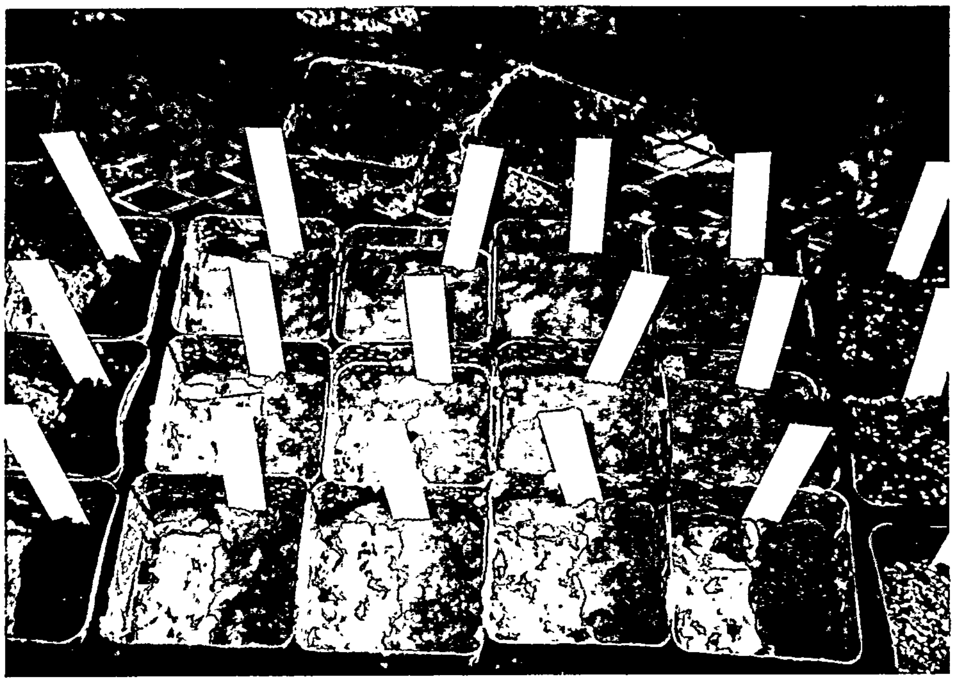


Mixture #6   Photographed February 28, 1994

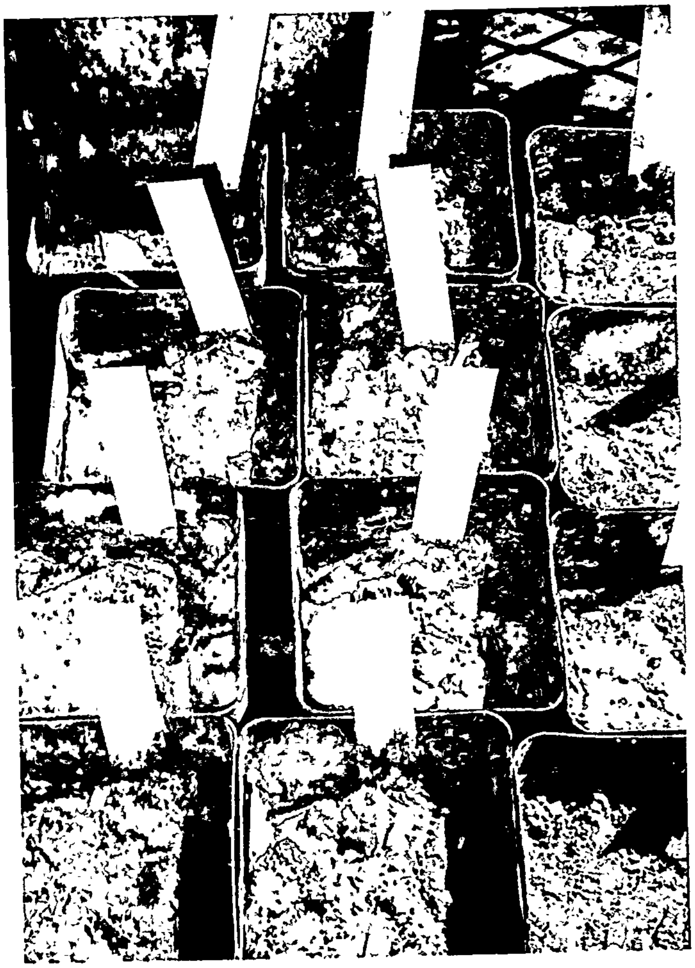


Mixture #7 Photographed January 28, 1994

Mixture #7 Photographed February 28, 1994



Mixture #8 Photographed January 28, 1994



Mixture #8 Photographed February 28, 1994

Appendix A6

Erosion Test

Observations

During the early stages, there was no visible erosion in any of the ash mixtures and only two exhibited signs of cracking: mixtures #1 and #4. Although none of the mixtures containing sludge exhibited any signs of cracking, they did undergo shrinkage which was evident from the voids appearing around the edge of the box during curing. It is hypothesized that this is largely due to the fiber-like qualities of the sludge. It is also believed to be the same reason why the sludge mixtures possessed some flexibility while also exhibiting cement-like properties.

With time, mixtures #1, #2, and #4, showed gradual signs of wind and rain erosion. Mixtures #2 and #4 were characteristically loose in nature and were easily disturbed by the elements. However, the cracks in mixture #1 grew in size and severity causing some fragmentation and subsequent erosion of the fine fly ash. Rust developed on the ferrous material in mixture #9 and subsequently, in mixtures #2 and #3. Eventually, the rust in mixtures #3 and #9 led to the formation of small cracks and also consequently caused some fragmentation and erosion.

During the month of February, considerable winds and rain were experienced, which dramatically affected most of the test mixtures--especially those containing sludge. The frequent heavy downpours caused their surface to flake and erode towards the low end of the box. The degree of damage sustained varied from minor flaking, as in mixture #6, to formation of grooves about 0.6 cm. in depth, as in mixtures #5 and #7. Mixtures #5 and #7 seemed to have a much higher capacity to retain moisture than any other mixture which was believed to be due to the high percentage of sludge. Mixture #8 seems to have been the only test mixture unaffected by the rain. This mixture behaved almost like concrete, and remained hard and durable. Table 1 on the following page summarizes the mixtures' performance for the three test criteria.

Selected photographs of the mixtures taken during the test period, appear beginning on page A6-3.

Mixtures	Erosion Resistance (least - most)	Material Strength (soft - hard)	Shrinkage (least - most)
Mix 1	********	******	******
Mix 2	**	**	n/a
Mix 3	****	*********	********
Mix 4	**	**	n/a
Mix 5	*****	****	********
Mix 6	*****	*****	*******
Mix 7	*****	***	****
Mix 8	*********	*******	**
Mix 9	****	*********	********

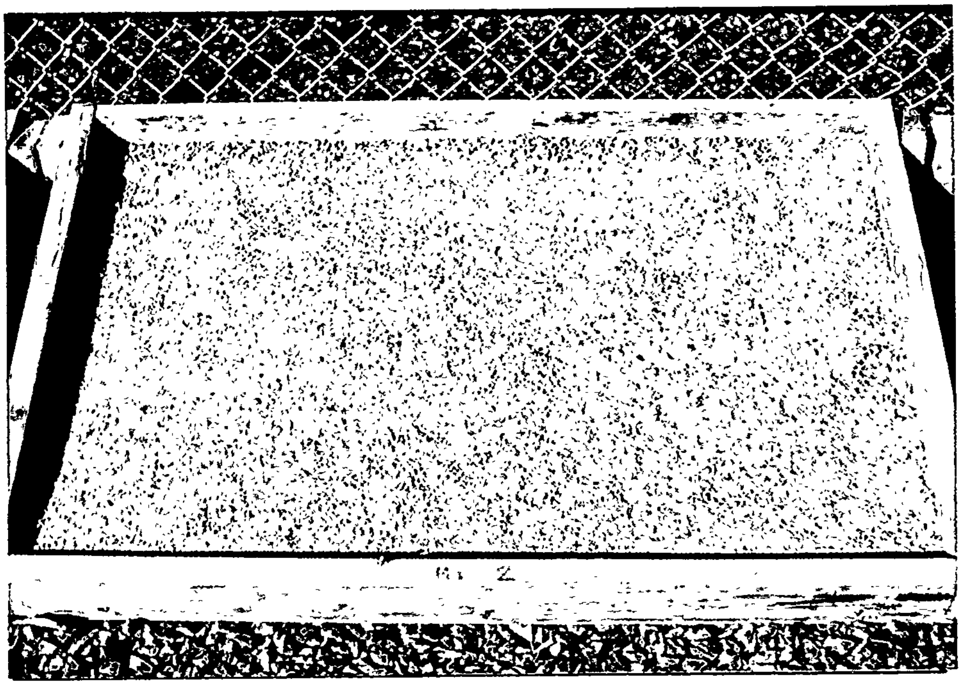
Table 1

Conclusions

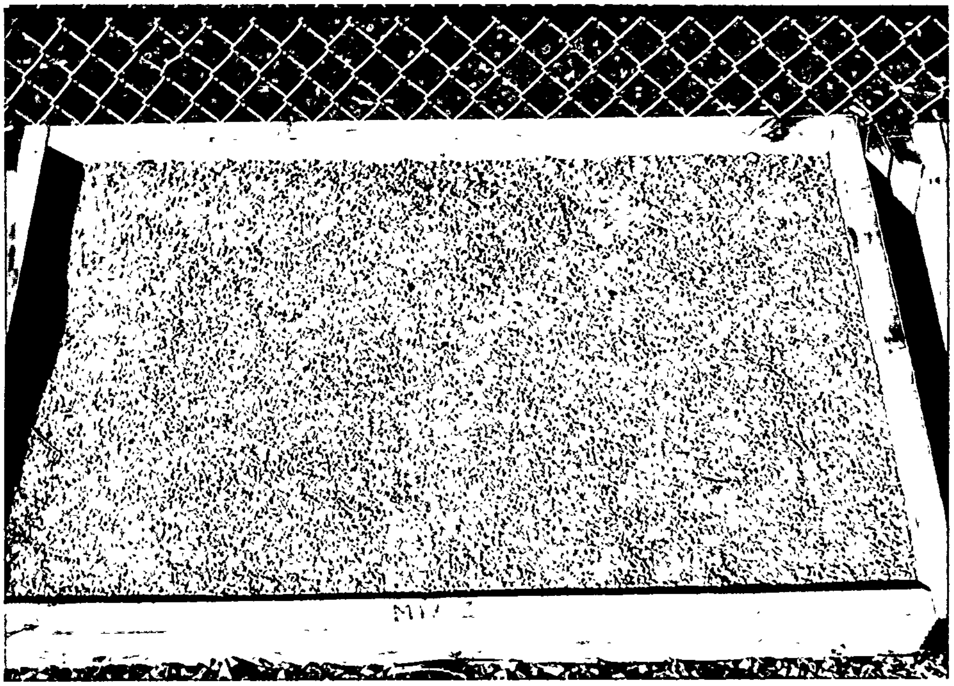
Overall, the mixtures containing fly ash fared quite well, and there was no single mixture which was clearly better than the rest. However, the economics of the mixtures must also be taken into account, if large scale applications are to be a reality. Among the mixtures which held up the best (1, 3, 5, 6, 7, 8, and 9), only one was truly economical: mixture #3. This mixture represents the entire ash stream produced by H-POWER, requires no additional processing, no stabilizing additives, and no mixing. Accordingly, mixture #3 was chosen as the top performer for this subtask.

Photographed November 22, 1993

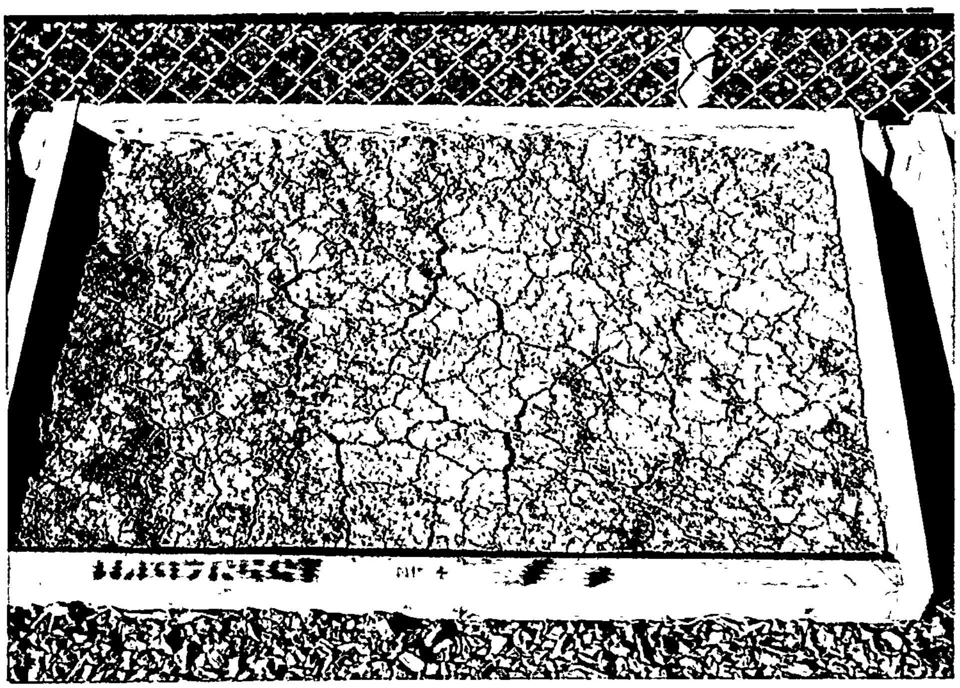
Mixture #1



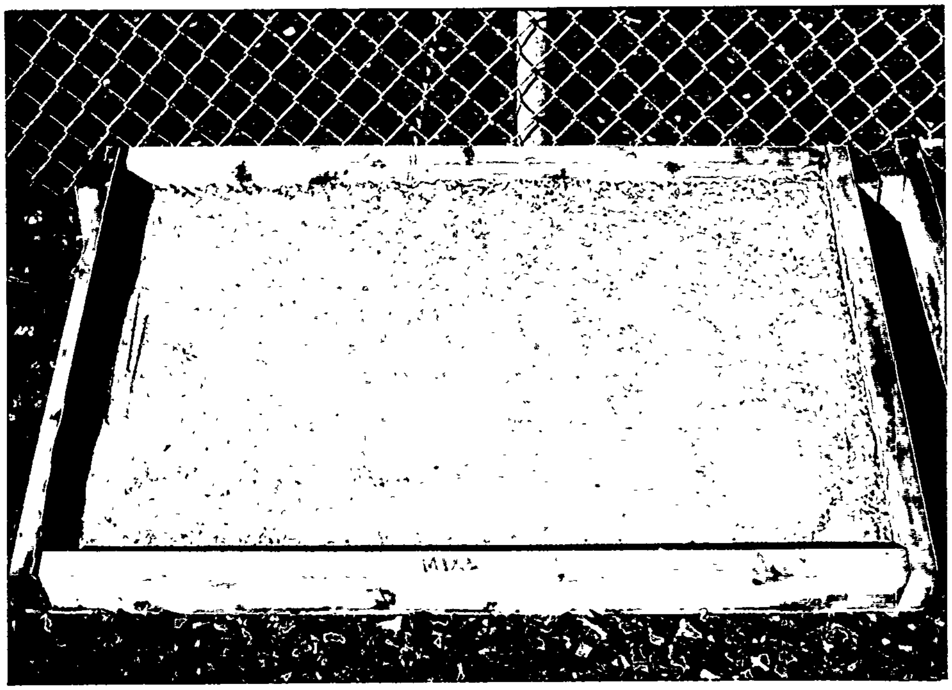
Mixture #2

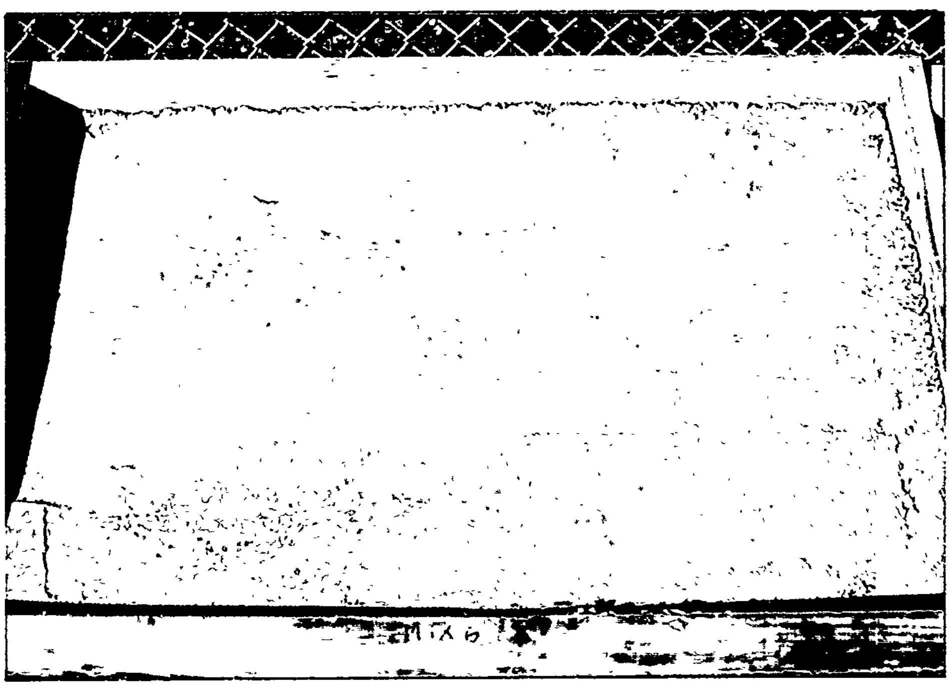


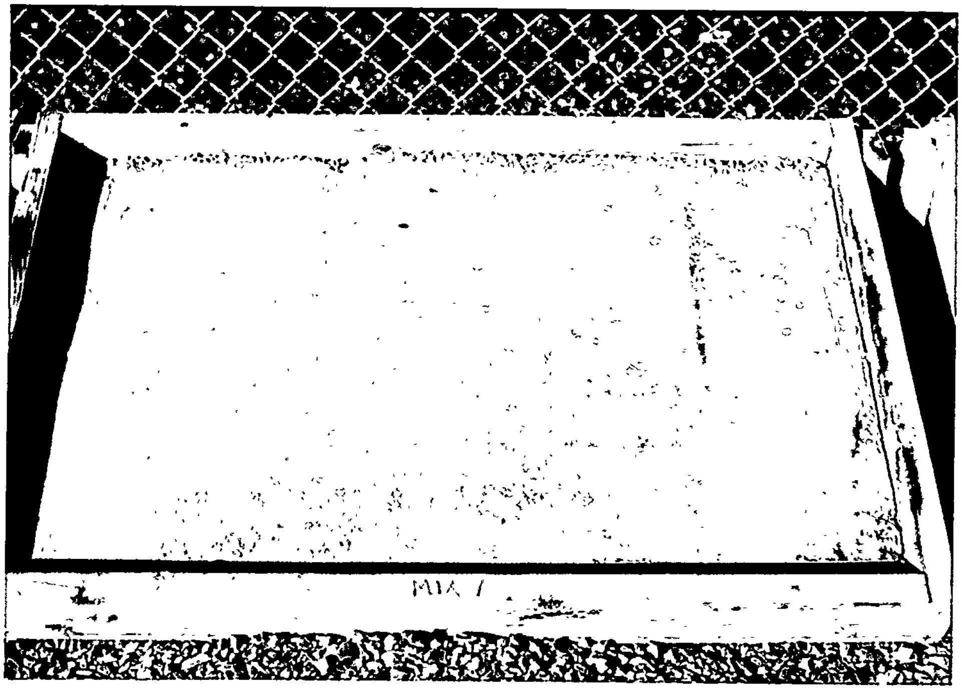
Mixture #3



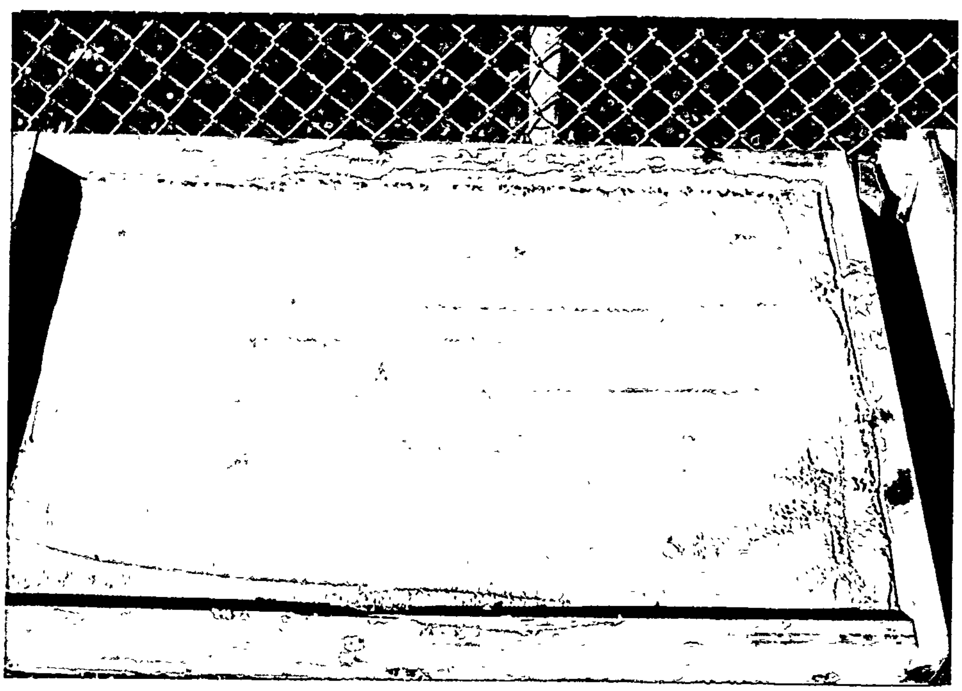
Mixture #4


Mixture #5

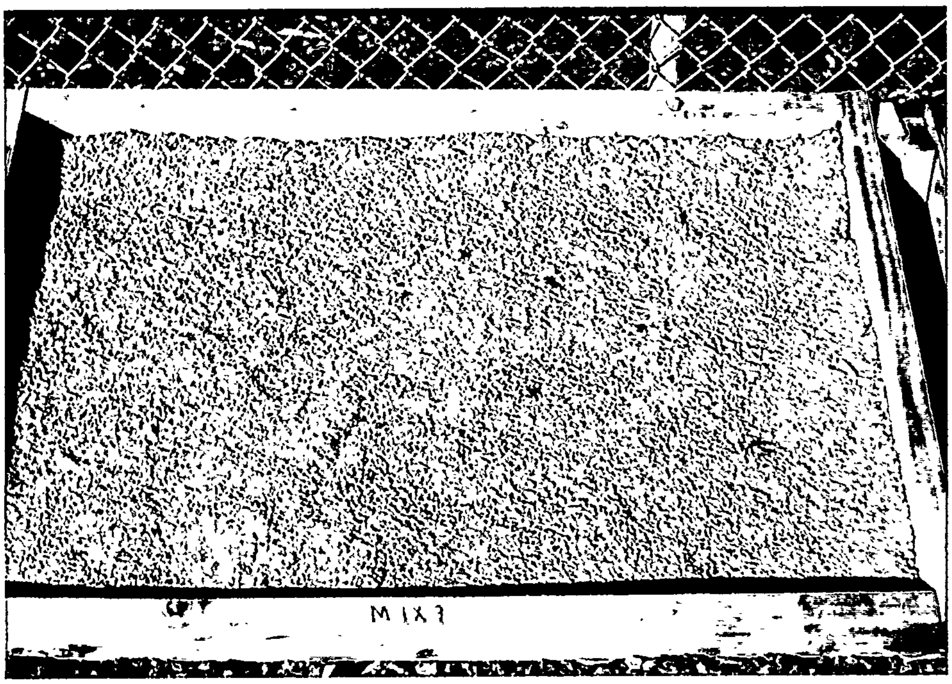

Mixture #6



Mixture #7

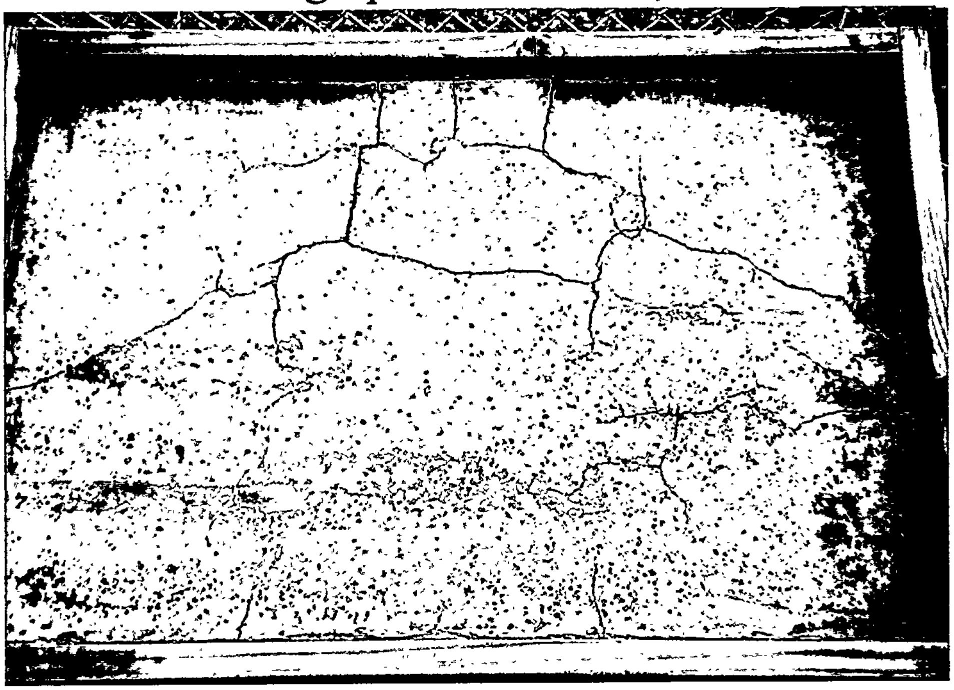


Mixture #8



Mixture #9

Photographed March 10, 1994



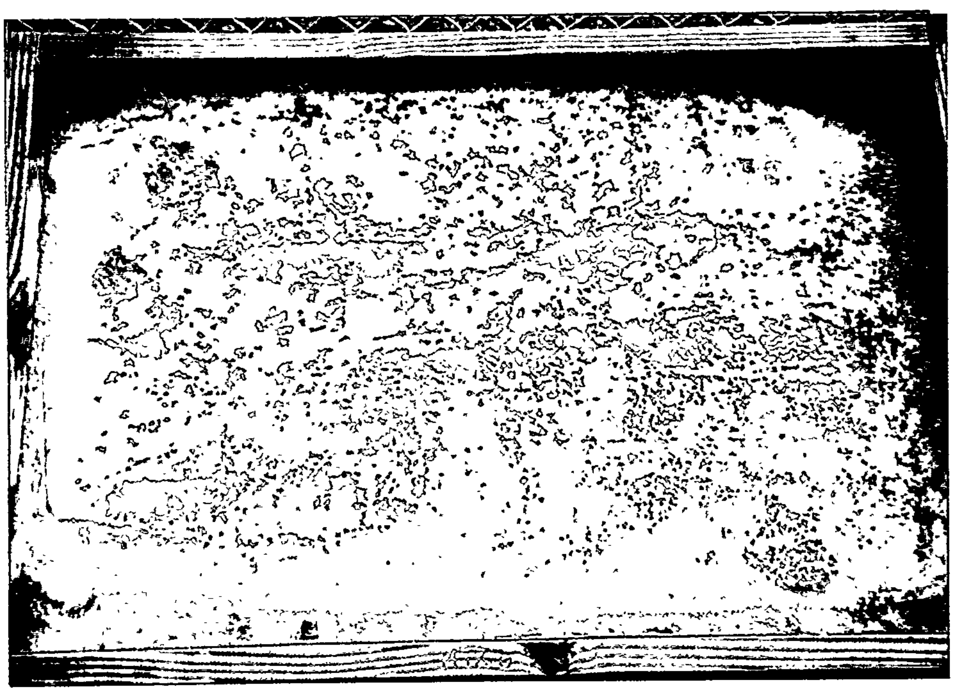
Mixture #1

Mixture #2

Mixture #3

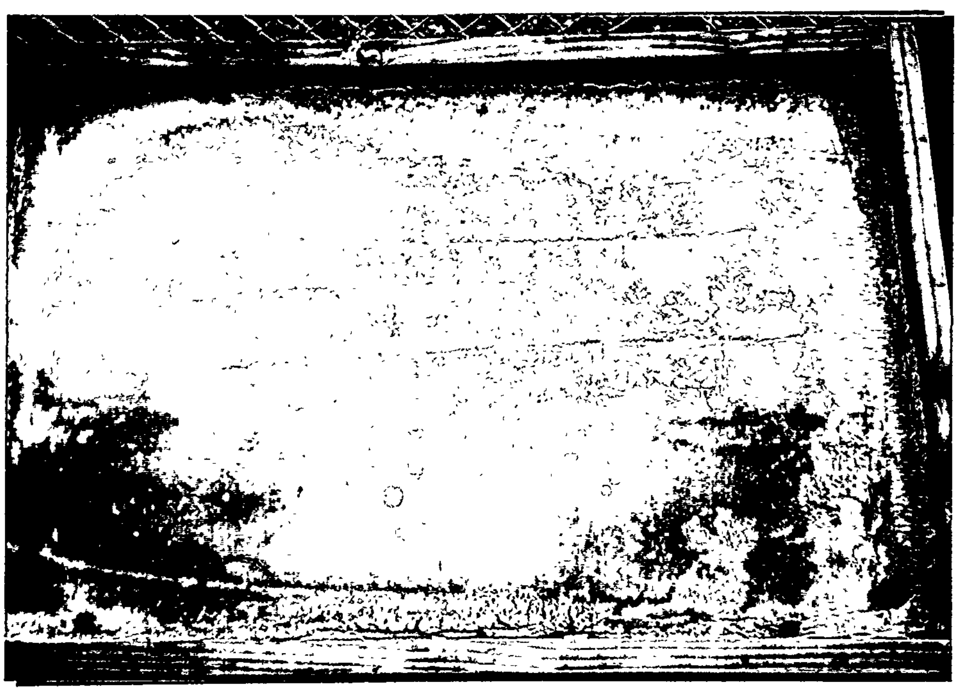
Mixture #4

Mixture #5

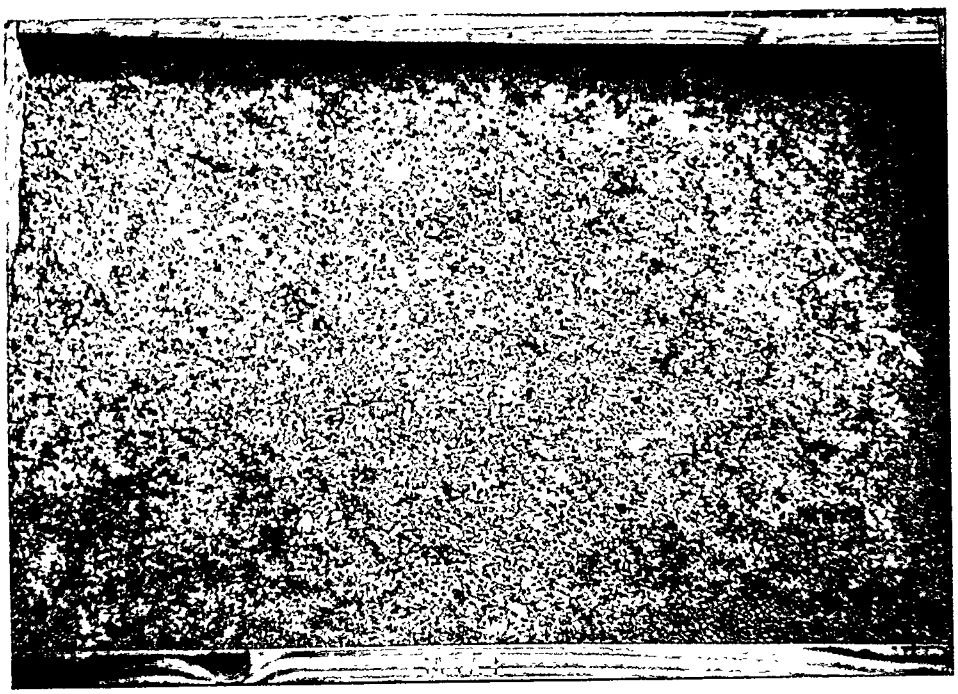


Mixture #6

Mixture #7



Mixture #8



Mixture #9

Appendix A7

Permeability Test Results

Three Task 1 ash mixtures (in addition to the control mixture) were chosen for permeability testing: mixtures 1, 5, and 9. These particular mixtures were selected on the assumption that they had the best chance of meeting the required criteria for final cover material.

Procedure

Prior to running the tests, modified proctor compaction tests were carried out to determine maximum dry density and optimum moisture of each mixture (a compaction test was also run on mixture 3 to determine its moisture-density relationship). The resulting compaction curves are included as Figures 2-6, beginning on page A7-4. A summary of the results appear in Table 1 below.

Mixture	Max Dry Density (pcf)	Optimum Moisture
1	81	33%
3	93	23%
4	111	20%
5	74	32%
9	99	22%

Table 1

After completing the compaction curves, samples were prepared at 90% of maximum dry density and at a moisture approximately 2% wet of optimum. The falling head permeameter was set up similar to that depicted in Figure 1.

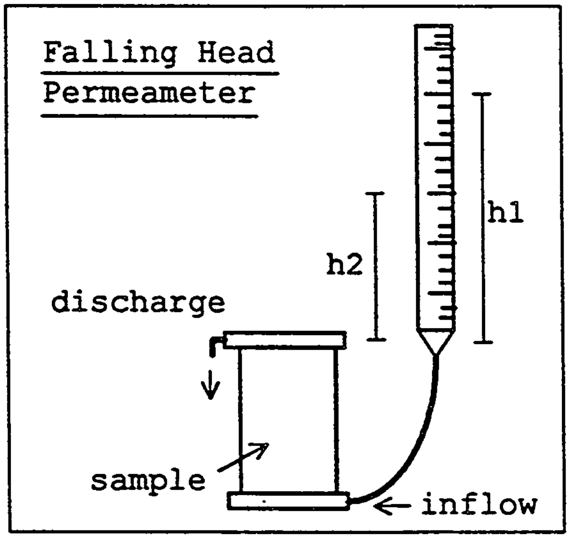


Figure 1

After the sample was prepared, a vacuum was applied to the discharge end of the permeameter to insure complete saturation of the sample. Once the sample was saturated, the vacuum was removed and periodic head measurements were recorded. The coefficient of hydraulic conductivity was then calculated using the following formula:

$$k = 2.303\, vl \frac{\log(\frac{h_i}{h_f})}{(h_i - h_f)at}$$

where
- v = volume change in burette (ml)
- l = length of sample (cm)
- h_i = initial head difference (cm)
- h_f = final head difference (cm)
- a = cross sectional area of sample (cm^2)
- t = duration of test run (sec)

After a sufficient number of runs were carried out (minimum of 4), an average was calculated for that sample. Three individual samples were prepared for each mixture, and an overall average calculated. These results appear in Table 2 below:

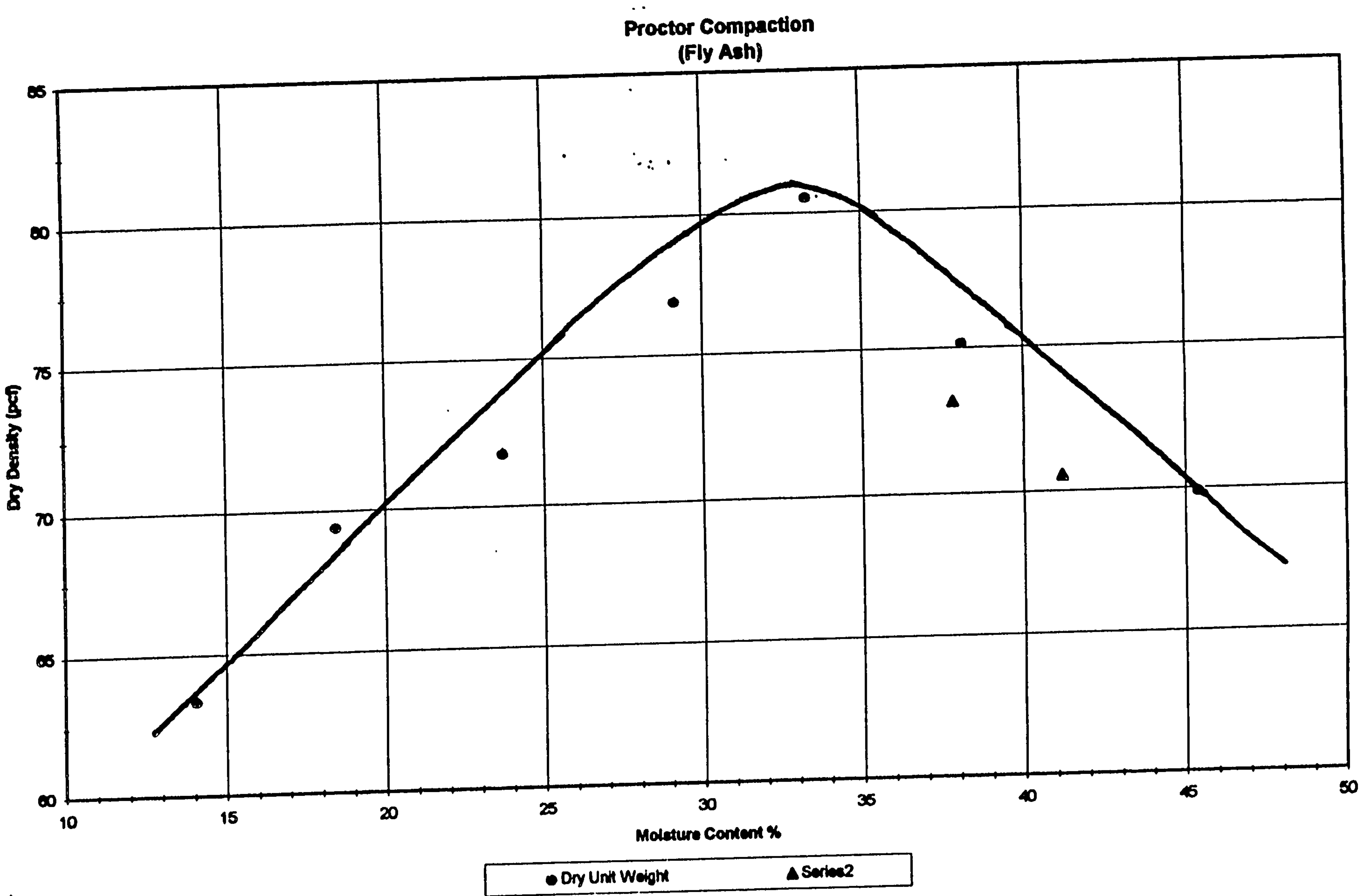
Mixture	k (cm/sec)
1	$1.66x10^{-6}$
4	$3.06x10^{-7}$
5	$4.39x10^{-6}$
9	$1.16x10^{-7}$

Table 2

Original laboratory data can be found in Tables 3-11, beginning on page A7-9.

Conclusions

The ash mixtures possess very low permeability coefficients, meeting the 1 X 10^{-5} cm/sec minimum criteria required for a final cover infiltration inhibiting liner (see Appendix A1). Pursuant to the results of the erosion resistance testing, permeability tests are also being carried out on mixture 3 to determine whether it can meet the criteria for cover material. Results of this test will be included as an addendum to this appendix.



Proctor Compaction
(Fly Ash)
Dry Density (pcf)
85
80
75
70
65
60
10
15
20
25
30
35
40
45
50
Moisture Content %
Dry Unit Weight
Series2

Figure 2

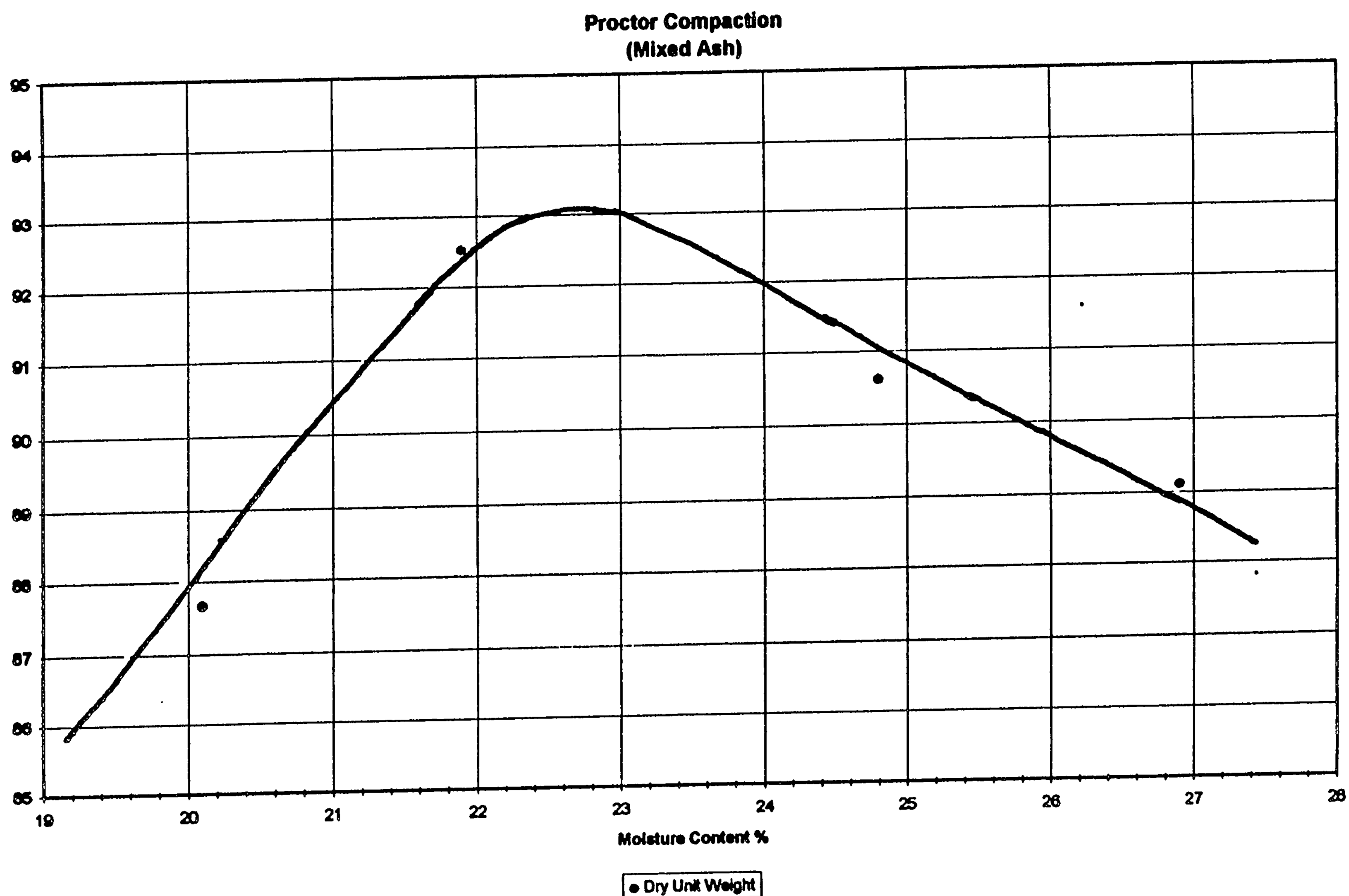

Proctor Compaction
(Mixed Ash)
95
94
93
92
91
90
89
88
87
86
85
19
20
21
22
23
24
25
26
27
28
Moisture Content %
Dry Unit Weight

Figure 3

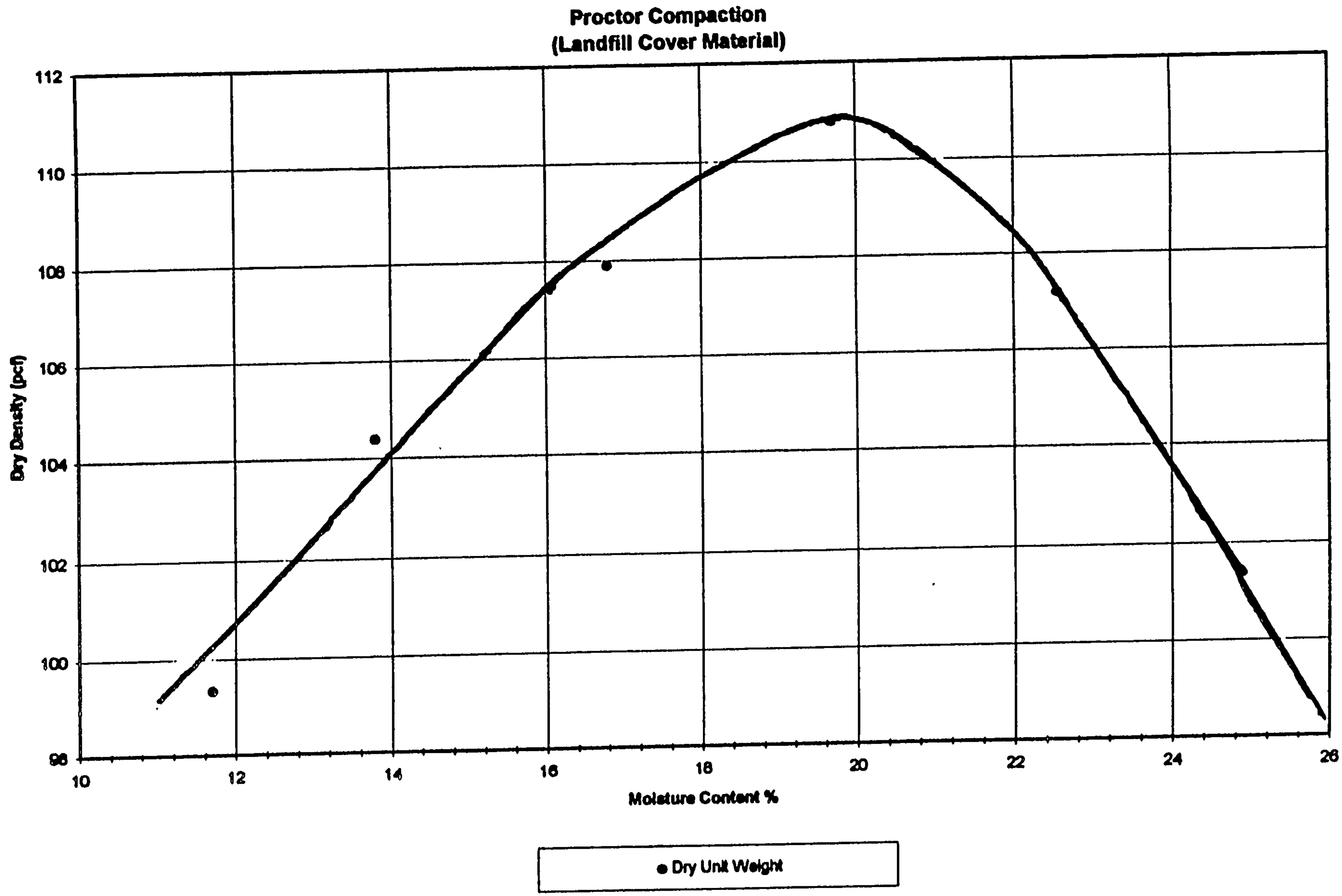

Proctor Compaction
(Landfill Cover Material)
Dry Density (pcf)
112
110
108
106
104
102
100
98
10
12
14
16
18
20
22
24
26
Moisture Content %
Dry Unit Weight

Figure 4

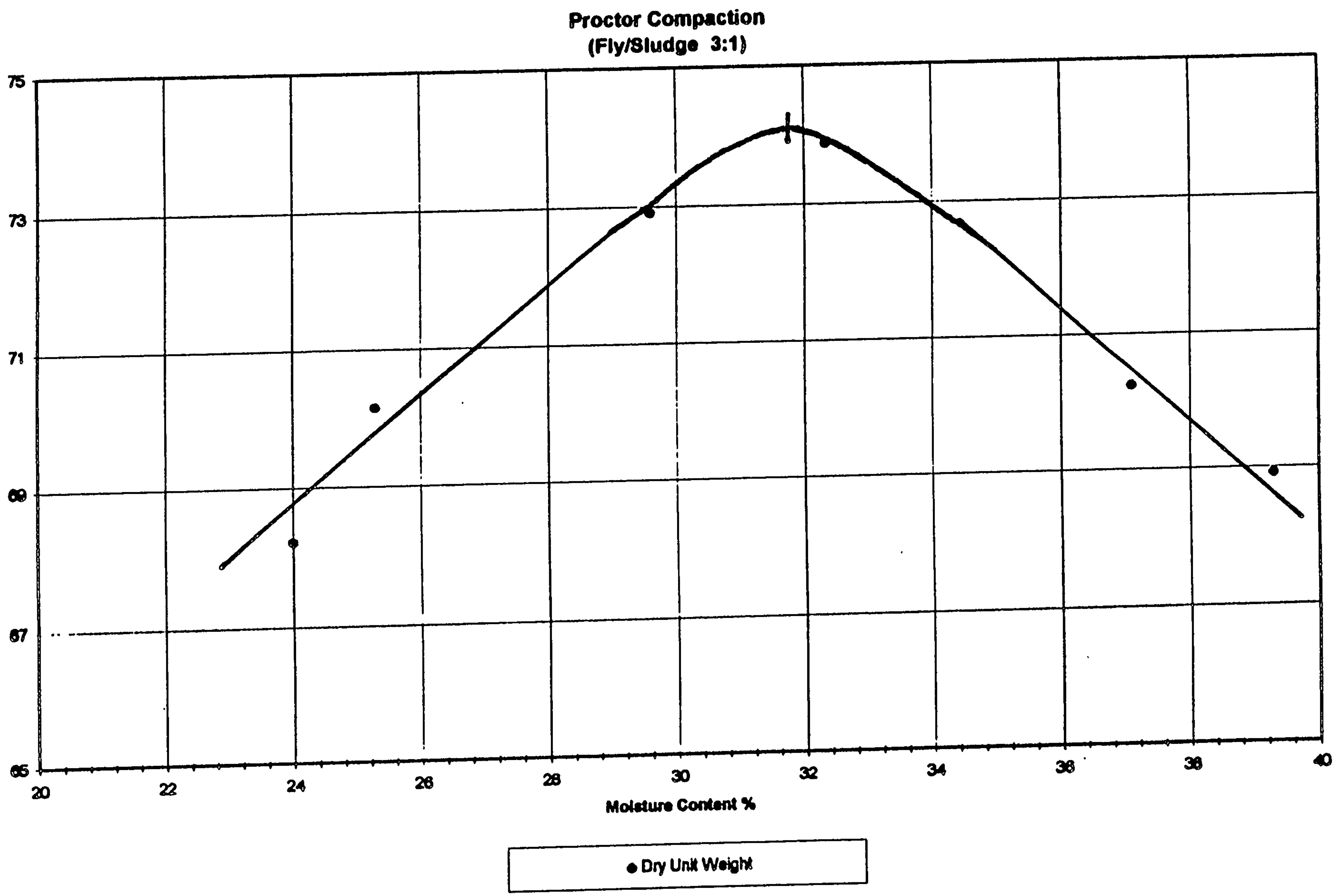

Proctor Compaction
(Fly/Sludge 3:1)
75
73
71
69
67
65
20
22
24
26
28
30
32
34
36
38
40
Moisture Content %
Dry Unit Weight

Figure 5

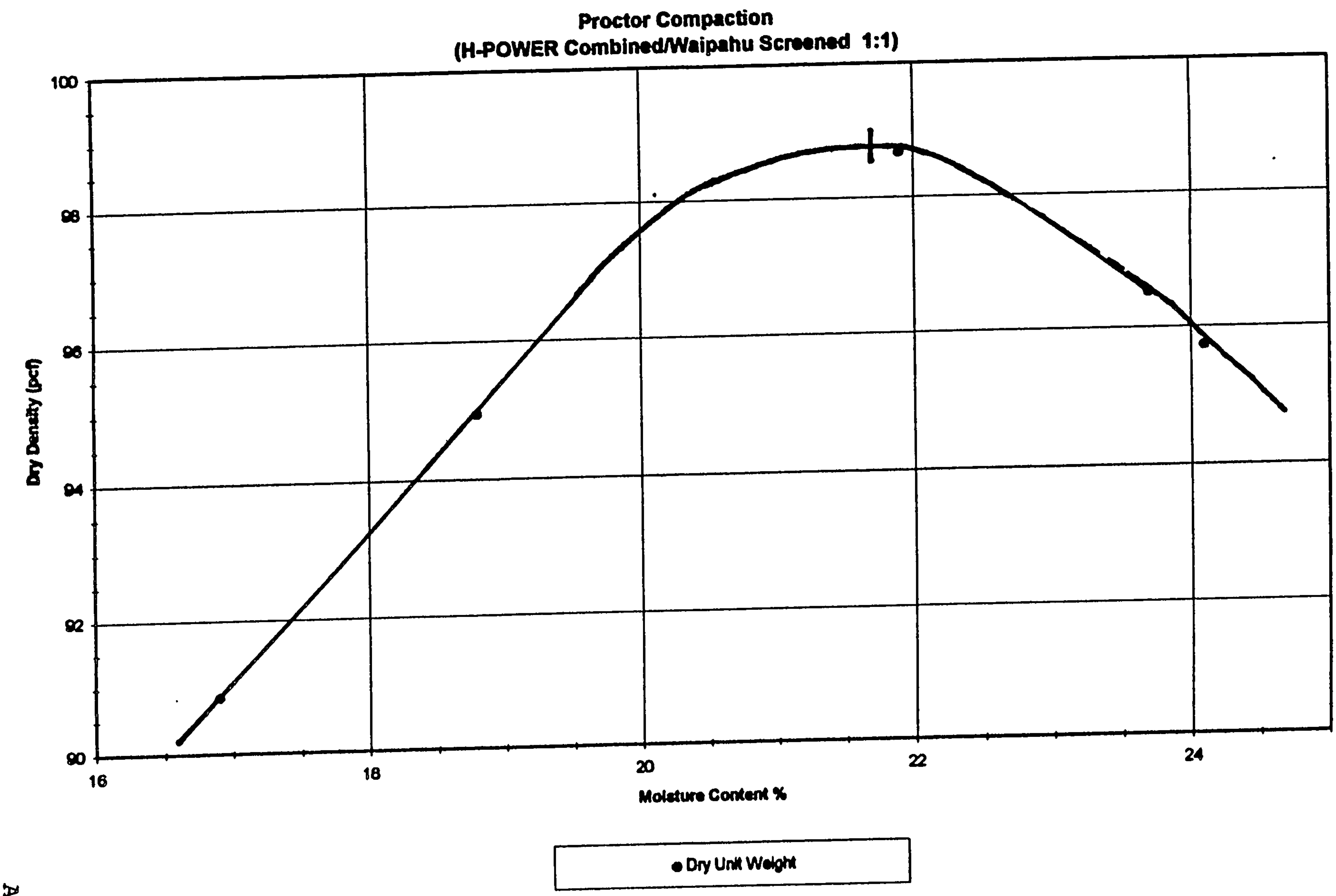

Proctor Compaction
(H-POWER Combined/Waipahu Screened 1:1)
Dry Density (pcf)
100
98
96
94
92
90
16
18
20
22
24
Moisture Content %
Dry Unit Weight

Figure 6

t (sec)	h init (cm)	h fin (cm)	vol (ml)	l (cm)	a (cm^2)	k (cm/sec)
116811	74.50	71.85	4.50	14.60	32.17	2.39E-07
82524	71.85	70.25	2.70	14.60	32.17	2.09E-07
142216	74.50	72.35	3.65	14.60	32.17	1.59E-07
85742	72.35	71.40	1.75	14.60	32.17	1.29E-07
86087	71.40	70.45	1.40	14.60	32.17	1.04E-07
303297	74.50	72.30	3.70	14.60	32.17	7.54E-08
252909	72.30	72.00	0.50	14.60	32.17	1.24E-08
					Avg	1.33E-07

Table 3--Mix #1 (1)

t (sec)	h init (cm)	h fin (cm)	vol (ml)	l (cm)	a (cm^2)	k (cm/sec)
660	138.1	137.14	1.6	3	32.17	1.64E-06
1260	137.14	135.4	2.9	3	32.17	1.58E-06
600	135.4	134.608	1.32	3	32.17	1.52E-06
660	134.608	133.72	1.48	3	32.17	1.56E-06
600	133.72	132.94	1.3	3	32.17	1.52E-06
600	132.94	132.19	1.25	3	32.17	1.47E-06
600	132.19	131.41	1.3	3	32.17	1.53E-06
600	131.41	130.66	1.25	3	32.17	1.48E-06
240	130.66	130.3	0.6	3	32.17	1.79E-06
360	130.3	129.88	0.7	3	32.17	1.39E-06
5940	129.88	122.62	12.1	3	32.17	1.51E-06
9420	122.62	112.06	17.6	3	32.17	1.49E-06
1980	112.06	109.99	3.45	3	32.17	1.46E-06
840	109.99	109.06	1.55	3	32.17	1.57E-06
2580	109.06	106.42	4.4	3	32.17	1.48E-06
					Avg	1.53E-06

Table 4--Mix #1 (2)

t (sec)	h init (cm)	h fin (cm)	vol (ml)	l (cm)	a (cm^2)	k (cm/sec)
46800	136	135.7	0.5	7.5	32.17	1.83E-08
16680	135.7	135.22	0.8	7.5	32.17	8.26E-08
5400	135.22	135.1	0.2	7.5	32.17	6.39E-08
6120	135.1	134.92	0.3	7.5	32.17	8.47E-08
45300	134.92	133.72	2	7.5	32.17	7.66E-08
13800	133.72	133.36	0.6	7.5	32.17	7.59E-08
17400	133.36	132.94	0.7	7.5	32.17	7.05E-08
6300	132.94	132.76	0.3	7.5	32.17	8.36E-08
46800	132.76	131.56	2	7.5	32.17	7.54E-08
6300	131.56	131.43	0.22	7.5	32.17	6.19E-08
3600	131.43	131.32	0.18	7.5	32.17	8.87E-08
19800	131.32	130.84	0.8	7.5	32.17	7.19E-08
7200	130.84	130.66	0.3	7.5	32.17	7.43E-08
221700	130.66	124.6	10.1	7.5	32.17	8.32E-08
39600	124.6	124.3	0.5	7.5	32.17	2.37E-08
					Avg	6.90E-08

Table 5--Mix #4 (1)

t (sec)	h init (cm)	h fin (cm)	vol (ml)	l (cm)	a (cm^2)	k (cm/sec)
9600	138.1	135.46	4.4	7.5	32.17	7.81E-07
6000	135.46	134.02	2.4	7.5	32.17	6.92E-07
1800	134.02	133.54	0.8	7.5	32.17	7.75E-07
5400	133.54	132.28	2.1	7.5	32.17	6.82E-07
1500	132.28	131.98	0.5	7.5	32.17	5.88E-07
5100	131.98	130.9	1.8	7.5	32.17	6.26E-07
4200	130.9	130.03	1.45	7.5	32.17	6.17E-07
4200	130.03	129.16	1.45	7.5	32.17	6.21E-07
37800	129.16	122.14	11.7	7.5	32.17	5.75E-07
9780	122.14	120.58	2.6	7.5	32.17	5.11E-07
10440	120.58	118.9	2.8	7.5	32.17	5.22E-07
3180	118.9	118.42	0.8	7.5	32.17	4.94E-07
4800	118.42	117.7	1.2	7.5	32.17	4.94E-07
4800	117.7	116.98	1.2	7.5	32.17	4.97E-07
6300	116.98	116.02	1.6	7.5	32.17	5.08E-07
3600	116.02	115.48	0.9	7.5	33.17	4.88E-07
47100	115.48	109.06	10.7	7.5	34.17	4.44E-07
9180	109.06	107.98	1.8	7.5	35.17	3.85E-07
2820	107.98	107.38	1	7.5	36.17	6.83E-07
8400	107.38	106.42	1.6	7.5	37.17	3.60E-07
8400	106.42	105.4	1.7	7.5	38.17	3.76E-07
13800	105.4	103.54	3.1	7.5	39.17	4.12E-07
47400	103.54	98.14	9	7.5	40.17	3.52E-07
					Avg	5.43E-07

Table 6--Mix #4 (2)

t (sec)	h init (cm)	h fin (cm)	vol (ml)	l (cm)	a (cm^2)	k (cm/sec)
1326	70.4	68	4	7.5	32.17	1.02E-05
1313	67.4	65	4	7.5	32.17	1.07E-05
1437	63.8	61.4	4	7.5	32.17	1.04E-05
1162	78	75.6	4	7.5	32.17	1.05E-05
1250	74.4	72.05	4	7.5	32.17	1.02E-05
2454	78	73.25	8	7.5	32.17	1.01E-05
2661	72.9	68.2	8	7.5	32.17	9.94E-06
					Avg	1.03E-05

Table 7--Mix #5 (1)

t (sec)	h init (cm)	h fin (cm)	vol (ml)	l (cm)	a (cm^2)	k (cm/sec)
116811	72.7	57.1	26.4	7.5	32.17	8.16E-07
82524	57.1	48.9	13.8	7.5	32.17	7.37E-07
142216	72.7	63.1	16.3	7.5	32.17	3.94E-07
85742	63.1	61.25	1.2	7.5	32.17	5.25E-08
					Avg	5.00E-07

Table 8--Mix #5 (2)

t (sec)	h init (cm)	h fin (cm)	vol (ml)	l (cm)	a (cm^2)	k (cm/sec)
92718	83.6	64.25	32.8	7.5	32.17	1.12E-06
126506	83.6	59.5	40.6	7.5	32.17	1.06E-06
2881	218.9	213.1	8.6	7.5	32.17	3.22E-06
8217	213.1	200.1	22.7	7.5	32.17	3.12E-06
37996	218.9	166.8	86.4	7.5	32.17	2.77E-06
21177	218.9	191	45.1	7.5	32.17	2.43E-06
26571	218.9	186.5	55	7.5	32.17	2.39E-06
42670	218.9	173.1	77.6	7.5	32.17	2.17E-06
23994	218.9	193.3	43.4	7.5	32.17	2.05E-06
					Avg	2.26E-06

Table 9--Mix #5 (3)

t (sec)	h init (cm)	h fin (cm)	vol (ml)	l (cm)	a (cm^2)	k (cm/sec)
116811	79.75	77	4.6	7.5	32.17	1.17E-07
82524	77	75.15	3.2	7.5	32.17	1.19E-07
142216	79.75	76.35	5.7	7.5	32.17	1.20E-07
85742	76.35	74.4	3.3	7.5	32.17	1.19E-07
86087	74.4	72.5	3.2	7.5	32.17	1.18E-07
303297	79.75	72.65	12	7.5	32.17	1.21E-07
252909	72.65	68.1	7.7	7.5	32.17	1.01E-07
					Avg	1.16E-07

Table 10--Mix #9 (1)

t (sec)	h init (cm)	h fin (cm)	vol (ml)	l (cm)	a (cm^2)	k (cm/sec)
17400	103.7	102.74	1.6	7.5	32.17	2.08E-07
6300	102.74	102.44	0.5	7.5	32.17	1.80E-07
46800	102.44	100.34	3.5	7.5	32.17	1.72E-07
6300	100.34	100.1	0.4	7.5	32.17	1.48E-07
3600	100.1	99.92	0.3	7.5	32.17	1.94E-07
19800	99.92	99.14	1.3	7.5	32.17	1.54E-07
7200	99.14	98.9	0.4	7.5	32.17	1.31E-07
49500	98.9	93.38	9.2	7.5	32.17	4.50E-07
39600	93.38	93.2	0.3	7.5	32.17	1.84E-08
					Avg	1.84E-07

Table 11--Mix #9 (2)

Appendix A8

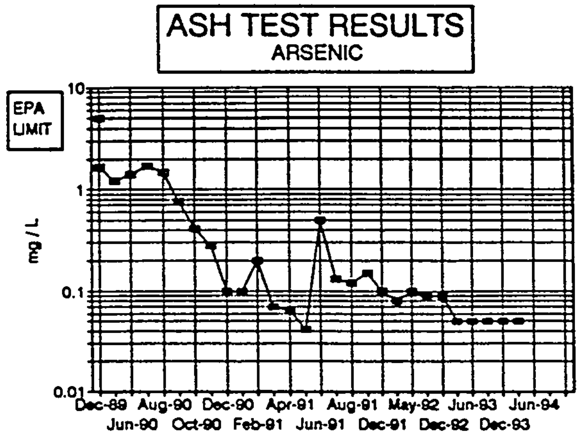
Ash TCLP Test Results

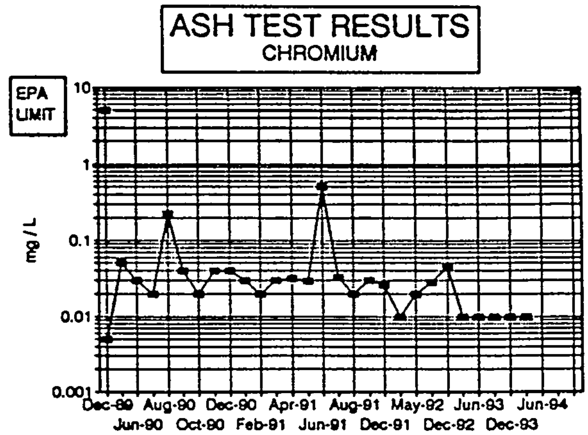
H-POWER has been conducting leachate testing on its ash since the plant became operational in 1989. To date, over 400 samples have consistently tested well below EPA limits for toxic metal concentrations. Table 1 below summarizes the results of the leachate testing. The figures on pages 2 and 3 provide a graphical representation of this data.

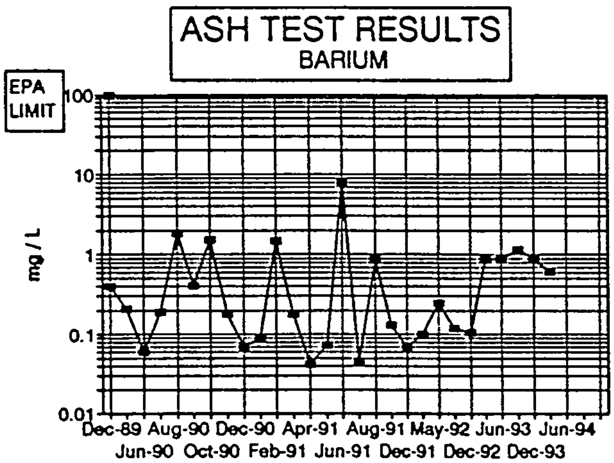
	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver	Copper	TCDD	TCDF
EPA STD MG/L	5	100	1	5	5	0.2	1	5	–	ng/gm	ng/gm
EPA Drinking Water MG/L	0.05	1	0.01	0.05	0.05	0.002	0.01	0.05	—	[no limits now available]	
Dec-89	1.64	0.4	0.34	0.005	1.88	0.003	0.64	0.03			
Feb-90	1.23	0.21	0.09	0.05	0.64	0.00062	0.42	0.03			
Jun-90	1.42	0.06	0.16	0.03	0.4	0.008	0.44	0.03			
Jul-90	1.72	0.19	0.16	0.02	1.22	0.00056	0.28	0.02			
Aug-90	1.47	1.82	0.23	0.22	1.49	0.001	0.72	0.02			
Sep-90	0.77	0.41	0.21	0.04	0.92	0.002	0.35	0.05			
Oct-90 **	0.407	1.53	0.017	0.02	0.23	0.003	0.1	0.02			
Nov-90	0.28	0.18	0.28	0.04	1.08	0.02	0.08	0.05			
Dec-90	0.1	0.07	0.29	0.04	2.73	0.0008	0.04	0.06			
Jan-91	0.1	0.09	0.21	0.03	0.54	0.004	0.04	0.03			
Feb-91 **	0.2	1.45	0.02	0.02	0.52	0.0008	0.08	0.05			
Mar-91	0.07	0.18	0.18	0.03	0.25	0.01	0.05	0.05	0.09		
Apr-91	0.065	0.042	0.118	0.032	0.0635	0.00095	0.047	0.04			
May-91	0.042	0.074	0.102	0.029	0.152	0.0033	0.033	0.016			
Jun-91	0.5	8.05	0.142	0.5	0.74	0.00068	0.1	0.5			
Jul-91	0.133	0.045	0.117	0.033	0.102	0.002	0.034	0.044			
Aug-91 **	0.12	0.88	0.02	0.02	0.33	0.005	0.08	0.19			
Sep-91	0.15	0.13	0.12	0.03	0.16	0.0003	0.27	0.03			
Dec-91	0.1	0.07	0.24	0.026	0.8	0.0016	0.047	0.018			
Mar-92	0.08	0.1	0.08	0.01	0.08	0.00099	0.04	0.02		0.267	1.37
May-92	0.1	0.25	0.19	0.02	0.181	0.00016	0.1	0.01		0.305	1.75
Aug-92	0.09	0.12	0.3	0.028	2.08	0.0007	0.06	0.04		0.143	1
Dec-92	0.09	0.106	0.47	0.045	1.73	0.0034	0.0662	0.0392			
Mar-93	0.05	0.89	0.23	0.01	0.34	0.00505	0.05	0.04			
Jun-93	0.05	0.89	0.21	0.01	0.58	0.0038	0.05	0.05			
Sep-93	0.05	1.14	0.01	0.01	0.26	0.00134	0.05	0.05		1.272	9.035
Dec-93	0.05	0.89	0.05	0.01	0.25	0.0015	0.05	0.05		0.427	2.85
Mar-94	0.05	0.61	0.08	0.01	0.108	0.0012	0.05	0.01			
AVERAGE	0.397393	0.745607	0.166643	0.0488571	0.709161	0.003063	0.155971	0.056686	0.09		

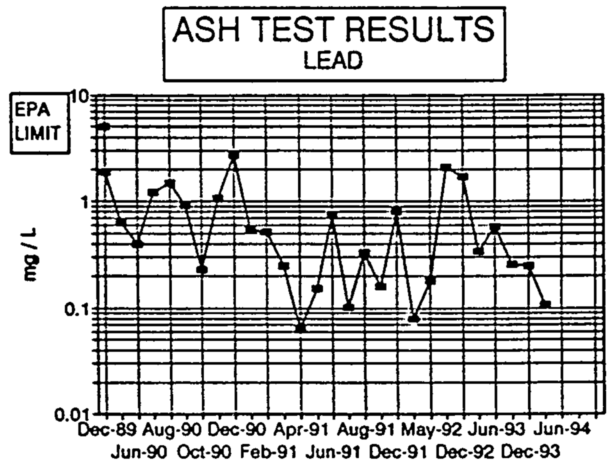
** Trimester testing using water leachate per EPA Method SW924
Maximum values of three batches tested as reported in ABB ltr dated 1/31/91

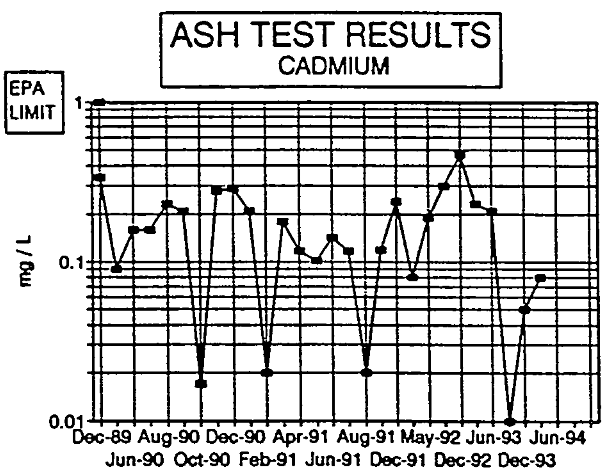
Table 1

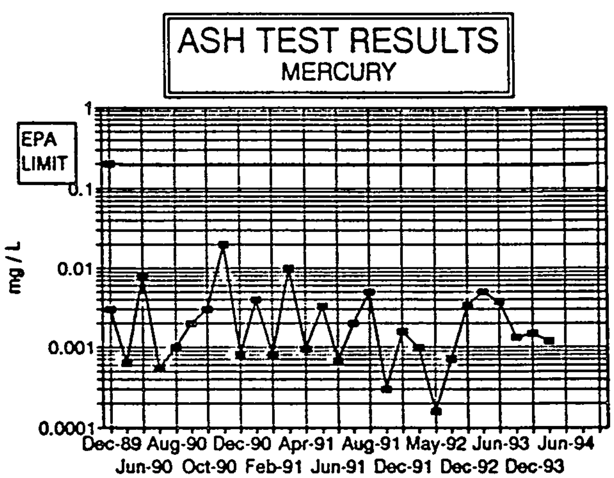

ASH TEST RESULTS
ARSENIC
EPA LIMIT
mg / L
10
1
0.1
0.01
Dec-89 Aug-90 Dec-90 Apr-91 Aug-91 May-92 Jun-93 Jun-94
Jun-90 Oct-90 Feb-91 Jun-91 Dec-91 Dec-92 Dec-93

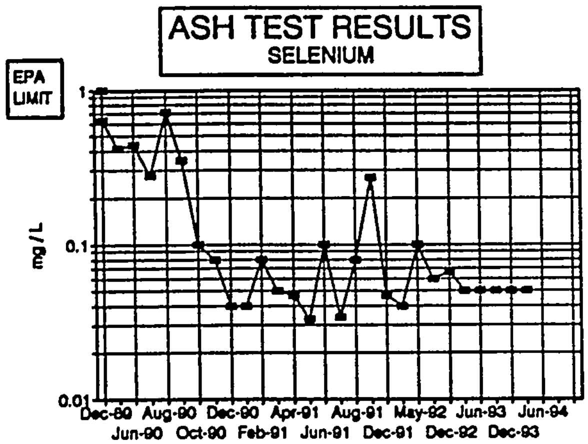

ASH TEST RESULTS
CHROMIUM
EPA LIMIT
mg / L
10
1
0.1
0.01
0.001
Dec-89 Aug-90 Dec-90 Apr-91 Aug-91 May-92 Jun-93 Jun-94
Jun-90 Oct-90 Feb-91 Jun-91 Dec-91 Dec-92 Dec-93

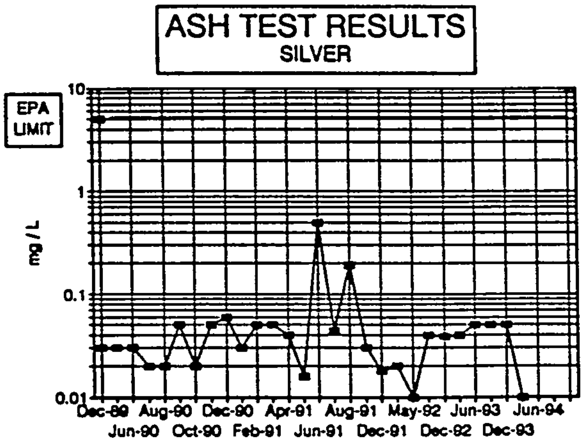

ASH TEST RESULTS
BARIUM
EPA LIMIT
mg / L
100
10
1
0.1
0.01
Dec-89 Aug-90 Dec-90 Apr-91 Aug-91 May-92 Jun-93 Jun-94
Jun-90 Oct-90 Feb-91 Jun-91 Dec-91 Dec-92 Dec-93


ASH TEST RESULTS
LEAD
EPA LIMIT
mg / L
10
1
0.1
0.01
Dec-89 Aug-90 Dec-90 Apr-91 Aug-91 May-92 Jun-93 Jun-94
Jun-90 Oct-90 Feb-91 Jun-91 Dec-91 Dec-92 Dec-93


ASH TEST RESULTS
CADMIUM
EPA LIMIT
mg / L
1
0.1
0.01
Dec-89 Aug-90 Dec-90 Apr-91 Aug-91 May-92 Jun-93 Jun-94
Jun-90 Oct-90 Feb-91 Jun-91 Dec-91 Dec-92 Dec-93


ASH TEST RESULTS
MERCURY
EPA LIMIT
mg / L
1
0.1
0.01
0.001
0.0001
Dec-89 Aug-90 Dec-90 Apr-91 Aug-91 May-92 Jun-93 Jun-94
Jun-90 Oct-90 Feb-91 Jun-91 Dec-91 Dec-92 Dec-93


ASH TEST RESULTS
SELENIUM
EPA LIMIT
mg / L
1
0.1
0.01
Dec-89 Aug-90 Dec-90 Apr-91 Aug-91 May-92 Jun-93 Jun-94
Jun-90 Oct-90 Feb-91 Jun-91 Dec-91 Dec-92 Dec-93


ASH TEST RESULTS
SILVER
EPA LIMIT
mg / L
10
1
0.1
0.01
Dec-89 Aug-90 Dec-90 Apr-91 Aug-91 May-92 Jun-93 Jun-94
Jun-90 Oct-90 Feb-91 Jun-91 Dec-91 Dec-92 Dec-93

Appendix B1

Sieve Analysis Results

Introduction

The sieve analyses were included in order to classify the various ash types as a possible aggregate source. Three ash types were tested: H-POWER processed bottom ash, H-POWER combined ash, and Waipahu Incinerator ash. The Waipahu ash used herein was first run through the BAMR at H-POWER. Both Hawaiian Bitumuls and Grace Pacific were instrumental in performing the analyses. Data was compiled from both sources and is presented in this appendix. The following U.S. Standard sieve sizes were used:

3/4" (19.05 mm)	1/2" (12.7 mm)	3/8" (9.53 mm)
#4 (4.75 mm)	#8 (2.36 mm)	#16 (1.18 mm)
#30 (0.60 mm)	#50 (0.30 mm)	#100 (0.15 mm)
#200 (0.075 mm)		

Recognizing that there are many different conventions for reporting particle size distributions, we have made an effort to use whichever method seemed to best characterize the material. In most cases, the data is reported as the percent retained on each particular screen size. This was done primarily to aid in the qualitative analysis of the ash, and also in anticipation of being able to use only selected size fractions. Whenever possible, the percent passing (or percent finer) is also reported.

Results

Table 1 contains a summary of the entire sieve analysis. The top of the table contains the individual trials along with the averages, reported as percent retained. The cumulative percent retained from (#16 and below) is also included as this size fraction seemed to be the best suited for the anticipated use. The bottom of the table includes only the average gradations for the ash types, but reported as percent passing each screen size.

Tables 2-7 contain the original sieve analysis data (two sets for each type), and Figures 1,2, and 3 are their respective graphical representations.

Tables 8-12 contain sieve data pertaining only to H-POWER combined ash. These tests were included to determine what effect dry mixing would have on the overall gradation. As the results in Figure 4 indicate, the "normally-mixed" and then oven-dried ash showed a considerably smaller amount of fine material (-#100), than did the samples which were dried prior to mixing. This is believed to be a result of the fly ash pelletizing upon mixing with the wet bottom ash.

SIEVE ANALYSIS

Summary

	Sieve Size Distribution (% Retained)											
U.S.S. Sieve Size	3\4	1\2	3\8	#4	#8	#16	#30	#50	#100	#200	<#200	Cum. % Retained
Sieve Size (mm)	19.00	12.70	9.53	4.75	2.36	1.18	0.60	0.30	0.15	0.075	<0.075	From #16 to -#200
H-POWER Bottom Ash - Trial 1	0.00%	3.33%	3.90%	17.75%	27.15%	23.33%	11.09%	5.63%	3.24%	2.46%	2.12%	47.87%
H-POWER Bottom Ash - Trial 2	2.20%	4.30%	4.34%	13.72%	27.20%	25.60%	10.33%	5.51%	3.25%	1.64%	1.91%	48.24%
H-POWER Bottom Ash - Average	1.10%	3.82%	4.12%	15.74%	27.18%	24.47%	10.71%	5.57%	3.25%	2.05%	2.02%	48.06%
H-POWER Combined Ash - Trial 1	0.15%	3.15%	3.37%	15.45%	26.66%	19.21%	10.37%	8.66%	7.26%	3.61%	2.10%	51.21%
H-POWER Combined Ash - Trial 2	0.74%	0.99%	2.82%	15.59%	25.63%	21.15%	11.12%	9.79%	7.27%	3.33%	1.58%	54.24%
H-POWER Combined Ash - Average	0.45%	2.07%	3.10%	15.52%	26.15%	20.18%	10.75%	9.23%	7.27%	3.47%	1.84%	52.73%
Waipahu Combined Ash - Trial 1	1.52%	11.35%	11.39%	24.21%	15.82%	10.06%	6.67%	5.63%	5.23%	7.06%	1.05%	35.70%
Waipahu Combined Ash - Trial 2	2.28%	9.03%	12.18%	16.07%	15.09%	12.90%	9.75%	7.75%	6.61%	3.79%	4.55%	45.35%
Waipahu Combined Ash - Average	1.90%	10.19%	11.79%	20.14%	15.46%	11.48%	8.21%	6.69%	5.92%	5.43%	2.80%	40.53%

	Sieve Size Distribution (% Passing)										
U.S.S. Sieve Size	3\4	1\2	3\8	#4	#8	#16	#30	#50	#100	#200	<#200
Sieve Size (mm)	19.00	12.70	9.53	4.75	2.36	1.18	0.60	0.30	0.15	0.075	<0.075
H-POWER Bottom Ash - Average	98.90%	95.09%	90.97%	75.23%	48.06%	23.59%	12.88%	7.31%	4.06%	2.01%	0.00%
H-POWER Combined Ash - Average	99.56%	97.49%	94.39%	78.87%	52.73%	32.55%	21.80%	12.58%	5.31%	1.84%	0.00%
Waipahu Combined Ash - Average	98.10%	87.91%	76.13%	55.99%	40.53%	29.05%	20.84%	14.15%	8.23%	2.80%	0.00%

Table 1

SIEVE ANALYSIS
H-POWER Bottom Ash
Trial 1

Size	Weight (g)	% Retained	Cum % Ret.	% Passing
3/4	0	0.00%	0.00%	100.00%
1/2	128.2	3.33%	3.33%	96.67%
3/8	150.3	3.90%	7.23%	92.77%
4	683.7	17.75%	24.98%	75.02%
8	1045.8	27.15%	52.14%	47.86%
16	898.5	23.33%	75.47%	24.53%
30	427	11.09%	86.55%	13.45%
50	216.9	5.63%	92.18%	7.82%
100	124.8	3.24%	95.43%	4.57%
200	94.7	2.46%	97.88%	2.12%
-200	81.5	2.12%	100.00%	0.00%
Total	3851.4			
F.M	4.37			

Table 2

SIEVE ANALYSIS

H-POWER Bottom Ash
Trial 2

Size	Weight (g)	% Retained	Cum % Ret.	% Passing
3/4	60.7	2.20%	2.20%	97.80%
1/2	118.6	4.30%	6.50%	93.50%
3/8	119.7	4.34%	10.83%	89.17%
4	378.7	13.72%	24.55%	75.45%
8	750.8	27.20%	51.75%	48.25%
16	706.7	25.60%	77.35%	22.65%
30	285.1	10.33%	87.68%	12.32%
50	152.2	5.51%	93.20%	6.80%
100	89.6	3.25%	96.44%	3.56%
200	45.4	1.64%	98.09%	1.91%
-200	52.8	1.91%	100.00%	0.00%
Total	2760.3			
F.M	4.51			

Table 3

SIEVE ANALYSIS
H-POWER Bottom Ash

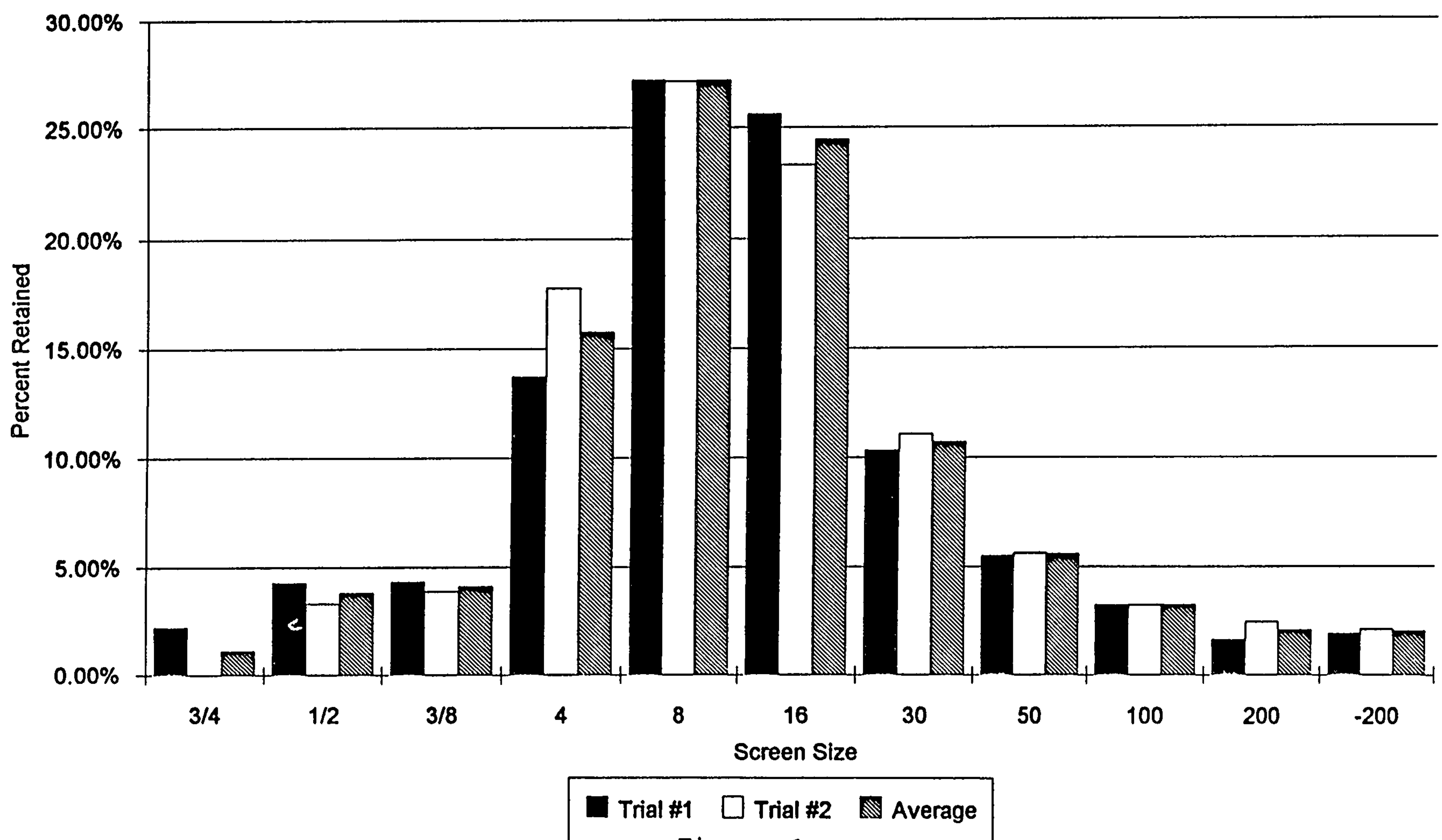


Figure 1

SIEVE ANALYSIS

H-POWER Combined Ash

Trial 1

Size	Weight (g)	% Retained	Cum % Ret.	% Passing
3/4	4.4	0.15%	0.15%	99.85%
1/2	93.2	3.15%	3.30%	96.70%
3/8	99.8	3.37%	6.67%	93.33%
4	456.9	15.45%	22.12%	77.88%
8	788.6	26.66%	48.79%	51.21%
16	568.1	19.21%	68.00%	32.00%
30	306.6	10.37%	78.36%	21.64%
50	256.2	8.66%	87.03%	12.97%
100	214.8	7.26%	94.29%	5.71%
200	106.8	3.61%	97.90%	2.10%
-200	62.1	2.10%	100.00%	0.00%
Total	2957.5			
F.M	4.09			

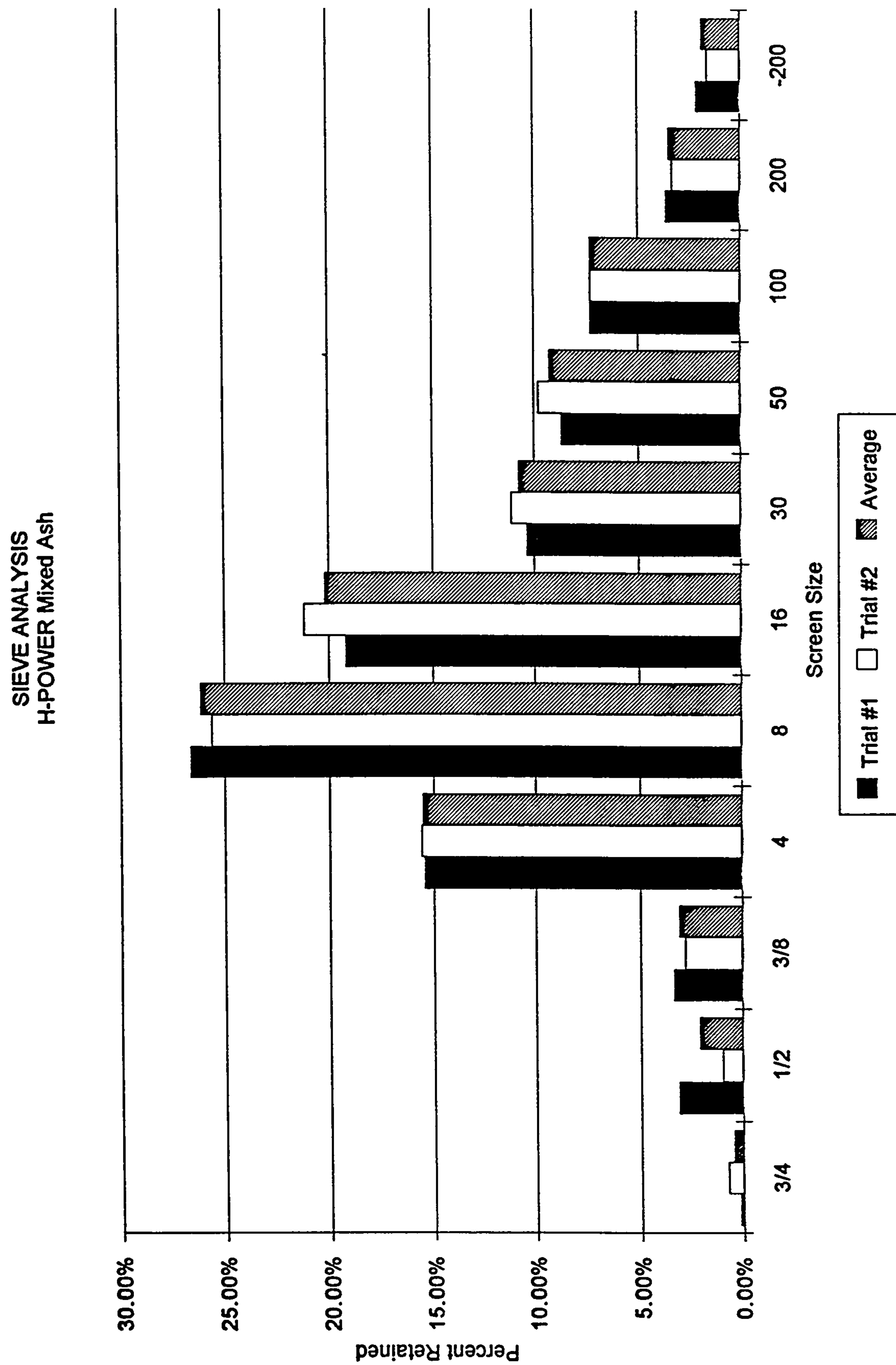
Table 4

SIEVE ANALYSIS

H-POWER Combined Ash
Trial 2

Size	Weight (g)	% Retained	Cum % Ret.	% Passing
3/4	41	0.74%	0.74%	99.26%
1/2	55.1	0.99%	1.73%	98.27%
3/8	156.6	2.82%	4.55%	95.45%
4	866.4	15.59%	20.13%	79.87%
8	1424.5	25.63%	45.76%	54.24%
16	1175.8	21.15%	66.91%	33.09%
30	618.2	11.12%	78.03%	21.97%
50	544.1	9.79%	87.82%	12.18%
100	404.1	7.27%	95.09%	4.91%
200	185.1	3.33%	98.42%	1.58%
-200	88.1	1.58%	100.00%	0.00%
Total	5559			
F.M	4.01			

Table 5


SIEVE ANALYSIS
H-POWER Mixed Ash
Percent Retained
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
3/4
1/2
3/8
4
8
16
30
50
100
200
-200
Screen Size
Trial #1
Trial #2
Average
Figure 2

SIEVE ANALYSIS

Waipahu Combined Ash

Trial 1

Size	Weight (g)	% Retained	Cum % Ret.	% Passing
3/4	56.3	1.52%	1.52%	98.48%
1/2	419.7	11.35%	12.87%	87.13%
3/8	421.2	11.39%	24.27%	75.73%
4	895	24.21%	48.47%	51.53%
8	584.9	15.82%	64.29%	35.71%
16	372	10.06%	74.36%	25.64%
30	246.5	6.67%	81.02%	18.98%
50	208	5.63%	86.65%	13.35%
100	193.4	5.23%	91.88%	8.12%
200	261.2	7.06%	98.95%	1.05%
-200	39	1.05%	100.00%	0.00%
Total	3697.2			
F.M	4.85			

Table 6

SIEVE ANALYSIS

Waipahu Combined Ash
Trial 2

Size	Weight (g)	% Retained	Cum % Ret.	% Passing
3/4	50.3	2.28%	2.28%	97.72%
1/2	199.3	9.03%	11.31%	88.69%
3/8	268.8	12.18%	23.50%	76.50%
4	354.4	16.07%	39.56%	60.44%
8	332.9	15.09%	54.66%	45.34%
16	284.6	12.90%	67.56%	32.44%
30	215.1	9.75%	77.31%	22.69%
50	170.9	7.75%	85.05%	14.95%
100	145.8	6.61%	91.66%	8.34%
200	83.6	3.79%	95.45%	4.55%
-200	100.3	4.55%	100.00%	0.00%
Total	2206			
F.M	4.53			

Table 7

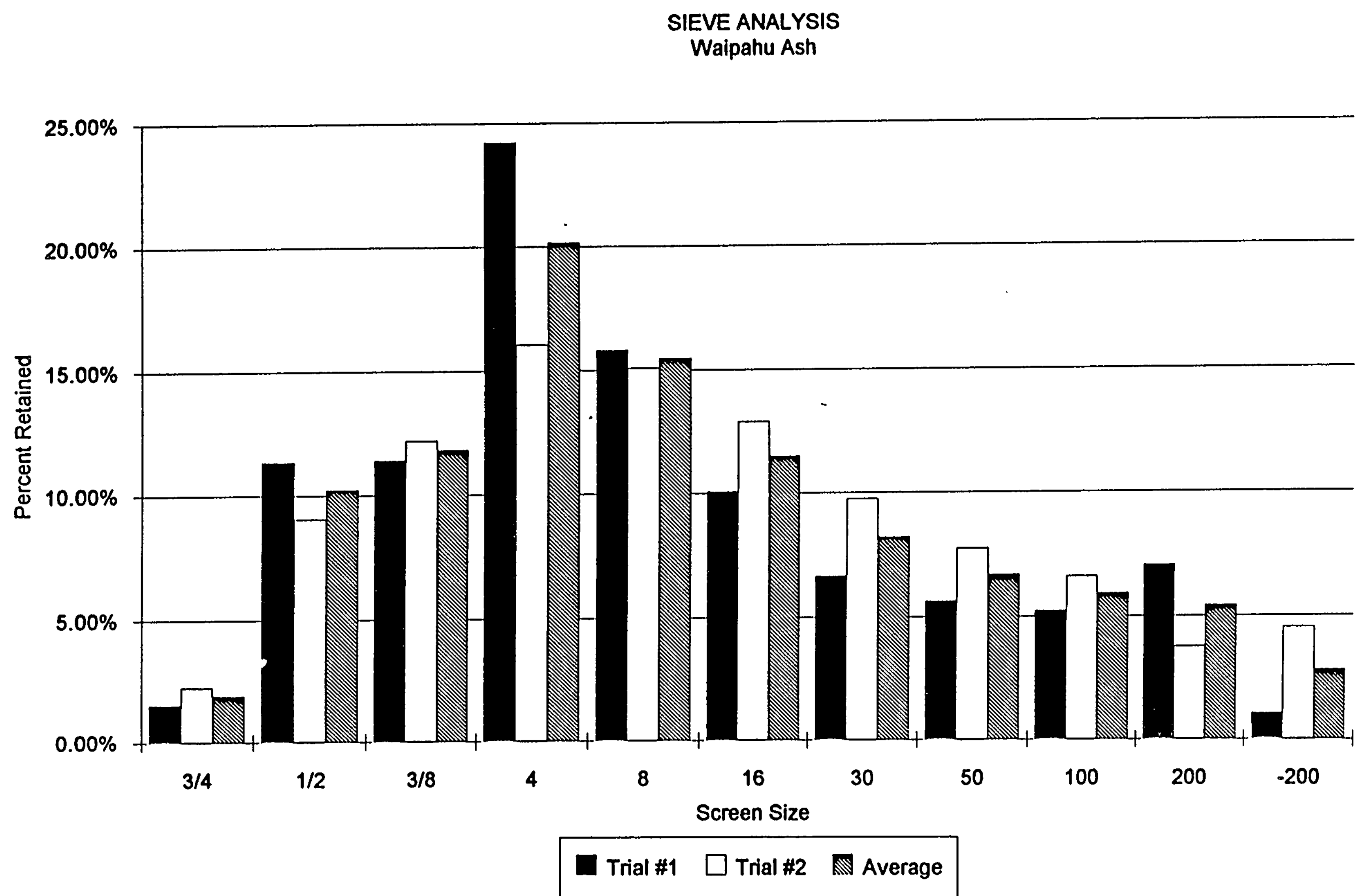

SIEVE ANALYSIS
Waipahu Ash
Percent Retained
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
3/4
1/2
3/8
4
8
16
30
50
100
200
-200
Screen Size
Trial #1
Trial #2
Average

Figure 3

SIEVE SIZE ANALYSIS
H-POWER Combined Ash

TEST DATE 7-Dec-93

SCREEN SIZE	WEIGHT (g)	PERCENT OF TOTAL
3/4	55.00	0.83%
1/2	110.00	1.66%
3/8	205.00	3.09%
4	950.00	14.32%
8	1640.00	24.72%
30	2750.00	41.45%
100	845.00	12.74%
200	75.00	1.13%
-200	5.00	0.08%
TOTAL	6635	100.00%

Table 8

SIEVE SIZE ANALYSIS
H-POWER Combined Ash
OVEN-DRIED

TEST DATE 18-Dec-93

SCREEN SIZE	WEIGHT (g)	PERCENT OF TOTAL
3/4	41.00	0.74%
1/2	55.10	0.99%
3/8	156.60	2.82%
4	866.40	15.59%
8	1424.50	25.63%
30	1794.00	32.27%
100	948.20	17.06%
200	185.10	3.33%
-200	88.10	1.58%
TOTAL	5559	100.00%

Table 9

SIEVE SIZE ANALYSIS
H-POWER Combined Ash
MIXED DRY

Trial 1

TEST DATE 18-Dec-93

SCREEN SIZE	WEIGHT (g)	PERCENT OF TOTAL
3/4	0.00	0.00%
1/2	32.30	1.76%
3/8	59.60	3.26%
4	219.60	12.00%
8	330.10	18.03%
30	497.80	27.19%
100	299.20	16.35%
200	221.40	12.10%
-200	170.50	9.31%
TOTAL	1830.5	100.00%

Table 10

SIEVE SIZE ANALYSIS
H-POWER Combined Ash
MIXED DRY

Trial 2

TEST DATE 18-Dec-93

SCREEN SIZE	WEIGHT (g)	PERCENT OF TOTAL
3/4	0.00	0.00%
1/2	35.30	1.60%
3/8	61.30	2.78%
4	270.00	12.25%
8	368.70	16.72%
30	534.80	24.26%
100	371.80	16.87%
200	340.00	15.42%
-200	222.60	10.10%
TOTAL	2204.5	100.00%

Table 11

SIEVE SIZE ANALYSIS
H-POWER Combined Ash
MIXED DRY

TOTAL

TEST DATE 18-Dec-93

SCREEN SIZE	WEIGHT (g)	PERCENT OF TOTAL
3/4	0.00	0.00%
1/2	67.60	1.68%
3/8	120.90	3.00%
4	489.60	12.13%
8	698.80	17.32%
30	1032.60	25.59%
100	671.00	16.63%
200	561.40	13.91%
-200	393.10	9.74%
TOTAL	4035	100.00%

Table 12

SIEVE SIZE ANALYSIS
H-POWER Combined Ash
MIXED DRY

AVERAGE

TEST DATE 18-Dec-93

SCREEN SIZE	WEIGHT (g)	PERCENT OF TOTAL	STANDARD DEVIATION
3/4	0.00	0.00%	0.00%
1/2	33.80	1.68%	0.05%
3/8	60.45	3.00%	0.15%
4	244.80	12.13%	0.08%
8	349.40	17.32%	0.42%
30	516.30	25.59%	0.94%
100	335.50	16.63%	0.17%
200	280.70	13.91%	1.07%
-200	196.55	9.74%	0.25%
TOTAL	2017.5	100.00%	

Table 13

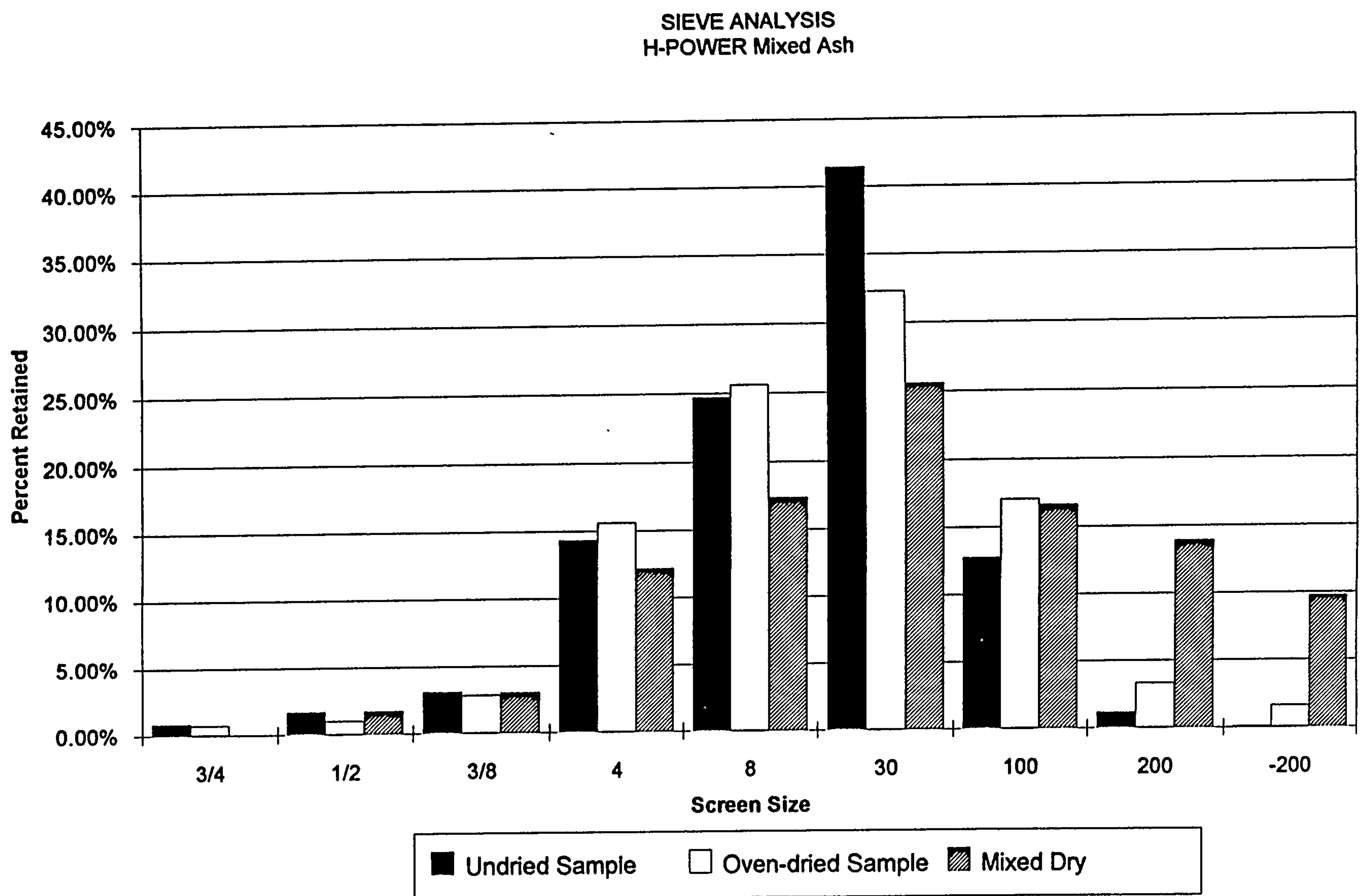

SIEVE ANALYSIS
H-POWER Mixed Ash
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Percent Retained
3/4
1/2
3/8
4
8
30
100
200
-200
Screen Size
Undried Sample
Oven-dried Sample
Mixed Dry

Figure 4

Appendix B2

Chemical Analysis of Screened Ash Fractions

Task 2 chemical analysis was carried out following the methods listed below:

Chemical Analysis Methods

Aluminum	EPA Method 3050M
Cadmium	EPA Method 6010
Calcium	EPA Method 6010
Copper	EPA Method 6010
Iron	EPA Method 6010
Lead	EPA Method 6010
Mercury	EPA Method 6010
Silicon	EPA Method 6010
Zinc	EPA Method 6010
pH	EPA Method 9045
Chloride	EPA Method 325.3
Sulfate	EPA Method 375.4
Moisture	CLP ILM 2.0

Summary Findings

The following is a detailed summary of the Task 2 chemical analysis findings. Please refer to the appropriate tables listed at the beginning of each section. Data appearing in the tables has been adapted from the E.L. Pacific laboratory report, which can be found beginning on page B2-6 of this appendix.

Aluminum through Chromium
Refer to Table 1 on page B2-3

Aluminum - Average: 43,428 PPM. This is slightly higher than the 40,000 PPM average for aluminum found in the Task 1 ash mixture analyses. A possible explanation for the difference is that the average in Task 2 only included the minus #4 ash fraction. About 15% of the ash included in the Task 1 mixture analyses, was in size fractions larger than were included in the Task 2 analysis. In general it is thought metals would tend to be concentrated more in the smaller size fractions. However, the results for both H-POWER and Waipahu combined ash show that highest concentration (83-86,000 PPM) was in the #8 size material, and was almost twice the concentration of the minus #200 material (41-50,000 PPM.) Overall, the results show very uniform distribution over the various size fractions. This is considered a positive result because if the smaller size fractions are the main source for aggregate, there is no evidence that aluminum or many of the other metals are more concentrated in these smaller fractions.

Calcium - Average: 70,953 PPM. The H-POWER combined ash concentrations averaged 109,423 PPM compared to 42,900 PPM for the Waipahu ash. The difference is due to the lime scrubber system at H-POWER. The concentrations found in the Task 2 analysis are consistent with the Task 1 results. There is, however, some enrichment in the #200 and smaller size fractions.

Cadmium - Average: 18 PPM. This is similar to the average for H-POWER fly and bottom ash found in the Task 1 analysis (2.5-26.5 PPM). There is some evidence of enrichment of cadmium in the minus #200 size fraction. Otherwise, the distribution appears consistent among all size fractions for all ash types.

Copper - Average: 6,109 PPM. This is much higher than that found in the Task 1 copper analysis (1,886 PPM). There is greater variability evident among the various size fractions than most of the other metals. Because of this variability and the small population of analyses, it is difficult to see any particular trends for this metal among the 3 types of ash or among the different size fractions. Copper levels in landfill soil samples averaged 98 PPM.

Iron - Average: 22,570 PPM. As with the other metals, the variability in iron concentrations is fairly consistent around the average with no evidence of enrichment in the smaller ash sizes. Moreover, Waipahu's enrichment--with one exception--is in the larger size fractions. Also note that the iron levels in local soil samples averaged 74,995 PPM.

Lead - Average: 3,547 PPM. Once again, the variability is not considered significant. Except for one high value (25,000 PPM for the #8 H-POWER bottom ash), all other size fractions and other ash types had fairly consistent concentrations around 2-3,000 PPM. There was no evidence of enrichment in the smaller sizes.

Mercury - The mercury elemental analysis averaged just slightly above the detection level of 0.2 PPM for two of the ash types. In fact 13 of the 21 samples analyzed were below mercury detection levels. While the H-POWER bottom ash and Waipahu ash were essentially at or below detection levels, there was evidence of mercury build up on the #100 and smaller size fractions of the H-POWER combined ash. These levels were still about the same as found in the soil control samples examined in Task 1 mixture

<u>**Silicon**</u> - Average: 106,730 PPM. The silicon concentrations were quite consistent among the 3 ash types and among the ash size fractions. The levels also compare with results from the soil control samples from Task 1.

Chemical Analysis in units of PPM unless otherwise indicated									
% in size fraction	Ash Type/Size	Al	Ca	Cd	Cu	Fe	Pb	Hg	Si
	H-POWER combined								
26.70%	#8	83,000	110,000	9	2,200	26,000	760	0.1*	169,000
19.20%	#16	55,000	120,000	10	47,000	37,000	5400	0.1*	162,000
10.40%	#30	63,000	150,000	15	3,200	27,000	3400	2.50	128,000
8.70%	#50	57,000	170,000	18	1,900	26,000	2200	1.30	130,000
7.30%	#100	51,000	180,000	18	2,000	27,000	2300	6.00	123,000
3.60%	#200	47,000	200,000	26	1,300	21,000	2400	4.10	89,000
2.10%	-200	41,000	250,000	42	1,200	15,000	5500	7.40	59,000
	Size fraction weighted avg.=	50,508	108,390	11	10,328	22,158	2,155	1.16	114,271
	H-POWER Bottom								
27.20%	#8	43,000	79,000	85	21,000	25,000	25000	0.1 *	198,000
25.60%	#16	69,000	92,000	1*	1,000	21,000	920	0.1 *	174,000
10.30%	#30	65,000	12,000	1*	4,300	27,000	760	0.1 *	157,000
5.50%	#50	73,000	150,000	6	3,800	28,000	1800	0.1 *	134,000
3.30%	#100	73,000	160,000	4	5,200	25,000	2400	0.2	114,000
1.60%	#200	71,000	150,000	16	3,600	16,000	2400	0.1 *	105,000
1.90%	-200	70,000	160,000	25	3,500	16,000	2100	0.1 *	91,000
	Size fraction weighted avg.=	44,945	65,246	25	6,916	17,882	7,370	0.08	129,112
	Waipahu Combined								
15.80%	#8	86,000	37,000	18	600	58,000	2200	0.1 *	186,000
10.10%	#16	62,000	69,000	4	570	99,000	500	0.1 *	163,000
6.70%	#30	70,000	87,000	11	5,900	7,200	450	0.1 *	138,000
5.60%	#50	61,000	89,000	23	4,000	66,000	2200	0.1 *	117,000
5.20%	#100	52,000	97,000	49	2,500	37,000	3100	0.1 *	128,000
7.10%	#200	51,000	130,000	110	2,400	30,000	5000	0.3	103,000
1.10%	-200	50,000	120,000	180	1,200	25,000	4300	0.5	108,000
	Size fraction weighted avg.=	34,831	39,222	18	1,085	27,670	1,115	0.07	76,806
	All ash type averages=	43,428	70,953	18	6,109	22,570	3,547	0.44	106,730
* Note: when results indicate non- detected, 1/2 detection level used in place of 0.00									

Table 1

Sodium through Density
Refer to Table 2 on page B2-5

Sodium - Average: 9,203 PPM. Like the iron analyses, there was little variability among the ash types or the ash size fractions. No sodium analyses were performed in the Task 1 mixtures.

Zinc - Average: 2,398 PPM. The averages for the H-POWER ash types were much lower than in the Task 1 analyses. The difference, however, is not considered significant. The consistency in the zinc concentrations found in the H-POWER combined ash was not evident in the Waipahu ash where a much wider variability was noted. There was also some enrichment in the smaller sizes of the H-POWER bottom ash. There is no explanation for the variability.

Sulfates - Average: 0.11%. The levels were higher in the Waipahu ash than in the H-POWER combined ash. This surprising result cannot be explained since one would expect the capture of SO_2 by the H-POWER scrubbers would result in much higher sulfate levels in that ash type. Perhaps the drying of the ash prior to sieving drove off the SO_4.

Chlorides - Average: 0.80%. The chlorides were higher in the H-POWER combined ash than the bottom ash as expected, but in levels lower than expected. The concentrations were, however, consistent with what was detected in the Task 1 analysis. There was evidence of some enrichment of chlorides in the #200 and smaller mesh sizes.

pH - The pH results were consistently in the range of about 11 -- 12 for H-POWER combined and bottom ash. The Waipahu combined ash, lacking a lime scrubber system, averaged 10.7.

Moisture - The moisture levels were affected by the drying required before performing the sieving. Thus analysis would not be worthwhile.

Density - The density levels are in the range of 2-3 g/cc for all ash types and size fractions except for #100 sieve fraction in the Waipahu combined ash which had a density of 11.3g/cc.

Chemical Analysis in units of PPM unless otherwise indicated									
% in size fraction	Ash Type/Size	Na	Zn	% SO4	% Cl2	pH	% moisture	Density, true g/cc	Density,app.
	H-POWER combined								
26.70%	#8	12,000	2,400	0.03	2.01	11.60	0.26	2.57	0.92
19.20%	#16	15,000	3,400	0.03	1.51	11.70	0.00	2.36	0.81
10.40%	#30	16,000	2,300	0.05	2.06	11.80	0.50	2.51	0.82
8.70%	#50	17,000	4,100	0.10	2.49	11.83	1.05	2.58	0.81
7.30%	#100	19,000	4,200	0.09	2.89	11.65	0.78	2.73	0.72
3.60%	#200	19,000	5,300	0.16	4.08	12.03	0.91	2.66	0.69
2.10%	-200	22,000	9,200	0.61	9.48	11.88	1.54	3.17	0.56
	Size fraction weighted avg.=	11,760	2,580	0.05	1.81	11.78	0.33	2.65	0.76
	H-POWER Bottom								
27.20%	#8	10,000	490	0.09	0.06	11.11	0.06	2.59	0.98
25.60%	#16	15,000	420	0.38	0.09	11.42	0.02	2.49	0.85
10.30%	#30	16,000	980	0.02	0.18	11.73	0.90	2.45	0.85
5.50%	#50	17,000	4,300	0.04	0.25	11.75	1.26	2.16	0.74
3.30%	#100	16,000	5,500	0.16	0.42	11.53	1.96	2.97	0.93
1.60%	#200	16,000	5,500	0.31	0.58	11.31	3.64	4.85	0.63
1.90%	-200	15,000	5,200	0.31	0.74	11.48	2.88	1.04	0.60
	Size fraction weighted avg.=	10,212	947	0.14	0.11	11.48	0.36	2.65	0.80
	Waipahu Combined								
15.80%	#8	7,700	700	0.12	0.19	10.69	0.00	2.73	0.91
10.10%	#16	12,000	640	0.21	0.34	11.02	0.01	2.91	0.90
6.70%	#30	12,000	21,000	0.32	3.55	10.59	0.22	2.67	0.73
5.60%	#50	12,000	7,000	0.41	0.65	10.64	0.40	2.37	0.59
5.20%	#100	13,000	9,100	0.46	0.93	10.74	0.16	11.30	0.55
7.10%	#200	13,000	15,000	0.44	1.08	10.88	0.16	4.13	0.67
1.10%	-200	12,000	14,000	0.85	0.88	10.50	2.18	2.25	0.80
	Size fraction weighted avg.=	5,636	3,666	0.15	0.47	10.72	0.08	4.05	0.74
	All ash type averages=	9,203	2,398	0.11	0.80	11.33	0.26	3.12	0.76
	* Note: when results indicate non- detected, 1/2 detection level used in place of 0.00								

Table 2

Conclusions

Task 2 chemical results were on the whole as expected. The data was relatively consistent with the Task 1 chemical data and showed no significant enrichment of trace metals in the smaller size fractions. The three ash types were also relatively consistent in their respective concentrations. One concern is the near 1% chloride content. This could possibly become a nuisance in situations where reuse may come in contact with steel rebar.

E.L. Pacific
Environmental Laboratory of the Pacific

A Full Service Laboratory, Engineering and Process...
930 Mapunapuna Street Suite 103 • Honolulu Hawaii 9...
Telephone (808) 833-5063 Facsimile (808) 833-739...

Laboratory Report

Client: H-Power
91-174 Hanua Street
Kapolei, HI 96707
Attention: Mr. Denny Kort

ELP Project No.: 545
Report Date: 28-Feb-9

Sample Description: Samples from 91-174 Hanua St.
Sample Matrix: Screened Ash

Date Collected: 29-Dec-9
Date Received: 29-Dec-9

				Client ID:		HM +8	HM +16	HM +30
				Matrix:		ash	ash	ash
				Lab ID:	Method Blank	122993-05	122993-06	122993-0
Date	**Analysis**	**Method**	**Units**	**MRL**	**Results**	**Results**	**Results**	**Results**
07-Feb-94	Metals Digestion***	EPA 3050M						
28-Jan-94	Metals Digestion	EPA 3050						
10-Feb-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	ND	**83,000**	**55,000**	**63,000**
10-Feb-94	Cadmium	EPA 6010	mg/Kg (ppm)	2	ND	**9**	**10**	**15**
10-Feb-94	Calcium	EPA 6010	mg/Kg (ppm)	20	ND	**110,000**	**120,000**	**150,00(**
10-Feb-94	Copper	EPA 6010	mg/Kg (ppm)	10	ND	**2,200**	**47,000**	**3,200**
10-Feb-94	Iron	EPA 6010	mg/Kg (ppm)	10	ND	**26,000**	**37,000**	**27,000**
10-Feb-94	Sodium	EPA 6010	mg/Kg (ppm)	20	ND	**12,000**	**15,000**	**16,000**
10-Feb-94	Lead	EPA 6010	mg/Kg (ppm)	20	ND	**760**	**5,400**	**3,400**
10-Feb-94	Zinc	EPA 6010	mg/Kg (ppm)	10	ND	**2,400**	**3,400**	**2,300**
03-Jan-94	Mercury	EPA 7471	mg/Kg (ppm)	0.2	ND	ND	ND	**2.5**
11-Jan-94	pH	EPA 9045	units	0.01	NA	**11.60**	**11.70**	**11.80**
26-Jan-94	Moisture	CLP ILM 2.0	%	NA	ND	**0.26**	**0.00**	**0.50**
05-Jan-94	Density, True**		g/cc	NA	NA	**2.57**	**2.36**	**2.51**
05-Jan-94	Density (apparent)**		g/cc	0.5	NA	**0.922**	**0.810**	**0.816**
07-Jan-94	Sulfate %	EPA 375.4	%	0.001	ND	**0.025**	**0.025**	**0.045**
07-Jan-94	Chloride %	EPA 325.3	%	0.001	ND	**2.01**	**1.51**	**2.06**
16-Feb-94	Silicon*	EPA 6010	mg/Kg	400	ND	**169,000**	**162,000**	**128,00(**

* Perkin-Elmer " Analytical Methods for AAS", Jan. 1982.
** Methods of Soil Ana' 'sis, American Society of Agronomy, Part 1, 1982.
*** Lithium Metaborate Fusion digestion procedure performed by E. DeCarlo, Ph.D., University of Hawaii.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

				Client ID:		HM +50	HM +100	HM +200	HM -200
				Matrix:		ash	ash	ash	ash
				Lab ID:	Method Blank	122993-08	122993-09	122993-10	122993-11
Date	Analysis	Method	Units	MRL	Results	Results	Results	Results	Results
07-Feb-94	Metals Digestion***	EPA 3050M							
28-Jan-94	Metals Digestion	EPA 3050							
10-Feb-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	ND	57,000	51,000	47,000	41,000
10-Feb-94	Cadmium	EPA 6010	mg/Kg (ppm)	2	ND	18	18	26	42
10-Feb-94	Calcium	EPA 6010	mg/Kg (ppm)	20	ND	170,000	180,000	200,000	250,000
10-Feb-94	Copper	EPA 6010	mg/Kg (ppm)	10	ND	1,900	2,000	1,300	1,200
10-Feb-94	Iron	EPA 6010	mg/Kg (ppm)	10	ND	26,000	27,000	21,000	15,000
10-Feb-94	Sodium	EPA 6010	mg/Kg (ppm)	20	ND	17,000	19,000	19,000	22,000
10-Feb-94	Lead	EPA 6010	mg/Kg (ppm)	20	ND	2,200	2,300	2,400	5,500
10-Feb-94	Zinc	EPA 6010	mg/Kg (ppm)	10	ND	4,100	4,200	5,300	9,200
03-Jan-94	Mercury	EPA 7471	mg/Kg (ppm)	0.2	ND	1.3	6.0	4.1	7.4
11-Jan-94	pH	EPA 9045	units	0.01	NA	11.83	11.65	12.03	11.88
26-Jan-94	Moisture	CLP ILM 2.0	%	NA	ND	1.05	0.78	0.91	1.54
05-Jan-94	Density, True**		g/cc	NA	NA	2.58	2.73	2.66	3.17
05-Jan-94	Density (apparent)**		g/cc	0.5	NA	0.813	0.715	0.685	0.560
07-Jan-94	Sulfate %	EPA 375.4	%	0.001	ND	0.096	0.090	0.160	0.610
07-Jan-94	Chloride %	EPA 325.3	%	0.001	ND	2.49	2.89	4.08	9.48
16-Feb-94	Silicon*	EPA 6010	mg/Kg	400	ND	130,000	123,000	89,000	59,000

* Perkin-Elmer " Analytical Methods for AAS", Jan. 1982.
** Methods of Soil Analysis, American Society of Agronomy, Part 1, 1982.
*** Lithium Metaborate Fusion digestion procedure performed by E. DeCarlo, Ph.D., University of Hawaii.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

Date	Analysis	Method	Units	MRL	Results	Results	Results	Results	Results
				Client ID:		HB +8	HB +16	HB +30	HB +50
				Matrix:		ash	ash	ash	ash
				Lab ID:	Method Blan	122993-12	122993-13	122993-14	122993-1
07-Feb-94	Metals Digestion***	EPA 3050M							
28-Jan-94	Metals Digestion	EPA 3050							
10-Feb-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	ND	**43,000**	**69,000**	**65,000**	**73,000**
10-Feb-94	Cadmium	EPA 6010	mg/Kg (ppm)	2	ND	**85**	ND	ND	**6**
10-Feb-94	Calcium	EPA 6010	mg/Kg (ppm)	20	ND	**79,000**	**92,000**	**12,000**	**150,000**
10-Feb-94	Copper	EPA 6010	mg/Kg (ppm)	10	ND	**21,000**	**1,000**	**4,300**	**3,800**
10-Feb-94	Iron	EPA 6010	mg/Kg (ppm)	10	ND	**25,000**	**21,000**	**27,000**	**28,000**
10-Feb-94	Sodium	EPA 6010	mg/Kg (ppm)	20	ND	**10,000**	**15,000**	**16,000**	**17,000**
10-Feb-94	Lead	EPA 6010	mg/Kg (ppm)	20	ND	**25,000**	**920**	**760**	**1,800**
10-Feb-94	Zinc	EPA 6010	mg/Kg (ppm)	10	ND	**490**	**420**	**980**	**4,300**
03-Jan-94	Mercury	EPA 7471	mg/Kg (ppm)	0.2	ND	ND	ND	ND	ND
11-Jan-94	pH	EPA 9045	units	0.01	NA	**11.11**	**11.42**	**11.73**	**11.75**
26-Jan-94	Moisture	CLP ILM 2.	%	NA	ND	**0.06**	**0.02**	**0.90**	**1.26**
05-Jan-94	Density, True**		g/cc	NA	NA	**2.59**	**2.49**	**2.45**	**2.16**
05-Jan-94	Density (apparent)**	---	g/cc	0.5	NA	**0.981**	**0.847**	**0.846**	**0.736**
07-Jan-94	Sulfate %	EPA 375.4	%	0.001	ND	**0.087**	**0.380**	**0.017**	**0.042**
07-Jan-94	Chloride %	EPA 325.3	%	0.001	ND	**0.055**	**0.091**	**0.18**	**0.25**
16-Feb-94	Silicon*	EPA 6010	mg/Kg	400	ND	**198,000**	**174,000**	**157,000**	**134,00(**

* Perkin-Elmer " Analytical Methods for AAS", Jan. 1982.
** Methods of Soil Analysis, American Society of Agronomy, Part 1, 1982.
*** Lithium Metaborate Fusion digestion procedure performed by E. DeCarlo, Ph.D., University of Hawaii.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

ELP Project No.: 5454
Report Date: 28-Feb-94

			Client ID:			HB +100	HB +200	HB -200	WAI +8
			Matrix:			ash	ash	ash	ash
			Lab ID:		Method Blank	122993-16	122993-17	122993-18	122993-19
Date	**Analysis**	**Method**	**Units**	**MRL**	**Results**	**Results**	**Results**	**Results**	**Results**
07-Feb-94	Metals Digestion***	EPA 3050M							
28-Jan-94	Metals Digestion	EPA 3050							
10-Feb-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	ND	73,000	71,000	70,000	86,000
10-Feb-94	Cadmium	EPA 6010	mg/Kg (ppm)	2	ND	4	16	25	18
10-Feb-94	Calcium	EPA 6010	mg/Kg (ppm)	20	ND	160,000	150,000	160,000	37,000
10-Feb-94	Copper	EPA 6010	mg/Kg (ppm)	10	ND	5,200	3,600	3,500	600
10-Feb-94	Iron	EPA 6010	mg/Kg (ppm)	10	ND	25,000	16,000	16,000	58,000
10-Feb-94	Sodium	EPA 6010	mg/Kg (ppm)	20	ND	16,000	16,000	15,000	7,700
10-Feb-94	Lead	EPA 6010	mg/Kg (ppm)	20	ND	2,400	2,400	2,100	2,200
10-Feb-94	Zinc	EPA 6010	mg/Kg (ppm)	10	ND	5,500	5,500	5,200	700
03-Jan-94	Mercury	EPA 7471	mg/Kg (ppm)	0.2	ND	0.2	ND	ND	ND
11-Jan-94	pH	EPA 9045	units	0.01	NA	11.53	11.31	11.48	10.69
26-Jan-94	Moisture	CLP ILM 2.0	%	NA	ND	1.96	3.64	2.88	0.00
05-Jan-94	Density, True**		g/cc	NA	NA	2.97	4.85	1.04	2.73
05-Jan-94	Density (apparent)**		g/cc	0.5	NA	0.927	0.630	0.599	0.908
07-Jan-94	Sulfate %	EPA 375.4	%	0.001	ND	0.16	0.31	0.31	0.12
07-Jan-94	Chloride %	EPA 325.3	%	0.001	ND	0.42	0.58	0.74	0.19
16-Feb-94	Silicon*	EPA 6010	mg/Kg	400	ND	114,000	105,000	91,000	186,000

* Perkin-Elmer " Analytical Methods for AAS", Jan. 1982.
** Methods of Soil Analysis, American Society of Agronomy, Part 1, 1982.
*** Lithium Metaborate Fusion digestion procedure performed by E. DeCarlo, Ph.D., University of Hawaii.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

		Client ID:				WAI +16	WAI +30	WAI +50	WAI +1(
		Matrix:				ash	ash	ash	ash
		Lab ID:			Method Blank	122993-20	122993-21	122993-22	122993-:
Date	**Analysis**	**Method**	**Units**	**MRL**	**Results**	**Results**	**Results**	**Results**	**Result**
07-Feb-94	Metals Digestion***	EPA 3050M							
28-Jan-94	Metals Digestion	EPA 3050							
10-Feb-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	ND	62,000	70,000	61,000	52,00(
10-Feb-94	Cadmium	EPA 6010	mg/Kg (ppm)	2	ND	4	11	23	49
10-Feb-94	Calcium	EPA 6010	mg/Kg (ppm)	20	ND	69,000	87,000	89,000	97,00(
10-Feb-94	Copper	EPA 6010	mg/Kg (ppm)	10	ND	570	5,900	4,000	2,500
10-Feb-94	Iron	EPA 6010	mg/Kg (ppm)	10	ND	99,000	7,200	66,000	37,00(
10-Feb-94	Sodium	EPA 6010	mg/Kg (ppm)	20	ND	12,000	12,000	12,000	13,00(
10-Feb-94	Lead	EPA 6010	mg/Kg (ppm)	20	ND	500	450	2,200	3,100
10-Feb-94	Zinc	EPA 6010	mg/Kg (ppm)	10	ND	640	21,000	7,000	9,100
03-Jan-94	Mercury	EPA 7471	mg/Kg (ppm)	0.2	ND	ND	ND	ND	ND
11-Jan-94	pH	EPA 9045	units	0.01	NA	11.02	10.59	10.64	10.74
26-Jan-94	Moisture	CLP ILM 2.0	%	NA	ND	0.01	0.22	0.40	0.16
05-Jan-94	Density, True**		g/cc	NA	NA	2.91	2.67	2.37	11.30
05-Jan-94	Density (apparent)**		g/cc	0.5	NA	0.900	0.725	0.593	0.549
07-Jan-94	Sulfate %	EPA 375.4	%	0.001	ND	0.21	0.32	0.41	0.46
07-Jan-94	Chloride %	EPA 325.3	%	0.001	ND	0.34	3.55	0.65	0.93
16-Feb-94	Silicon*	EPA 6010	mg/Kg	400	ND	163,000	138,000	117,000	128,00

* Perkin-Elmer " Analytical Methods for AAS", Jan. 1982.
** Methods of Soil Analysis, American Society of Agronomy, Part 1, 1982.
*** Lithium Metaborate Fusion digestion procedure performed by E. DeCarlo, Ph.D., University of Hawaii.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

				Client ID:		WAI +200	WAI -200
				Matrix:		ash	ash
				Lab ID:	Method Blank	122993-24	122993-25
Date	**Analysis**	**Method**	**Units**	**MRL**	**Results**	**Results**	**Results**
07-Feb-94	Metals Digestion***	EPA 3050M					
28-Jan-94	Metals Digestion	EPA 3050					
10-Feb-94	Aluminum	EPA 6010	mg/Kg (ppm)	20	ND	51,000	50,000
10-Feb-94	Cadmium	EPA 6010	mg/Kg (ppm)	2	ND	110	180
10-Feb-94	Calcium	EPA 6010	mg/Kg (ppm)	20	ND	130,000	120,000
10-Feb-94	Copper	EPA 6010	mg/Kg (ppm)	10	ND	2,400	1,200
10-Feb-94	Iron	EPA 6010	mg/Kg (ppm)	10	ND	30,000	25,000
10-Feb-94	Sodium	EPA 6010	mg/Kg (ppm)	20	ND	13,000	12,000
10-Feb-94	Lead	EPA 6010	mg/Kg (ppm)	20	ND	5,000	4,300
10-Feb-94	Zinc	EPA 6010	mg/Kg (ppm)	10	ND	15,000	14,000
03-Jan-94	Mercury	EPA 7471	mg/Kg (ppm)	0.2	ND	0.3	0.5
11-Jan-94	pH	EPA 9045	units	0.01	NA	10.88	10.50
26-Jan-94	Moisture	CLP ILM 2.0	%	NA	ND	0.16	2.18
05-Jan-94	Density, True**		g/cc	NA	NA	4.13	2.25
05-Jan-94	Density (apparent)**		g/cc	0.5	NA	0.466	0.798
07-Jan-94	Sulfate %	EPA 375.4	%	0.001	ND	0.44	0.85
07-Jan-94	Chloride %	EPA 325.3	%	0.001	ND	1.08	0.88
16-Feb-94	Silicon*	EPA 6010	mg/Kg	400	ND	103,000	108,000

* Perkin-Elmer " Analytical Methods for AAS", Jan. 1982.
** Methods of Soil Analysis, American Society of Agronomy, Part 1, 1982.
*** Lithium Metaborate Fusion digestion procedure performed by E. DeCarlo, Ph.D., University of Hawaii.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

Quality Control Data

SPIKES		Lab ID: / Units:	LCS1 %R	LCS2 %R	RPD	MS %R	MSD %R	RPD
Lab ID	Analysis	Method	Results	Results	Results	Results	Results	Results
122993-55	Aluminum	EPA 6010	94	94	0	****	****	****
122993-05	Cadmium	EPA 6010	103	109	6	****	****	****
122993-05	Cadmium	EPA 6010	NA	NA	NA	79	77	3
122993-05	Cadmium	EPA 6010	88	88	0	79	77	3
122993-25	Calcium	EPA 6010	83	81	2	****	****	****
122993-25	Calcium	EPA 6010	117	117	0	****	****	****
122993-25	Copper	EPA 6010	94	97	3	****	****	****
122993-25	Copper	EPA 6010	103	106	3	****	****	****
122993-25	Iron	EPA 6010	101	102	1	****	****	****
122993-25	Iron	EPA 6010	106	108	2	****	****	****
122993-25	Sodium	EPA 6010	93	90	3	****	****	****
122993-25	Sodium	EPA 6010	99	105	6	****	****	****
122993-25	Lead	EPA 6010	101	103	2	****	****	****
122993-25	Lead	EPA 6010	104	108	4	****	****	****
122993-25	Zinc	EPA 6010	97	97	0	****	****	****
122993-25	Zinc	EPA 6010	103	104	1	****	****	****
122993-20	Mercury	EPA 7471	99	99	0	121	115	5
122993-20	Mercury	EPA 7471	116	108	7	109	100	9
012294-08	Sulfate %	EPA 375.4	115	113	2	108	104	4
122993-18	Sulfate %	EPA 375.4	94	97	3	102	101	1
122993-25	Chloride %	EPA 325.3	99	99	0	101	99	2
122993-10	Chloride %	EPA 325.3	100	98	2	99	100	1

DUPLICATES		Lab ID: / Units: are mg/L unless otherwise noted	OS	D	RPD percent
Lab ID	Analysis	Method	Results	Results	Results
122993-05	pH	EPA 9045	11.599	11.67	1
011094-01	pH	EPA 9045	7.031	7.051	0
122993-24	Density (true)	g/cc	4.13	4.11	0
122993-24	Density (apparent)	g/cc	0.466	0.503	8
122993-08	Density (true)	g/cc	2.58	2.24	14
122993-08	Density (apparent)	g/cc	0.813	0.804	1

**** Native analyte greater than 4 times the spike added, therefore recovery not calculable.

Approved by: [signature]
Jeffrey Bryson, Laboratory Manager

Approved by: [signature]
Dirk Koeppenkastrop, PhD, Laboratory Director

Definitions

D	Duplicate
LCS	Laboratory Control Sample
MS	Matrix Spike
MSD	Matrix Spike Duplicate
MRL	Method Reporting Limit
NA	Not Applicable
ND	Not Detected at the MRL
NR	Not Requested
OS	Original Sample
%R	Percent Recovery
PDS	Post Digestion Spike
RPD	Relative Percent Difference

Approved by:
Jeffrey Bryson, Laboratory Manager

Approved by:
Dirk Koeppenkastrop, PhD, Laboratory Director

Appendix B3

Permabase Preliminary Investigation

HONOLULU, HAWAII

REFUSE DERIVED FUEL COMBUSTOR ASH

FOR USE IN PERMABASE-PLUS

PRELIMINARY INVESTIGATION

PERMABASE, INC.

Post Office Box 7578
Sun City Florida 33586
813 645-3068

HONOLULU, HAWAII

REFUSE DERIVED FUEL COMBUSTOR ASH

FOR USE IN PERMABASE-PLUS

PRELIMINARY INVESTIGATION

One five gallon bucket of RDF bottom ash was received September 28, 1993, by Permabase personnel for evaluation as a potential aggregate in the proprietary soil cement material PERMABASE-PLUS. Review of the State of Hawaii, Department of Transportation Standard Specifications for Road and Bridge Construction Section 308 - Portland Cement Treated Base revealed that cement treated base is designed in Hawaii by controlling the quality of the ingredients and adding 5% cement. This was confirmed in conversation with Walter Quroiwua of the HDOT Quality Control laboratory, Honolulu. The tests used to control the quality of the cement treated base ingredients are:

Los Angeles Abrasion	AASHTO T 96
Sand Equivalent	AASHTO T 176
Plasticity Index	AASHTO T 90
Flat or Elongated pieces	HWY-TC 4
Grading	AASHTO T 27

Combustor ash represents approximately 25% of the aggregate in PERMABASE-PLUS. Since the other 75% of the aggregate is composed of "local" materials we did not conduct the above five tests on our designs. However, through proper aggregate selection and combination we are confident that PERMABASE-PLUS made in part with Honolulu's RDF combustor ash can meet the appropriate quality requirements.

Our preliminary evaluation was based on Florida Department of Transportation design criteria in order to provide a correlation between the ash from Honolulu and previously tested ash. Tests were also conducted using a crushed concrete aggregate with the ash meeting the grading requirements specified in the HDOT manual. We chose crushed concrete due to the products universal availability and the potential for reuse.

Material Evaluation

Bottom Ash: As delivered, the bottom ash was all minus 1 1/2 inch material. Visual observation revealed a relatively large amount of glass/ceramic shards and a nugget appearance to the ash. Ferrous metals appeared to consist largely of wires, nails and screws. Sieve analysis and dry weight evaluation determined that 67% of the bottom ash was retained on the #4 (4.75mm) sieve which needs to be removed or reduced in size before use. The sieve analysis also showed that 2.1% of the material was smaller than a #200 (75 micron) sieve and would be considered fly ash.

Of the material retained on the #4 (4.75mm) sieve, 22% remained after the crushing process. This material consisted of ferrous, aluminum, other metals and paper/plastic/organics. Non-crushable material as a percentage of total dry weight of ash is as follows:

Ferrous:	6.6%
Aluminum:	5.0%
Misc Metal:	2.9%
Paper, etc:	0.1%

Crushed Concrete Aggregate: A sample of this aggregate was obtained by Permabase personnel from a crushed concrete recycling operation in the Tampa Bay area. The aggregate was then size separated in the laboratory in the following manner: +1/2" material removed; -1/2"/+#4 material separated from -#4 material. PERMABASE-PLUS aggregate was then proportioned utilizing the processed Honolulu ash and the two sized fractions of the crushed concrete to conform to the HDOT grading specification.

Leisey Sand: This material consists of a fine graded silica sand, minus #30 (600 micron) sieve, plus #200 (75 micron) sieve. This sand was used as a standard of comparison with other previously designed ash/sand soil cement products.

PERMABASE-PLUS

Two mixtures of PERMABASE-PLUS were created in the laboratory for comparative study. Mixture One consisted of 3 parts Leisey sand and 1 part processed bottom ash. Mixture Two consisted of 3 parts crushed concrete and 1 part processed bottom ash to meet the HDOT grading requirement. Both mixtures were proportioned with 5% cement prior to compaction of test specimens with varying moisture contents in accordance with AASHTO T 134. These specimens were then held for seven days in a moisture curing tank before unconfined compressive strength testing.

Comparison of Ash Products

The Florida approved methods for evaluating soil cement are based on seven day unconfined compressive strength data. Previous ash investigations at ten combustors located throughout the United Sates have provided unconfined compressive strength data at 5% cement content from 290 pounds per square inch (psi) to 610 psi. Unit weights from these same materials range from 91 pounds per cubic foot (pcf) to 108 pcf.

Analysis performed on the Honolulu materials reveals that the unit weight of the Leisey sand/ash mixture at approximately 106 pcf fits well within the range of other sand/ash mixtures tested to date. When crushed concrete is utilized in the mix, the unit weight increased to 111 pcf.

Compressive strength data generated by the seven day specimens revealed that the Leisey sand/ash results at 314 psi were within the range of results generated by other Leisey sand/ash PERMABASE-PLUS products. The seven day strength for the crushed concrete/ash specimens at 661 psi is well above the typical strengths achieved with sand mixtures.

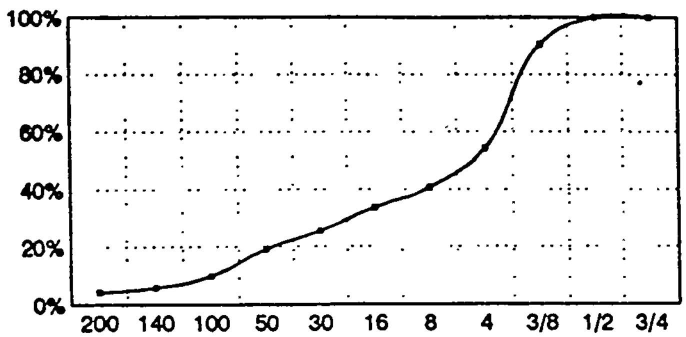
Conclusion

The purpose for this preliminary investigation was to determine the suitability of the materials supplied for the use as a soil cement base product based on its ability to withstand a load. ***Our evaluation reveals that the composite materials, as represented by our specimens, will make an excellent soil cement base product if properly prepared.***

Further evaluation will be necessary to determine optimum material characteristics and to make recommendations based on local Hawaiian aggregates and design specifications. Further investigation will also be necessary to determine the suitability of Honolulu combined ash for an aggregate in PERMABASE-PLUS. Laboratory analyses are included for your review on the attached sheets.

PERMABASE-PLUS

Honolulu RDF Ash/Crushed Concrete
Sieve Analysis



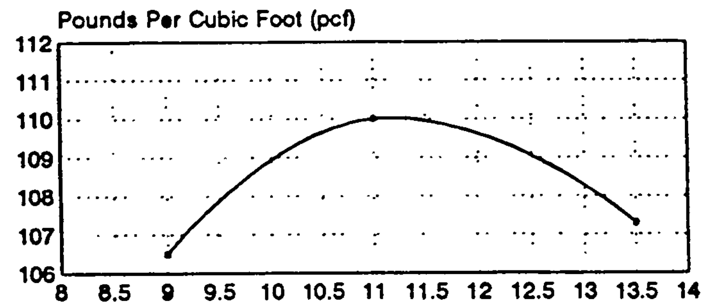
% Passing →	4.3%	5.8%	10%	19.3%	25.5%	33.6%	40.6%	54.2%	90.4%	100%	100%

Sieve Size

Made with Crushed Concrete

PERMABASE-PLUS

Honolulu RDF Ash/Crushed Concrete
Moisture/Density



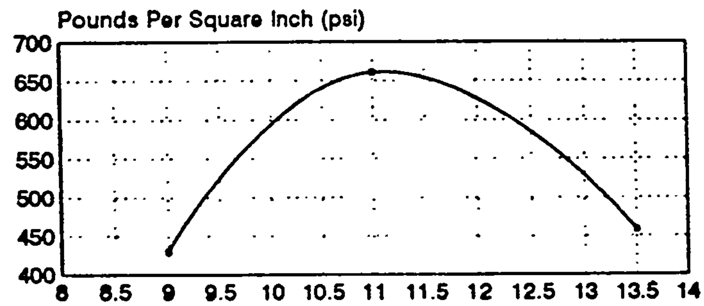
PCF →			106.5				110					107.3

Moisture Content

Maximum Density: 110.2 pcf
Optimum Moisture: 11.2%

PERMABASE-PLUS

Honolulu RDF Ash/Crushed Concrete
Compressive Strength



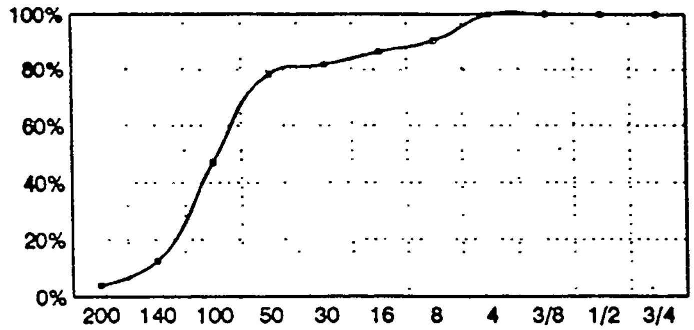
PSI →			430				661					458

Moisture Content

Peak Stress: 661 psi
Peak Moisture: 11.0%

PERMABASE-PLUS

Honolulu RDF Ash/Sand
Sieve Analysis



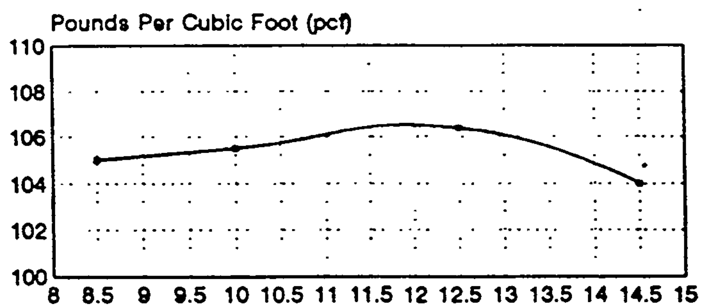
% Passing →	4%	12.5%	47%	78.3%	81.8%	86.4%	90.4%	99.8%	100%	100%	100%

Sieve Size

Made with Florida Sand

PERMABASE-PLUS

Honolulu RDF Ash/Sand
Moisture/Density



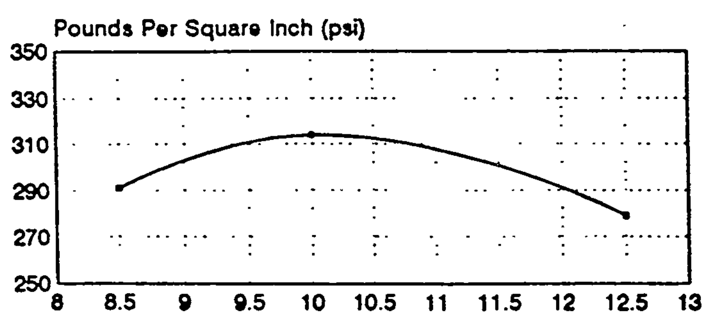
PCF →		105			105.5					106.4				104

Moisture Content

Maximum Density: 106.5 pcf
Optimum Moisture: 12%

PERMABASE-PLUS

Honolulu RDF Ash/Sand
Compressive Strength



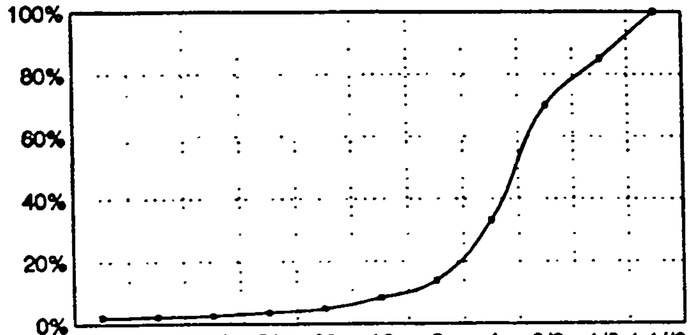
PSI →		291			314					279

Moisture Content

Peak Stress: 314 psi
Peak Moisture: 10.0%

PERMABASE-PLUS

Honolulu Unprocessed Ash
Sieve Analysis

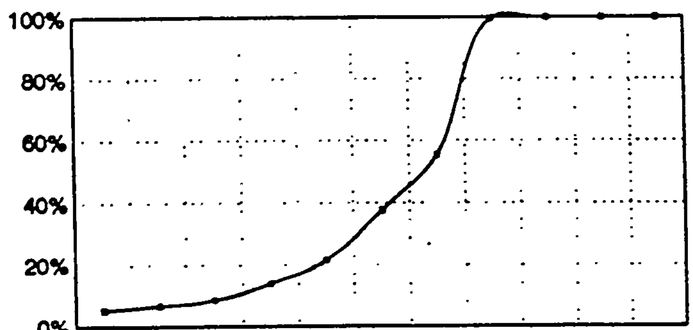


	200	140	100	50	30	16	8	4	3/8	1/2	1 1//2
% Passing ◆	2.1%	2.3%	2.7%	3 7%	4 9%	8.3%	14%	33 1%	70%	85%	100%

Sieve Size

PERMABASE-PLUS

Honolulu Processed Ash
Sieve Analysis



	200	140	100	50	30	16	8	4	3/8	1/2	1
% Passing ◆	5 3%	6.7%	8.5%	14%	21.5%	37.7%	55 5%	99 6%	100%	100%	100%

Sieve Size

Appendix B4

Permabase Task 2 Investigation Report

PERMABASE

HONOLULU, HAWAII
MUNICIPAL SOLID WASTE COMBUSTION ASH
FOR USE IN PERMABASE-PLUS
PHASE 1 TASK 2 INVESTIGATION

PERMABASE INC.
Post Office Box 7578
Sun City Florida 33586
813 645 3068

HONOLULU, HAWAII

MUNICIPAL SOLID WASTE COMBUSTION ASH

FOR USE IN PERMABASE-PLUS

PHASE I TASK 2 INVESTIGATION

FEBRUARY, 1994

Permabase, Inc., in cooperation with Ogden Martin Systems Inc., is continuing its participation in the City and County of Honolulu's investigation of Municipal Solid Waste Combustor Ash utilization sponsored by the National Renewable Energy Laboratory (NREL). Several laboratory tests were conducted on H-Power ash and locally available Hawaiian construction materials. The purpose of these tests was to determine the suitability of H-Power ash for use in the patented soil cement material PERMABASE-PLUS while meeting the local Hawaiian Department of Transportation specifications.

On December 28, 1993, the following materials were received by personnel of Permabase, Inc.:

1) One five gallon bucket of H-Power bottom ash
2) One five gallon bucket of H-Power combined ash
3) One five gallon bucket of Red Base Rock
4) One five gallon bucket of #4 Rock
5) One five gallon bucket of #3 Sand

Items 3, 4 and 5 were provided for the City and County of Honolulu by Grace Pacific Corporation (GP) from their rock quarry and processing facility on Oahu.

PERMABASE-PLUS is a combination of MSW ash, cement, water and a locally produced aggregate. Each of these ingredients can be utilized in varying amounts depending on the quality and availability of the raw materials, and the structural and environmental specifications which apply. The Hawaii Department of Transportation (HDOT), as outlined in the Standard Specifications for Road and Bridge Construction, Section 308 - Portland Cement Treated Base, requires aggregates to be tested by the following procedures:

Los Angeles Abrasion	AASHTO T 96
Sand Equivalent	AASHTO T 176
Plasticity	AASHTO T 90
Flat or Elongated Pieces	HWY-TC 4
Grading	AASHTO T 27

After evaluation of the five materials received and a review of the specifications, Permabase, Inc. decided to utilize GP #4 Rock and GP #3 Sand in combination with H-Power combined ash.

The bottom ash was not tested at this time for two reasons: 1) It is the philosophy of Permabase, Inc. to utilize the entire ash stream, reducing the need for separate handling, treatment and disposal; and, 2) the combined ash represents the worst case condition by including the fly ash. As noted below, the fly ash fraction of the ash impacts the structural integrity of a roadway in the Sand Equivalent Test, the Plasticity Test and the Grading Test, while at the same time impacts the environmental tests by introducing a greater potential of leachable inorganic metals. By providing evidence that PERMABASE-PLUS performs satisfactorily with combined ash, it will also provide positive evidence that PERMABASE-PLUS produced with bottom ash only will meet the specifications.

The GP Red Base Rock as received met the grading requirements of the HDOT specification. If more fines were added to this material in the form of ash, it would no longer meet this specification. This would then require a secondary screening operation at the quarry, resulting in a "new" waste product. Therefore, Permabase, Inc. felt it would not be practical to combine ash with Red Rock for these tests.

DISCUSSION OF TESTING PROCEDURES

The Los Angeles Abrasion procedure tests an aggregate for hardness. Depending upon the grading of the aggregate, certain size fractions (in this case the plus 1/2 inch) of the aggregate are placed in a tumbler with steel balls and rotated 500 times. The size fraction of the aggregate is then removed and screened to determine the amount of material which was crushed by the steel balls. Due to the HDOT grading specifications and the necessity to crush the ash to a minus 3/8 inch size before use in the PERMABASE-PLUS aggregate, the ash itself does not impact the results of the Los Angeles Abrasion. However, it is necessary to select an aggregate when designing the PERMABASE-PLUS aggregate which will meet the requirements of this rigorous test.

The Sand Equivalent procedure tests an aggregate for suspended fines. The procedure defines these suspended fines as clay and dust and is conducted on the minus #4 sieve (4.75 mm) fraction of the aggregate. The sand equivalent number is determined through a precise procedure as a ratio between the particles which settle within a solution and those that do not. Since all the ash is crushed to a minus 3/8 inch sieve in the PERMABASE-PLUS procedure, the ash will directly impact these test results. Although there are no clays in the ash, the dust particles - typically the minus #200 (75 microns) sieve material - will remain in suspension.

The Plasticity procedure tests an aggregate for its ability to retain water. The procedure is conducted on the minus #40 (425 micron) sieve fraction of the aggregate. The ash will make up a large portion of this fraction, and will impact the test results.

The Flat or Elongated Pieces procedure tests for detrimental shapes in aggregates. This procedure is conducted on the plus 3/8 inch fraction of the aggregate. Again because the ash is crushed to a minus 3/8 inch before use in PERMABASE-PLUS, the ash will not impact these test results.

The Grading Procedure tests an aggregate for its grain size distribution. By controlling size distribution, this specification impacts all the above tests and in turn controls the quality of the aggregate. The HDOT "3/4 Inch Maximum" aggregate requires that at least 45% of the aggregate is larger than a #4 (4.75 mm) sieve. This in turn controls the Los Angeles Abrasion grading selection and the Flat and Elongated Pieces Procedure. This same specification also limits the minus #200 (75 micron) sieve portion to a maximum of 9%. This in turn impacts the Sand Equivalent and Plasticity test results.

ADDITIONAL AGGREGATES

Two PERMABASE-PLUS aggregates were also prepared utilizing H-Power combined ash and a Florida crushed concrete (CC). This combination offers an opportunity for the City and County of Honolulu to not only recycle combustor ash, but also a demolition debris currently being landfilled. Although not commercially available at this time, Permabase, Inc. felt that this option may at some time become available in Honolulu.

AGGREGATE DESIGN PROPORTIONS

Many combinations of aggregate and ash can be created in differing proportions to create PERMABASE-PLUS aggregate. Due to sample size and time limitations, Permabase, Inc. chose to prepare four aggregate combinations. Permabase, Inc. selected a minimum content of 25% ash as a practical level of recycling necessary for commercial viability, and a maximum of 50% ash due to HDOT specification limits. If commercial application is warranted, the "fine tuning" of practice and experience will determine the optimum aggregate combination. The four aggregates were prepared for testing in the following combinations:

Aggregate #1: 50% GP #4 Rock
25% GP #3 Sand
25% H-Power Combined Ash

Aggregate #2: 50% GP #4 Rock
50% H-Power Combined Ash

Aggregate #3: 50% Coarse Graded Crushed Concrete
25% Fine Graded Fine Graded Concrete
25% H-Power Combined Ash

Aggregate #4: 50% Coarse Graded Crushed Concrete
50% H-Power Combined Ash

NOTE: Coarse graded aggregates are larger than the #4 (4.75 mm) sieve.

Results of HDOT testing procedures appear on the enclosed Laboratory Test Results matrix.

CONCLUSION

Processed H-Power ash can be successfully combined with locally available natural aggregates or recycled materials to meet all specifications as detailed in Section 308 - Portland Cement Treated Base, of the Hawaii Department of Transportation Standard Specifications for Road and Bridge Construction.

RECOMMENDATION

Phase II of the NREL sponsored test protocol will include a large scale field study at the current County landfill. For this demonstration, Permabase, Inc. recommends the PERMABASE-PLUS Aggregate combination #1 - 50% GP #4 Rock, 25% GP #3 Sand and 25% H-Power Combined Ash. These materials are readily available and will ensure a structurally sound, easily workable aggregate mix for the demonstration. The 50% ash combination is not recommended at this time due to sensitivity of moisture content near optimum moisture. In the laboratory, the mixture with 50% ash tends to become too fluid, too quickly once optimum moisture is attained. This characteristic may be controlled by the use of more absorbent aggregates or possibly by removing part of the fly ash, but for the purposes of Phase II, should not be used.

PERMABASE-PLUS
Honolulu MSW Ash/Various Aggregates
Laboratory Test Results

Test Method	Specification	Aggregate 1	Aggregate 2	Aggregate 3	Aggregate 4
L.A. Abrasion AASHTO T 96	50% Max	9.7%	9.7%	48.3%	48.3%
Sand Equivalent AASHTO T 176	35% Min	68.3%	71.9%	70%	71.9%
Plasticity Index AASHTO T 90	6 Max	Non Plastic	Non Plastic	Non Plastic	Non Plastic
Flat or Elongated Pieces HWY-TC4	25% Max	3.1%	3.1%	5.3%	5.3%
Grading AASHTO T 27	Passing				
1" Sieve	100%	100%	100%	100%	100%
3/4" Sieve	90 - 100%	92%	91%	100%	100%
#4 Sieve	35 - 55%	49%	51%	50%	50%
#200 Sieve	3 - 9%	4.8%	4.7%	4.1%	3.9%

Table 1

TEST SUMMARY MATRIX

HDOT Test Results

Honolulu MSW Ash/Various Aggregates

Test Method:	L.A. Abrasion AASHTO T 96	Sand Equivalent AASHTO T 176	Plasticity Index AASHTO T 90	Flat or Elongated Pieces HWY-TC4	Grading AASHTO T 27 (Percent Passing)			
					l" Sieve	3/4" Sieve	#4 Sieve	#200 Sieve
Specifications:	50% Max	35% Min	6 Max	255 Max	100%	90-100%	35-55%	3-9%
Aggregate 1	9.70%	68.30%	Non Plastic	3.10%	100%	92%	49%	4.80%
Aggregate 2	9.70%	71.90%	Non Plastic	3.10%	100%	91%	51%	4.70%
Aggregate 3	-48.30%	70%	Non Plastic	5.30%	100%	100%	50%	4.10%
Aggregate 4	48.30%	71.90%	Non Plastic	5.30%	100%	100%	50%	3.90%

Table 2

Appendix C1

1991 Mid-Connecticut Ash Test Results

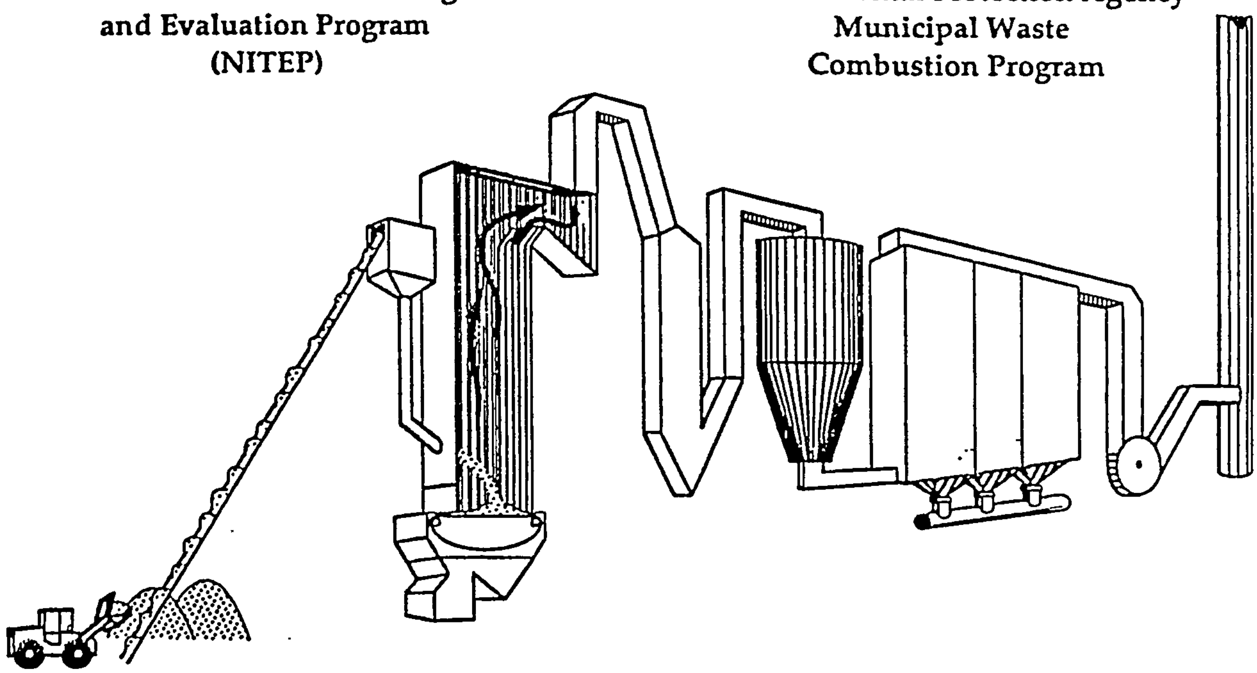
THE ENVIRONMENTAL CHARACTERIZATION OF RDF COMBUSTION TECHNOLOGY

Mid-Connecticut Facility
Hartford, Connecticut

Sponsored by

Environment Canada
National Incinerator Testing
and Evaluation Program
(NITEP)

United States
Environmental Protection Agency
Municipal Waste
Combustion Program



Volume II

Test Program and Results

April 1991

MS121A

THE ENVIRONMENTAL CHARACTERIZATION
OF
RDF COMBUSTION TECHNOLOGY

Mid-Connecticut Facility
Hartford, Connecticut

VOLUME II

TEST PROGRAM AND RESULTS

Compiled by

Alliance Technologies Corporation
Lowell, Massachusetts

for

Environment Canada
National Incinerator Testing
And Evaluation Program
(NITEP)

United States
Environmental Protection Agency
Municipal Waste
Combustion Program

Any comments concerning its content should be directed to:

NITEP
Industrial Programs Branch
Urban Activities Division
Conservation and Protection
Environment Canada
Ottawa, Ontario
K1A OH3

Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

April 1991

Table 7-14. Dry Bottom Ash QC Data for Metals

ANALYTE	PT-06 (mg/kg)	DUPL (mg/kg)	RPD (%)	PT-11 (mg/kg)	DUPL (mg/kg)	RPD (%)	PT-06 (mg/kg)	Conc. Spiked (mg/kg)	PT-06/ Spike Ratio	Spiked Sample (mg/kg)	Recovery (%)
CADMIUM	4.6	5.8	23%	6.8	6.9	1%	4.6	2500	0	2300	92%
BERYLLIUM	-	<1		-	<1		-	2500		2400	96%
CALCIUM	75643	89100	16%	80687	96700	18%	75643	2500	30	92000	CT*
VANADIUM	105	120	13%	68	75.2	10%	105	2500	0	2590	99%
ALUMINUM	58396	66100	12%	47439	56800	18%	58396	2500	23	69000	CT*
MAGNESIUM	7704	9200	18%	7785	10600	31%	7704	2500	3	11700	160%
BARIUM	403	470	15%	187	240	25%	403	2500	0	3050	106%
ZINC	1261	1450	14%	1370	1830	29%	1261	2500	1	3860	104%
MANGANESE	499	550	10%	511	690	30%	499	2500	0	2850	94%
COBALT	22	27.4	22%	24	45.7	62%	22	2500	0	2300	91%
COPPER	1121	1300	15%	4882	6000	21%	1121	2500	0	3600	99%
IRON	14796	16400	10%	25301	32600	25%	14796	2500	6	19100	172%
LEAD	1016	1170	14%	2254	3000	28%	1016	2500	0	3500	99%
CHROMIUM	158	160	1%	170	270	45%	158	2500	0	2400	90%
NICKEL	96	100	4%	243	370	41%	96	2500	0	2900	112%
SILVER	-	<1		-	<1		-	2500		2550	102%
PHOSPHORUS	78	68.7	-13%	389	540	33%	78	2500	0	2800	109%
SODIUM	48765	66000	30%	54251	63000	15%	48765	2500	20	68000	CT*
BISMUTH	385	560	37%	787	1200	42%	385	2500	0	3060	107%
INDIUM	-	<1		-	<1		-	2500		2500	100%
MOLYBDENUM	15	17.9	18%	12	14.9	22%	15	2500	0	2780	111%
TIN	394	400	2%	235	310	28%	394	2500	0	2910	101%
SILICON	43775	51500	16%	48817	63000	25%	43775	2500	18	52800	CT*
TITANIUM	7967	9300	15%	5271	6000	13%	7967	2500	3	11800	153%
ARSENIC	7.8	8.6	10%	6.5	8.25	24%	7.8	25	0	34.1	105%
SELENIUM	-	<2.5		0.8	0.9	12%	-	25		25.9	104%
ANTIMONY	-	<1.25		2.2	2.6	17%	-	25		29.7	119%
TELLURIUM	-	<2.5		3.5	3.89	11%	-	25		31.3	125%
MERCURY	0.322			-			0.322				

*CT = Cannot test for percent recovery on spiked samples when original sample concentration is more than 10 times spike concentration.

Table 7-16. Fabric Filter Ash Sample QC Data for Metals (continued)

ANALYTE	PT-05 (mg/kg)	DUPL (mg/kg)	RPD (%)	PT-05 (mg/kg)	Conc. Spiked (mg/kg)	PT-05/ Spike Ratio	Spiked Sample (mg/kg)	Percent Recovery (%)	Canviro PT-06 (mg/kg)	Canviro QA #1 (mg/kg)	Canviro QA #2 (mg/kg)	RTI QA1 (mg/kg)	CV (%)
CADMIUM	71.5	68.1	-5%	71.5	1000	0	1100	103%	100	120	120	64	23%
BERYLLIUM	<1	<1		<1	1000		920	92%	<1	<1	<1	1	
CALCIUM	125000	120000	-4%	125000	1000	125	126000	CT*	152000	142000	136000	47676	35%
VANADIUM	140	150	7%	140	1000	0	140	0%	120	160	160	60	35%
ALUMINUM	59300	61900	4%	59300	1000	59	61000	CT*	54600	56300	57300	22646	30%
MAGNESIUM	8700	8900	2%	8700	1000	9	10100	140%	7300	9100	8400	3496	31%
BARIUM	98.1	110	11%	98.1	1000	0	1230	113%	100	110	210	260	40%
ZINC	5580	5350	-4%	5580	1000	6	6500	92%	10200	9200	8900	4768	25%
MANGANESE	970	950	-2%	970	1000	1	1990	102%	780	830	860	1017	10%
COBALT	87.6	90.6	3%	87.6	1000	0	1040	95%	48.2	64.5	67.9	60	12%
COPPER	440	440	0%	440	1000	0	1400	96%	390	410	460	721	27%
IRON	18600	19300	4%	18600	1000	19	20000	140%	13000	13000	13700	9913	12%
LEAD	2030	2020	0%	2030	1000	2	3100	107%	3820	3060	3120	2682	13%
CHROMIUM	270	270	0%	270	1000	0	1320	105%	160	160	180	144	8%
NICKEL	760	790	4%	760	1000	1	1770	101%	390	390	430	340	8%
SILVER	<1	<1		<1	1000		940	94%	<1	<1	<1	4	
PHOSPHORUS	26.7	24.7	-8%	26.7	1000	0	1300	127%	19.7	21.6	35.4	5662	170%
SODIUM	72200	70300	-3%	72200	1000	72	73000	CT*	109000	115000	113000	26619	41%
BISMUTH	430	430	0%	430	1000	0	1590	116%	290	340	280	ND	
INDIUM	<1	<1		<1	1000		1240	124%	<1	<1	<1		
MOLYBDENUM	94.9	110	15%	94.9	2500	0	2250	86%	84.4	80	73.8	56	[illegible]
TIN	460	510	10%	460	2500	0	2360	76%	560	420	580	186	36%
SILICON	58800	57700	-2%	58800	2500	24	60600	72%	73700	66400	73000	155300	40%
TITANIUM	11400	12300	8%	11400	2500	5	14400	120%	12000	8620	8960	7052	20%
ARSENIC	15.4	15.1	-2%	15.4	25	1	40.6	101%	19.5	18.9	17.8	33	27%
SELENIUM	0.94	1.06	12%	0.94	25	0	27.1	105%	0.63	0.69	0.65	3	75%
ANTIMONY	9.19	9.69	5%	9.19	25	0	35.8	106%	10.4	10.5	10.1	240	147%
TELLURIUM	<2.5	<2.5		<2.5	25		30	120%	<2.5	<2.5	<2.5	NRM	
MERCURY	0.322			0.322					-			37	

*CT = Cannot test for percent recovery on spiked samples when original sample concentration is more than 10 times spike concentration.

TABLE 9-5. PERFORMANCE TEST DATA SUMMARY: ASH ORGANIC/METALS

STEAM LOAD OPERATION TEST #		INTERM GOOD PT-02	NORMAL POOR PT-03	NORMAL POOR PT-04	INTERM VERY POOR PT-05	HIGH POOR PT-06	NORMAL POOR PT-07	NORMAL GOOD PT-08	NORMAL GOOD PT-09	INTERM GOOD PT-10	NORMAL GOOD PT-11	HIGH GOOD PT-12	LOW GOOD PT-13	LOW GOOD PT-14
DRY BOTTOM ASH														
ORGANICS:														
TOTAL PCDD	(mg/h)	ND	ND	ND	ND	ND	ND	0.900	0.120	ND	ND	ND	NC	ND
	(ng/g)	ND	ND	ND	ND	ND	ND	0.25	0.04	ND	ND	ND	NC	ND
	(mg/tonne *)	ND	ND	ND	ND	ND	ND	0.031	0.004	ND	ND	ND	NC	ND
TOTAL PCDF	(mg/h)	ND	ND	ND	ND	ND	ND	1.536	0.297	ND	ND	ND	NC	ND
	(ng/g)	ND	ND	ND	ND	ND	ND	0.43	0.09	ND	ND	ND	NC	ND
	(mg/tonne *)	ND	ND	ND	ND	ND	ND	0.054	0.010	ND	ND	ND	NC	ND
TOTAL CB	(mg/h)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(ng/g)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(mg/tonne *)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
TOTAL PCB	(mg/h)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(ng/g)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(mg/tonne *)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
TOTAL CP	(mg/h)	73.3	15.1	38.7	42.8	46.4	66.6	14.5	11.4	9.8	ND	ND	NC	25.8
	(ng/g)	20.7	4.2	10.3	14.6	13.6	18.0	4.1	3.4	3.4	ND	ND	NC	10.5
	(mg/tonne *)	2.66	0.49	1.26	1.58	1.69	2.52	0.51	0.38	0.38	ND	ND	NC	1.36
TOTAL PAH	(mg/h)	45431	774	371	221	464	618	84	46	32	31	663	NC	108
	(ng/g)	12853	217	99	76	136	168	24	14	11	11	196	NC	44
	(mg/tonne *)	1647	25.1	12.1	8.2	16.9	23.4	2.9	1.5	1.2	1.2	23.7	NC	5.7
METALS:														
ANTIMONY	(g/h)	ND	ND	ND	3.1	ND	3.9	12.4	ND	ND	6.0	7.1	NC	4.0
	(ug/g)	ND	ND	ND	1.1	ND	1.1	3.6	ND	ND	2.2	2.1	NC	1.7
	(g/tonne *)	ND	ND	ND	0.11	ND	0.15	0.43	ND	ND	0.24	0.25	NC	0.21
ARSENIC	(g/h)	46	31	32	30	26	21	46	30	19	18	46	NC	28
	(ug/g)	13.7	8.9	8.7	10.5	7.8	5.9	13.1	9.1	6.8	6.5	14.1	NC	11.5
	(g/tonne *)	1.68	0.99	1.04	1.10	0.96	0.81	1.59	0.97	0.73	0.70	1.66	NC	1.47
CADMIUM	(g/h)	18	30	22	17	16	18	24	20	18	18	14	NC	22
	(ug/g)	5.4	8.7	6.0	5.9	4.6	5.1	7.0	6.1	6.6	6.8	4.3	NC	9.1
	(g/tonne *)	0.67	0.98	0.71	0.61	0.57	0.70	0.85	0.64	0.70	0.73	0.51	NC	1.16
CHROMIUM	(g/h)	616	1084	782	555	534	602	810	679	518	464	622	NC	761
	(ug/g)	181	314	214	196	158	166	232	210	186	170	189	NC	316
	(g/tonne *)	22	35	25	21	19	23	28	22	20	18	22	NC	40
COPPER	(g/h)	33,583	11,271	13,586	10,851	3,795	4,874	8,292	20,599	9,869	13,312	52,861	NC	10,525
	(ug/g)	9,878	3,267	3,728	3,835	1,121	1,348	2,371	6,383	3,546	4,882	16,067	NC	4,369
	(g/tonne *)	1,218	366	443	401	138	185	289	677	378	523	1,890	NC	556

TABLE 9-5. PERFORMANCE TEST DATA SUMMARY: ASH ORGANIC/METALS (Continued)

STEAM LOAD OPERATION TEST #		INTERM GOOD PT-02	NORMAL POOR PT-03	NORMAL POOR PT-04	INTERM VERY POOR PT-05	HIGH POOR PT-06	NORMAL POOR PT-07	NORMAL GOOD PT-08	NORMAL GOOD PT-09	INTERM GOOD PT-10	NORMAL GOOD PT-11	HIGH GOOD PT-12	LOW GOOD PT-13	LOW GOOD PT-14
LEAD	(g/h)	3,218	5,500	5,050	5,414	3,439	6,590	13,099	3,864	4,303	6,147	4,240	NC	8,675
	(ug/g)	947	1,594	1,386	1,913	1,016	1,823	3,746	1,197	1,546	2,254	1,289	NC	3,601
	(g/tonne *)	117	179	165	200	125	249	457	127	165	242	152	NC	458
MERCURY	(g/h)	ND	ND	0.130	ND	1.090	0.980	ND	ND	0.230	ND	0.085	NC	ND
	(ug/g)	ND	ND	0.035	ND	0.322	0.272	ND	ND	0.081	ND	0.026	NC	ND
	(g/tonne *)	ND	ND	0.004	ND	0.040	0.037	ND	ND	0.009	ND	0.003	NC	ND
NICKEL	(g/h)	1,931	867	631	833	326	331	594	705	293	663	565	NC	802
	(ug/g)	568	251	173	294	96	92	170	218	105	243	172	NC	333
	(g/tonne *)	70	28	21	31	12	13	21	23	11	26	20	NC	42
ZINC	(g/h)	4,813	3,414	4,539	3,262	4,269	4,935	5,942	3,603	5,092	3,737	3,618	NC	4,523
	(ug/g)	1,416	990	1,245	1,153	1,261	1,365	1,699	1,116	1,830	1,370	1,100	NC	1,877
	(g/tonne *)	175	111	148	121	155	187	207	118	195	147	129	NC	239
GRATE SIFTINGS ASH														
METALS:														
ANTIMONY	(g/h)	5.75	3.81	5.60	2.62	3.13	5.91	0.61	6.96	1.03	4.96	2.47	NC	1.87
	(ug/g)	41	30	53	25	44	51	6.1	59	11	45	23	NC	21
	(g/tonne *)	0.209	0.124	0.183	0.097	0.114	0.224	0.021	0.229	0.039	0.195	0.088	NC	0.098
ARSENIC	(g/h)	1.84	1.00	0.83	0.84	0.67	1.19	0.97	1.58	0.70	1.06	1.39	NC	0.86
	(ug/g)	13.2	8.0	7.9	8.1	9.4	10.3	9.7	13.4	7.7	9.7	13.1	NC	9.7
	(g/tonne *)	0.067	0.033	0.027	0.031	0.024	0.045	0.034	0.052	0.027	0.042	0.050	NC	0.046
CADMIUM	(g/h)	0.88	1.02	1.30	1.16	0.82	1.32	1.29	0.63	1.02	1.33	1.38	NC	0.78
	(ug/g)	6.3	8.1	12.4	11.3	11.5	11.4	12.9	5.3	11.2	12.1	13.0	NC	8.8
	(g/tonne *)	0.032	0.033	0.042	0.043	0.030	0.050	0.045	0.021	0.039	0.052	0.049	NC	0.041
CHROMIUM	(g/h)	60	29	48	47	20	37	21	39	35	34	20	NC	26
	(ug/g)	430	233	461	454	284	319	208	328	388	311	192	NC	297
	(g/tonne *)	2.18	0.94	1.58	1.73	0.73	1.40	0.73	1.27	1.36	1.34	0.73	NC	1.39
COPPER	(g/h)	307	93	218	98	819	208	156	192	1,505	420	171	NC	352
	(ug/g)	2,196	745	2,079	956	11,534	1,797	1,563	1,630	16,533	3,819	1,616	NC	3,958
	(g/tonne *)	11.1	3.0	7.1	3.6	29.8	7.9	5.5	6.3	57.7	16.5	6.1	NC	18.6
LEAD	(g/h)	2,869	268	522	400	1,195	1,859	443	2,084	482	782	907	NC	760
	(ug/g)	20,494	2,142	4,971	3,881	16,829	16,022	4,429	17,665	5,294	7,105	8,558	NC	8,545
	(g/tonne *)	104.0	8.7	17.0	14.8	43.4	70.4	15.5	68.5	18.5	30.7	32.4	NC	40.2
MERCURY	(g/h)	0.127	0.293	0.201	0.208	0.072	0.135	0.229	0.052	ND	0.021	0.081	NC	0.050
	(ug/g)	0.910	2.350	1.920	2.020	1.020	1.160	2.290	0.440	ND	0.200	0.760	NC	0.560
	(g/tonne *)	0.005	0.010	0.007	0.008	0.003	0.005	0.008	0.002	ND	0.001	0.003	NC	0.003

TABLE 9-5. PERFORMANCE TEST DATA SUMMARY: ASH ORGANIC/METALS (Continued)

STEAM LOAD OPERATION TEST #		INTERM GOOD PT-02	NORMAL POOR PT-03	NORMAL POOR PT-04	INTERM VERY POOR PT-05	HIGH POOR PT-06	NORMAL POOR PT-07	NORMAL GOOD PT-08	NORMAL GOOD PT-09	INTERM GOOD PT-10	NORMAL GOOD PT-11	HIGH GOOD PT-12	LOW GOOD PT-13	LOW GOOD PT-14
NICKEL	(g/h)	143	27	44	117	21	44	30	54	33	50	27	NC	38
	(ug/g)	1,025	214	416	1,136	303	381	295	455	361	453	253	NC	432
	(g/tonne *)	5.20	0.87	1.42	4.33	0.78	1.67	1.03	1.77	1.26	1.96	0.96	NC	2.03
ZINC	(g/h)	161	205	446	184	199	780	217	235	485	293	205	NC	145
	(ug/g)	1,153	1,639	4,248	1,789	2,798	6,727	2,171	1,994	5,330	2,664	1,930	NC	1,628
	(g/tonne *)	5.9	6.7	14.5	6.8	7.2	29.5	7.6	7.7	18.6	11.5	7.3	NC	7.7
ECONOMIZER ASH														
ORGANICS:														
TOTAL PCDD	(mg/h)	ND	ND	ND	0.0060	0.0003	ND	0.0017	0.0014	ND	ND	ND	NC	ND
	(ng/g)	ND	ND	ND	0.43	0.03	ND	0.09	0.09	ND	ND	ND	NC	ND
	(ug/tonne*)	ND	ND	ND	0.221	0.011	ND	0.058	0.045	ND	ND	ND	NC	ND
TOTAL PCDF	(mg/h)	0.0008	0.0049	0.0023	0.0252	0.0125	0.0064	0.0116	0.0076	0.0002	ND	0.0019	NC	ND
	(ng/g)	0.03	0.44	0.15	1.83	1.20	0.45	0.65	0.49	0.02	ND	0.11	NC	ND
	(ug/tonne*)	0.029	0.159	0.076	0.931	0.456	0.242	0.403	0.249	0.008	ND	0.066	NC	ND
TOTAL CB	(mg/h)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(ng/g)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(ug/tonne*)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
TOTAL PCB	(mg/h)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(ng/g)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(ug/tonne*)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
TOTAL CP	(mg/h)	0.333	0.045	0.304	0.138	0.042	0.113	0	0.216	0.143	0.352	0.170	NC	0.401
	(ng/g)	14.0	4.0	20.0	10.0	4.0	8.0	0	14.0	15.0	26.0	10.0	NC	24.0
	(ug/tonne*)	12.1	1.5	9.9	5.1	1.5	4.3	0	7.1	5.5	13.8	6.1	NC	21.2
TOTAL PAH	(mg/h)	0.29	1.5	0.78	6.6	11.4	0.76	0.21	0.23	ND	0.19	ND	NC	ND
	(ng/g)	12	130	51	475	1,087	54	12	15	ND	14	ND	NC	ND
	(ug/tonne*)	10.4	47	25	242	413	29	7.4	7.6	ND	7.4	ND	NC	ND
METALS:														
ANTIMONY	(g/h)	0.15	0.06	0.15	0.18	0.10	0.16	0.04	ND	0.14	0.10	0.05	NC	0.13
	(ug/g)	6.2	5.5	10.1	12.7	9.3	11.0	2.2	ND	14.3	7.4	2.7	NC	8.1
	(g/tonne *)	0.0054	0.0020	0.0050	0.0065	0.0035	0.0059	0.0014	ND	0.0052	0.0039	0.0017	NC	0.0071
ARSENIC	(g/h)	0.28	0.15	0.19	0.20	0.18	0.15	0.16	0.17	0.12	0.18	0.21	NC	0.24
	(ug/g)	11.9	13.0	12.5	14.6	17.6	10.7	9.3	10.9	12.7	13.1	12.4	NC	14.4
	(g/tonne *)	0.0103	0.0047	0.0062	0.0074	0.0067	0.0057	0.0057	0.0055	0.0047	0.0070	0.0075	NC	0.0127
CADMIUM	(g/h)	0.24	0.07	0.12	0.08	0.06	0.09	0.17	0.10	0.06	0.08	0.15	NC	0.11
	(ug/g)	10.2	6.6	7.9	5.9	6.2	6.5	9.9	6.5	5.9	5.7	8.9	NC	6.5
	(g/tonne *)	0.0088	0.0024	0.0039	0.0030	0.0023	0.0035	0.0061	0.0033	0.0021	0.0030	0.0054	NC	0.0058

TABLE 9-5. PERFORMANCE TEST DATA SUMMARY: ASH ORGANIC/METALS (Continued)

STEAM LOAD OPERATION TEST #		INTERM GOOD PT-02	NORMAL POOR PT-03	NORMAL POOR PT-04	INTERM VERY POOR PT-05	HIGH POOR PT-06	NORMAL POOR PT-07	NORMAL GOOD PT-08	NORMAL GOOD PT-09	INTERM GOOD PT-10	NORMAL GOOD PT-11	HIGH GOOD PT-12	LOW GOOD PT-13	LOW GOOD PT-14
CHROMIUM	(g/h)	5.2	1.8	8.2	4.5	1.6	3.1	2.8	12.8	2.6	2.8	3.6	NC	5.2
	(ug/g)	220	160	540	330	150	220	160	830	270	210	210	NC	310
	(g/tonne *)	0.19	0.06	0.27	0.17	0.06	0.12	0.10	0.42	0.10	0.11	0.13	NC	0.27
COPPER	(g/h)	10.5	6.2	10.3	9.4	5.3	8.3	39.9	28.0	8.4	7.3	9.9	NC	18.9
	(ug/g)	440	550	680	679	509	590	2259	1,820	880	540	580	NC	1130
	(g/tonne *)	0.38	0.20	0.34	0.35	0.19	0.32	1.39	0.92	0.32	0.29	0.35	NC	1.00
LEAD	(g/h)	14.0	10.4	14.3	13.1	6.9	13.8	20.1	11.7	9.4	11.8	16.7	NC	15.7
	(ug/g)	590	929	940	949	659	980	1,140	760	980	870	979	NC	940
	(g/tonne *)	0.51	0.34	0.47	0.48	0.25	0.52	0.70	0.38	0.36	0.46	0.60	NC	0.83
MERCURY	(mg/h)	0.500	0.390	ND	0.280	0.250	0.300	0.370	0.310	ND	ND	ND	NC	0.470
	(ug/g)	0.021	0.035	ND	0.020	0.024	0.021	0.021	0.020	ND	ND	ND	NC	0.028
	(mg/tonne *)	0.018	0.013	ND	0.010	0.009	0.011	0.013	0.010	ND	ND	ND	NC	0.025
NICKEL	(g/h)	9.8	1.5	11.7	17.8	1.8	4.1	2.3	12.2	2.9	2.8	4.4	NC	11.0
	(ug/g)	410	130	770	1289	170	290	130	790	300	210	260	NC	660
	(g/tonne *)	0.35	0.05	0.38	0.66	0.06	0.15	0.08	0.40	0.11	0.11	0.16	NC	0.58
ZINC	(g/h)	22.4	16.2	26.7	19.4	18.4	19.1	26.5	30.0	13.9	31.8	22.9	NC	30.4
	(ug/g)	940	1,449	1,759	1,408	1,758	1,349	1,499	1,950	1460	2350	1349	NC	1819
	(g/tonne *)	0.81	0.53	0.87	0.72	0.67	0.72	0.92	0.99	0.53	1.25	0.82	NC	1.60
FABRIC FILTER ASH														
ORGANICS: TOTAL PCDD	(mg/h)	NC	NC	117	41	281	85	27	147	32	105	6	NC	209
	(ng/g)	NC	NC	84	96	227	154	62	112	27	49	20	NC	184
	(mg/tonne *)	NC	NC	3.8	1.5	10.2	3.2	0.9	4.8	1.2	4.1	0.2	NC	11.0
TOTAL PCDF	(mg/h)	NC	NC	238	30	349	149	42	292	55	213	18	NC	188
	(ng/g)	NC	NC	172	71	282	271	96	222	47	100	56	NC	166
	(mg/tonne *)	NC	NC	7.8	1.1	12.7	5.6	1.4	9.6	2.1	8.4	0.6	NC	9.9
TOTAL CB	(mg/h)	NC	NC	1,467	465	2,086	518	316	1,667	798	1,507	223	NC	1,957
	(ng/g)	NC	NC	1,059	1,085	1,684	941	729	1,266	684	704	708	NC	1,727
	(mg/tonne *)	NC	NC	48	17	76	20	11	55	31	59	8	NC	103
TOTAL PCB	(mg/h)	NC	NC	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(ng/g)	NC	NC	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
	(mg/tonne *)	NC	NC	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	ND
TOTAL CP	(mg/h)	NC	NC	4,598	1,231	7,552	2,748	710	5,711	2,243	4,762	456	NC	2,511
	(ng/g)	NC	NC	3,320	2,870	6,095	4,997	1,636	4,336	1,924	2,225	1,447	NC	2,216
	(mg/tonne *)	NC	NC	150	46	275	104	25	188	86	187	16	NC	133