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GEOMATRIX

18 January 1993
Project 1736.10

Mr. Rahn Verhaeghe
Alameda Real Estate Investments
1150 Marina Village Parkway, Ste. 100
Alameda, CA 94501

Subject: Phase I and Phase II Evaluation of Fill Material
Proposed Buildings 4 and 5 - Parcel H
Marina Village Development
Alameda, California

1101 Marina Village

Dear Rahn:

Please find the subject Phase I and Phase II Evaluation of Fill Material report for Buildings 4 and 5, Parcel H. If you have any questions, please don't hesitate to call us.

Sincerely,

GEOMATRIX CONSULTANTS, INC.

Elizabeth Nixon

Elizabeth Nixon
Project Manager

Tom Graf

Tom Graf, P.E.
Vice President

EAN/slr
CONTR\1736BLDG.LTR

Attachment

cc: K. Tinsley/R. Arulanantham - Alameda County Health Care Services Agency
R. Hiett - California Regional Water Quality Control Board
J. Sieger - Vintage Properties

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PHASE I AND PHASE II EVALUATION OF FILL MATERIAL PROPOSED BULDINGS 4 AND 5 - PARCEL H

Marina Village Development
Alameda, California

Prepared for

Alameda Real Estate Investments
1150 Marina Village Parkway
Alameda, California

Prepared by

Geomatrix Consultants, Inc.
100 Pine Street - 10th Floor
San Francisco, California 94111

January 1993
Project No. 1736.10

Geomatrix Consultants

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Marina Village Development
Alameda, California

1.0 INTRODUCTION

Geomatrix Consultants, Inc. (Geomatrix) prepared this report on behalf of Alameda Real Estate Investments (AREI) in accordance with our 2 April 1992 Work Plan for Evaluating Fill near Proposed Buildings 4 and 5, Alameda Marina Village, Alameda, California (Phase I) and our September 1992 Work Plan for Soil Sampling and Analysis, Parcel H Marina Village, Alameda, California (Phase II). This report is being submitted to the Alameda County Health Care Services Agency (ACHCSA) for their review. The report evaluates petroleum hydrocarbons and total and soluble lead contained in fill material on a parcel of land that AREI plans to develop for commercial/office use (Figures 1 and 2).

1.1 PURPOSE

AREI plans to develop the 2-acre site with two office buildings, paved parking lots, and landscaped areas. The buildings will cover about 65 percent of the parcel, paved surfaces will cover about 25 percent, and landscaping about 10 percent. The boundaries of the site and the layout of the two office buildings are shown on Figure 2. The site is zoned for commercial use as designated by the master plan for the entire Marina Village development, adopted by the Alameda City Council.

Recent studies have indicated that surface fill at the site contains high boiling petroleum hydrocarbons, characterized as "asphalt-like." The origin of the asphalt-like material in the fill is uncertain, but apparently it was part of the fill or was introduced when the fill was placed in the early 1900s. AREI proposes to leave the fill beneath the development.

During a meeting with the Regional Water Quality Control Board (RWQCB) and the ACHCSA on 19 May 1992, and at a second meeting with the ACHCSA on 26 May 1992, the agencies expressed concern about potential threats to groundwater and surface water quality and to human health due to leaving the petroleum-containing fill beneath the proposed development. Tasks included in Phase I were performed to address these concerns. As requested by the RWQCB, a feasibility study evaluating remedial alternatives for soil containing petroleum hydrocarbons also was performed as part of Phase I activities.

During meetings between Geomatrix and the ACHCSA on May 26 and on 15 July 1992, the ACHCSA requested that the lead content of the fill soil be characterized, because historical site usage included a steel manufacturing plant. Because development plans included regrading activities, we proposed that lead characterization work be completed once the site was regraded so that the data would represent actual soil conditions beneath the development. The purpose of the total lead characterization is to evaluate if lead concentrations in the fill would present a risk to public health; if results indicated a potential risk, then further evaluation of risk or risk management measures would be undertaken. The ACHCSA also requested that the solubility of lead be evaluated to assess the potential for soluble lead to migrate to underlying groundwater. Tasks included in Phase II were performed to address these concerns.

Phase II activities also included characterizing the petroleum hydrocarbon concentrations in the fill after the site was regraded, to provide data on petroleum hydrocarbon distribution in soil beneath the development.

1.2 REPORT ORGANIZATION

This report is organized as follows: Section 2 presents a description of Phase I activities and results; Section 3 presents a description of Phase II activities and results; Section 4 proposes a site management plan to address remaining petroleum hydrocarbons in soil beneath the site; and Section 5 summarizes our conclusions and presents our recommendations for the site.

2.0 PHASE I

Phase I activities were performed to summarize site history; evaluate groundwater quality downgradient of the site; evaluate potential risks to human health from the petroleum hydrocarbons in the soil; and to evaluate the feasibility and costs of remediating the petroleum hydrocarbons in soil.

2.1 PHASE I SCOPE OF WORK

The Phase I scope of work included:

- identifying the origin of the fill material;
- summarizing data regarding previous characterization of petroleum hydrocarbons contained in the fill;
- installing 2 shallow groundwater monitoring wells and 1 piezometer;
- sampling and chemically analyzing groundwater from the 2 wells;
- measuring groundwater levels in the 2 wells, 1 piezometer, and an existing well to establish the depth and direction of groundwater flow;
- preparing a health risk assessment (HRA) to evaluate possible threats to human health from petroleum hydrocarbons contained in the fill, based on a future-use scenario; and
- evaluating the feasibility of remediating petroleum hydrocarbons in fill, including estimating costs and considering net benefit to groundwater quality.

Phase I of this report describes the origin and chemical characterization of fill soil based on historical accounts and soil sampling and analysis performed in 1991. Field methods used for installing wells and sampling groundwater during Phase I activities are described, and chemical analyses and results are presented. The feasibility analysis consists of identifying remedial alternatives and the cost of qualitatively assessing the benefit to shallow groundwater quality. The HRA, which was performed by Industrial Compliance of Little

Rock, Arkansas, evaluates possible threats from the petroleum-containing soil to human health after the property has been developed. The approach and conclusions of the HRA are summarized herein; a copy of the complete HRA is attached as Appendix A.

2.2 ORIGIN AND CHARACTERIZATION OF FILL

According to an historical account of the Marina Village area, in "A History of Tract 29 and Environs, Marina Village, Alameda, California, 1900-Present," prepared in September 1989 by Dr. Laurence H. Shoup of Archaeological/Historical Consultants in Oakland, California, fill material beneath the site and vicinity likely was placed in the early 1900s when marshlands were filled to create land to support a growing shipbuilding industry. The fill soil reportedly was generated from dredging for nearby shipping channels, harbors, and estuaries. According to AREI, the original building on the site, which was constructed in 1916, was used as a steel fabrication plant. By the 1960s, the site and vicinity were no longer used for industrial purposes and were primarily vacant. The steel fabrication plant was demolished in the late 1970s, after Marina Village Associates acquired the site. The site has been vacant since that time.

In 1988, soil generated from a nearby excavation was stockpiled on the site. The stockpiled soil, which contained petroleum hydrocarbons, was placed on plastic sheeting to separate it from underlying soil. When AREI began preliminary work for property development in June 1991 (repositioning stockpiled soil for use as surcharge fill), fill soil beneath the stockpiled soil and plastic sheeting was sampled and analyzed for petroleum hydrocarbons. Samples were collected and analyzed in June and August of 1991. Results of the analyses are summarized in draft letter reports from Geomatrix to AREI dated 23 August 1991 and 5 November 1991. Copies of these letter reports are included as Appendix B.

Analysis of composited soil samples collected in June 1991 indicated that fill soil contained high boiling petroleum hydrocarbons at concentrations of 30 to 4100 milligrams per kilogram (mg/kg). Friedman & Bruya of Seattle, Washington, a laboratory that specializes in identifying the components of petroleum products, characterized the petroleum as a high boiling, asphalt-like hydrocarbon.

To evaluate further the distribution of petroleum hydrocarbons in the fill soil, Geomatrix collected discrete samples from beneath the stockpiled soil in August 1991. We performed field analysis of the samples by thin layer chromatography using a diesel standard for comparison. Results indicated total petroleum hydrocarbon (TPH) concentrations of 50 to more than 1000 mg/kg were detected in 16 samples at depths of about 1 foot below the top of the fill. In samples collected at depths of 3 feet below the fill surface, TPH concentrations generally did not exceed 50 mg/kg, with the exception of 7 locations that contained 50 to more than 1000 mg/kg TPH. Samples collected at depths of 5 feet below the fill surface contained no detectable petroleum hydrocarbons. Based on observations made during sampling, the fill layer over native bay sediments is about 5 feet thick. Analytical results suggest that the petroleum hydrocarbons are present in the upper 3 feet of the fill. The estimated total volume of fill containing petroleum hydrocarbons within the boundaries of the proposed development is about 10,000 cubic yards.

The stockpiled soil generated in 1988 was moved to another location within Marina Village in October 1992, and only the original fill material remains. Therefore, this report addresses the original fill soil and not the stockpiled soil formerly overlying the fill.

2.3 PHASE I FIELD ACTIVITIES

The following sections describe installing the two monitoring wells and piezometer, collecting groundwater samples from the two wells, and measuring groundwater levels. Gregg Drilling and Testing of Concord, California, drilled the well boreholes using a mobile B-53 drill rig outfitted with 7-inch outside diameter hollow-stem augers. The well boreholes were advanced to depths of 13 to 16 feet below grade.

2.3.1 Installation of Monitoring Wells

On 15 and 16 April 1992, monitoring wells GMW-3 and GMW-4 and piezometer GP-1 were installed at the locations shown on Figure 2. The wells and piezometer were constructed of 2-inch-diameter, flush-threaded, schedule-40 polyvinyl chloride (PVC) well casing and 0.010-inch factory-slotted PVC well screen. The two wells were installed with screen intervals of 3 to 13 feet below grade; the screened interval of the piezometer is 6 to 16 feet below grade. The screened intervals were designed to intersect the shallow groundwater surface. A filter pack of Lonestar 0/30 sand was poured into the annular space from the bottom of each screen interval to approximately 6 inches above the well screen. A 6- to 12-inch-thick bentonite pellet seal was placed on top of the filterpack before grouting the annular space to the ground surface with cement or sand-cement grout. Well GMW-3 was completed flush with the ground surface with a locking expansion well cap and a traffic-rated christy box. Well GMW-4 and piezometer GP-1 were completed with locking expansion well caps and steel stove-pipe protective casing. Elevations and locations of the wells and piezometer were surveyed by Stedman Engineers of Walnut Creek, California, on 27 April 1992. Well construction is summarized in Table 1; construction details and lithologic descriptions are presented on the boring logs in Appendix C.

2.3.2 Development and Sampling Monitoring Wells

The wells and piezometer were developed on 22 and 23 April 1992 by swabbing and purging. The well screen was swabbed with a surge-block and purged with a QED pump. The temperature, pH, and conductivity of the groundwater were noted during purging. Color and clarity of the groundwater were also noted. The wells were developed until these indicator parameters had stabilized and more than 10 casing volumes of water had been removed. Equipment lowered into the wells during development and sampling was steam cleaned or washed with Alconox and rinsed with municipal and deionized water before each use.

Groundwater samples were collected for chemical analysis from wells GMW-3 and GMW-4 on 24 April and again on 18 May 1992. Groundwater samples were collected after purging 3 casing volumes plus 1 filterpack volume from each well. During purging, temperature, pH, and conductivity were measured and color and clarity noted to ascertain that representative groundwater was entering the well screens. Groundwater samples were collected by lowering a Teflon bailer to the desired depth using a stainless steel reel mounted on top of a surveyor's tripod. Samples were collected in appropriate containers that were labeled and stored in an ice-filled chest for transport under Geomatrix chain-of-custody procedures to a state-certified analytical laboratory for chemical analysis.

2.3.3 Measurements of Groundwater Levels

On 6 May 1992, Geomatrix measured the depth to groundwater in the new monitoring wells and piezometer and in an existing monitoring well (LF-2 on Figure 2) installed by Levine-Fricke, Inc., in 1988. Groundwater elevation data are presented in Table 1. The measured depth to groundwater in these wells ranged from 6.42 to 9.24 feet below the top of the well casing. Groundwater elevations ranged from -4.27 to 0.16 feet relative to the City of Alameda Datum. The potentiometric surface map for the site is shown as Figure 3. The average horizontal hydraulic gradient across the site is approximately 0.01 foot/foot. Groundwater flows to the northwest beneath the site.

2.4 CHEMICAL ANALYSES AND RESULTS

Groundwater samples collected on 24 April 1992 were analyzed by Quanteq Laboratories of Pleasant Hill, California, a state-certified laboratory, using U. S. Environmental Protection Agency (EPA) Method 3510/8015 for petroleum hydrocarbons. A groundwater sample from well GMW-3 was also analyzed for total dissolved solids (TDS) using EPA Method 160.1. Groundwater samples collected on 18 May 1992 were analyzed by EPA Method 3510/8015 for petroleum hydrocarbons by Chromalab, Inc., of San Ramon, California, a state-certified laboratory. Analytical results are summarized in Table 2; copies of laboratory data sheets are included in Appendix D.

Results from the first sampling event indicated that groundwater contained low concentrations of TPH characterized as diesel (1.4 and 2.3 milligrams per liter, mg/l). TPH as motor oil was not reported above the laboratory detection limit of 0.2 mg/l in the two groundwater samples. Total dissolved solids were reported at a concentration of 2400 mg/l. In the second sampling event, TPH characterized as diesel and TPH as motor oil were not reported above the laboratory detection limits of 0.05 and 0.5 mg/l, respectively.

2.5 HEALTH RISK ASSESSMENT

On behalf of AREI, Geomatrix retained Industrial Compliance (IC) of Little Rock, Arkansas, to prepare an HRA for the site. The risk assessment focused on a future-use scenario in which the petroleum-containing fill soil remains beneath the proposed development. Potential health risks were evaluated for construction workers and tenants of the buildings after construction. The following summarizes the methods and findings of the HRA, which is attached as Appendix A.

The HRA includes a thorough review of the physical and chemical characteristics of asphaltic materials. IC reviewed the literature regarding the toxicity and carcinogenicity of asphalt based on human and animal studies. Most human toxicity studies have focused on the effects of asphalt from occupational exposures in which asphalt is heated to more than 150°F. The animal studies generally have included mechanisms for increasing the bio-availability of asphalt through the use of solvents. These toxicity studies, which simulate exposure to asphalt, can be considered "worst case," because the asphaltic material at the site is contained in soil, is at ambient temperature, and is unlikely to be dissolved in solvent. An exposure assessment was performed to identify possible exposure pathways for the asphaltic material for occupants of the proposed development or construction workers who may encounter the soil during subsurface construction.

Based on the physical and chemical properties of asphalt and the toxicity and exposure assessments, IC characterized the risk for future building occupants and construction workers. The risk characterization concluded that the asphaltic material in the fill soil does not present a significant risk to human health, based on the low potential for human contact, and that asphalt toxicity is unlikely to result from exposure to the asphaltic material at ambient temperatures.

2.6 FEASIBILITY ANALYSIS

This section evaluates the feasibility of remediating site soil to reduce petroleum hydrocarbon concentrations. The primary purpose of remediating site soil would be to protect the quality of underlying groundwater and surface water runoff, and to prevent erosion of petroleum-containing soil into nearby surface water bodies. The primary concern for shallow groundwater quality beneath the site is the potential for migration and release of chemicals to the nearby Oakland Inner Harbor (the Harbor). Therefore, the quality of shallow groundwater and surface water runoff discharging to the Harbor should be consistent with the California RWQCB "Water Quality Control Plan for the San Francisco Bay Basin Region," December 1986 (Basin Plan). The Basin Plan's objective for discharge of oils to inland surface waters is that water shall not contain oil in concentrations that produce a visible film or coating on the surface of the water or on objects in the water. Additionally, soil containing residual oil must not be discharged to surface waters.

Based on results of recent chemical analyses, groundwater flowing beneath the site meets the Basin Plan guidelines for discharge to surface waters. Extractable petroleum hydrocarbons in soil in the range of several milligrams per kilogram, as are found at the site, do not produce a visible film or sheen on water. Additionally, the shortest distance to the Harbor from the site is about 600 feet; assuming a worst-case scenario whereby groundwater containing several milligrams per kilogram petroleum hydrocarbons flowed from the site, natural attenuation, adsorption to soil, and biodegradation along the flow path would significantly reduce petroleum concentrations before groundwater reached the Harbor. Although surface water runoff has not been monitored at the site, it is unlikely that surface water in contact with the soil would develop an oily residue, given the absence of visible residual oil in the soil, the high degree of adsorption of the oil to the soil, and the low leachability of the oil, as demonstrated by the very low to nondetectible petroleum concentrations in shallow groundwater. Erosion of unprotected petroleum-containing soil could occur via surface water runoff that may drain to the Harbor. However, once the site is developed, the fill will be protected from erosion by surface water because the ground surface will be covered with buildings, paving, and landscaping.

Because the quality of shallow groundwater beneath the property and vicinity (the background quality) is relatively poor, drinking water is not considered a potentially beneficial use of the shallow groundwater. The California State Water Resources Control Board (CSWRCB, Resolution 88-63) defines potential sources of drinking water as having a TDS concentration of 3000 mg/l or less and a sustainable yield of 200 gallons per day. Although groundwater beneath the site contains slightly less than 3000 mg/l TDS (2400 mg/l TDS), it exceeds the federal secondary maximum contaminant level of 500 mg/l, and therefore would be undesirable as drinking water. Based on the lithology of the site, it is unlikely that the shallow sediments could yield 200 gallons of water per day. Other considerations limiting potential use of shallow groundwater as drinking water include the site's close proximity to the saline water of the Harbor, the plan to use municipally supplied water at the development, and the absence of drinking water supply wells downgradient of the site. For these reasons, shallow groundwater at the site is not considered to have a potential beneficial use as drinking water.

Based on the above discussion, remediating the soil to reduce petroleum concentrations likely would not measurably improve the beneficial uses of groundwater or reduce the potential for release of petroleum to surface waters. The potential for erosion of soil could be reduced by erosion control measures, such as drainage control, or by covering the ground surface. However, for the purpose of evaluating the feasibility and cost of soil remediation, several methods for reducing petroleum concentrations in soil are described below. These methods include excavation followed by:

- on-site biotreatment
- on-site thermal treatment
- off-site disposal.

Rough cost estimates for each method are included in the descriptions and are based on remediation of approximately 10,000 cubic yards of soil containing petroleum hydrocarbons. The estimated cost ranges reflect contractor fees, consultant fees for oversight of remediation, analytical testing, and post-remediation groundwater monitoring. For the purpose of the cost estimate, we assumed that post-remediation groundwater monitoring would be performed quarterly for one year after remediation is complete.

On-Site Biotreatment

On-site biotreatment would consist of excavating the petroleum-containing fill and biotreating the soil on site. Chemical nutrients would be added to the soil to enhance microbiological degradation of the petroleum hydrocarbons. Based on a treatability study performed on the soil in 1991, further degradation (more than what has occurred naturally) of the petroleum would require a relatively long time, because the petroleum is highly weathered and strongly adsorbed to the soil. Further treatability studies would be needed to identify appropriate agents to facilitate petroleum availability to microorganisms, and to predict the amount of petroleum reduction that could be achieved. Based on our experience with biotreating high-boiling, weathered petroleum hydrocarbons in soil, one to two years of active treatment may be necessary before petroleum content is reduced substantially. Following treatment, the soil would be replaced on site. The cost for biotreating the soil is estimated to be $500,000 to $800,000.

On-Site Thermal Treatment

On-site thermal treatment would involve processing excavated soil through an on-site thermal treatment unit. The soil would be stockpiled, passed through a high-temperature heating unit, stockpiled following treatment, and sampled to confirm reduction of petroleum hydrocarbon concentrations. Following treatment, the soil would be replaced in the excavation. Implementing this option would involve obtaining appropriate permits for operating the treatment unit and discharging emissions to the air. The cost for on-site thermal treatment is estimated to be $1,000,000 to $1,500,000.

Off-Site Disposal

Petroleum-containing soil would be excavated and temporarily stockpiled on site. The excavated soil would be sampled and analyzed to evaluate petroleum hydrocarbon concentrations. Soil containing TPH at concentrations less than 100 mg/kg would be transported off-site to a Class III permitted (municipal) disposal facility. Soil containing TPH at concentrations greater than 100 mg/kg would be transported to a Class II permitted disposal facility or to a facility that recycles petroleum-affected soil. The excavation would be backfilled with imported fill material and compacted to grade. The cost for off-site disposal is estimated to be $1,000,000 to $1,500,000.

All three remediation methods described above are technically feasible and proven methods for handling petroleum-containing soil. However, costs for implementing any of the options are significant, primarily because of the large quantity of soil and the high cost of treatment or disposal. Given that soil remediation is not expected to improve the beneficial uses of groundwater, that the costs are high, and that other methods are available for protecting the soil against erosion, remediating the soil to reduce petroleum concentrations is not a practical means of addressing the fill soil.

As a practical alternative to soil remediation, we recommend that a site management plan be implemented to address environmental concerns. Our proposed plan is described below in Section 4.0.

3.0 PHASE II

Phase II included soil sampling and chemical analysis of the fill material after the site was regraded in October 1992. The purpose of the sampling and analysis was to document the concentrations of petroleum hydrocarbons and total and soluble lead in the soil that would remain beneath the development. A statistical approach was used to characterize total lead concentrations in accordance with methodology recommended in U.S. EPA SW-846, Chapter Nine, Methods for Evaluating Solid Waste (SW-846). The 90 percent upper confidence limit (UCL) of the arithmetic mean concentration of total lead in soil was calculated to compare to regulatory criteria for allowing unrestricted site use.

3.1 PHASE II SCOPE OF WORK

The Phase II scope of work included:

- selecting 30 near surface sample locations based on a statistically random sampling grid and collecting 30 soil samples at 1 of 2 depth intervals at each location;
- collecting additional soil samples for possible analysis, in the event that additional analyses were needed;
- chemically analyzing 30 soil samples for total petroleum hydrocarbons characterized as oil, and for total lead;
- based on results of total lead, the eight samples with the highest total lead concentrations were analyzed for soluble lead using the Toxicity Characteristic Leaching Procedure (TCLP); and
- statistically analyzing the total lead concentration data to calculate the 90 percent UCL of the arithmetic mean concentration.

3.2 SELECTING SOIL SAMPLE LOCATIONS AND DEPTH INTERVALS

Soil sampling locations were selected to provide sufficient areal coverage and statistically valid representation of site soil, based on "Simple Random Sampling" procedures outlined in SW-846. The two-acre site was divided into a 20-by-20-foot sample grid, and divided into two depth intervals (0-to-2 feet and 2-to-4 feet below final grade) from which 30 random locations were selected using a random number generator. The sample grid, and selected locations and depth intervals are shown on Figure 4. An additional 10 locations were randomly selected to collect samples, in the event that analytical results of the first 30 samples indicated more data was necessary for statistical analysis.

3.3 PHASE II FIELD ACTIVITIES

On 4 November 1992, Stedman Engineers surveyed and staked the selected random sample locations. On 5 November 1992, a Geomatrix field engineer collected soil samples from the 40 random locations. O.C. Jones, an earthwork contractor from Oakland (check), California was retained by AREI to assist in sample collection. Soil samples were collected at each staked location by excavating soil from the specified depth interval using a backhoe. Approximately 3 to 5 gallons of the excavated soil was then mixed in a plastic tub in order to homogenize the soil within the 2-foot depth interval. Approximately 1 gallon of the homogenized soil was placed in a sealable plastic bag for lead analysis, and 8 to 12 ounces of the homogenized soil was placed in a laboratory-supplied glass jar for TPH as oil (TPHo) analysis. All samples were labeled and transported to Quanteq Laboratories of Pleasant Hill, California, following Geomatrix chain-of-custody procedures. Jar samples were placed in an ice-cooled container for transport to the laboratory. A copy of the chain-of-custody record is included in Appendix E.

3.4 LABORATORY SAMPLE PREPARATION, CHEMICAL ANALYSES, AND RESULTS

To thoroughly homogenize the 30 samples to be analyzed for total lead, the 1-gallon volume of samples were milled to a 10-mesh sieve size by Woodward Clyde Consultants, of Pleasant Hill, California. Before milling, the moisture content of each sample was measured, and then the sample was dried. A subsample of each homogenized sample was used by Quanteq Laboratories, a state-certified laboratory, for total lead analysis by EPA Method 6010 or 7420. After receipt of results, two of the samples were selected for duplicate analysis; a second subsample of each sample was collected and analyzed. Eight of the 30 samples that contained the highest total lead concentrations were analyzed for soluble lead by TCLP. The 30 samples collected for TPHo analysis were analyzed using EPA Method GCFID 3550. Copies of laboratory sheets for all analyses are included in Appendix E.

Results of chemical analyses are summarized in Table 3. Total lead results ranged from 37 to 300 mg/kg in 28 of the samples. The remaining 2 samples contained 710 and 930 mg/kg; duplicate sample analysis results of these two samples indicated 310 and 380 mg/kg of total lead, respectively. Soluble lead concentrations in the 8 samples analyzed ranged from 0.2 to 0.7 mg/l in 7 of the samples, and was not detected above a detection limit of 0.1 mg/l in the remaining sample. TPHo concentrations in the 30 samples ranged from 90 to 1200 mg/kg.

Total lead data was further analyzed statistically to allow comparison to regulatory criteria, as described below in section 3.5. Further statistical analysis was not completed on soluble lead data because soluble lead concentrations were relatively uniform.

3.5 STATISTICAL ANALYSIS OF TOTAL LEAD DATA

Statistical methods presented in SW-846 were followed to evaluate the analytical results for total lead. A copy of relevant portions of SW-846 is included as Appendix E. As described above, a "Simple Random Sampling" plan (Section 9.1.1.3.1 of SW-846) was adopted. A confidence interval (CI) of 80 percent was used in the statistical evaluation, because this is the CI that the EPA document recommends as sufficient to evaluate solid waste, and is acceptable to the ACHCSA. The upper limit of the CI (UCL) then was compared with the regulatory threshold (RT) of 180 mg/kg to evaluate total lead concentrations. SW-846 acknowledges that for all practical purposes, an 80 percent CI is equivalent to a 90 percent UCL for waste classification, because there is only a 10 percent chance that the RT would be equaled or exceeded. We selected an RT of 180 mg/kg based on conversations with ACHCSA regarding lead concentrations considered acceptable to ACHCSA for unrestricted site use.

The following are the general procedures outlined in the EPA document and used in this study to evaluate whether the total lead concentrations in the fill soil are a potential health risk, based on simple random sampling.

1. Calculate: $\bar{x}$, s, s^2, and $s_{\bar{x}}$ for each set of analytical data, where
$\bar{x}$ = the sample arithmetic mean, n = number of samples,
s = sample standard deviation, s^2 = variance, and

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad s^2 = \frac{\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2/n}{n} \qquad s_{\bar{x}} = \frac{s}{n^{1/2}}$$

2. Test for normality:

If $\bar{x}$ is greater than s^2, the sample is considered to have been selected from a normally distributed population; proceed to Step 3.

If $\bar{x}$ is approximately equal to s^2, the sample was not selected from a normally distributed population; perform a square root transformation on the data and recalculate $\bar{x}$ and s before proceeding to Step 3.

If $\bar{x}$ is less than s^2, the sample was not selected from a normally distributed population; perform an arcsine transformation on the data and recalculate $\bar{x}$ and s before proceeding to Step 3.

3. Calculate UCL:

UCL is given by:

$$UCL = \bar{x} + t_{\alpha} s_{\bar{x}}$$

t_{α} is found in a table in SW-846 or any reference book on statistics.

If the data were transformed in Step 2, use the recalculated x and s.

4. Compare UCL with RT:

If the data were transformed in Step 2, back transform the UCL calculated in Step 3 before comparing with RT. If UCL is less than RT, the soil is considered to have a concentration less than the regulatory threshold. If UCL equals or exceeds RT, additional sampling and analysis may be undertaken or it can be concluded that the soil has a concentration exceeding the regulatory threshold.

Because $\bar{x}$ was less than s^2, we performed an arcsine transformation on the data. The transformation was performed by the method described in "Statistics for the Biological Sciences," second edition (Schefler, 1980). To be conservative in the analysis, we used "Statistics for the Biological Sciences" second edition, by William C. Schefler, 1980. To be conservative in the analysis, we used the higher lead concentrations from the two samples (I22 and K24) where duplicate samples were analyzed. The back transformed UCL was calculated to be 161 mg/kg. This statistical analysis demonstrates that the 90 percent UCL of total lead in site soil is less than the RT criteria of 180 mg/kg; therefore, the total lead in soil is not considered to be a potential health risk to future site users.

4.0 SITE MANAGEMENT PLAN

We recommend implementing a site management plan. In the plan, petroleum-containing soil would remain on site as fill beneath the proposed buildings, paved parking lots, and landscaping. The development would effectively cover the petroleum-containing soil, protecting it from contact with surface water and from potential erosion. Within this self-managed plan, AREI would implement the plan and report information to the ACHCSA and RWQCB. The proposed management plan contains the following components:

- groundwater quality monitoring
- notification in case of future disturbance of the soil
- a remedial contingency plan

Groundwater Monitoring

Shallow groundwater downgradient of the site would be monitored regularly for petroleum hydrocarbons. The monitoring program would consist of sampling and analyzing groundwater quarterly for one to two years, then sampling annually or biennially depending on results. Groundwater elevations would be measured to monitor groundwater depths and flow direction. Because current groundwater elevations indicate that groundwater flows to the northwest, we propose adding a well along the downgradient edge of the site, near the northwest corner (see Figures 2 and 3). Assuming that an additional well is installed, groundwater level measurements from the 3 existing wells, 1 piezometer, and the proposed well could be used to monitor groundwater flow.

Results of the groundwater monitoring would be reported to both the ACHCSA and the RWQCB. Reports would include analytical results for petroleum hydrocarbons in groundwater and potentiometric surface maps showing groundwater flow direction. If changes in the data occurred, the ACHCSA and RWQCB would be consulted, and the groundwater monitoring plan would be adjusted as necessary.

Notice Mechanism

To notify future owners of the property that near-surface fill contains petroleum hydrocarbons, a mechanism will be developed to inform contractors performing future excavation at the site. The notice will contain information regarding the nature and extent of petroleum hydrocarbons in the soil and should describe and reference the various reports prepared to evaluate the soil. The notice should specify that during possible future excavation work, exposed soil should be prevented from eroding (or migrating) away from the site and that soil disposal be in accordance with applicable regulations. The HRA performed for the site will be made available to future owners.

Remedial Contingency Plan

The RWQCB has requested that a remedial plan for controlling discharge of groundwater from the site be developed for implementation in the event that groundwater monitoring shows an unacceptable increase in petroleum concentrations. Because the petroleum in the soil has been present for at least 50 years and does not appear to have significantly affected underlying shallow groundwater, we do not anticipate increases in petroleum concentrations in groundwater in the future; therefore, it is unlikely that a remedial program will be implemented in the future.

We recommend that the remedial contingency plan consist of a shallow trench designed to intercept shallow groundwater flowing from the site. The alignment of the trench would be placed along the downgradient side of the site based on the predominant direction of groundwater flow, and would have to account for site structures. Based on the direction of groundwater flow measured in May 1992, the trench would be aligned as shown on Figure 5. The preliminary trench design would consist of the following:

The interceptor trench would be 18 to 24 inches wide, with an 8-inch-diameter, filter fabric wrapped, perforated polyvinyl chloride (PVC) drain pipe placed at the trench bottom. The trench would be backfilled with uniform coarse sand. Cone penetration tests (CPTs) would be performed before installation to determine site stratigraphy along the trench alignment, and the trench would be keyed into low-permeability native sediments underlying the existing site fill material. A typical cross-section of the trench is shown on Figure 6. The bottom of the trench would be sloped at a 1 percent grade to three vertical access pipes, located as shown on Figure 5, to promote drainage toward the pipes. Based on available information indicating that approximately 4 to 5 feet of fill overlie native low-permeability sediments, we anticipate the trench depth to be 5 to 8 feet deep below grade. Final trench depth would depend on the actual fill/native sediment interface depth, as evaluated using the CPT data, spacing of the vertical access pipes, and slope of the trench bottom. The vertical access pipes would consist of 8-inch diameter PVC pipe that connects to the drain pipe at the bottom of the trench, and extends to the ground surface. The pipes would be accessed at the surface through a traffic rated utility box placed over each pipe, flush with surrounding grade. The access pipes could be used to extract groundwater collected in the trench, should the need arise. The contingency plan could be implemented within about a year of the decision to proceed with the plan.

5.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

AREI is planning a commercial development on a 2-acre parcel within the Marina Village Development in Alameda, California. In 1991, soil sampling and chemical analysis of surface and near-surface fill soil revealed that weathered, asphaltic-material was present in the fill soil. The origin of the fill soil appears to be materials dredged from the bay in the early 1900s to fill marshlands. The origin of the asphalt-like material is uncertain, but apparently it was either contained in the original dredge material or introduced to the fill during construction of a building in 1916. The work described in this report was performed to address possible environmental and human health issues that may arise from leaving the petroleum containing soil in place beneath the development. Additionally, fill soil was evaluated for total and soluble lead. Environmental and human health issues include:

- potential erosion of unprotected petroleum-containing soil into adjacent surface waters;

- effect on groundwater quality and potential migration of petroleum toward the Oakland Inner Harbor via groundwater flow or surface water runoff;
- potential health risks to occupants of the proposed development and to construction workers who may contact the petroleum-containing soil;

- potential health risk caused by lead in the soil; and

- potential for soluble lead to leach from the soil to underlying groundwater.

The following conclusions were reached.

- Based on groundwater data obtained from 2 monitoring wells and 1 piezometer installed at the site, petroleum in the fill soil has little to no effect on underlying shallow groundwater.

- Erosion of unprotected soil generally will not occur after the property is developed, because the proposed buildings, parking lots, and landscaping will cover 100 percent of the property; however, future construction could expose petroleum-containing soil, creating a situation whereby surface water could wash soil from the site. A notice mechanism for the property should be established to inform future owners of this situation.

- A feasibility analysis evaluating possible improvements to beneficial uses of groundwater if soil were remediated, and an assessment of remediation costs, suggest that remediating the soil to reduce petroleum concentrations would not produce a net benefit to groundwater quality. Because current concentrations are low to nondetectible, and the shallow groundwater already meets criteria specified in the Basin Plan for discharge to surface waters, improvements to the quality of groundwater would not result in net beneficial uses.

- Based on IC's HRA that evaluated possible human health risks for future occupants and construction workers, the asphalt-like material in the soil does not present a significant health risk to site occupants or construction workers.

- Potential health risks to future site users associated with total lead were not identified; the 90 percent UCL of the arithmetic mean concentration (161 mg/kg) is below 180 mg/kg, which is the concentration criteria adopted by the ACHSCA to trigger requirements for further risk assessment for unrestricted use scenarios.

- The solubility of total lead in the soil is relatively low and is not considered to be a threat to groundwater quality.

The following recommendations were made based on a proposed site management plan.

- Groundwater monitoring would consist of groundwater sampling and analysis for petroleum hydrocarbons in shallow groundwater downgradient of the property and measurement of groundwater flow and gradient.

- A notice mechanism should be developed for the property. The notice would include information on site conditions and would specify that measures to prevent soil erosion be taken during future excavation activities and that soil disposal be in accordance with applicable regulations.

- A remedial contingency plan would be implemented if unacceptable concentrations of petroleum hydrocarbons are detected in groundwater. The remediation would consist of a shallow trench aligned downgradient of the property, designed to passively intercept groundwater flow. The likelihood of having to implement this remedial plan is considered to be very low.

TABLE 1 - PHASE I

WELL CONSTRUCTION DATA AND GROUNDWATER LEVEL MEASUREMENTS

Marina Village
Alameda, California

Well Number	Well Depth (feet below grade)	Screened Interval (feet below grade)	Ground Elevation[1] (feet)	Elevation of Top of PVC Casing[1] (feet)	Date Groundwater Level Measured	Depth to Groundwater Below Top of Casing (feet)	Groundwater Elevation (feet)
GP-1	17	7-17	6.07	6.66	6 May 1992	8.29	-1.63
GMW-3	13	3.5-13.5	4.55	4.39	6 May 1992	6.42	-2.03
GMW-4	13	3-13	6.80	7.36	6 May 1992	7.20	0.16
LF-2[2]	15	5-15	4.52	4.97	6 May 1992	9.24	-4.22

Notes: (1) Ground and top of PVC casing elevations were surveyed by Stedman & Associates, Inc., of Walnut Creek, California. Elevations are relative to City of Alameda Datum (6.4 feet above Mean Sea Level).

(2) LF-2 was installed by Levine-Fricke, Inc. in 1988.

TABLE 2 - PHASE I

ANALYTICAL RESULTS FOR GROUNDWATER SAMPLES[1]
Marina Village
Alameda, California

Results in milligrams per liter (mg/l)

Well Number	Sample Date	Extractable Hydrocarbons as Diesel	Extractable Hydrocarbons as Motor Oil	Total Dissolved Solids
GMW-3	4/27/92	1.4	<0.2	2,400
	5/18/92	<0.05	<0.5	NA[2]
GMW-4	4/27/92	2.3	<0.2	NA
	5/18/92	<0.05	<0.5	NA

[1] Samples collected on 4/27/92 analyzed by Quanteq Laboratories of Pleasant Hill, California. Samples collected on 5/18/92 analyzed by Chromalab, Inc., of San Ramon, California. Samples analyzed by EPA Method 3510/8015 for petroleum hydrocarbons and EPA Method 160.1 for total dissolved solids.

[2] NA indicates sample not analyzed for compound indicated.

TABLE 3 - PHASE II

ANALYTICAL RESULTS FOR SOIL SAMPLES

Parcel H
Marina Village Development
Alameda, California
5 November 1992

Sample Number	Sample Depth (ft)	Total Lead (mg/kg)	Soluble Lead by TCLP (mg/l)	Total Petroleum Hydrocarbons as Oil (mg/kg)
B06	2-4	75	--	200
B11	0-2	85	--	130
B13	0-2	130	--	410
B24	2-4	150	<0.1	390
D09	2-4	44	--	190
D22	0-2	180	0.2	540
E11	0-2	37	--	90
E20	2-4	130	--	300
F24	0-2	110	--	390
G08	0-2	110	--	230
G11	2-4	83	--	160
G13	2-4	57	--	240
G21	2-4	140	0.2	420
H13	2-4	60	--	150
I13	0-2	92	--	370
I22	2-4	900/380	0.3	370
J04	0-2	87	--	210
J18	0-2	73	--	230
J21	2-4	99	--	340
K03	2-4	76	--	320
K08	0-2	62	--	440
K09	2-4	97	--	370
K15	2-4	120	--	610
K21	2-4	120	--	360
K24	0-2	710/310	0.6	470
L12	0-2	110	--	500
L15	2-4	190	0.2	1200

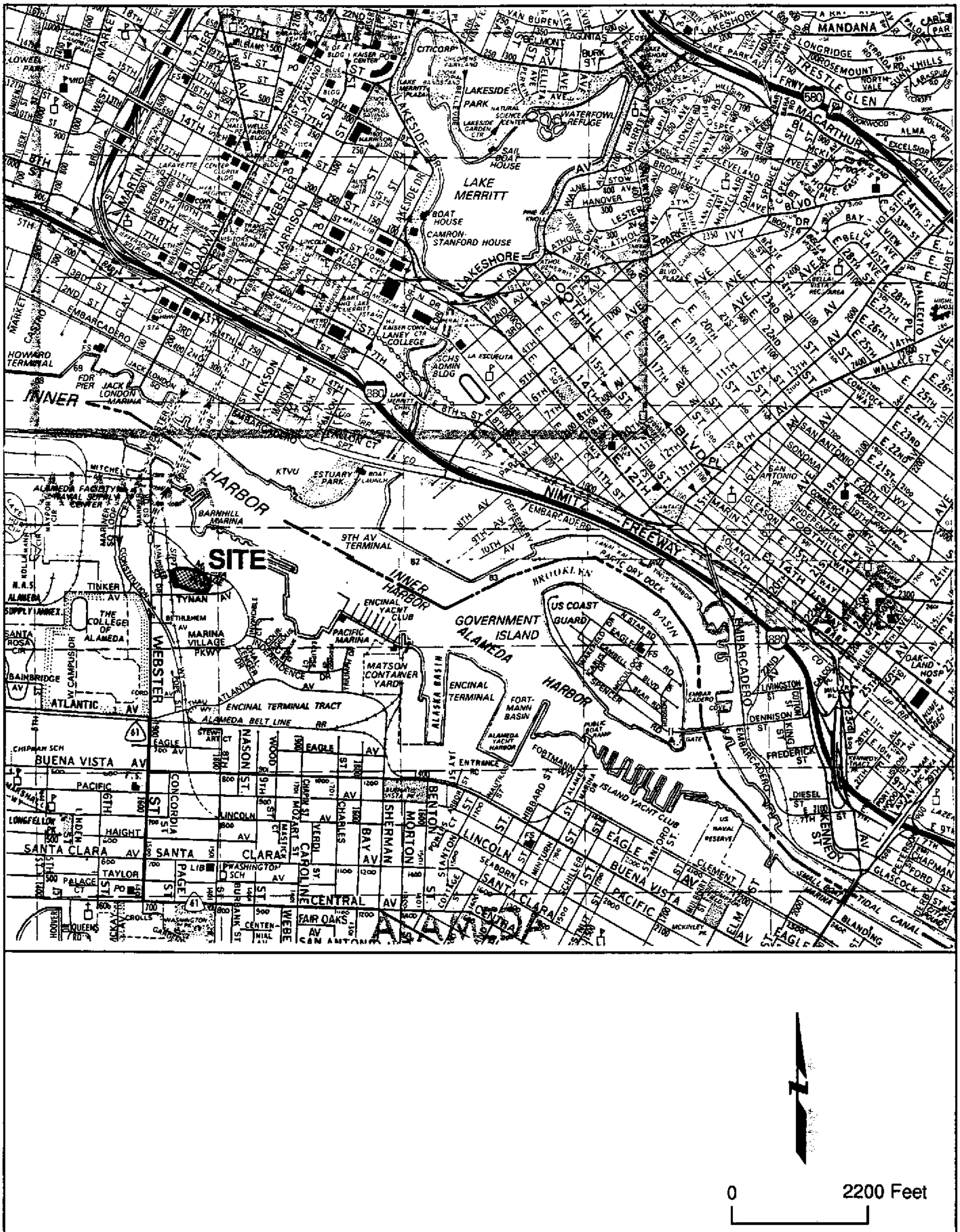
TABLE 3 - PHASE II

ANALYTICAL RESULTS FOR SOIL SAMPLES

Sample Number	Sample Depth (ft)	Total Lead (mg/kg)	Soluble Lead by TCLP (mg/l)	Total Petroleum Hydrocarbons as Oil (mg/kg)
L22	0-2	210	0.3	560
M06	0-2	72	--	230
O24	0-2	300	0.7	380

Notes:

1. Samples collected by Geomatrix Consultants, Inc. on 4 November 1992, and analyzed by Quanteq Laboratories of Pleasant Hill, California, by EPA Methods 6010 or 7420 for total lead, the Toxicity Characteristic Leaching Procedure (TCLP) and EPA Method 6010 for soluble lead, and modified EPA Method 8015 for total petroleum hydrocarbons characterized as oil, respectively, unless otherwise indicated.
2. / indicates duplicate analysis. The higher concentration was used in the statistical analysis.
3. -- indicates sample was not analyzed.
4. mg/kg = milligrams per kilogram.
5. mg/l = milligrams per liter.

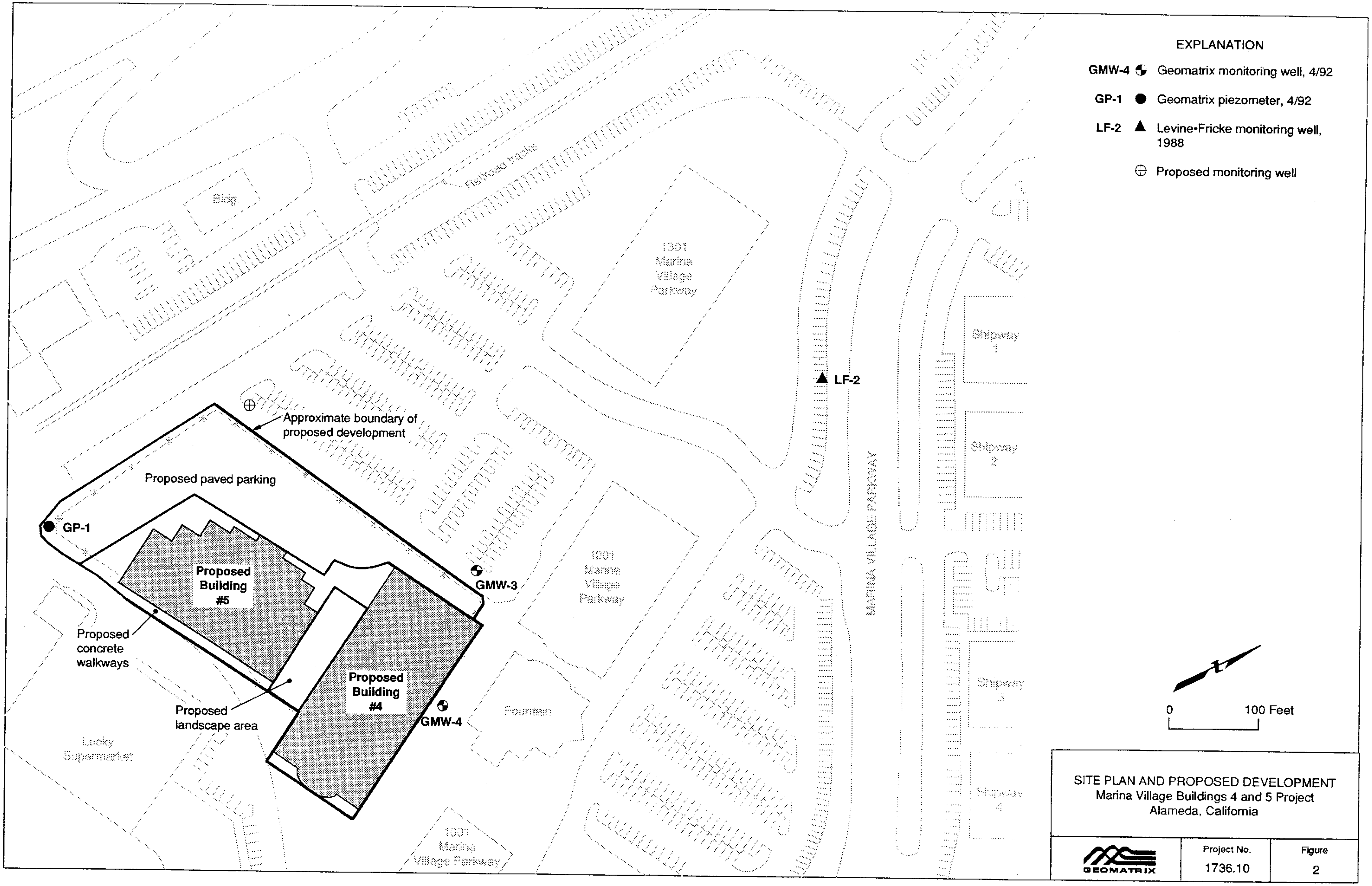


GEOMATRIX

SITE LOCATION MAP
Marina Village Buildings 4 and 5 Project
Alameda, California

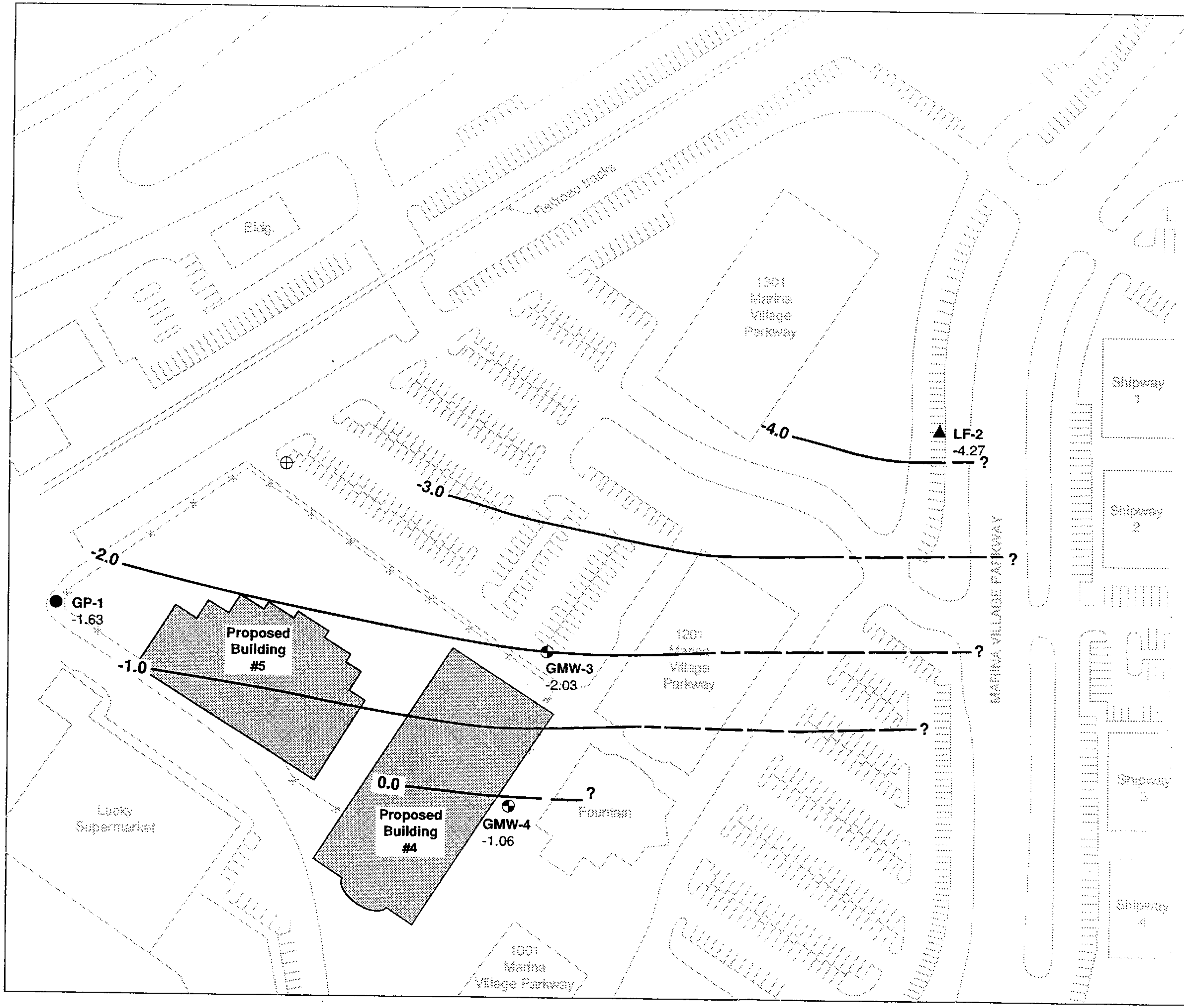
Figure
1

Project No.
1736.10



SITE PLAN AND PROPOSED DEVELOPMENT
Marina Village Buildings 4 and 5 Project
Alameda, California

GEOMATRIX	Project No.	Figure
	1736.10	2



EXPLANATION

GMW-4	⊕	Geomatrix monitoring well, 4/92
GP-1	●	Geomatrix piezometer, 4/92
LF-2	▲	Levine•Fricke monitoring well, 1988
	⊕	Proposed monitoring well
-2.0	—— —	Line of equal elevation in feet

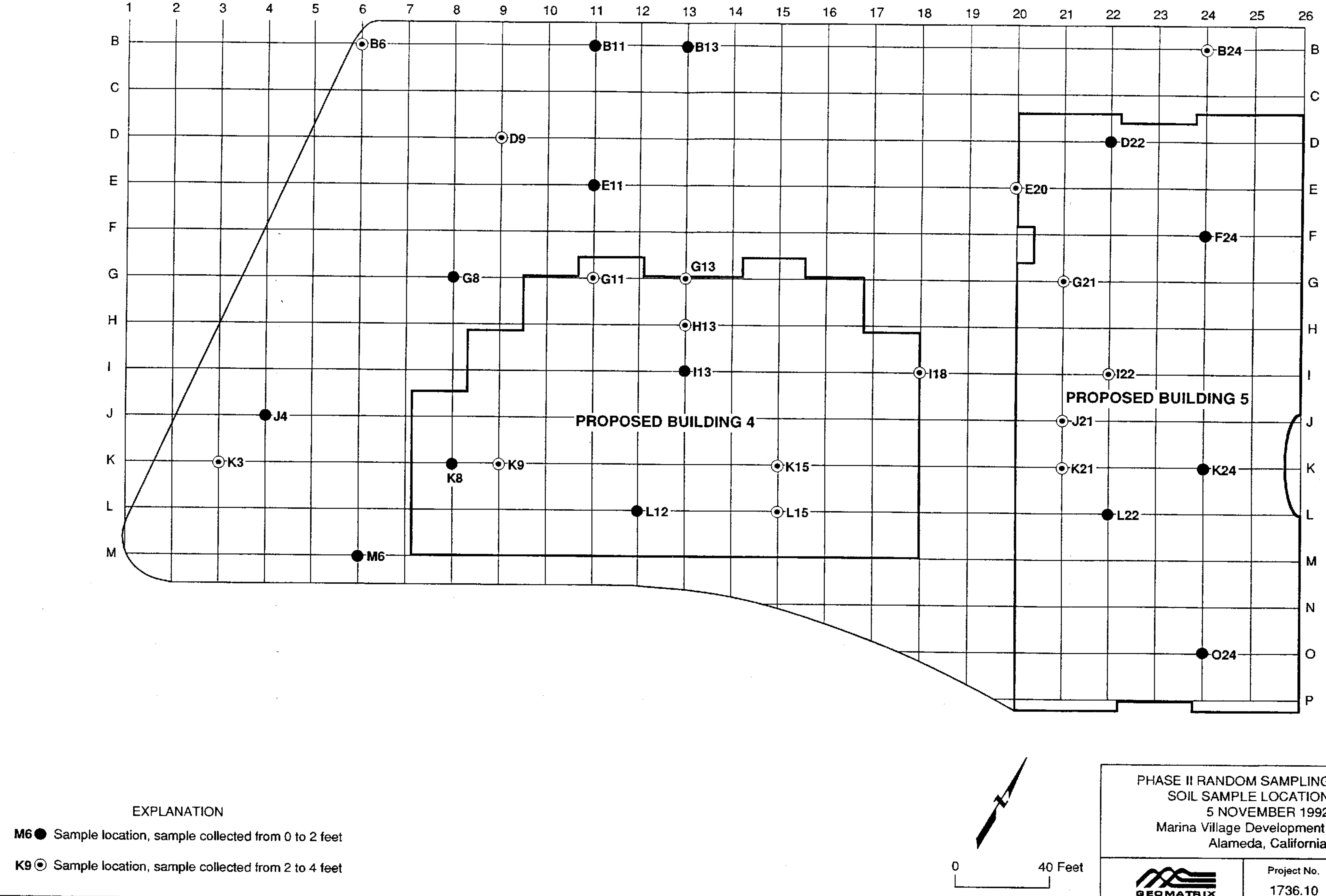
Notes

1. Elevation datum: City of Alameda.
2. Contours based on interpretation of available data. Contours are shown as solid lines for clarity and are not intended to imply certainty.

0 100 Feet

PHASE I
POTENTIOMETRIC SURFACE MAP
6 MAY 1992
Marina Village Buildings 4 and 5 Project
Alameda, California

GEOMATRIX	Project No.	Figure
	1736.10	3



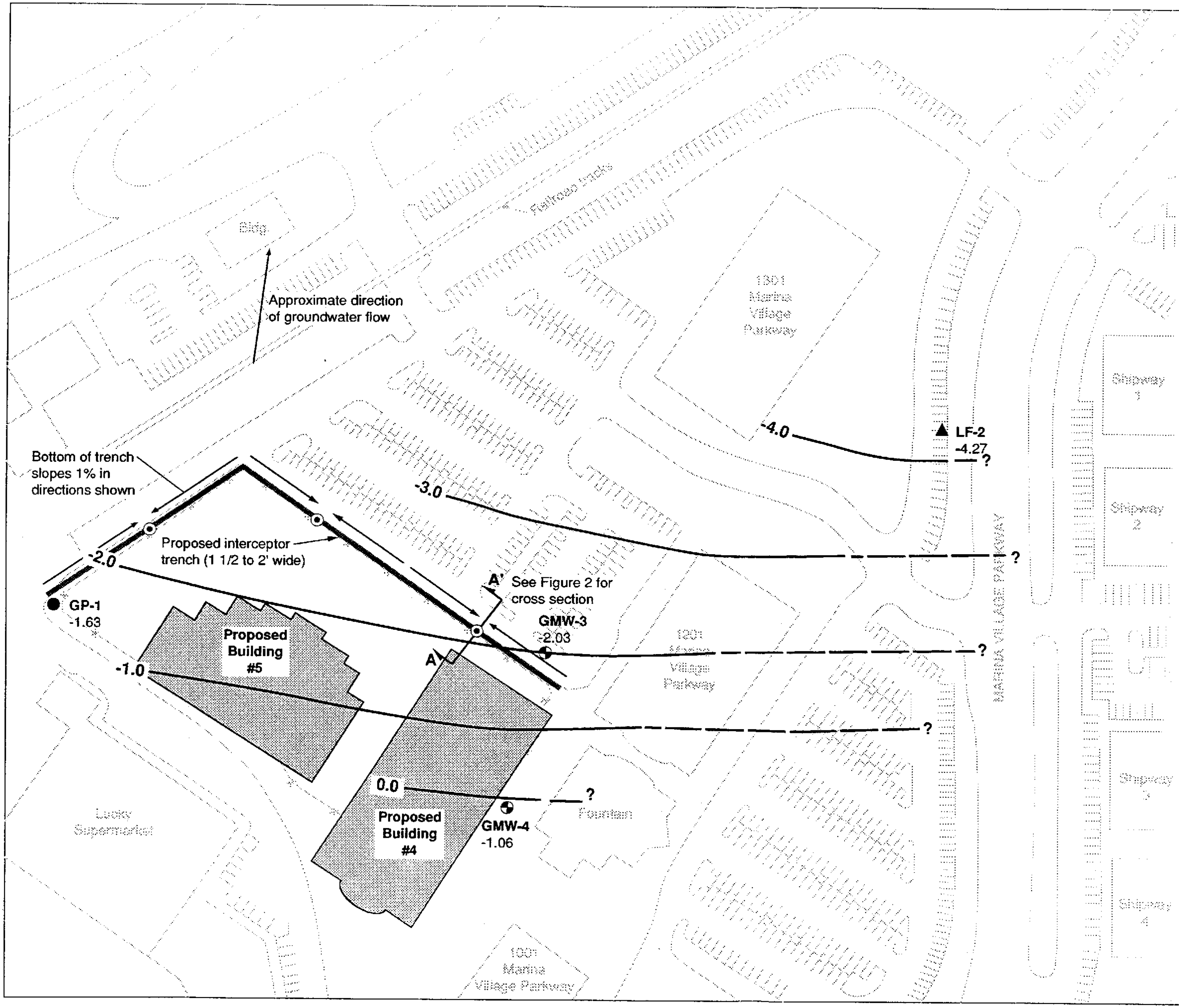
EXPLANATION

M6 ● Sample location, sample collected from 0 to 2 feet

K9 ⊙ Sample location, sample collected from 2 to 4 feet

PHASE II RANDOM SAMPLING GRID AND
SOIL SAMPLE LOCATION PLAN
5 NOVEMBER 1992
Marina Village Development Parcel H
Alameda, California

GEOMATRIX	Project No.	Figure
	1736.10	4



EXPLANATION

GMW-4 ◐ Geomatrix monitoring well, 4/92

GP-1 ● Geomatrix piezometer, 4/92

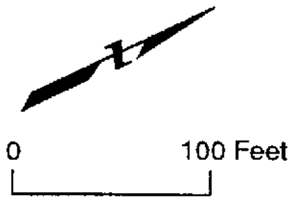
LF-2 ▲ Levine•Fricke monitoring well, 1988

-2.0 —— Potentiometric surface line of equal elevation (in feet), 6 May 1992

⊙ Proposed access pipe

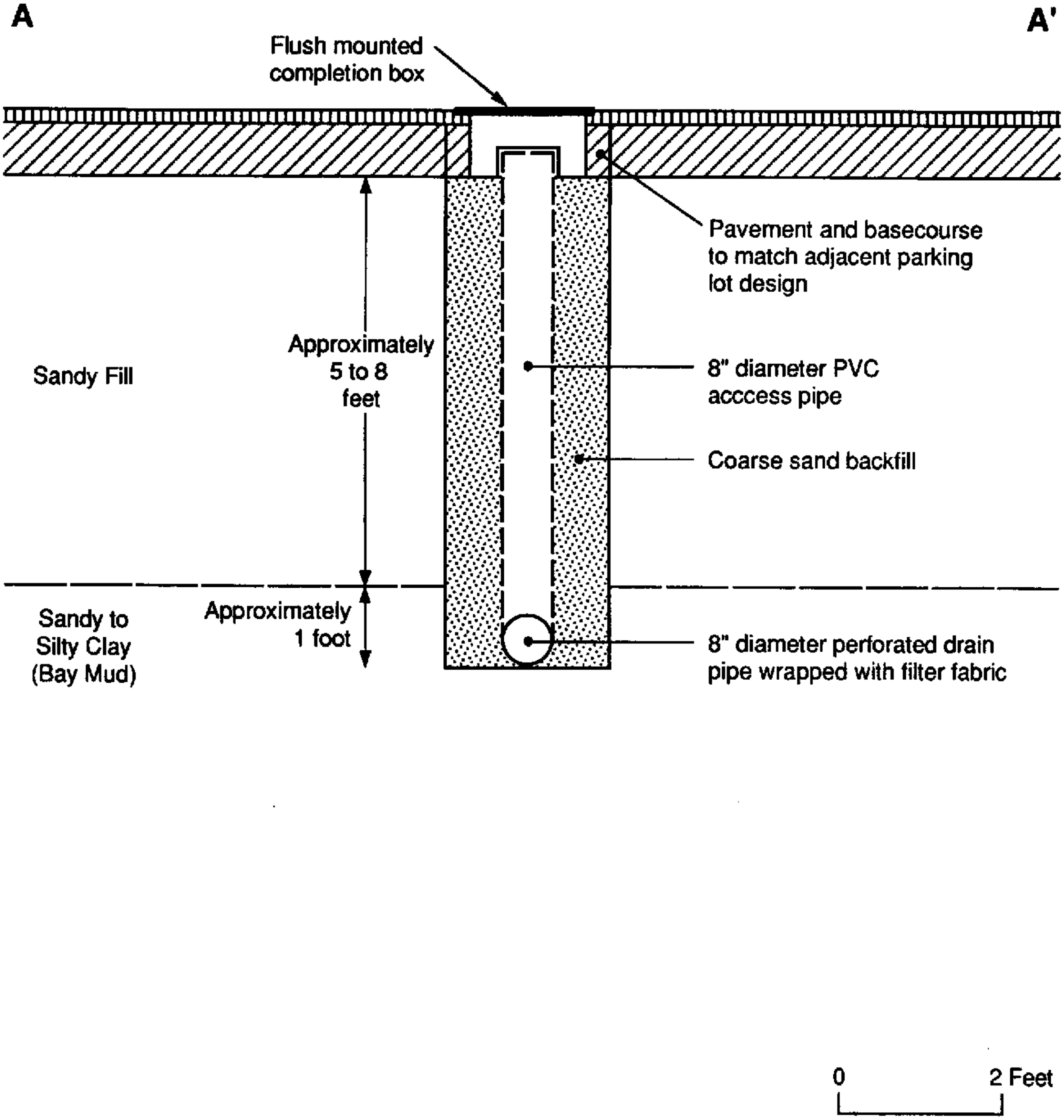
Notes

1. Elevation datum: City of Alameda.
2. Contours based on interpretation of available data. Contours are shown as solid lines for clarity and are not intended to imply certainty.



CONTINGENCY PLAN
INTERCEPTOR TRENCH ALIGNMENT
Marina Village Development Parcel H
Alameda, California

GEOMATRIX	Project No.	Figure
	1736.10	5



GEOMATRIX

TYPICAL CROSS SECTION OF CONTINGENCY PLAN INTERCEPTOR TRENCH AND ACCESS PIPE

Marina Village Development Parcel H
Alameda, California

Figure	6
Project No.	1736.10

APPENDIX A

HUMAN HEALTH RISK ASSESSMENT OF "ASPHALTIC MATERIAL" IN SOIL

Marina Village Development
Alameda, California

Prepared by Industrial Compliance
June 1992

HUMAN HEALTH RISK ASSESSMENT OF "ASPHALTIC MATERIAL" IN SOIL AT THE MARINA VILLAGE DEVELOPMENT

ALAMEDA, CALIFORNIA

Prepared for:

Geomatrix
100 Pine Street, 10th floor
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Prepared by:
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Toxicology and Health Related Sciences Division
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Little Rock, Arkansas 72212

June 1992

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1.0 INTRODUCTION AND OBJECTIVES

The purpose of this document is to review the results of fill material analyses at the Marina Development site in Alameda, California and characterize the potential human toxicity of "high boiling aromatic hydrocarbons present in asphalt" (Friedman and Bruya, 1991). Since there is little information concerning the human toxicity of "asphalt" and there is uncertainty surrounding the exact chemical character and origin of the "asphaltic material" present at the site, a quantitative assessment of human health risk was not possible. Throughout this document, the materials characterized as "high boiling aromatic hydrocarbons present in asphalt" will be referred to as "asphaltic material" in recognition of the unknown source of the petroleum hydrocarbons in site soil which appear to resemble "asphalt."

At present, risk assessment techniques have not been developed by the EPA or other regulatory agencies to assess the human health effects of exposure to complex petroleum hydrocarbon mixtures such as asphalt, diesel fuel, gasoline, or crude oil. Due to the lack of adequate animal testing and uncertainties regarding the effects of "weathering" (i.e., the loss of components of a complex petroleum hydrocarbon mixture due to volatilization, biodegradation, biotransformation, and dissolution of mixture components) on the physical, chemical, and toxicological properties of petroleum hydrocarbon mixtures, methodologies for assessing the risks associated with contact with these mixtures in soil have been slow to develop.

In order to address many of the uncertainties surrounding the potential toxicity and carcinogenicity of the "asphaltic material," we have performed a thorough review of available animal and human literature concerning the toxicological and carcinogenic effects of diesel fuel. In order to provide the reader with necessary background information concerning the risks associated with contact with "asphaltic material" present in soil, we have also reviewed the physical and chemical characteristics of several types of aphalts and high boiling fractions of crude oil.

Section 2 of this report provides a discussion of the physical and chemical properties of several types of asphalt and provides an analysis of the degree to which "asphaltic material" contained in site fill material resembles any of several classes of asphalt materials which are produced commercially. Petroleum hydrocarbon mixtures which may be sources of "asphaltic material" are also discussed.

Methods and assumptions used to assess human exposure to "asphaltic material" are presented in Section 3. Section 4 provides a summary of human and animal data concerning the toxicity of asphalt and "asphaltic materials." Judgements concerning the degree of human health risk, if any, which are associated with contact with "asphaltic materials" in site soils are discussed in terms of the above physical, chemical, and toxicological comparison to asphalt and other "asphaltic materials."

The principal guidance documents used to prepare this report are the "Human Health Evaluation Manual (Volume I)," and the "Exposure Factors Handbook" (USEPA, 1989a; 1989b). These documents provide federal guidance for evaluating exposures and risks.

For information on site background, history, a description of the sampling and analyses performed to date, we refer the reader to reports previously submitted by Geomatrix.

2.0 PHYSICAL/CHEMICAL CHARACTERIZATION OF "ASPHALTIC MATERIALS"

As explained in Section 1.0, constituents detected in Marina Development fill materials have been designated as "asphaltic materials" by virtue of their resemblence to the chemical constituents in asphalt. In order to physically and chemically classify the "asphaltic material" as a true asphalt, it is necessary to know something about the origin and production of the "asphaltic material." This is particularly germane to a toxicological evaluation of asphalt, since certain classes of asphalt appear to be potentially carcinogenic in animal studies whereas other classes lack carcinogenic potential.

A review of the production and physical and chemical characteristics of asphalts is provided in Section 2.1.

Section 2.1 Production and Physical/Chemical Characteristics of Asphalts

Although asphalts occur naturally as natural asphalts, rock asphalts and lake asphalts, the term 'asphalt' in this report refers only to the product recovered from petroleum refining. This description of asphalts does not include 'tar sands,' which occur naturally in various parts of the world (Athabasca, West Canada; Nigeria). The term 'asphalt' (used in the United States) is synonymous with the European terms 'bitumen' and 'asphaltic bitumen.'

2.1.1 Synonyms and trade names of asphalts

<u>Asphalts</u>

CAS No.: 8052-42-4
CAS Name: Asphalt

Synonyms: Bitumen; asphalt bitumen; asphaltum; petroleum asphalt

Oxidized asphalts
CAS No.: 64742-93-4

CAS Name: Asphalt, oxidized

Synonym: Bitumen, oxidized

2.1.2 Description of Asphalts

Asphalts are viscous liquids or solids consisting essentially of hydrocarbons and their derivatives, which are soluble in carbon disulphide. Asphalts are substantially non-volatile at ambient temperatures and soften gradually when heated. They are black or black-brown in colour and possess waterproofing and adhesive properties. Asphalts are obtained by refinery processes from petroleum. Asphalts are also found as natural deposits or as components of naturally-occurring asphalts, in which they are associated with mineral matter.

Asphalts should not be confused with coal-tar products such as coal-tars or coal-tar pitches. The latter are manufactured by the high-temperature carbonization of bituminous coals and differ from asphalts substantially in composition and physical characteristics. A concise review of the differences between asphalts and coal-tar products has been given by Puzinauskas and Corbett (1978). Similarly, asphalts should not be confused with petroleum pitches, which often contain highly aromatic residues, produced by thermal cracking, coking or oxidation from selected petroleum fractions.

Asphalts are classified in terms of specification tests related to their intended applications, for example, penetration, softening-point and viscosity. The penetration test measures, in tenths of a millimeter, the indentation of a specially prepared and controlled sample of asphalt at 25° C by a steel needle of specified dimensions, under a load of 100 g (British Standards Institution, 1974 as cited in IARC, 1985). In the softening-point test, the temperature of a sample of asphalt in the form of a disc is raised at 5°C per minute while being subjected to loading by a small steel ball. As the temperature rises, the asphalt softens, and the particular temperature at which the asphalt is deformed by a distance of 2.54 cm is recorded as the softening-point in °C (British Standards Institution, 1983a as cited in IARC, 1985).

The most important types of asphalts are described below. For the purposes of this report they have been categorized into eight classes, which represent the major types used in industry.

Class 1: *Penetration asphalts* are classified by their penetration value. They are usually produced from the residue from atmospheric distillation of petroleum crude oil by applying further distillation under vacuum, partial oxidation (air rectification), solvent precipitation, or a combination of these processes. In the United States, asphalts that are approximately equivalent to those described here are called *asphalt* cements or *viscosity-graded asphalts*, and are specified on the basis of viscosity measurements at 60°C.

Class 2: *Oxidized asphalts* are classified by their softening-points and penetration values. They are produced by passing air through hot, soft asphalt under controlled temperature conditions. This process alters the characteristics of the asphalt to give reduced temperature susceptibility and greater resistance to different types of imposed stress. In the United States, asphalts produced using air blowing are known as *air-blown asphalts* or *roofing asphalts* and are similar to oxidized asphalts.

Class 3: *Cutback asphalts* are produced by mixing penetration asphalts or oxidized asphalts with suitable volatile diluents from petroleum crudes such as white spirit, kerosene or gas oil, to reduce their viscosity and render them more fluid for ease of handling. When the diluent evaporates, the initial properties of asphalt are recovered. In the United States, cutback asphalts are sometimes referred to as *road oils.*

Class 4: *Hard asphalts* are normally classified by their softening-point. They are manufactured similarly to penetration asphalts, but have lower penetration values and higher softening-points, i.e., they are more brittle.

Class 5: *Asphalt emulsions* are fine dispersions of droplets of asphalt (from classes 1, 3 or 6) in water. They are manufactured using high-speed shearing devices, such as colloid mills. The asphalt content can range from 30-70% by weight. They can be anionic, cationic or non-ionic. In the United States, they are referred to as *emulsified asphalts*.

Class 6: *Blended or fluxed asphalts* may be produced by blending asphalts (primarily penetration asphalts) with solvent extracts (aromatic by-products from the refining of base oils), thermally cracked residues or certain heavy petroleum distillates with final boiling-points above 350°C. Coal-tar products are also sometimes used as fluxes. There is only limited evaporation of the flux.

Class 7: *Modified asphalts* contain appreciable quantities (typically 3-15% by weight) of special additives, such as polymers, elastomers, sulphur and other products used to modify their properties; they are used for specialized applications.

Class 8: *Thermal asphalts* are produced by extended distillation, at high temperature, of a petroleum residue. Some cracking occurs during this process. Currently, they are not manufactured in Europe or the United States.

2.1.3 Chemical Composition and Physical Properties of Asphalts

The chemical composition of asphalts depends both on the original crude oil and on the processes used during refining. Asphalts can generally be described as complex mixtures containing a large number of different chemical compounds of relatively high molecular weight: typically, 82-85% combined carbon, 12-15% hydrogen, 2-8% sulphur, 1-3% nitrogen and 1-2% oxygen. Asphalts contain predominantly cyclic hydrocarbons (aromatic and/or naphthenic) and a lesser quantity of saturated components, which, because of slow and lengthy processing at moderate temperatures, are mainly of very low chemical reactivity.

Generally, the molecules present in asphalts are combinations of well-established structural petroleum units: alkanes, cycloalkanes, aromatics and heteromolecules containing sulphur, oxygen, nitrogen (Broome, 1973 as cited in IARC, 1985) using solvent precipitation and adsorption chromatography. The composition of asphalts is summarized graphically in Figure 2-1.

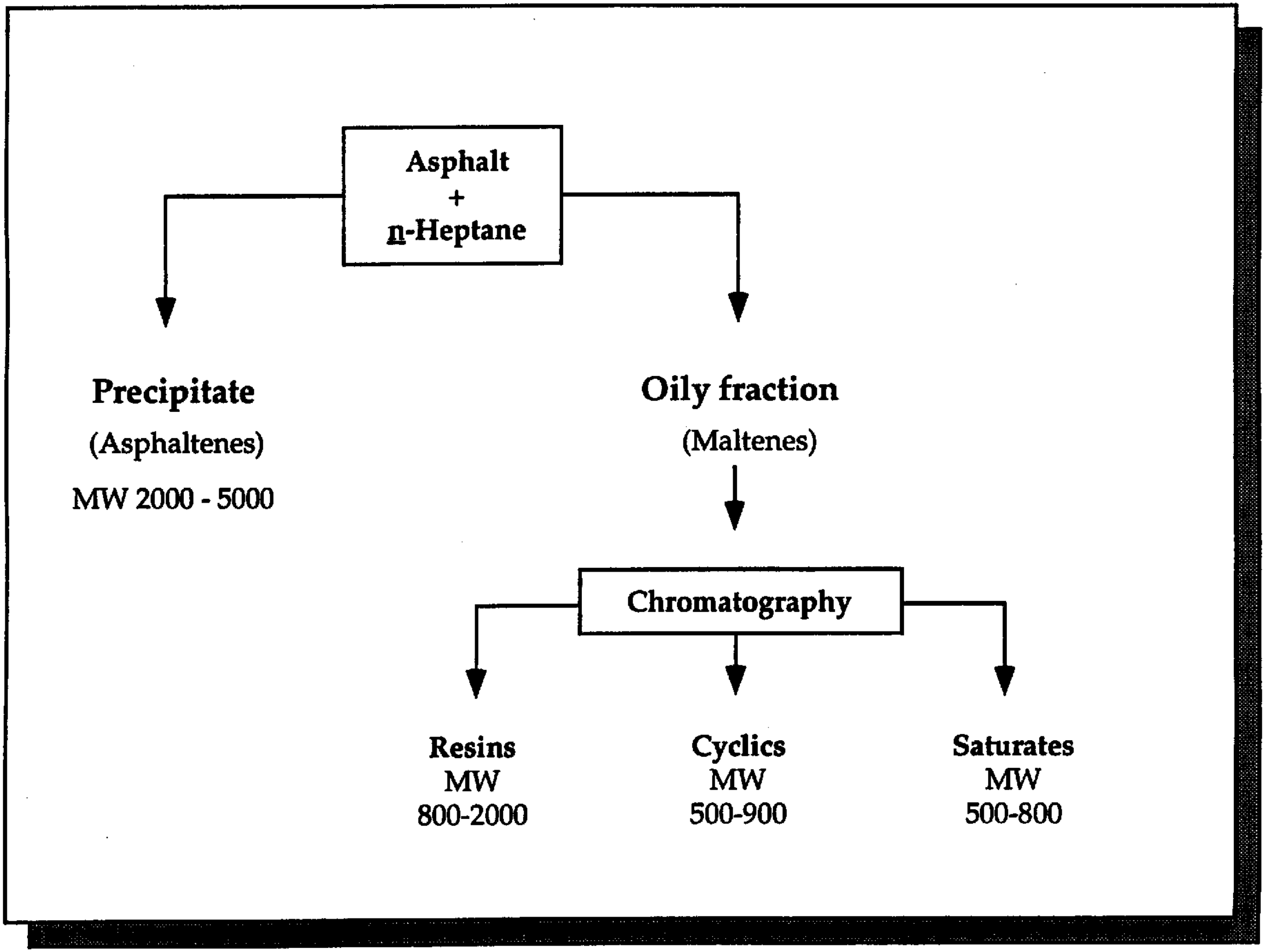
Asphalt
+
n-Heptane
Precipitate
(Asphaltenes)
MW 2000 - 5000
Oily fraction
(Maltenes)
Chromatography
Resins
MW
800-2000
Cyclics
MW
500-900
Saturates
MW
500-800

Figure 2-1

The most successful separation, in terms of understanding physical properities, is one in which asphaltenes are separated as insolubles in normal heptane. The components soluble in normal heptane (maltenes) are adsorbed on activated alumina/silica gel in a chromatorgraphic column. Elution with solvents of progressively higher polarity desorbs and separates three fractions, which are designated as saturates, cyclics (naphthene-aromatics) and resins (polar aromatics).

Asphaltenes are black amorphous solids containing, in addition to carbon and hydrogen, some nitrogen, sulphur and oxygen. Trace elements such as nickel and vanadium may also be present. Asphaltenes are generally considered as highly polar aromatic materials of molecular weights of 2000-5000 (number average), and constitute 5-25% of the weight of asphalts.

Saturates comprise predominantly the straight- and branched-chain aliphatic hydrocarbons present in asphalts, together with alkyl naphthenes and some alkyl aromatics. The average molecular weight range is similar to that of the cyclics, and the components include both waxy and non-waxy saturates. This fraction forms 5-20% of the weight of asphalts.

Cyclics (naphthene aromatics) comprise the compounds of lowest molecular weight in asphalts and represent the major proportion of the dispersion medium for the peptized asphaltenes. They constitute 45-60% by weight of the total asphalt and are dark viscous liquids. They are compounds with aromatic and naphthenic aromatic nuclei with side chain constituents and have molecular weights of 500-900 (number average).

Resins (polar aromatics) are dark-coloured, solid or semi-solid, very adhesive fractions of relatively high molecular weight present in the maltenes. They are dispersing agents or peptizers for the asphaltenes, and the proportion of resins to asphaltenes governs to a degree the sol- or gel-type character of asphalts. Resins separated from asphalts are found to have molecular weights of 800-2000 (number average) but there is a wide molecular distribution. This component constitutes 15-25% of the weight of asphalts.

With penetration asphalts, the asphaltene content increases as penetration decreases; however, oxidized asphalts have higher asphaltene contents than those of penetration grades. During air-blowing, cyclics are converted to resins, which are in turn converted to asphaltenes, whereas vacuum distillation selectively decreases the saturate content, leading to an increased concentration of the other components.

Asphalts (penetration, oxidized and hard types) are subject to hardening from oxidation and polymerization reactions. Although minor loss of volatile components contributes to hardening, the formation of additional asphaltenes by oxidaton is reported to be the main cause (Evans, 1978 as cited in IARC, 1985).

Asphalts can be regarded as colloidal systems (Witherspoon, 1962) consisting of asphaltene micelles dispersed in an oily medium of lower molecular weight (maltenes). The micelles are considered to be asphaltenes with an adsorded sheath of aromatic resins of high molecular weight as a stabilizing solvating layer. Away from the center of the micelle there is a gradual transition to less aromatic resins, and such layers extend outwards into the less aromatic, oily dispersion medium.

Polynuclear aromatic hydrocarbons (PAHs) exist in crude oils (Bingham et al., 1979 as cited in IARC, 1985) but are generally present in more limited amounts in asphalts (Lawther, 1971; Brandt & De Groot, 1985 as cited in IARC, 1985). This is because the principal refinery process used for the manufacture of asphalts, namely vacuum distillation, removes the majority of compounds of lower molecular weight with lower boiling-points, including PAHs with 3-7 fused rings, and because the maximum temperatures involved in the production of vacuum residue range from 350-450°C and are not high enough to initiate significant PAH formation. Other types of asphalt (e.g., thermal asphalts [class 8]) may contain higher levels of PAHs (up to 272 µg/kg), which are formed during cracking operation (Yanysheva et al., 1963). PAHs may also be re-introduced by the flux used in blended or fluxed asphalts [class 6]. Data on PAH content are available only on asphalts in classes 1,2 and 8.

The production and use of asphalts is reviewed in Figure 2-2.

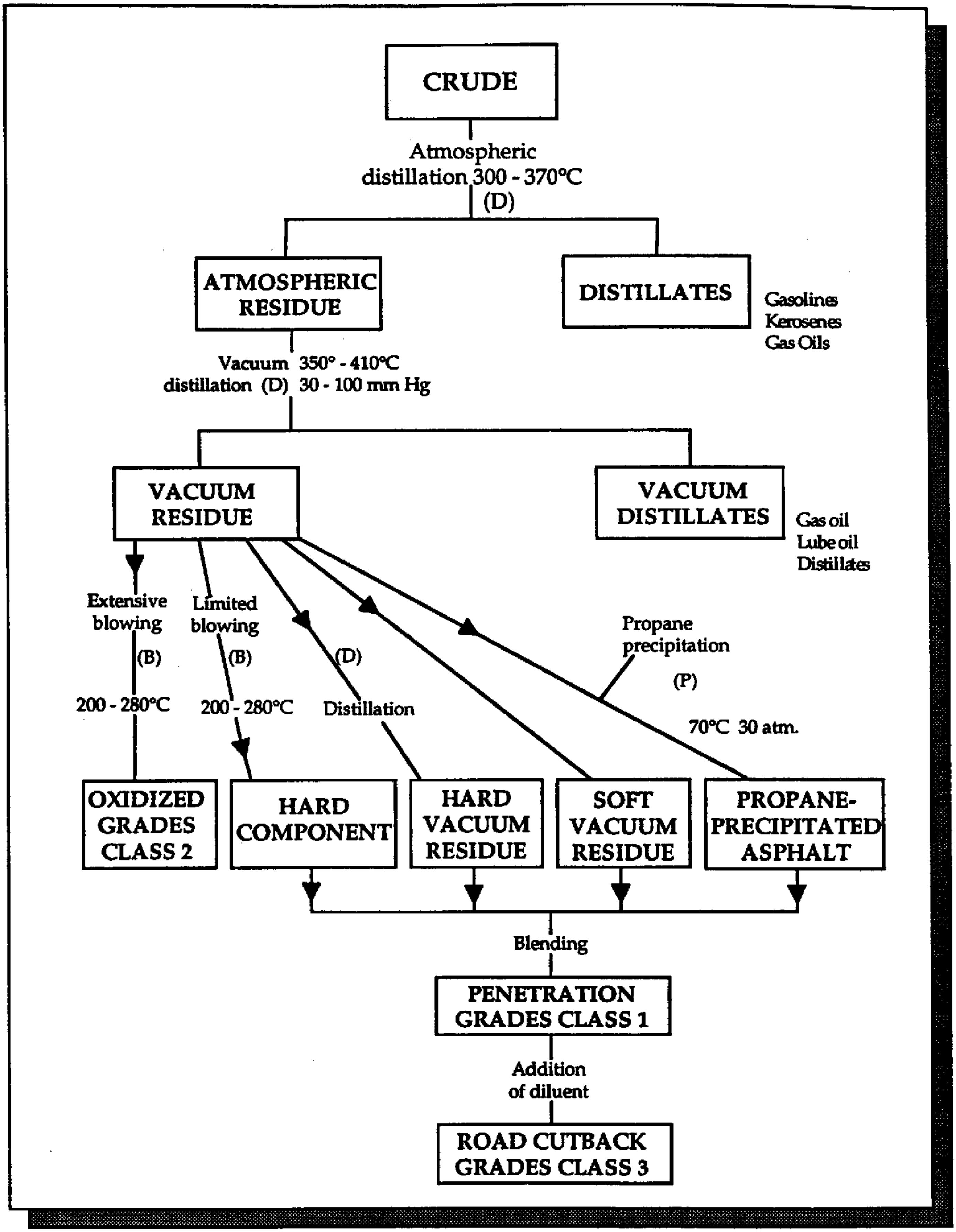
CRUDE
Atmospheric distillation 300 - 370°C
(D)
ATMOSPHERIC RESIDUE
DISTILLATES
Gasolines
Kerosenes
Gas Oils
Vacuum distillation (D)
350° - 410°C
30 - 100 mm Hg
VACUUM RESIDUE
VACUUM DISTILLATES
Gas oil
Lube oil
Distillates
Extensive blowing
(B)
200 - 280°C
Limited blowing
(B)
200 - 280°C
(D)
Distillation
Propane precipitation
(P)
70°C 30 atm.
OXIDIZED GRADES CLASS 2
HARD COMPONENT
HARD VACUUM RESIDUE
SOFT VACUUM RESIDUE
PROPANE-PRECIPITATED ASPHALT
Blending
PENETRATION GRADES CLASS 1
Addition of diluent
ROAD CUTBACK GRADES CLASS 3

Figure 2-2

2.2 "Weathered" Petroleum Hydrocarbon Mixtures as Sources of "Asphaltic Materials"

Owing to the uncertainty regarding the source of constituents (termed "asphaltic material" for the purpose of this report) in Marina Development site soils, the term 'asphalt' cannot be unequivocally applied to these materials. In fact, "weathered" mixtures of petroleum hydrocarbons may take on the appearance of asphalt-like materials. For example, Bossert and Bartha (1984) state that:

> "It is a common observation that the asphaltene portion of crude oils tends to increase rather than decrease during biodegradation, indicating that other hydrocarbon fractions are transformed to asphaltenes. Attack on hydrocarbons by oxygenases produces free radicals and other reactive intermediates that may chemically react with each other forming partially oxygenated, cross-linked, high molecular weight asphaltenes that are quite resistant to further biodegradation."

As discussed in Section 2.1.3, asphaltenes make up approximately 5% to 25% of asphalt by weight. Sullivan et al. (1991) also note that crude oil is largely composed of long chain alkanes and asphaltenes. Thus, weathered petroleum mixtures may also serve as sources of "asphalt-like" materials in the environment.

2.3 Description and Characterization of Asphaltic Material Detected in Marina Development Site Soils

Ten samples of fill material from the Marina Development site were analyzed for extractable hydrocarbons as diesel fuel and as oil. As diesel, no extractable hydrocarbons were detected. However, when analyzed as oil, concentrations of extractable hydrocarbons ranging from 30 mg/kg to 4,100 mg/kg were detected. The arithmetic and geometric means of these concentrations were 764 and 334 mg/kg, respectively. One composite sample characterized as having 980 mg/kg extractable hydrocarbons (as oil) was found to contain 410 mg/kg of "total high boiling compounds" as characterized by Friedman and Bruya (1991). The sample containing 4100 mg/kg extractable hydrocarbons as oil was determined to have 2500 mg/kg as "total high boiling compounds." According to Dr. Jim Bruya of Friedman and Bruya, the "total high boiling compounds" are comprised of hydrocarbons with boiling points in excess of 431°C (808°F) (personal communication, Dr. Jim Bruya).

Using thin layer chromatography, the composited samples were further characterized as containing "moderately polar and polar compounds, such as those found in asphalt" and "high boiling aromatic hydrocarbons present in asphalt." The composited sample was also determined to contain biogenic material as well as asphalt-like material. Unfortunately, this information was insufficient to definitively characterize the "asphaltic material" as asphalt or another type of petroleum hydrocarbon mixture. According to Dr. Bruya, other petroleum hydrocarbon sources such as "highly reused hydraulic fluid" or "roofing tar" may also appear as similar spectra (personal communication, Dr. Jim Bruya). Thus, although the "asphaltic material" detected at the Marina Development site resembles true asphalt in some respects, the same characterization may also be applied to other petroleum hydrocarbon mixtures with high boiling points.

3.0 EXPOSURE ASSESSMENT

As stated by the EPA, an exposure pathway "describes the course a chemical or physical agent takes from the source to the exposed individual. An exposure pathway analysis links the sources, locations, and types of environmental releases with population locations and activity patterns to determine the significant pathways of human exposure" (EPA 1989a).

An exposure pathway is made up of four elements. These are

- A source and mechanism of chemical release,
- A retention or transport medium,
- A point of potential human contact with the affected medium, and
- A route of exposure at the point of contact.

Designation of an exposure pathway as "complete" indicates that human exposure is possible, but does not necessarily mean that exposure is actually occurring. These principles of exposure assessment are applied to "asphaltic material" in soil as they are intended for use in future development at the Marina Development site.

3.1 Identification of Exposure Pathways

Typically, direct exposure to chemicals in soil may result via three routes of exposure. These are the incidental ingestion of soil, skin exposure to soil, and inhalation of soil particles. For direct soil exposure, complete exposure pathways require that the affected soil be available for skin contact or exposed to air such that affected soils may be entrained by winds. Given plans for future development of the site, it is unlikely that soils containing "asphaltic material" will be available for human contact. The lack of potential for humans to be exposed to "asphaltic material" in soil is discussed below.

Plans indicate that the Marina Development site will be developed as a commercial office park. The proposed development includes construction of two office buildings, paved parking lots, walkways, and landscaping. Development plans indicate that 65% of the property will be covered by construction of the two office buildings, 25% by paving, and 10% by landscaping. Once in place, the stockpiled soil and fill containing the "asphaltic material" will comprise a three- foot thick layer beneath the site surface. A one-half to one foot layer of imported fill will be placed on the affected soil to form the subbase for the buildings, pavement, and landscaped areas. For these reasons, it is highly unlikely that future office workers would have direct contact with the "asphaltic material" in soil.

Even if exposure to "asphaltic material" in soil were to occur, other factors also mitigate against the fact that there would be significant exposure. Firstly, 85% of the property will be covered by building foundations and pavement. Thus, at most, only one-third of an acre (of the two acre site) will have exposed surface soil which is available for human contact. In addition, the "asphaltic material" in soil has been characterized as being composed of compounds of 28 carbons and higher (Friedman and Bruya, 1991). Such compounds tend to be tightly adsorbed to soil. Desorption of hydrophobic chemicals (such as polycyclic aromatic hydrocarbons) from soil is not an energetically favored reaction, indicating that mass transfer of hydrophobic chemicals from the soil particle to the skin may take far longer than the 4 to 8 hour period in which skin is in contact with soil or dusts (Watkin and Hull, 1991).

Thus, given future exposure conditions, it is unlikely that an office worker would be exposed to the "asphaltic material" in soil.

3.2 Hypothetical Future Exposure to "Asphaltic Material"

Construction workers or utility line crews may be briefly exposed to "asphaltic material" in soil during soil excavation. Typically, such activities span a period of days to months. When assessed over a lifetime, human exposures to "asphaltic material" associated with construction or other ground intrusive activities are likely to be less than those assumed to result from 25 years of exposure in an office park setting.

4.0 TOXICITY ASSESSMENT

A discussion of the toxic properties of asphalt is presented below. However, from the available analytical results, we are unclear as to the extent to which "asphaltic material" in Marina Development soil resembles asphalt (or a fraction of petroleum hydrocarbons derived from asphalt). In the interest of determining the possible risks associated with these petroleum hydrocarbons in soil, we have characterized the risks of this material in accord with its tentative characterization as an asphalt-like material.

Toxicity studies of asphalt may be broadly classified into two different categories; human and animal. Each group of studies is associated with strengths and weaknesses. For example, it is obvious that the human health risks associated with asphalt exposure are better predicted by human studies. However, nearly all of the human studies involve exposure to asphalt heated to high temperatures. At the high temperatures necessary to work with asphalt, the types of exposures are different from those experienced at ambient temperatures. Polynuclear aromatic hydrocarbon vapors are emitted when asphalt is heated to its high working temperatures. At ambient temperatures, these emissions are insignificant. Thus, workers exposed to heated asphalts are exposed to hazards which are not experienced by the individual exposed to asphalt at ambient temperatures.

More controlled studies of different grades of asphalt are available from animal studies. For example, in controlled experiments, animal exposures are limited to asphalt, whereas in human studies, many workers exposed to asphalt are also often exposed to potentially carcinogenic petroleum hydrocarbon mixtures such as coal tar or roofing tar. Thus, potentially carcinogenic effects observed in exposed humans cannot be unequivocally attributed to asphalt exposure. However, studies in animals are of suspect applicability to man. The mouse, which is widely used in skin painting studies to determine the carcinogenicity of petroleum hydrocarbon mixtures, is described by Williams and Weisburger (1991) to be "exquisitely sensitive" to the carcinogenic effects of PAHs, a common component of certain petroleum hydrocarbon mixtures. Thus, the interpretation of both human and animal studies is subject to certain limitations. These studies and their applicability to risks associated with exposure to "asphaltic material" in soil are discussed below.

4.1 Human Studies

4.1.1 Noncarcinogenic Effects

It is noteworthy that the adverse effects associated with occupational asphalt exposure are due to work with asphalts heated to high temperatures. For example, the Institute of Petroleum (1979) recommends working temperatures of 65°C to 230°C (149°F to 446°F) for varying classes of asphalts. Hazards of exposure to hot asphalts include skin burns, conjunctivitis (Emmett et al., 1977), eczema (Chanial and Joseph, 1964), and respiratory tract irritation characterized by bronchitis, rhinitis, oropharyngitis and laryngitis among exposed workers (Zeglio, 1950).

These physical and toxic effects would not occur in persons exposed to asphalts at ambient temperatures. At ambient temperatures, asphalts are viscous liquids or solids (i.e., roads) and would not be expected to cause adverse health effects. No literature was available describing the adverse effects of exposure to asphalts at ambient temperatures.

4.1.2 Carcinogenic Effects

Interpretation of epidemiological and case report studies of workers exposed to hot asphalts is complicated by concomitant exposures to coal tars or other petroleum hydrocarbon mixtures which are potentially carcinogenic in man and inadequate control of personal habits known to be associated with increased cancer risk (i.e., smoking). As described above, studies of workers exposed to asphalt are indicative of the adverse health effects associated with exposure to hot asphalt rather than the cooled material. The applicability of studies of the carcinogenic effects associated with exposure to hot asphalt are of little significance to persons who may exposed to asphalts at ambient temperatures. However, for the sake of completeness, these studies are briefly reviewed below.

Oliver (1908) reported two cases of scrotal cancer, a rare tumor, in workers exposed to asphalts for 13 and 20 years, respectively. Concomitant exposure to coal-tars and pitches was reported in one case.

Henry (1947) reviewed 3753 cases of skin cancer in 2975 persons. Of these cases, 13 were in 12 persons applying road surface material and nine were in makers of road material. Most of the exposed workers were also in contact with potentially carcinogenic coal-tars.

The largest studies of persons exposed to asphalt are complicated by inadequate control for the potential carcinogenic effects of tobacco use. For example, although Hammond et al. (1976) observed increased standardized mortality ratios for lung cancer, bladder cancer, and skin cancer in 5939 workers who were members of a roofers' union, data regarding smoking were not included in the study. In addition, roofers are commonly exposed hot pitches. As reviewed by the International Agency for Research on Cancer (IARC), evidence is sufficient to consider coal tar pitches to be a human carcinogen.

Similarly, although Menck and Henderson (1976) observed that roofers in Los Angeles County were at a significantly increased risk of lung cancer, the authors failed to account for the potentially confounding effects of exposure to pitches and tobacco.

In a survey of occupations, Decoufle et al. (1977) examined cases of cancer and non-neoplastic diseases recorded at Roswell Park Memorial Hospital, NY, during 1956-1965. Persons employed in clerical jobs were used for comparison with those in other occupations. Relative risks were adjusted for age and smoking habits. A non-significant relative risk of 2.95 was reported for cancer of the buccal cavity and pharynx among roofers and slaters.

Milham (1982) conducted a proportional mortality analysis of deaths among white male residents in the State of Washington during 1950-1979. Among roofers and slaters, there were four deaths due to laryngeal cancer (proportionate mortality ratio, (PMR) 270) and 53 deaths due to cancer of the bronchus and lung (PMR, 161). However, as in the Hammond et al. (1976) and Menck and Henderson (1976) studies, Milham failed to account for the confounding effect of tobacco use. In addition, as with all studies of roofers and slaters, the results of the Milham study are further complicated by potential concomitant exposure to pitches.

4.2 Animal Studies

Animal studies of asphalts give some idea as to the differences in toxic properties of asphalts derived from different refining processes. In particular, different classes of asphalts have been tested in mouse skin painting studies and subcutaneous injection studies with varying results. Owing to uncertainties regarding the classification of the "asphaltic material" detected in Marina Development soils, this additional information concerning toxicological differences between different classes of asphalts is of limited usefulness in providing a basis for the further characterization of the "asphaltic material" detected in soils.

4.2.1 Noncarcinogenic Effects

As in human studies of persons occupationally exposed to asphalt, a number of animal studies have reported that chronic inhalation of asphalt fumes, aerosols, and smoke is associated with emphysema, bronchiolar dilatation, pneumonitis and severe localized bronchitis in guinea pigs, rats and mice (Hueper and Payne, 1960; Simmers, 1964). As in the human studies, these respiratory effects were associated with exposures to asphalts heated to working temperatures (approximately 120°C).

Skin effects after exposure to samples of eight different asphalts [class 1] were studied in random-bred Swiss albino mice (Wallcave et al., 1971). Mice were given twice-weekly applications of 25µl of 10% asphalt dissolved in benzene to shaved areas of the back for an average of 81 weeks. Epidermal hyperplasia was a general finding. Inflammatory infiltration of the dermis, cutaneous ulceration with abscess formation and amyloidosis (an abnormal accumulation of polysaccharide in the tissues) of the spleen and kidney were commonly observed.

4.2.2 Carcinogenicity Studies

Skin painting studies of different asphalts have been conducted in various strains of mice by Simmers et al., 1959; Simmers, 1965a; Simmers, 1965b; Kireeva, 1968; Hueper and Payne, 1960; Wallcave et al., 1971; and Emmett et al., 1981. These results indicate varying degrees of skin carcinogenicity for different types of asphalts (or asphalt fractions) with results ranging from essentially noncarcinogenic (Wallcave et al., 1971; Hueper and Payne, 1960) to moderately carcinogenic (Emmett et al., 1981).

In addition, studies of the carcinogenicity of subcutaneously injected asphalts have also been studied in mice. The applicability of these studies may be questioned by virtue of the fact that they mimic no realistically anticipated route of environmental exposure to asphalt. The results of mouse skin painting studies and subcutaneous injection studies are reviewed below.

A pooled sample of six steam- and air-blown (oxidized) petroleum asphalts (asphalt classes 1 and 2) liquefied with benzene (dose unspecified) was applied twice weekly onto the interscapular skin of 68 (32 males and 36 females) C57 black mice. A group of 63 mice (31 males and 32 females) were similarly treated with benzene alone. Epidermoid carcinomas appeared on the skin of 12 treated animals, the first tumor appearing during the 54th week after the beginning of the experiment. No skin tumor was found in control animals (Simmers et al., 1959).

In another experiment, heated steam-refined petroleum asphalt (a pool of three samples) (asphalt class 1) was applied to the skin of 50 (25 males and 25 females) C57 black mice three times weekly. Interpretation of this study is complicated by an epidemic of pneumonitis which left only 32 survivors after 7 weeks and 6 survivors after one year of the study. After the first year of the study, eight males and five females were added to the group. The number of paintings ranged from 16-240. Topical squamous-cell carcinomas were found in three of 21 autopsied mice. A further group of 50 mice was treated one to three times weekly with heated air-refined (oxidized) petroleum asphalt (asphalt class 2). No carcinoma was observed at the site of treatment in the 32 mice surviving more than seven weeks (10 autopsied). In a complementary group (10 males and 10 females), the air-refined asphalt, diluted in toluene (one volume of toluene to 10 of melted asphalt) was applied three times weekly for up to two years (284 applications). Topical squamous-cell carcinomas developed in nine of 20 mice autopsied. Of 15 toluene-treated control animals, one developed a skin papilloma (Simmers, 1965a).

In a third experiment, a mixture of 'aromatics' and 'saturates' (a fraction of a class 1 asphalt), isolated by fractionation of a steam-refined asphalt from a California crude petroleum, was applied three times weekly (about 33.4 mg per application) to the intrascapular non-shaved skin of 25 male and 25 female C57 black mice. The number of applications ranged from 72 to 242 because of differential survival. Of 30 mice studied microscopically, 13 showed skin papillomas and cancers (seven epidermoid carcinomas, five showed baso-squamous cancers and one sebaceous-gland carcinoma). Other tumors found included one epidermoid carcinoma of the anus and two leiomyosarcomas (one subcutaneous and one intestinal) (Simmers, 1965b). Unfortunately, the study was flawed by the failure to include a control group.

One group of 100 and three groups of 50 male and female black C57 mice were treated by skin application with road petroleum asphalts (asphalt class 1) obtained by steam distillation of crudes from Venezuela, Mississippi and California, and by steam-vacuum distillation of one Oklahoma crude, respectively. Each mouse received one drop of asphalt liquefied with acetone on the neck skin twice weekly for up to two years. One skin carcinoma was observed in the group treated with the Mississippi sample, and one skin papilloma was observed in the groups treated with the Oklahoma and the Mississippi samples. No skin tumor was found in the groups treated with the Venezuela or California samples or in 200 untreated mice (Hueper and Payne, 1960).

A group of 50 (25 male and 25 female) C57 black mice received skin paintings twice weekly on the nape of the neck with a heated sample of an air-blown asphalt (asphalt class 2) used for roofing purposes [dose unspecified]. Treatment was continued for up to two years; one skin carcinoma was reported (Hueper and Payne, 1960). Interpretation of this study is flawed by the failure of the authors to include a control group.

Two cracking-residue (destructive thermal distillation) bitumens (straight distillation) (BN-5, BN-4, BN 3 and BN-2) [class 1] in benzene (40% solutions) were tested for carcinogenicity by weekly skin painting for 19 months (70 applications) to ss-57 white mice. With the cracking-residue bitumen BN-5, nine of 49 survivors at the time of appearance of the first tumor (ninth month) developed tumors at the treatment site: five cornified squamous-cell carcinomas, one fibrosarcoma and three papillomas. In addition, seven animals developed pulmonary adenomas and adenocarcinomas and one, a squamous-cell carcinoma of the forestomach. With the cracking-residue bitumen BN-4, four of the 42 mice alive at the appearance of the first tumor (10th month) had skin tumors, two of which were carcinomas (one cornified, one noncornified) and two papillomas, and all four had pulmonary adenomas. With the residual bitumens, BN-5, BN-4, BN-3 and BN-2, tumors were reported in two (one cornified squamous-cell carcinoma and one sebaceous carcinoma) of 43, none of 30, two (one febrosarcoma and one papilloma) of 43 and none of 30 mice surviving 9 months, respectively. In addition, lung tumors were observed in 5/43, 1/30, 1/43 and 1/30 mice, respectively. In 23 control mice painted with benzene only, no skin tumor was seen; one mouse developed lung adenomas (Kireeva, 1968).

The carcinogenic activity of eight road-paving-grade asphalts (asphalt class 1) produced by vacuum distillation from well-defined crude sources was studied. The different asphalts dissolved in benzene (10% solutions) were applied twice weekly to the skin of groups of 24-32 male and female random-bred Swiss Albino mice with a calibrated dropper delivering 25 µl of solution, corresponding to 2.5 mg of asphalt per application. Mean survival times were 81 weeks for asphalt-treated and 82 weeks for benzene-treated mice. At the end of the experiment, six of 218 animals treated with the different asphalts developed skin tumors: one carcinoma and five 'papillomatous growth.' In 26 control mice treated with benzene only, one 'papillomatous growth' was observed (Wallcave et al., 1971).

Emmett et al. (1981) treated 50 male C3H/HeJ mice with standard roofing petroleum asphalt (asphalt class 2) dissolved in toluene (1:1 on a weight basis). Each animal received 50 mg of the solution on the intrascapular skin twice weekly for 80 weeks. No skin tumor was observed in 26 mice that survived 60 or more weeks or in 37 of a control group of 50 mice treated with toluene only. Of 50 positive-control mice treated with benzo[*a*]pyrene (0.1% toluene solution, 50 µg/application), 31/39 (79%) surviving at the time of appearance of the first skin tumor had skin tumors (24 malignant, seven papillomas; average latent period of papillomas, 32 weeks).

A pooled sample of six different steam- and air-blown (oxidized) petroleum asphalts (asphalt classes 1 and 2), suspended in olive oil (1%) was injected subcutaneously (s.c.) in the interscapular region of 62 (33 males and 29 females) C57 black mice. Each mouse received 0.2 ml per injection twice weekly for 41 weeks, then once weekly. A control group of 60 animals (32 males and 28 females) received similarly olive oil only. In the treatment group, the first sarcoma appeared 36 weeks after the beginning of the experiment. A total of eight sarcomas was observed at the injection site. No injection-site tumor was noted in the control group (Simmers et al., 1959).

In a further study, two groups of 50 (25 male and 25 female) C57 black mice received two s.c. injections (at intervals of three and four months, respectively) of 200 mg per injection of heated steam-refined asphalt (asphalt class 1) or heated air-refined (oxidized) asphalt (asphalt class 2). For injection, the steam-refined asphalt was heated to 70°C and the air-refined asphalt to 100°C. No skin tumor was observed in 32 autopsied mice from the group receiving steam-refined asphalt. Five malignant tumors (two rhabdomyosarcomas, one sebaceous-gland carcinoma, two not described) were found in the 38 autopsied mice treated with air-refined asphalt (Simmers, 1965a). No control was included in the study.

Four groups of 50 (25 males and 25 females) C57 black mice received six intramuscular (i.m.) injections every two weeks in the right thigh of 0.1 ml of a tricaprylin dilution (equal parts) of petroleum asphalts (asphalt class 1) obtained by steam distillation of crudes from Mississippi, California and Venezuela and by steam-vacuum distillation of one Oklahoma crude. After two years, injection-site sarcomas were noted in one mouse in each of the groups treated with samples from crudes from Mississippi, California and Venezuela. No such tumor was observed in the group treated with the sample from Oklahoma crude or in tricaprylin controls (Hueper and Payne, 1960).

Four groups of 30 Bethesda black rats each received 12 i.m. injections every two weeks into the right thigh of 0.2 ml of a tricaprylin dilution (equal parts) of petroleum asphalts (asphalt class 1) obtained by steam distillation of crudes from Mississippi, California and Venezuela, and by steam-vacuum distillation of one Oklahoma crude. After two years of observation, one, six, two and four rats, respectively, had sarcomas at the site of injection (Hueper & Payne, 1960). No vehicle control group was included.

4.3 Mutagenicity Studies

An extract of a 'road-coating tar' [cutback bitumen class 3] in dimethyl sulphoxide (DMSO) was mutagenic to *Salmonella typhimurium* TA98 in the presence of an Aroclor-induced rat-liver metabolic system (S9). Vapors, particles and aerosols emitted at 550°C, 350°C and 250°C (collected in DMSO) were also weakly mutagenic, both in the presence and absence of S9 in *S. typhimurium* TA98 and/or TA100 (Penalva et al., 1983).

4.4 Summary of the Toxicity and Carcinogenicity of Asphalt

Human and animal studies of the toxic effects of asphalt are limited to asphalts which have been heated to temperatures which are typically in excess of 150°F. As such, exposure conditions which exist at ambient temperatures will not resemble those in which asphalt is heated to high temperatures (as in roofing and road asphalting operations). Thus, the respiratory and dermatological effects associated with exposure to hot asphalt are unlikely to result from nonoccupational exposure conditions.

Interpretations of human studies of the carcinogenicity of asphalt are limited by the researchers failure to control for the effects of lifestyle habits (i.e., tobacco use) and exposure to potentially carcinogenic coal tar pitches or other potentially carcinogenic petroleum hydrocarbon mixtures. As with the noncarcinogenic effects of asphalts, it is noteworthy that persons who may be at risk from exposure to asphalt (such as roofers and roadworkers) are exposed to hot asphalts and the potentially carcinogenic polycyclic aromatic hydrocarbons which are emitted at the elevated temperatures which must be used to work with asphalt.

Animal studies of the carcinogenicity of asphalt are complicated by the fact that while certain asphalt classes and origins appear to be essentially noncarcinogenic or only weakly carcinogenic when painted on the skin of mice (Hueper and Payne, 1961; Wallcave et al., 1971; Emmett et al., 1981), other studies indicate some carcinogenic potential for asphalts (Simmers et al., 1959; Simmers et al., 1965a; Simmers et al., 1965b; Kireeva, 1968). Given the different sources of origin of crude oils used to manufacture asphalts, the different classes of asphalt studied, and the variable susceptibility of different strains of mice to the carcinogenic effects of dermally applied petroleum hydrocarbons, it is very difficult to predict which types, fractions, or sources of asphalt may have carcinogenic potential. In addition, experimental design flaws in certain studies (Hueper and Payne, 1960; Simmers 1965b) limit their interpretation.

It is also worthwhile to note that solvents were used as a vehicle for the application of the asphalts. Although application of asphalt in a solvent could be considered an experimental necessity, humans are unlikely to be exposed to asphalts dissolved in solvents. There is little doubt that the defatting effects of solvents may enhance the dermal penetration and therefore, the carcinogenic potential, of dermally applied asphalts. For this reason, experimental conditions under which the carcinogenicity of asphalts have been tested (i.e., dissolved in solvent and applied to the skin or injected subcutaneously) are unlikely to mimic human exposure conditions.

5.0 RISK CHARACTERIZATION

Although it cannot be unequivocally stated that the "asphaltic material" detected in soil at the Marina Development site poses no human health risk, several factors indicate that the human health risk, if any, which is associated with the intended use of the "asphaltic material" in Marina Development soils will be low. These considerations are based on: 1) the intended future use of the site and; 2) an assessment of the conditions under which asphalt exerts its toxicity or carcinogenicity.

As stated in Section 3 of this report, development plans for the site indicate that 65% of the property will be covered by construction of the two office buildings, 25% by paving, and 10% by landscaping. Once in place, the stockpiled soil and fill containing the "asphaltic material" will comprise a three- foot thick layer beneath the site surface. A one-half to one foot layer of imported fill will be placed on the affected soil to form the subbase for the buildings, pavement, and landscaped areas. Thus, it is very unlikely that future office workers would be exposed to the "asphaltic material."

Secondly, a review of human and animal toxicity studies indicates that asphalts exert their toxicity primarily when they are heated to temperatures of 150°F or higher. The observed toxicity of asphalt fumes and vapors at high temperatures appears to be due to the enhanced volatilization of compounds such as polycyclic aromatic hydrocarbons. At ambient temperatures, these compounds have very low vapor pressures and are unlikely to be emitted from asphalt to any significant degree. Thus, the respiratory and dermatological effects observed during exposure to heated asphalts would be unlikely to result at ambient temperatures.

Animal studies indicate that certain classes of asphalts may be potentially carcinogenic to the skin. However, the experimental methods used in these studies are unlikely to represent typical human environmental exposure conditions. For example, asphalts painted on the skin of mice were first dissolved in solvents. Solvents have the well-recognized ability to enhance the penetration of normally insoluble elements and thereby enhance the carcinogenicity of dermally applied chemicals (Emmett, 1991). It is unlikely that persons at the Marina Development site would be exposed to "asphaltic material" dissolved in solvent. Rather, the partitioning of "asphaltic material" into soil would tend to retard its dermal absorption for persons exposed to these soils. This effect of soil on hydrophobic compounds is termed the "matrix" effect and is known to reduce the dermal absorption of polycyclic aromatic hydrocarbons and other hydrophobic chemicals applied to the skin in soil (Wester et al., 1990; Watkin and Hull, 1991).

In summary, based on the low potential for human contact with "asphaltic material" in soil coupled with the fact that asphalt toxicity is unlikely to result at ambient temperatures, it is unlikely that the "asphaltic material" present in soil at the Marina Development site would be associated with significant human health risks.

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APPENDIX B

DRAFT SUMMARY REPORT FOR SOIL SAMPLES BENEATH STOCKPILED SOIL

Marina Village
Alameda, California

Prepared by Geomatrix Consultants, Inc.
23 August 1991

and

DRAFT SOIL SAMPLING AND CHEMICAL ANALYSIS, PARCEL H

Marina Village
Alameda, California

Prepared by Geomatrix Consultants, Inc.
5 November 1991

One Market Plaza
Spear Street Tower, Suite 717
San Francisco, CA 94105
(415) 957-9557

DRAFT

GEOMATRIX

23 August 1991
Project 1736.05

Mr. Jim Karam
Vintage Properties/Alameda Commercial
1150 Marina Village Parkway, Suite 100
Alameda, California 94501

Subject: Summary Report for Soil Samples Beneath Stockpiled Soil
Marina Village, Alameda, California

Dear Jim:

The following is a description of soil sampling activities, chemical analysis methods and results, and discussion regarding the subject work.

INTRODUCTION

The purpose of soil sampling completed at the stockpile site was to confirm that soil underlying stockpiled petroleum-affected soil was not affected by petroleum contained in the overlying soil. The underlying soil was separated from the stockpiled soil by a layer of plastic sheeting when the stockpile was originally generated in 1988. Alameda Commercial is currently relocating a portion of the stockpiled soil in order to surcharge a proposed building site in the vicinity of the stockpile.

SOIL SAMPLING

In order to gain access to the underlying soil, an earthwork contractor retained by Alameda Commercial removed soil above the plastic sheeting in the vicinity of areas A, B, C, and D (see Figure 1). Soil samples were collected using a backhoe supplied by Alameda Commercial to a depth of 1 to 2 feet below the plastic sheeting. Four soils samples per area were collected and composited for analysis from each of areas A, B, C, and D (Figure 1 shows sample locations).

Along the northern edge of the stockpile, plastic was not found at the stockpile/grade interface. The soil was apparently moved somewhat from this original location over the plastic sheeting. Trenches E, F, and G were dug within this zone to reach grade equivalent to the adjacent plastic sheeting. Two samples from the bottom of each trench were collected approximately 1 foot below the adjacent curb level to approximate what was considered to be "original grade" before stockpiling (Samples E1, E2, F1, F2, G1, and G2). These samples were composited by location for analysis. Additionally, four samples of overlying "fill" were collected and composited for analysis at each trench location. Figure 2 shows the trench locations.

DRAFT

CHEMICAL ANALYTICAL METHODS AND RESULTS

A total of ten composited soil samples were analyzed for extractable petroleum hydrocarbons using EPA Method 8015 by Med-Tox Associates, a state-certified analytical laboratory. All soil samples tested contained residual concentrations of heavier petroleum, characterized as oil. Analytical results are shown on Figures 1 and 2. Laboratory data sheets are attached.

The composited samples from area A, B, C, and D contained oil at concentrations ranging from 80 to 980 mg/kg (parts per million, or ppm). The samples collected from the bottoms of Trenches E, F, and G contained oil at concentrations ranging from 30 to 4,100 ppm. Soil from the overlying fill in the vicinity of Trenches E, F, and G contained oil in the range of 360 to 690 ppm.

It is not known presently to what depth the soil in this area is affected by petroleum hydrocarbons.

EVALUATION OF ANALYTICAL RESULTS AND ADDITIONAL TESTING

Review of the patterns and retention times of the peaks in the sample chromatograms supplied by Med-Tox revealed the possibility that biogenic, non-petroleum based constituents may be contributing significantly to the values being reported as total petroleum hydrocarbons. Consequently two samples (composites from Area A and the bottom of Trench F) were selected from the batch and submitted for re-analysis to Friedman and Bruya, Inc. of Seattle, Washington, a state-certified analytical laboratory.

Friedman and Bruya were asked to perform two tasks: (1) to further characterize the nature of hydrocarbons (oxygenated, saturated, etc.) present in the samples by TLC (Thin Layer Chromatography; and (2) to reanalyze the samples for TPH (extractables/high boilers) following silica gel cleanup/treatment. Silica gel is typically used in DHS/oil and grease analysis to separate and remove animal fats/fatty acids from petroleum based constituents. A decrease in the TPH value following silica gel treatment would indicate the presence of biogenic/non-petroleum based compounds in the sample.

Results of analysis performed by Friedman and Bruya showed that the TPH concentrations of Sample 2A (composite form Area A) was 410 ppm, compared to the originally reported concentrations of 980 ppm. The TPH concentrations of Samples 6A (composite from the bottom of Trench F) was 2,500 ppm, compared to the originally reported concentration of 4,100 ppm. Since these samples were treated with silica gel prior to TPH analysis, the elevated concentrations reported earlier were most likely reflecting the contribution of non-petroleum based, biogenic materials present in the samples. TLC traces of each sample revealed the presence of moderately polar and polar compounds in the samples. The TLC patterns themselves were indicative of high boiling, asphalt-like hydrocarbons present in the samples. Laboratory data sheets are attached.

DISCUSSION

Based on the above soil sampling and analysis, soil beneath the stockpile and plastic sheeting contains high boiling point, asphaltic-like petroleum hydrocarbons. Since soil samples were composites, it is not possible to ascertain the specific distribution of petroleum hydrocarbons in the soil; however, since petroleum hydrocarbons were detected in all the composite samples representing seven distinct areas, it is likely that the petroleum hydrocarbons are widespread in the soil. Discrete sampling would need to be performed the evaluate the lateral and vertical distribution of the petroleum hydrocarbons.

Previous petroleum characterization of the overlying stockpiled soil indicated a mixture of extractable TPH, including various diesels and heavier oils. Characterization of the underlying soil performed as part of this study indicate that the petroleum is similar to high boiling point aromatics present in asphalt. These differences in characterization suggest that the overlying stockpiled soil has not affected the underlying soil and that the source of petroleum in the underlying soil is different than that of the stockpiled soil.

We hope this information has been helpful in your project planning for site development. Please call either of the undersigned if you have questions or require further information.

Sincerely,

GEOMATRIX CONSULTANTS, INC.

Elizabeth A. Nixon Senior Project Engineer	Tom Graf Vice President

EAN/TG/bp
B:1736-SUM.LTR

Attachments: Figures (2)
Laboratory Certificates

Subject Sampling Plan - Alameda Marina Village

Project No. 1736.05

Task No.

By

Checked By

DRAFT

File No.

Date 6/19/91

Date

Sheet 1 of 2

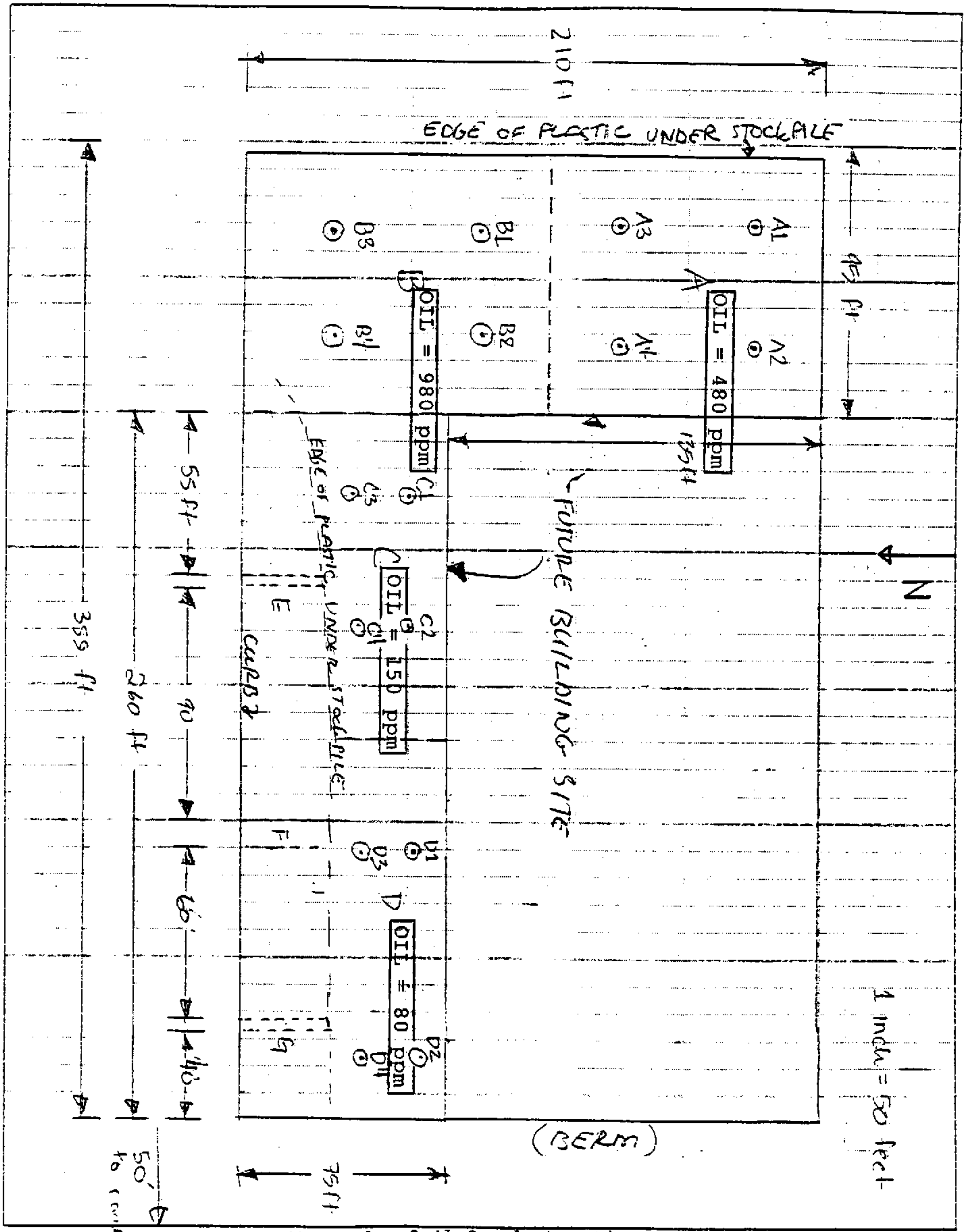

Figure 1: Soil Sample Locations
Areas A, B, C, & D

GEOMATRIX CONSULTANTS

Subject Sampling Plan - Alameda Marina Village

By

Date

Checked By

Date

DRAFT

Project No. 1736.05

Task No.

File No.

Sheet 2 of 2

GEOMATRIX

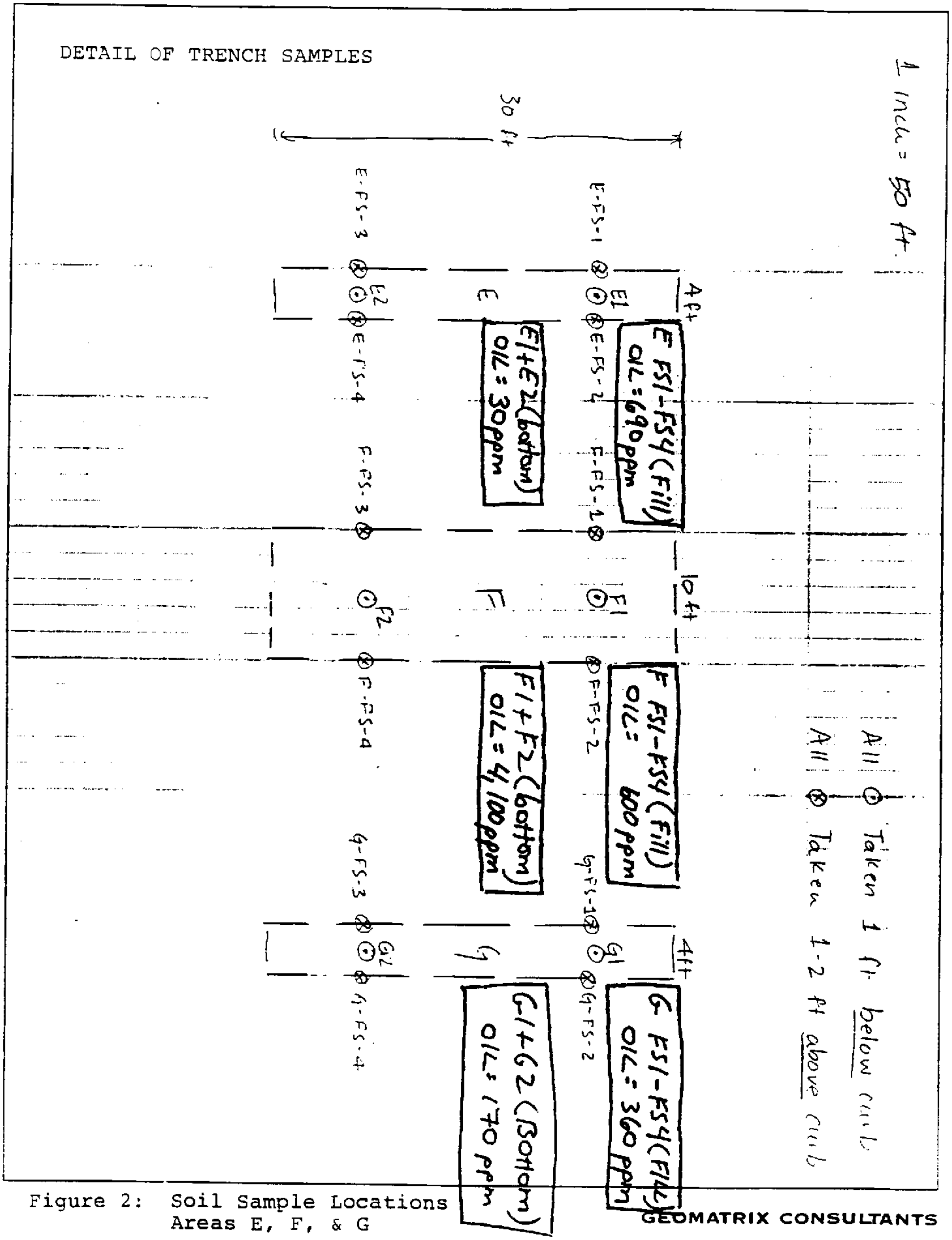

Figure 2: Soil Sample Locations
Areas E, F, & G

GEOMATRIX CONSULTANTS

ANALYTICAL SERVICES

MED-TOX ASSOCIATES, INC

DRAFT

CERTIFICATE OF ANALYSIS

GEOMATRIX CONSULTANTS
ONE MARKET PLAZA
SPEAR STREET TOWER SUITE 717
SAN FRANCISCO, CA 94105
ATTN: ELIZABETH NIXON

CLIENT PROJ. ID: 1736.05
C.O.C. NO: 04747, 04745

REPORT DATE: 06/24/91

DATE SAMPLED: 06/19/91

DATE RECEIVED: 06/19/91

MED-TOX JOB NO: 9106138

ANALYSIS OF: COMPOSITE SOIL SAMPLES

See attached for results

Andrew Bradeen

Andrew Bradeen, Manager
Organic Laboratory

Results FAXed 06/20/91

GEOMATRIX CONSULTANTS

DATE SAMPLED: 06/19/91
DATE RECEIVED: 06/19/91
CLIENT PROJ. ID: 1736.05

REPORT DATE: 06/24/91

MED-TOX JOB NO: 9106138

Sample Identification		Extractable Hydrocarbons as Diesel (mg/kg)	Extractable Hydrocarbons as Oil (mg/kg)
Client Id.	Lab No.		
A1-A4 (COMP)	01A	ND	480
B1-B4 (COMP)	02A	ND	980
C1-C4 (COMP)	03A	ND	150
D1-D4 (COMP)	04A	ND	80
E1-E2 (COMP)	05A	ND	30
F1-F2 (COMP)	06A	ND (50)	4,100
E-FS-1-4 (COMP)	07A	ND	690
F-FS-1-4 (COMP)	08A	ND	600
G-FS-1-4 (COMP)	09A	ND	360
G1-G2 (COMP)	10A	ND	170
Detection Limit (Unless otherwise indicated by parentheses)		10	20

Method: 3550 GCFID

Instrument: C

Date Extracted: 06/19/91

Date Analyzed: 06/19/91

ND = Not Detected

MED-TOX
ASSOCIATES, INC

DRAFT

QUALITY CONTROL DATA

GEOMATRIX CONSULTANTS

CLIENT PROJ. ID: 1736.05

MED-TOX JOB NO: 9106138

DRAFT

DATE EXTRACTED: 06/19/91
DATE ANALYZED: 06/19/91
SAMPLE SPIKED: 9106138-04A

MED-TOX JOB NO: 9106138
CLIENT PROJ. ID: 1736.05
INSTRUMENT: C

MATRIX SPIKE RECOVERY SUMMARY
TPH EXTRACTABLE SOILS
METHOD 3550
(SOIL MATRIX; EXTRACTION METHOD)

ANALYTE	Spike Conc. (mg/kg)	Sample Result (mg/kg)	MS Result (mg/kg)	MSD Result (mg/kg)	Average Percent Recovery	RPD
Diesel	84.8	ND	74.2	72.6	86.6	2.2

CURRENT QC LIMITS (Revised 05/02/91)

Analyte	Percent Recovery	RPD
Diesel	(48.8-126.6)	19.1

MS = Matrix Spike
MSD = Matrix Spike Duplicate
RPD = Relative Percent Difference
ND = Not Detected

9106153

DRAFT

GEOMATRIX CONSULTANTS
ONE MARKET PLAZA
SPEAR STREET TOWER SUITE 717
SAN FRANCISCO, CALIFORNIA 94105
(415) 957-9557

Chain of Custody Record

DATE 6/19/91   PAGE 1 OF ____

PROJECT NO.
1736.05

SAMPLERS: (SIGNATURE)
Elizabeth E. L

DATE	TIME	SAMPLE NUMBER	GENERAL MINERAL	PRIORITY POLLUTANT METALS	EPA METHOD 624	EPA METHOD 625	EPA METHOD 601	EPA METHOD 602	EPA METHOD 608	PETROLEUM HYDROCARBONS	EPA Method 8015	Diesel → Oil	(TPH - Extractables)			NUMBER OF CONTAINERS
6/19		A1 } 01A									✓					1
6/19		A2 }									✓					1
|		A3 } composite									✓					1
|		A4 }									✓					1
|		B1 }									✓					1
|		B2 } 02A									✓					1
|		B3 } comp									✓					1
|		B4 }									✓					1
|		C1 }									✓					1
|		C2 } comp 03A									✓					1
|		C3 }									✓					1
|		C4 }									✓					1
|		D1 }									✓					1
|		D2 } comp 04A									✓					1
|		D3 }									✓					1
|		D4 }									✓					1
|		E1 } comp 05A									✓					1
|		E2 }									✓					1
|		F1 } comp 06A									✓					1
|		F2 }									✓					1

REMARKS
(SAMPLE PRESERVATION, HANDLING PROCEDURES, OBSERVATIONS, ETC.)

24 hour turnaround!

Results to Elizabeth Nixon

Fax or call when ready

TOTAL NUMBER OF CONTAINERS 20

RELINQUISHED BY: michelle [illegible]	DATE 6-19	RECEIVED BY: Ann Gillespie	RELINQUISHED BY: Elizabeth L	DATE 6-19-91	RECEIVED BY: (LAB) michelle [illegible]
SIGNATURE michelle [illegible]		SIGNATURE Ann Gillespie	SIGNATURE Elizabeth T. L.		SIGNATURE michelle [illegible]
PRINTED NAME MED-TOX	TIME 1737	PRINTED NAME MED-TOX	PRINTED NAME Geomatrix	TIME 1630	PRINTED NAME med-tox
COMPANY		COMPANY	COMPANY		LABORATORY
RELINQUISHED BY:	DATE	RECEIVED BY:	METHOD OF SHIPMENT:		
SIGNATURE		SIGNATURE	LABORATORY COMMENTS / OBSERVATIONS		
PRINTED NAME	TIME	PRINTED NAME			
COMPANY		COMPANY			

DISTRIBUTION: WHITE, CANARY - LABORATORY PINK - ORIGINATOR

9106137

DRAFT

GEOMATRIX CONSULTANTS

ONE MARKET PLAZA
SPEAR STREET TOWER SUITE 717
SAN FRANCISCO, CALIFORNIA 94105
(415) 957-9557

Chain of Custody Record

DATE 6-19-91 PAGE 2 OF 2

PROJECT NO. 1736.05

SAMPLERS: (SIGNATURE) Elizabeth

DATE	TIME	SAMPLE NUMBER	GENERAL MINERAL	PRIORITY POLLUTANT METALS	EPA METHOD 624	EPA METHOD 625	EPA METHOD 601	EPA METHOD 602	EPA METHOD 608	PETROLEUM HYDROCARBONS	TPH-Extractables EPA 8015	Diesel + Motor Oil			NUMBER OF CONTAINERS	REMARKS (SAMPLE PRESERVATION, HANDLING PROCEDURES, OBSERVATIONS, ETC.)
~~2/19~~		~~G2~~													~~1~~	
6/19		E-FS-1									✓				1	24 hour turnaround
		E-FS-2 C7A									✓				1	
		E-FS-3 comp									✓				1	
		E-FS-4									✓				1	Fax or call
		F-FS-1									✓				1	when ready
		F-FS-2 C8A									✓				1	
		F-FS-3 comp									✓				1	
		F-FS-4									✓				1	
		G-FS-1									✓				1	Results to
		G-FS-2 C7A									✓				1	Elizabeth Nixon
		G-FS-3 comp									✓				1	
		G-FS-4									✓				1	
6/19		G1 comp ICA									✓				1	
		G2									✓				1	

TOTAL NUMBER OF CONTAINERS 14

RELINQUISHED BY:
michelle C[illegible]
SIGNATURE
michelle [illegible]
PRINTED NAME
MED-TOX
COMPANY

DATE 6-19-91
TIME 1735

RECEIVED BY:
Gina Gillespie
SIGNATURE
Gina Gillespie
PRINTED NAME
MED-TOX
COMPANY

RELINQUISHED BY:
Elizabeth [illegible]
SIGNATURE
Elizabeth [illegible]
PRINTED NAME
Geomatrix
COMPANY

DATE 6-19-91
TIME

RECEIVED BY: (LAB)
michelle C[illegible]
SIGNATURE
michelle [illegible]
PRINTED NAME
MED-TOX
LABORATORY

RELINQUISHED BY:
SIGNATURE
PRINTED NAME
COMPANY

DATE
TIME

RECEIVED BY:
SIGNATURE
PRINTED NAME
COMPANY

METHOD OF SHIPMENT:

LABORATORY COMMENTS / OBSERVATIONS

DISTRIBUTION: WHITE, CANARY - LABORATORY PINK - ORIGINATOR

DRAFT

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

Andrew John Friedman
James E. Bruya, Ph.D.
(206) 285-8282

3008-B 16th Avenue West
Seattle, WA 98119
FAX: (206) 283-5044

July 9, 1991

Tim Eckard, Project Leader
Geomatrix Consultants
One Market Plaza
Spear Street Tower, Suite 717
San Francisco, CA 94105

Dear Mr. Eckard:

Enclosed are the results of the analyses of the samples submitted on June 26, 1991 from Project 1736.05.

We appreciate this opportunity to be of service to you on this project. If you have any questions regarding this material, or if you just want to discuss any aspect of your projects, please do not hesitate to contact me.

Sincerely,

Lisa Bentley

Lisa A. Bentley, Chemist

LAB

Enclosures

FRIEDMAN & BRUYA, INC.
ENVIRONMENTAL CHEMISTS

DRAFT

Date of Report: July 9, 1991
Date Submitted: June 26, 1991
Project: 1736.05

RESULTS OF ANALYSES OF THE SOIL SAMPLES FOR FINGERPRINT CHARACTERIZATION BY CAPILLARY GAS CHROMATOGRAPHY

Sample #	GC Characterization
Composite B1, B2, B3, B4	The gas chromatographic trace showed an absence of significant levels of volatile or semi-volatile compounds. The thin layer chromatographic trace showed the presence of moderately polar and polar compounds, such as those found in asphalt. A band of material was seen at Rf 0.0 to 1.0 (methylene chloride). This band is visible under both short and long wave UV light, as well as iodine staining and is indicative of the high boiling aromatic hydrocarbons present in asphalt.

FRIEDMAN & BRUYA, INC.
ENVIRONMENTAL CHEMISTS

DRAFT

Date of Report: July 9, 1991
Date Submitted: June 26, 1991
Project: 1736.05

RESULTS OF ANALYSES OF THE SOIL SAMPLES FOR FINGERPRINT CHARACTERIZATION BY CAPILLARY GAS CHROMATOGRAPHY

Sample #	GC Characterization
Composite F1, F2	The gas chromatographic trace showed the presence of very high boiling compounds, such as those found in motor oil or biogenic material. This characterization is based on the presence of a relatively smooth envelope of peaks present from ca n-C_{18} to beyond n-C_{34} with a maximum near n-C_{28}. This composite was cleaned with silica gel and then separated into three fractions: saturated hydrocarbons, aromatic hydrocarbons, and the more polar compounds such as alcohols, phenols, and carboxylic acids. These fractions were then analyzed by GC. The compounds seen earlier in the first GC analysis were highly reactive and were lost during the silica clean up. This behavior suggests that the compounds are biogenic in nature. The thin layer chromatographic trace showed the presence of moderately polar and polar compounds, such as those found in asphalt. A band of material was seen at Rf 0.0 to 1.0 (methylene chloride). This band is visible under both short and long wave UV light, as well as iodine staining and is indicative of the high boiling aromatic hydrocarbons present in asphalt. Both asphalt as well as biogenic material appear to be present in this composite sample.

FRIEDMAN & BRUYA, INC.

ENVIRONMENTAL CHEMISTS

DRAFT

Date of Report: July 9, 1991
Date Submitted: June 26, 1991
Project: 1736.05

RESULTS OF ANALYSES OF THE SOIL SAMPLES FOR TOTAL HIGH BOILING COUMPOUNDS BY GC/FID (MODIFIED 8015)

Results Reported as µg/g (ppm)

Sample #	Total High Boiling Compounds (ppm)
Composite B1, B2, B3, B4	410
Composite F1, F2	2,500
Quality Assurance	
Method Blank	<50
Composite F1, F2 (Duplicate)	1,800
Composite F1, F2 (Matrix Spike) Percent Recovery	a
Composite F1, F2 (Matrix Spike Duplicate) Percent Recovery	a
Sample Spiked at	1,000

a - The amount spiked was insufficient to give meaningful recovery data.

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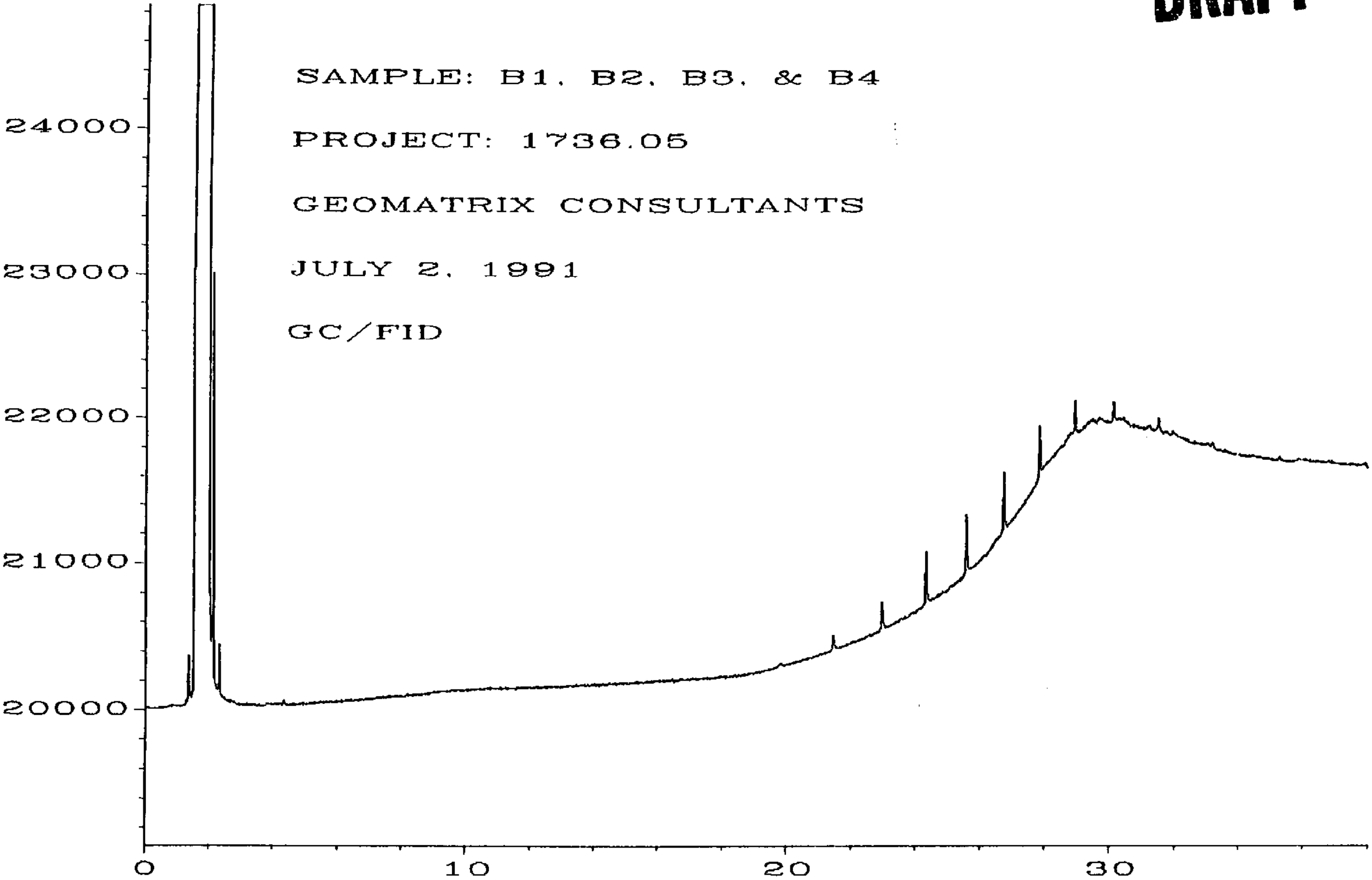
Sig. 1 in A:\047F2201.D


SAMPLE: B1, B2, B3, & B4

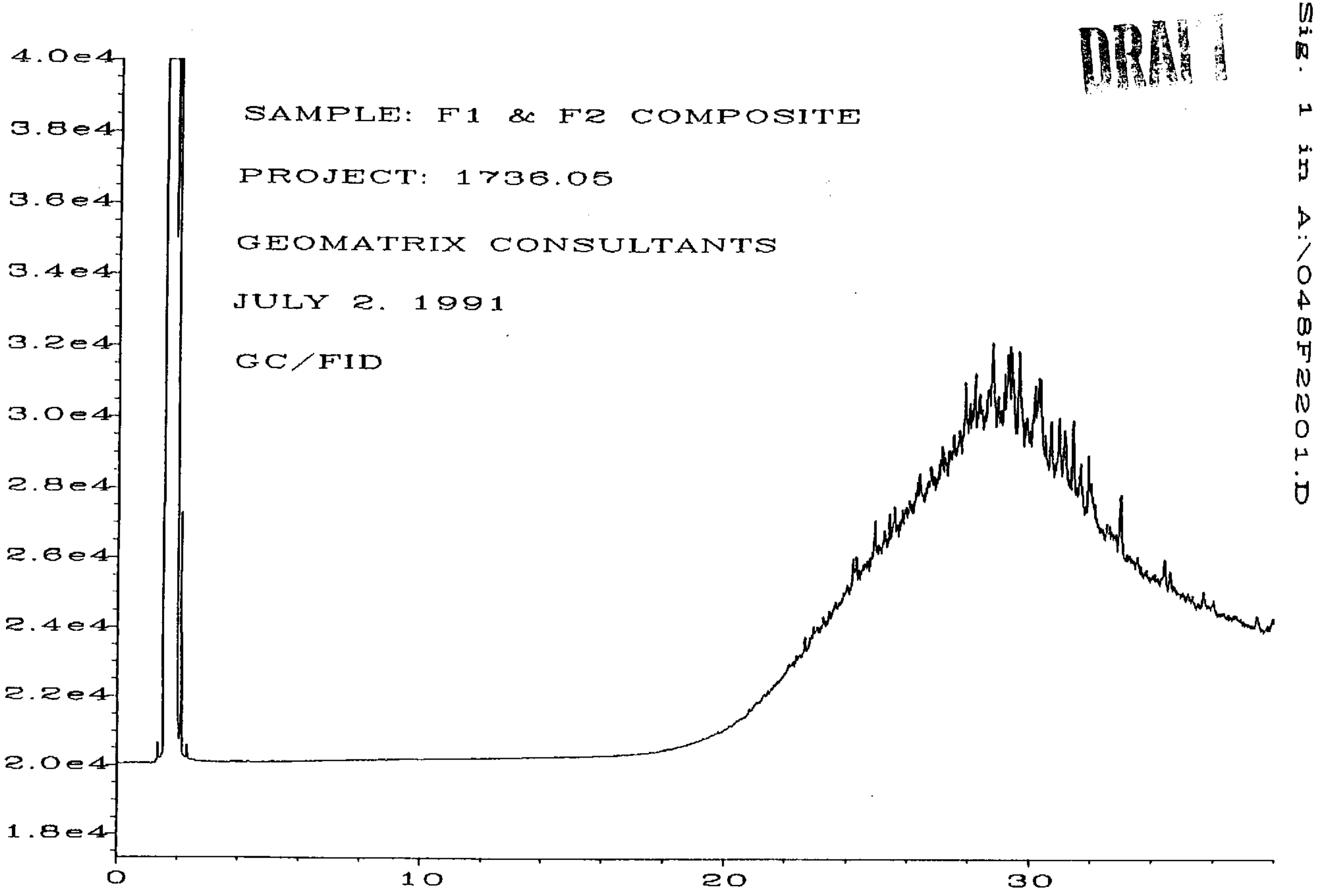
PROJECT: 1736.05

GEOMATRIX CONSULTANTS

JULY 2, 1991

GC/FID

DRAFT


SAMPLE: F1 & F2 COMPOSITE
PROJECT: 1736.05
GEOMATRIX CONSULTANTS
JULY 2. 1991
GC/FID
Sig. 1 in A:\048F2201.D
4.0e4
3.8e4
3.6e4
3.4e4
3.2e4
3.0e4
2.8e4
2.6e4
2.4e4
2.2e4
2.0e4
1.8e4
0
10
20
30

DRAFT

04841

ATRIX CONSULTANTS
ARKET PLAZA
EAR STREET TOWER SUITE 717
SAN FRANCISCO, CALIFORNIA 94105
(415) 957-9557

Supplementary Chain of Custody Record

DATE 6/19/91

PAGE 1 OF 1

JECT NO. 1736.05

AMPLERS: (SIGNATURE)

ATE	TIME	SAMPLE NUMBER	GENERAL MINERAL	PRIORITY POLLUTANT METALS	EPA METHOD 624	EPA METHOD 625	EPA METHOD 601	EPA METHOD 602	EPA METHOD 608	PETROLEUM HYDROCARBONS	TPH-Extractable (Ht+D)				NUMBER OF CONTAINERS
6/17/91		B1													11
		B2 Composite 4									X				11
		B3 02A													11
		B4													11
		F1 Comp 2													1
✓		F2 06A									X				11

TOTAL NUMBER OF CONTAINERS 6

REMARKS
(SAMPLE PRESERVATION, HANDLING PROCEDURES, OBSERVATIONS, ETC.)

Attn: Jim Bruya

As we discussed today, you will receive these samples from Med Tox Labs by Fed Ex.

Please:
① Composite B1, B2, B3 + B4 into one sample & Composite F1 & F2 as one sample.
② Run TLC to characterize samples (sat, oxygenated etc hydrocarbon ranges)
③ perform silica gel cleanup followed by Mod. EPA 8015 to quantify samples.
Results to Tim Eckard.

LINQUISHED BY:
NATURE
NTED NAME
PANY

DATE
TIME

RECEIVED BY:
SIGNATURE
PRINTED NAME
COMPANY

RELINQUISHED BY:
SIGNATURE
PRINTED NAME
COMPANY

DATE
TIME

RECEIVED BY: (LAB)
SIGNATURE
PRINTED NAME
LABORATORY

LINQUISHED BY:
NATURE
ED NAME
NY

DATE
TIME

RECEIVED BY:
SIGNATURE
PRINTED NAME
COMPANY

METHOD OF SHIPMENT:

LABORATORY COMMENTS / OBSERVATIONS
please call if you have any questions.
6/25/91

100 Pine Street, 10th Floor
San Francisco, CA 94111
(415) 434-9400 • FAX (415) 434-1365

GEOMATRIX

5 November 1991
Project 1736.06

DRAFT

Mr. Jim Karam
Vintage Properties/Alameda Commercial
1150 Marina Village Parkway, Suite 100
Alameda, California 94501

Subject: Soil Sampling and Chemical Analysis
Parcel H, Marina Village
Alameda, California

Dear Jim:

The following describes soil sampling activities and chemical analyses performed in August 1991 at the subject site.

INTRODUCTION

The purpose of the recent soil sampling and chemical analyses performed by Geomatrix was to evaluate the lateral and vertical distribution of petroleum hydrocarbons in soil beneath and in the immediate vicinity of soil stockpiled on Parcel H in the Marina Village Development. A layer of plastic sheeting separates the stockpile from underlying material.

Geomatrix's previous study of possible petroleum hydrocarbons in soil beneath the stockpile was described to Vintage Properties (Vintage) in our draft letter report dated 23 August 1991. That study, which consisted of collecting composite soil samples from beneath the plastic sheeting, indicated that heavy petroleum hydrocarbons (asphalt-like) were present in the soil. Only areas outside of proposed buildings footprints (see Figure 1) were investigated, because surcharging of building areas inhibited access to underlying soil.

SOIL SAMPLING

Our recent efforts involved collecting soil samples at 16 locations near proposed buildings number 4 and 5, as shown on Figure 1. Ten of the sample locations were within the boundaries of the plastic sheeting and original stockpile; six were outside those boundaries. At six locations, samples were collected at elevations of 1, between 2.5 and

DRAFT

3, and 5 feet above mean sea level (MSL). At ten locations, samples were collected at elevations of between 2.5 and 3 and 5 feet above MSL. The elevation of the ground surface at each sampling point was established by a surveyor retained by Alameda Commercial. A backhoe supplied by Vintage was used to dig test pits to the depths desired for sample collection. A trowel was used to collect soil samples from the backhoe bucket or directly from the test pit. Each sample was placed in a laboratory-supplied, 4-ounce glass jar having a Teflon-lined cap. Samples jars were labeled with identifying data. Soil sample locations and depths are summarized in Table 1.

The ground surface at the sampling locations typically ranged from approximately 5.5 to 8.7 feet above MSL. Plastic sheeting typically was observed at elevations ranging from 5 to 6 feet above MSL. Fill material consisting of gravel, clay, and miscellaneous debris was encountered from the ground surface to 2.5 feet MSL. The fill material generally was underlain by a layer of sand. Bay Mud typically was observed beneath the sand, at 2.0 to 0.3 feet MSL. In addition, concrete slabs were encountered at approximately 1 foot MSL in the northeast section of the site. At sampling locations S5 and S6, this concrete prevented the collection of soil samples at approximately 1 foot MSL.

Slightly stained soil, asphaltic in appearance, was observed at elevations ranging from 3 to 5 feet above MSL, primarily in the vicinity of proposed building number 4. A wood sample coated with asphaltic material was collected slightly above the Bay Mud (elevation 2 feet MSL) at sampling location S15.

CHEMICAL ANALYTICAL METHODS AND RESULTS

Geomatrix staff analyzed 31 soil samples and the asphalt-covered wood sample on 22 August 1991. The analyses were performed using thin layer chromatography (TLC), a technique for analyzing semi- and nonvolatile constituents. TLC involves distributing components in two mixtures, a solid phase and a liquid phase. The liquid phase is used to move analytes physically from one point to another through the solid, or immobile, phase. Samples are analyzed by examining the pattern and intensity of the extracts (each soil sample is extracted in acetone solvent) on silica gel plates. The plates typically are examined by placing them in an iodine chamber or under ultraviolet light. To measure the concentration of an analyte, the intensity of the sample spots is compared to known standards. Because quantification requires visual judgement, the values calculated by TLC are order-of-magnitude estimates. Generally, for positive samples, TLC estimates are

DRAFT

more accurate for samples that have relatively high concentrations (more than 500 parts per million [ppm]).

The approximate concentrations of analytes estimated for the soil samples are summarized in Table 1. Concentrations of petroleum hydrocarbons in samples collected at elevations of 1, 2.5 to 3, and 5 feet above MSL are shown on Figures 2, 3, and 4, respectively. The highest concentrations were observed in samples collected at elevations of approximately 5 feet MSL (Figure 4). At this elevation, most samples that indicated petroleum hydrocarbon concentrations greater than 1000 ppm were located to the north of the two proposed buildings, adjacent to the asphalt curb. Samples collected at elevations of 2.5 to 3 MSL (Figure 2) showed concentrations generally an order of magnitude less than those observed for samples at 5 MSL. Soil samples collected at 1 foot MSL generally indicated no detectable petroleum hydrocarbons.

CONCLUSIONS AND RECOMMENDATIONS

Soil sampling and TLC results suggest that petroleum-affected soil generally lies at or above an elevation of approximately 3 feet MSL. Affected soil appears to be present throughout the study area. If further characterization of the petroleum is desired, we recommend submitting two of the samples and the sample of asphalt to a laboratory that specializes in fuel identification. We would be happy to arrange such testing for you.

If you have any questions regarding this report, please contact either of the undersigned.

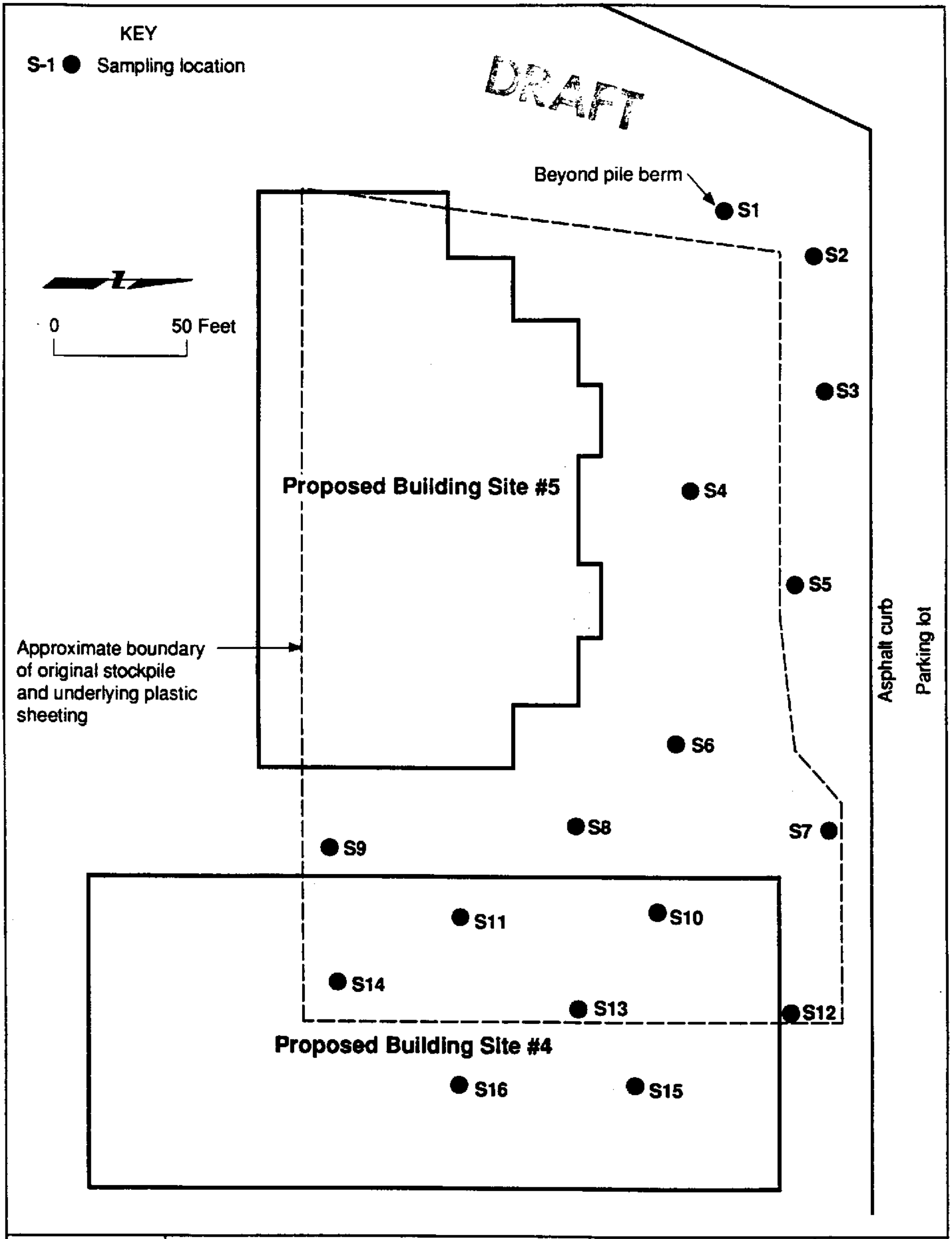
Sincerely yours,

GEOMATRIX CONSULTANTS

Elizabeth Nixon
Senior Project Engineer

Tom Graf, P.E.
Vice President

1736\SOILSAMP.DOC
Attachment

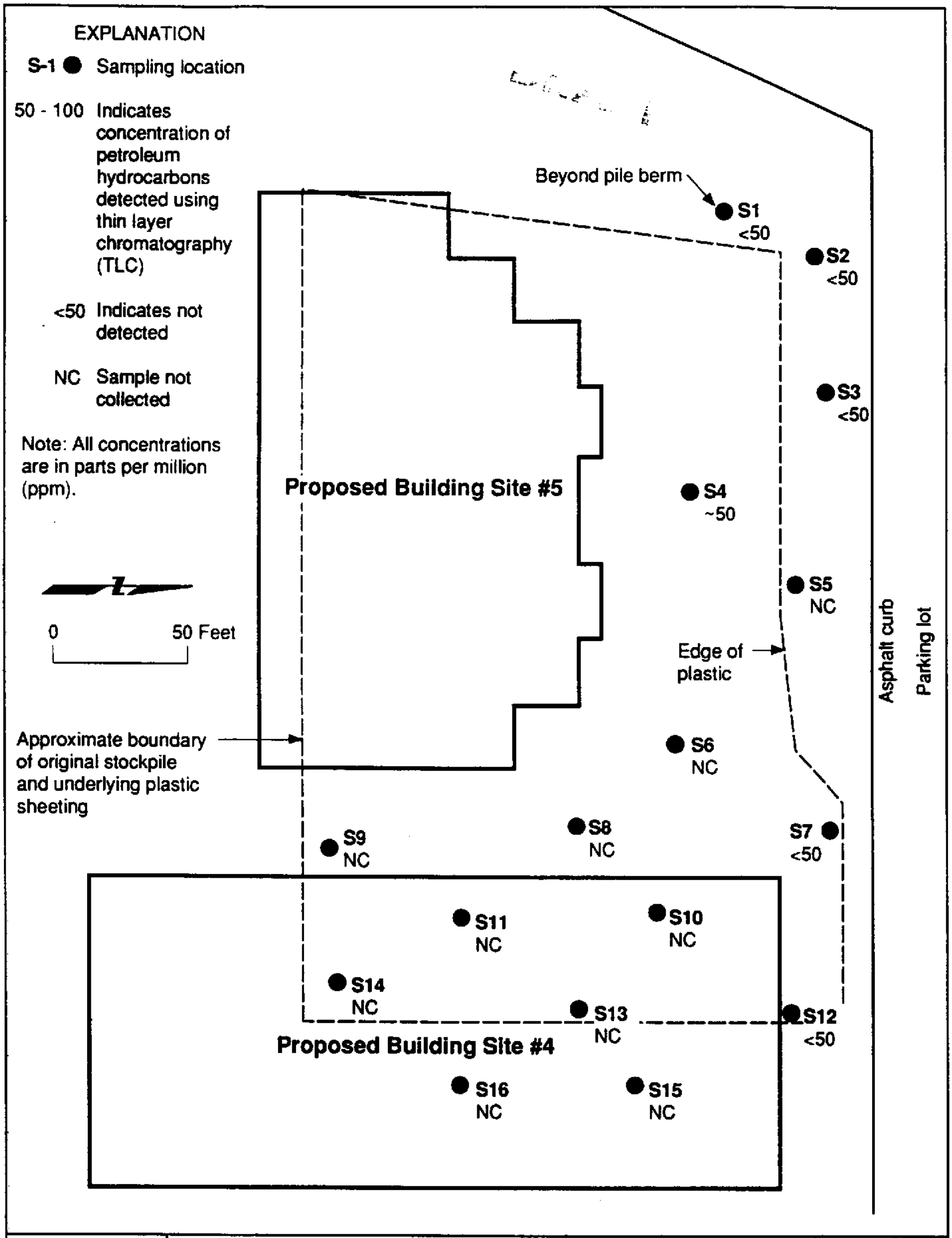


GEOMATRIX

SOIL SAMPLE LOCATIONS
Alameda Marina Village
Alameda, California

Figure
1

Project No.
1736.06

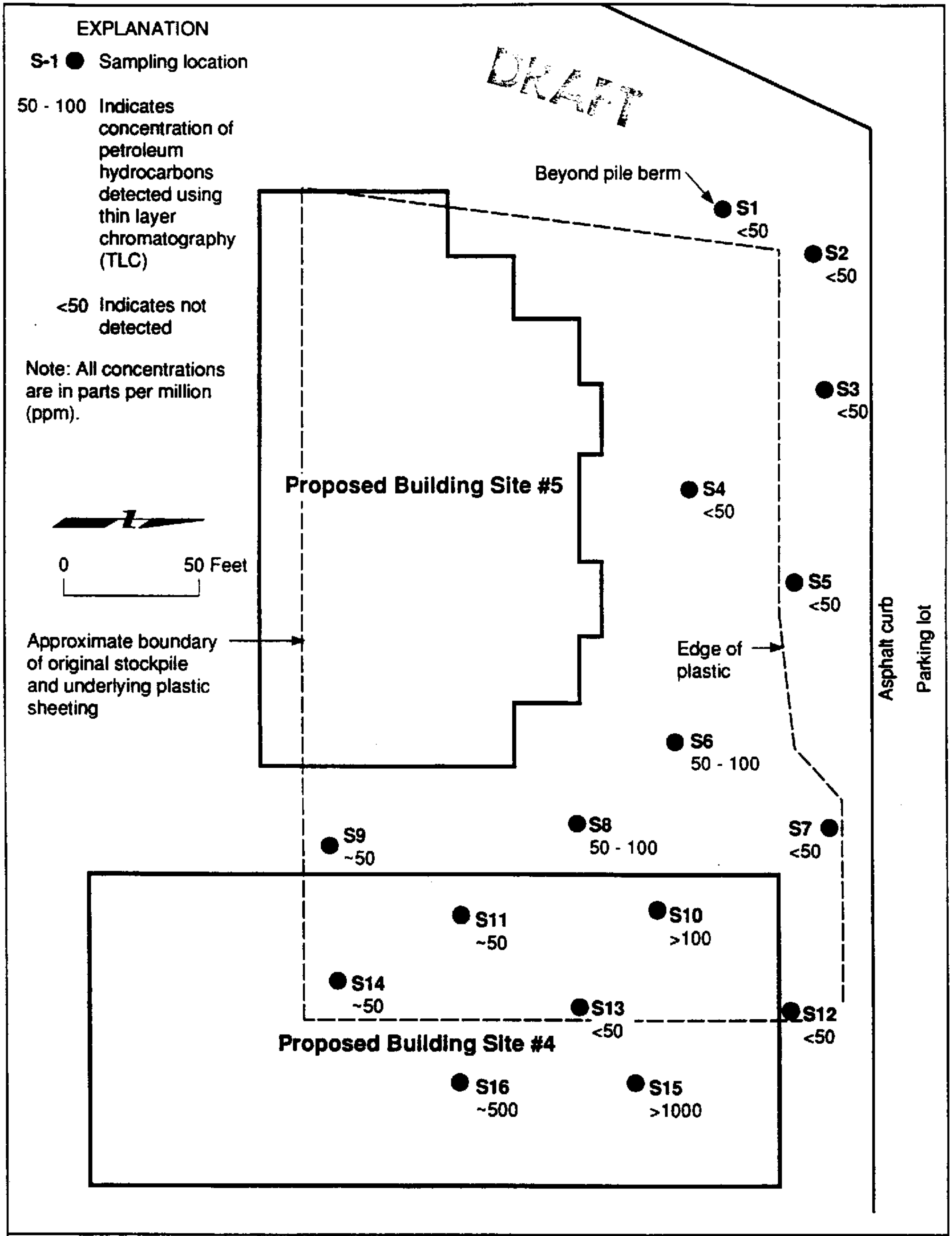


GEOMATRIX

TLC RESULTS FOR SOIL SAMPLES COLLECTED AT ELEVATION 1 FOOT MSL
Alameda Marina Village
Alameda, California

Figure
2

Project No.
1736.06

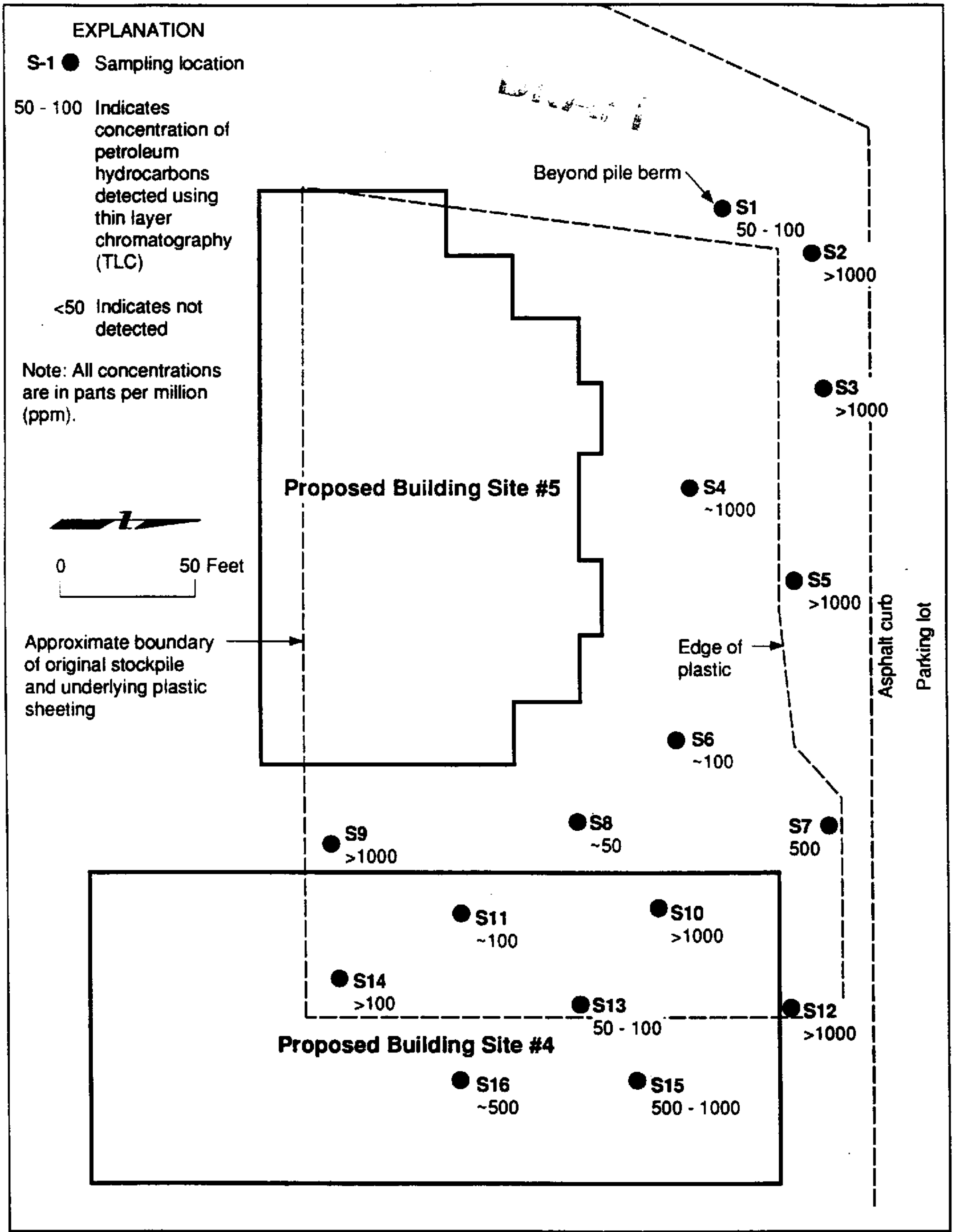


GEOMATRIX

TLC RESULTS FOR SOIL SAMPLES COLLECTED
AT ELEVATION 2.5 - 3 FEET MSL
Alameda Marina Village
Alameda, California

Figure
3

Project No.
1736.06



GEOMATRIX

TLC RESULTS FOR SOIL SAMPLES COLLECTED
AT ELEVATION 5 FEET MSL
Alameda Marina Village
Alameda, California

Figure
4

Project No.
1736.06

DRAFT

TABLE 1

TLC ANALYSIS RESULTS FROM SOIL SAMPLES FOR VICINITY OF SOIL STOCKPILE, PARCEL H, MARINA VILLAGE
Alameda, California
21 August 1991

Sample Location	Ground Elevation (feet)	Elevation of Plastic (feet)	TLC Results (ppm) Sample Elevation ~5.0 Ft	TLC Results (ppm) Sample Elevation ~3.0 Ft	TLC Results (ppm) Sample Elevation ~1.0 Ft
S1	8.60	NA	~100	<50	<50
S2	8.53	NA	>>1000	<50	<50
S3	8.67	NA	>1000	<50	<50
S4	8.54	5.5	~1000	<50	~50
S5	7.84	NA	>1000	<50	NC
S6	7.25	6.75	~100	~50	NC
S7	6.31	6.1	~500	<50	<50
S8	6.64	6.5	~50	~100	NC
S9	7.40	6.5	>1000	~50	NC
S10	7.15	6.3	>1000	>100	NC
S11	7.68	6.6	~100	~50	NC
S12	5.81	5.0	>100	<50	<50
S13	6.24	6.1	~100	<50	NC
S14	7.25	6.3	~100	~50	NC
S15	5.57	NA	500-1000	1000-2000	NC
S16	6.38	NA	~500	~500	NC

TLC = thin layer chromatography
ppm = parts per million
NC = Not collected
NA = Plastic not encountered

Note: Samples were compared to prepared diesel standards of 50, 100, 500, and 1000 ppm; reported results are best approximations of concentrations compared to these standards.

Elevations are relative to mean sea level; sample elevations surveyed by Vintage Properties.

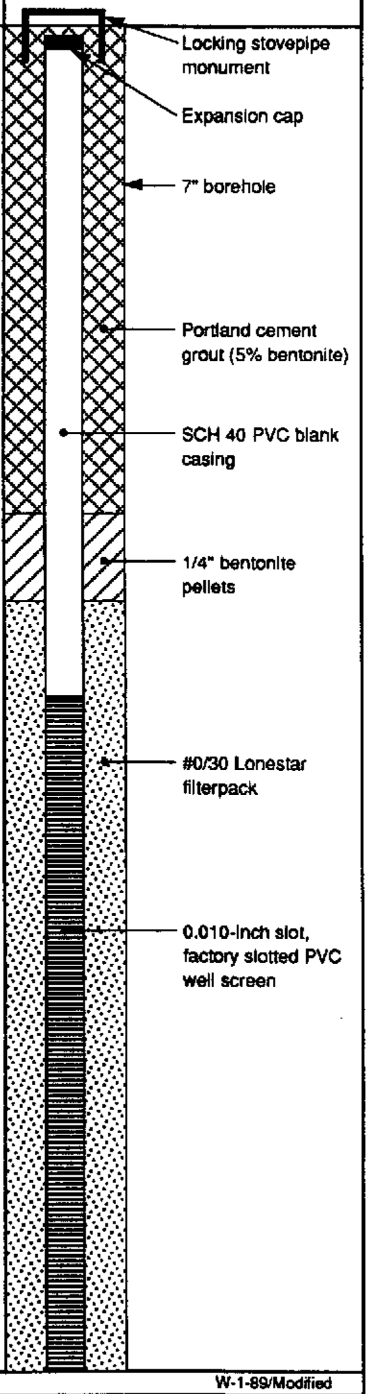
APPENDIX C

SOIL BORING AND WELL COMPLETION LOGS

PROJECT: MARINA VILLAGE DEVELOPMENT. BUILDING 4 AND 5 PROJECT Alameda, California		**Log of Well No. GP-1**	
BORING LOCATION: North of Lucky Supermarket, Building 4 and 5 area		ELEVATION AND DATUM: 6.07', City of Alameda datum	
DRILLING CONTRACTOR: Gregg Drilling and Testing		DATE STARTED: 4/15/92	DATE FINISHED: 4/15/92
DRILLING METHOD: Hollow stem auger		TOTAL DEPTH: 17'	SCREEN INTERVAL: 7'-17'
DRILLING EQUIPMENT: Mobile B-53		DEPTH TO WATER ATD: 9'	CASING: 2" Sch 40 PVC
SAMPLING METHOD: 5 foot continuous dry core sampler		LOGGED BY: L. J. Krause	
HAMMER WEIGHT: ---	DROP: ---	RESPONSIBLE PROFESSIONAL: Dawn Zemo	REG. NO. RG 4824

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/Foot	DESCRIPTION NAME (USCS Symbol): color, moist, % by wt., plast., density, structure, cementation, react. w/HCl, geo. inter. Surface Elevation:	TEST RESULTS
0				SANDY SILT (ML) [Fill] Dark grayish brown (10YR 4/2), dry	
1				Moist 2 inch cobble	
2				Increase in gravel and percentage clay, color change to very dark grayish brown (2YR 3/2)	
3.4				SILT/CLAYEY SILT (ML) [Fill] Dark grayish brown (10YR 4/2), moist, trace fine sand, low plasticity, soft	
5.7				CLAYEY SILT (ML) Dark gray (5Y 4/1), moist, 60% fines, 40% shell fragments, low plasticity, soft	
7				Thin layers of fine sand, increase in clay, decrease in shell fragments to trace	
9				SAND (SP) ATD ∇ Dark gray (5Y 4/1), wet, fine to medium sand, trace fine shell fragments, H_2S odor	
10				CLAYEY SILT (ML) Dark gray (5Y 4/1), wet, low plasticity, soft	
11				1-inch thick black organic layer Color change to thin layers of dark gray (5Y 4/1) and dark grayish brown (2.5Y 4/2), many tiny rootlets	
14					

WELL CONSTRUCTION DETAILS



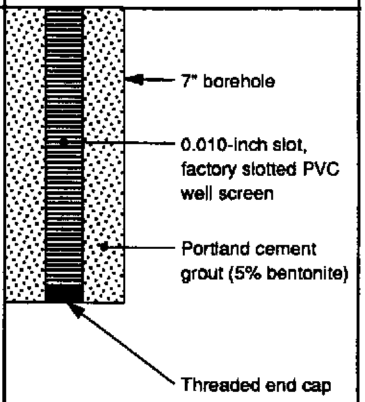
W-1-89/Modified

Geomatrix Consultants	Project No. 1736.10	Figure C1

PROJECT: MARINA VILLAGE DEVELOPMENT. BUILDING 4 AND 5 PROJECT
Alameda, California

Log of Well No. GP-1

DEPTH (feet)	SAMPLES: Sample No.	SAMPLES: Sample	SAMPLES: Blows/ Foot	DESCRIPTION NAME (USCS Symbol): color, moist, % by wt., plast., density, structure, cementation, react. w/HCl, geo. inter.	TEST RESULTS	WELL CONSTRUCTION DETAILS
				SILT (ML) (Continued)		
15						
16						
17				Bottom of boring at 17 feet		
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						



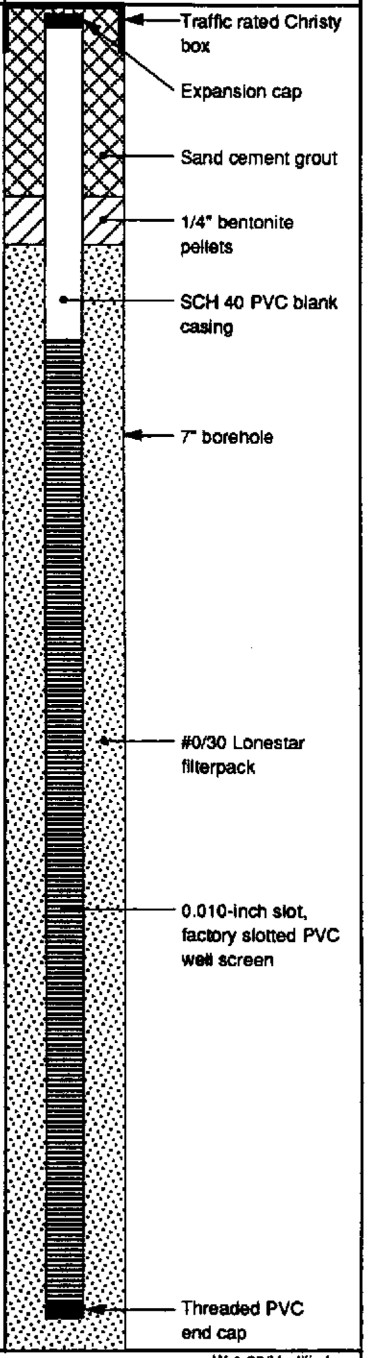
W-2-89/Modified

Geomatrix Consultants | Project No. 1736.10 | Figure C1 (cont)

Log of Well No. GMW-3

PROJECT: MARINA VILLAGE DEVELOPMENT. BUILDING 4 AND 5 PROJECT Alameda, California	
BORING LOCATION: West of Building 1201	ELEVATION AND DATUM: 4.55', City of Alameda datum
DRILLING CONTRACTOR: Gregg Drilling and Testing	DATE STARTED: 4/16/92 — DATE FINISHED: 4/16/92
DRILLING METHOD: Hollow stem auger	TOTAL DEPTH: 14' — SCREEN INTERVAL: 3.5'-13.5'
DRILLING EQUIPMENT: Mobile B-53	DEPTH TO WATER ATD: 5' — CASING: 2" Sch 40 PVC
SAMPLING METHOD: 5 foot continuous dry core sampler	LOGGED BY: L. J. Krause
HAMMER WEIGHT: --- DROP: ---	RESPONSIBLE PROFESSIONAL: Dawn Zemo — REG. NO. RG 4824

DEPTH (feet)	SAMPLES: Sample No.	Sample	Blows/ Foot	DESCRIPTION NAME (USCS Symbol): color, moist, % by wt., plast., density, structure, cementation, react. w/HCl, geo. inter. Surface Elevation:	TEST RESULTS	WELL CONSTRUCTION DETAILS
0				ASPHALT		
0.5–1.5				CLAYEY GRAVEL [Fill] Dark olive gray (3Y 5/2), moist		
1.5–5				SAND [Fill] Light olive brown (2.5Y 5/4), moist, fine grained sand		
5				Wet ATD ∇		
5–7				SILTY CLAY (CL) Dark gray (5Y 4/1), wet, trace fine sand, gray, black, and green/blue mottling, low plasticity, soft		
7				Fine to medium-grained sand lens		
7–9				SANDY CLAY (CL) Grayish green (5G 4/2), wet, 40% fine sand, 60% clay, firm, medium plasticity Sand lens Sand lens with shell fragments		
9–11				Interbedded SILT (ML) and SAND (SP) Dark gray (N4/), wet, fine to medium-grained sand with trace fine shell fragments (SP) and nonplastic silt (ML)		
11–14				CLAYEY SILT (ML) Black (2.5Y 2/), wet, trace fine sand, rootlets Color change to dark greenish gray (5BG 4/1)		
14				Bottom of boring at 14 feet		



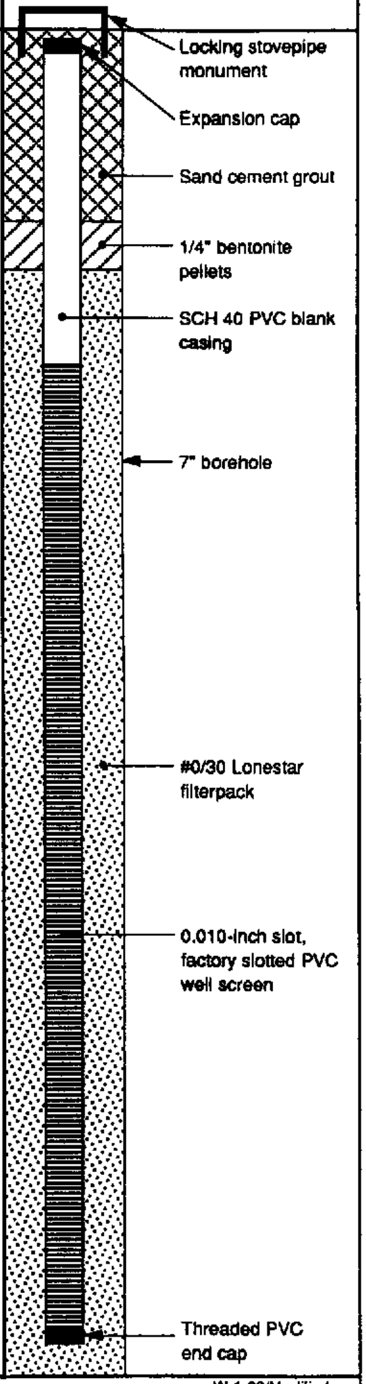
W-1-89/Modified

Geomatrix Consultants | Project No. 1736.10 | Figure C2

PROJECT: MARINA VILLAGE DEVELOPMENT. BUILDING 4 AND 5 PROJECT Alameda, California	**Log of Well No. GMW-4**
BORING LOCATION: West of fountain between buildings 1201 and 1001	ELEVATION AND DATUM: 6.80', City of Alameda datum
DRILLING CONTRACTOR: Gregg Drilling and Testing	DATE STARTED: 4/16/92 DATE FINISHED: 4/16/92
DRILLING METHOD: Hollow stem auger	TOTAL DEPTH: 14' SCREEN INTERVAL: 3.5'-13.5'
DRILLING EQUIPMENT: Mobile B-53	DEPTH TO WATER ATD: 5' CASING: 2" Sch 40 PVC
SAMPLING METHOD: 5 foot continuous core sampler	LOGGED BY: L. J. Krause
HAMMER WEIGHT: --- DROP: ---	RESPONSIBLE PROFESSIONAL: Dawn Zemo REG. NO. RG 4824

DEPTH (feet)	SAMPLES: Sample No.	Sample	Blows/ Foot	DESCRIPTION NAME (USCS Symbol): color, moist, % by wt., plast., density, structure, cementation, react. w/HCl, geo. inter. Surface Elevation:	TEST RESULTS
0				GRASS	
1				GRAVELLY CLAY [Fill] Very dark gray (5Y 3/1), moist	
2				1 inch organic rich layer (peat moss)	
3				Red bricks	
				SAND [Fill] Dark gray (5 Y 4/1), moist, fine to medium sand, no fines	
5				ATD ▽	
				SAND (SP) interbedded with CLAYEY SILT (ML) Dark gray (5Y 4/1) mottled with tan, gray and green, wet, fine to medium sand, nonplastic, soft, silt	
14				Bottom of boring at 14 feet	

WELL CONSTRUCTION DETAILS



W-1-89/Modified

Geomatrix Consultants | Project No. 1736.10 | Figure C-3

APPENDIX D

LABORATORY DATA SHEETS FOR GROUNDWATER SAMPLES

Quanteq Laboratories
An Ecologics Company

FORMERLY MED-TOX

Certificate of Analysis

PAGE 1 OF 2

DOHS CERTIFICATION NO. E772

AIHA ACCREDITATION NO. 332

GEOMATRIX CONSULTANTS
100 PINE STREET
10TH FLOOR
SAN FRANCISCO, CA 94111
ATTN: ELIZABETH NIXON

CLIENT PROJ. ID: 1736.10
C.O.C. NO: 0923

REPORT DATE: 05/13/92

DATE SAMPLED: 04/27/92

DATE RECEIVED: 04/28/92

QUANTEQ JOB NO: 9204234

ANALYSIS OF: WATER SAMPLES

Client Sample Id.	Quanteq Lab Id.	Extractable Hydrocarbons as Diesel (mg/L)	Extractable Hydrocarbons as Oil (mg/L)	Total Dissolved Solids (mg/L)
GMW-3	01A	1.4	ND	---
GMW-3	01B	---	---	2,400
GMW-4	02A	2.3	ND	---
Detection Limit		0.05	0.2	10
Method:		3510 GCFID SILICA GEL CLEANUP	3510 GCFID SILICA GEL CLEANUP	160.1
Instrument:		C	C	ME1
Date Extracted:		05/07/92	05/07/92	---
Date Analyzed:		05/08/92	05/08/92	05/04/92

ND = Not Detected

Andrew Bradeen
Andrew Bradeen, Manager
Organic Laboratory

Sherri Moore
Sherri Moore, Manager
Inorganic Laboratory

Results FAXed 05/11/92

QUALITY CONTROL DATA

DATE EXTRACTED: 05/07/92
DATE ANALYZED: 05/08/92
CLIENT PROJ. ID: 1736.09

QUANTEQ JOB NO: 9204234
SAMPLE SPIKED: D.I. WATER
INSTRUMENT: C

MATRIX SPIKE RECOVERY SUMMARY
TPH EXTRACTABLE WATER
METHOD 3520 GCFID
(WATER MATRIX; EXTRACTION METHOD)

ANALYTE	Spike Conc. (mg/L)	Sample Result (mg/L)	MS Result (mg/L)	MSD Result (mg/L)	Average Percent Recovery	RPD
Diesel	2.51	ND	1.63	1.56	63.5	4.3

CURRENT QC LIMITS (Revised 08/15/91)

Analyte	Percent Recovery	RPD
Diesel	(49-101)	29

MS = Matrix Spike
MSD = Matrix Spike Duplicate
RPD = Relative Percent Difference
ND = Not Detected

R-1, S-C

9204234

Chain-of-Custody Record

№ 0923

Date: 4/27/92

Page 1 of 1

Project No.: 1736.10

Samplers (Signatures): Gregory R. Vamman

	Date	Time	Sample Number	EPA Method 8010	EPA Method 8020	EPA Method 8240	EPA Method 8270	TPH as gasoline	TPH as diesel	TPH as BTEX	Oil + Diesel (TPH) 3550		TDS										Cooled	Soil (S) or water (W)	Acidified	Number of containers
01A	4/27/92	13:28	GMW-~~2~~3								X												X	W	X	1
B	11	11	GMW-~~2~~3										X										X	W		1
02AB	11	14:35	GMW-~~1~~4								X												X	W	X	2
	~~11~~	~~14:35~~																								

REMARKS

Additional comments

① Please run silica gel cleanup on TPH (oil & diesel) samples prior to running analysis

Turnaround time: Standard

Results to: Elizabeth Nixon

Total No. of containers: 4

Relinquished by: Gregory R. Vamman
Signature: Gregory R. Vamman
Printed name: Geomatrix
Company:
Date: 4/27/92

Received by: Kim Flores
Signature: Kim Flores
Printed name: 4/28/92 10:45
Company: Quanteq
Time: 5:40 pm.

Relinquished by: Kim Flores
Signature: Kim Flores
Printed name: 4/28/92 12:55
Company: Quanteq
Date:

Received by:
Signature:
Printed name:
Company:
Time:

Relinquished by:
Signature:
Printed name:
Company:
Date:

Received by: Denise Harrington
Signature: DENISE HARRINGTON
Printed name: Quanteq
Company:
Time: 4/28/92 1255

Method of shipment: PICK-UP

Laboratory comments and Log No.:

Geomatrix Consultants
100 Pine St. 10th Floor
San Francisco, CA. 94111
(415) 434-9400

CHROMALAB, INC.

Environmental Laboratory (1094)

5 DAYS TURNAROUND

May 19, 1992

ChromaLab File # 0592162

Geomatrix Consultants

Attn: Elizabeth Nixon

Re: Two rush water samples for Diesel and Motor Oil analysis

Project Number: 1736.10

Date Sampled: May 18, 1992
Date Submitted: May 18, 1992
Date Extracted: May 19, 1992
Date Analyzed: May 19, 1992

Results:

SAMPLE I.D.	DIESEL (μg/l)	Motor Oil (μg/l)
GMW-3	N.D.	N.D.*
GMW-4	N.D.	N.D.*
BLANK	N.D.	N.D.
SPIKE RECOVERY	92%	88%
DUPLICATE SPIKE RECOVERY	93%	91%
DETECTION LIMIT	50	500
METHOD OF ANALYSIS	3510/8015	3510/8015

*Unknown hydrocarbon that resembles crude oil is found in both samples. It has similar boiling point range as motor oil. If quantified as diesel, GMW-3 has 0.15ppm while GMW-4 has 0.12ppm. Both are below the detection limit of 0.5ppm for oil.

ChromaLab, Inc.

Charles N. Woolley

Charles Woolley
Analytical Chemist

Eric Tam
Laboratory Director

CHROMALAB FILE # 592162
ORDER # 6469

Chain-of-Custody Record

No 1315

Date: 5/18/92

Page 1 of 1

Project No.: 1736.10

Samplers (Signatures): Stephanie Robertson

Date	Time	Sample Number	EPA Method 8010	EPA Method 8020	EPA Method 8240	EPA Method 8270	TPH as gasoline	TPH as diesel/oil	TPH as BTEX	Cooled	Soil (S) or water (W)	Acidified	Number of containers	REMARKS Additional comments
5/18/92	1620	GMW-3						X		Y	W	N	2	Run silica gel cleanup prior to analysis.
5/18/92	1655	GMW-4						X		Y	W	N	2	Need results tomorrow 9am faxed

Turnaround time: 16hrs.

Results to: Elizabeth Nixon

Total No. of containers: 4

Relinquished by:	Date:	Relinquished by:	Date:	Relinquished by:	Date:	Method of shipment: lab pickup @ site
Signature: Stephanie Robertson	5/18/92	Signature:		Signature:		Laboratory comments and Log No.:
Printed name: Stephanie A. Robertson		Printed name:		Printed name:		
Company: Geomatrix		Company:		Company:		
Received by:	**Time:**	**Received by:**	**Time:**	**Received by:**	**Time:**	
Signature: SEAN HALSEY	1725	Signature:		Signature:		
Printed name:		Printed name:		Printed name:		
Company: CHROMALAB		Company:		Company:		

Geomatrix Consultants
100 Pine St. 10th Floor
San Francisco, CA. 94111
(415) 434-9400 Fax 434-1365

APPENDIX E

LABORATORY DATA SHEETS FOR SOIL SAMPLES

Quanteq Laboratories
An Ecologics Company

Certificate of Analysis

DOHS CERTIFICATION NO. E772
AIHA ACCREDITATION NO. 332

GEOMATRIX CONSULTANTS
100 PINE STREET, SUITE 1000
SAN FRANCISCO, CA 94111
ATTN: ELIZABETH NIXON
CLIENT PROJ. ID: 1736.10
C.O.C. NOS: 3218, 3219, 3216,
C.O.C. NOS: 3217, 3220, 3221,

REPORT DATE: 11/30/92
DATE SAMPLED: 11/05/92
DATE RECEIVED: 11/05/92
ADDITIONAL ANALYSIS
REQUESTED: 11/19,23/92
**QUANTEQ JOB NO: 9211054,
9211055, 9211056**

PROJECT SUMMARY:

On November 5, 1992, this laboratory received sixty-three (63) soil samples. Client requested thirty (30) of the samples to be analyzed for Total Petroleum Hydrocarbons as Oil, Total Lead and Moisture Content. The remaining samples were placed on hold. Samples were received in 1 gallon plastic bags for Total Lead and Moisture Content analysis and 500 ml glass jars for Total Petroleum Hydrocarbons as Oil. The samples were cool upon receipt.

Prior to analysis of Total Lead, the samples were dried, homogenized and ground to pass through a #10 sieve. This preparation and the Moisture Content analysis was performed by Woodward-Clyde Consultants in Pleasant Hill, California. The results for Total Lead were derived from the dried samples and calculated back to a wet basis from the Moisture Content results. Analysis for Total Petroleum Hydrocarbons as Oil was performed on the samples as received.

On November 19, 1992, client requested additional analysis on samples G21 2-4, B24 2-4, D22 0-2, L15 2-4, L22 0-2 and 024 0-2 (92111054-03B, 9211055-08B, -13B, 9211056-10B, -12B, and -14B) for Toxicity Characteristic Leaching Procedure and analysis of the extracts for Lead.

On November 23, 1992, client requested additional analysis on samples I22 2-4 and K24 0-2 (9211054-15B and 9211056-07B) for Toxicity Characteristic Leaching Procedure and analysis of the extracts for Lead.

The results for Extractable Hydrocarbons as oil for samples G13 2-4, J21 2-4 (9211054-01A,19A and 9211056-06A) include hydrocarbons found in the diesel range.

All laboratory quality control parameters were found to be within established limits. Batch QC data is included at the end of this report.

If you have any questions, please contact Client Services at (510) 930-9090.

Larry Klein

Larry Klein
Laboratory Manager

Results FAXed 11/17-23/92

GEOMATRIX CONSULTANTS

DATE SAMPLED: 11/05/92
DATE RECEIVED: 11/05/92
CLIENT PROJ. ID: 1736.10

REPORT DATE: 11/30/92
QUANTEQ JOB NO: 9211054

Client Sample Id.	**Quanteq Lab Id.**	**TCLP Lead (mg/L)**	**Wet Weight Total Lead (mg/kg)**	**Extractable Hydrocarbons as Oil (mg/kg)**
G13 2-4	01A	---	---	240*
G13 2-4	01B	---	57	---
G21 2-4	03A	---	---	420
G21 2-4	03B	---	140	---
G21 2-4	03C	0.2**	---	---
H13 2-4	08A	---	---	150
H13 2-4	08B	---	60	---
I13 0-2	11A	---	---	370
I13 0-2	11B	---	92	---
I22 2-4	15A	---	---	370
I22 2-4	15B	---	380**	---
I22 2-4	15C	0.33 (0.04)	---	---
J4 0-2	16A	---	---	210
J4 0-2	16B	---	87	---
J18 0-2	17A	---	---	230
J18 0-2	17B	---	73	---
J21 2-4	19A	---	---	340*
J21 2-4	19B	---	99	---
K3 2-4	23A	---	---	320
K3 2-4	23B	---	76	---
K8 0-2	24A	---	---	440
K8 0-2	24B	---	62	---
Reporting Limit: (Unless otherwise indicated in parentheses)		0.1	5	5
Method/Instrument		6010/ICP **7420/V12	6010/ICP **7420/V12	3550 GCFID
Date Extracted:		---	---	11/09/92
Date Analyzed:		11/23-30/92	11/16-20/92	11/11/92

* Includes hydrocarbons in the diesel range.

GEOMATRIX CONSULTANTS

DATE SAMPLED: 11/05/92
DATE RECEIVED: 11/05/92
CLIENT PROJ. ID: 1736.10

REPORT DATE: 11/30/92

QUANTEQ JOB NO: 9211055

Client Sample Id.	Quanteq Lab Id.	TCLP Lead (mg/L)	Wet Weight Total Lead (mg/kg)	Extractable Hydrocarbons as Oil (mg/kg)
B6 2-4	02A	---	---	200
B6 2-4	02B	---	75	---
B11 0-2	03A	---	---	130
B11 0-2	03B	---	85	---
B13 0-2	04A	---	---	410
B13 0-2	04B	---	130	---
B24 2-4	08A	---	---	390
B24 2-4	08B	---	150	---
B24 2-4	08C	ND	---	---
D9 2-4	10A	---	---	190
D9 2-4	10B	---	44	---
D22 0-2	13A	---	---	540
D22 0-2	13B	---	180	---
D22 0-2	13C	0.2	---	---
E11 0-2	14A	---	---	90
E11 0-2	14B	---	37	---
E20 2-4	16A	---	---	300
E20 2-4	16B	---	130	---
F24 0-2	20A	---	---	390
F24 0-2	20B	---	110	---
G8 0-2	21A	---	---	230
G8 0-2	21B	---	110**	---
G11 2-4	23A	---	---	160
G11 2-4	23B	---	83**	---
Reporting Limit:		0.1	5	5
Method/Instrument		7420/V12	6010/ICP ** 7420/V12	3550 GCFID
Date Extracted:		---	---	11/10/92
Date Analyzed:		11/23/92	11/13-16/92	11/12/92

GEOMATRIX CONSULTANTS

DATE SAMPLED: 11/05/92
DATE RECEIVED: 11/05/92
CLIENT PROJ. ID: 1736.10

REPORT DATE: 11/30/92

QUANTEQ JOB NO: 9211056

Client Sample Id.	Quanteq Lab Id.	TCLP Lead (mg/L)	Wet Weight Total Lead (mg/kg)	Extractable Hydrocarbons as Oil (mg/kg)
K9 2-4	02A	---	---	370
K9 2-4	02B	---	97	---
K15 2-4	04A	---	---	610
K15 2-4	04B	---	120	---
K21 2-4	06A	---	---	360*
K21 2-4	06B	---	120	---
K24 0-2	07A	---	---	470
K24 0-2	07B	---	310	---
K24 0-2	07C	0.60 (0.04)	---	---
L12 0-2	08A	---	---	500
L12 0-2	08B	---	110	---
L15 2-4	10A	---	---	1,200
L15 2-4	10B	---	190	---
L15 2-4	10C	0.2**	---	---
L22 0-2	12A	---	---	560
L22 0-2	12B	---	210	---
L22 0-2	12C	0.3**	---	---
M6 0-2	13A	---	---	230
M6 0-2	13B	---	72	---
024 0-2	14A	---	---	380
024 0-2	14B	---	300	---
024 0-2	14C	0.7**	---	---
Reporting Limit: (Unless otherwise indicated in parentheses)		0.1	5	5
Method/Instrument		6010/ICP **7420/V12	7420/V12	3550 GCFID
Date Extracted:		---	---	11/10/92
Date Analyzed:		11/23-30/92	11/16-20/92	11/13/92

* Includes hydrocarbons in the diesel range.

QUALITY CONTROL DATA

DATE EXTRACTED: 11/09/92
DATE ANALYZED: 11/10/92
CLIENT PROJ. ID: 1736.10

QUANTEQ JOB NO: 9211054
SAMPLE SPIKED: 9211022-05A
INSTRUMENT: C

MATRIX SPIKE RECOVERY SUMMARY
TPH EXTRACTABLE SOILS
METHOD 3550 GCFID

ANALYTE	Spike Conc. (mg/kg)	Sample Result (mg/kg)	MS Result (mg/kg)	MSD Result (mg/kg)	Average Percent Recovery	RPD
Diesel	40.2	ND	24.1	24.6	60.6	2.1

CURRENT QC LIMITS (Revised 05/15/92)

Analyte	Percent Recovery	RPD
Diesel	(44.1-105.8)	24.3

MS = Matrix Spike
MSD = Matrix Spike Duplicate
RPD = Relative Percent Difference
ND = Not Detected

QUALITY CONTROL DATA

DATE EXTRACTED: 11/10/92
DATE ANALYZED: 11/12/92
CLIENT PROJ. ID: 1736.10

QUANTEQ JOB NO: 9211055
SAMPLE SPIKED: 9210207-03A
INSTRUMENT: C

MATRIX SPIKE RECOVERY SUMMARY
TPH EXTRACTABLE SOILS
METHOD 3550 GCFID

ANALYTE	Spike Conc. (mg/kg)	Sample Result (mg/kg)	MS Result (mg/kg)	MSD Result (mg/kg)	Average Percent Recovery	RPD
Diesel	40.2	ND	26.5	27.3	66.9	3.1

CURRENT QC LIMITS (Revised 05/15/92)

Analyte	Percent Recovery	RPD
Diesel	(44.1-105.8)	24.3

MS = Matrix Spike
MSD = Matrix Spike Duplicate
RPD = Relative Percent Difference
ND = Not Detected

QUALITY CONTROL DATA

DATE EXTRACTED: 11/10/92
DATE ANALYZED: 11/13/92
CLIENT PROJ. ID: 1736.10

QUANTEQ JOB NO: 9211056
SAMPLE SPIKED: 9211022-03A
INSTRUMENT: C

MATRIX SPIKE RECOVERY SUMMARY
TPH EXTRACTABLE SOILS
METHOD 3550 GCFID

ANALYTE	Spike Conc. (mg/kg)	Sample Result (mg/kg)	MS Result (mg/kg)	MSD Result (mg/kg)	Average Percent Recovery	RPD
Diesel	40.2	ND	31.6	29.7	76.3	6.1

CURRENT QC LIMITS (Revised 05/15/92)

Analyte	Percent Recovery	RPD
Diesel	(44.1-105.8)	24.3

MS = Matrix Spike
MSD = Matrix Spike Duplicate
RPD = Relative Percent Difference
ND = Not Detected

QUALITY CONTROL DATA

MATRIX: SOIL

QUANTEQ JOB NO: 9211054,
9211055, 9211056

CLIENT PROJ. ID: 1736.10

MATRIX SPIKE RECOVERY SUMMARY

COMPOUND	INST./ METHOD	SAMPLE SPIKED	SAMPLE RESULT	SPIKE ADDED	OBSERVED RECOVERIES (mg/kg) MS	MSD	% REC.	RPD	QC CONTROL LIMITS % REC. LIMIT	RPD LIMIT
Pb, Lead	ICP/6010	9211054-01B	64.2	100	144	151	83	5	65-97	11
Pb, Lead	ICP/6010	9211055-20B	122.5	100	205.5	220.6	91	7	65-97	11
Pb, Lead	7420/V12	ERA SAND	ND	100	109	114	112	4	75-125	20

METHOD STANDARD RECOVERY SUMMARY

COMPOUND	INST./ METHOD	BLANK RESULT	TRUE VALUE	OBSERVED RECOVERIES (ug) MS	MSD	% REC.	RPD	QC CONTROL LIMITS % REC. LIMIT	RPD LIMIT
Pb, Lead	V12/7420	ND	0.5	0.510	0.459	97	11	80-120	15

MATRIX: TCLP

MATRIX SPIKE RECOVERY SUMMARY

COMPOUND	INST./ METHOD	SAMPLE SPIKED	SAMPLE RESULT	SPIKE ADDED	OBSERVED RECOVERIES (mg/L) MS	MSD	% REC.	RPD
Pb, Lead	ICP/6010	9211054-15C	0.325	0.50	0.794	0.795	94	<1
Pb, Lead	V12/7420	9211056-14C	0.68	2.0	2.80	NA	106	---

NA = Not Analyzed
ND = Not Detected
< = Less than

PLEASANT HILL LABORATORY

WATER CONTENT

PROJECT NAME QUANTEO 9211054 PROJECT NO. 90C0368A

TESTED BY D. WEBER REDUCED BY S. CAPPS DATE 11/12/92

LOCATION: PAGE 1 OF 1

SAMPLE NUMBER	WET WT. + TARE	DRY WT. + TARE	TARE	SAMPLE DESCRIPTION	% MOISTURE
1B	1197.2	1100.0	222.9	BROWN CLAYEY SILTY SAND WITH GRAVEL	11.1
3B	1203.3	1124.2	219.1	BROWN GRAVELLY CLAYEY SAND TO SANDY CLAY	8.7
8B	1268.6	1196.6	221.8	BROWN CLAYEY SILTY SAND WITH GRAVEL	7.4
11B	1308.5	1222.9	218.9	BROWN GRAVELLY SANDY CLAY	8.5
15B	1225.9	1129.9	218.9	BROWN GRAVELLY SANDY CLAY	10.5
16B	1137.7	1041.1	222.1	GRAY BROWN SANDY CLAY WITH GRAVEL	11.8
17B	1357.3	1230.6	223.6	BROWN GRAVELLY SANDY CLAY	12.6
19B	1535.8	1409.9	219.3	GRAY BROWN SANDY CLAY WITH GRAVEL	10.6
23B	1297.1	1199.7	223.0	GRAY BROWN SANDY CLAY WITH GRAVEL	10.0
24B	1126.5	1028.9	218.7	GRAY BROWN SANDY CLAY WITH GRAVEL	12.1

**Woodward-Clyde
Consultants**

PLEASANT HILL LABORATORY

WATER CONTENT

PROJECT NAME QUANTEQ 9211055 PROJECT NO. 90C0368A

TESTED BY D. WEBER REDUCED BY S. CAPPS DATE 11/12/92
LOCATION: PAGE 1 OF 2

SAMPLE NUMBER	WET WT. + TARE	DRY WT. + TARE	TARE	SAMPLE DESCRIPTION	% MOISTURE
02B	1217.1	1130.7	225.6	GRAY BROWN CLAYEY SILTY SAND W/GRAVEL	9.6
03B	1135.5	1014.5	223.3	GRAY BROWN CLAYEY SILTY SAND W/GRAVEL	15.3
04B	1138.3	1030.4	219.0	GRAY BROWN CLAYEY SILTY SAND W/GRAVEL	13.3
08B	1158.7	1079.6	221.7	GRAY BROWN CLAYEY SILTY SAND W/GRAVEL	9.2
10B	1129.4	1051.1	221.7	GRAY BROWN CLAYEY SILTY SAND W/GRAVEL	9.4
13B	1118.9	1030.4	224.1	GRAY BROWN GRAVELLY CLAYEY SAND	11.0
14B	1110.1	1020.5	217.3	BROWN CLAYEY SILTY SAND W/GRAVEL	11.2
16B	1332.5	1239.4	218.7	BROWN GRAVELLY CLAYEY SAND	9.1
20B	1517.1	1404.5	223.6	BROWN GRAVELLY CLAYEY SAND	9.5
21B	1118.5	1040.8	223.1	BROWN GRAVELLY CLAYEY SAND	9.5

Woodward-Clyde Consultants

PLEASANT HILL LABORATORY

WATER CONTENT

PROJECT NAME QUANTEQ 9211055 PROJECT NO. 90C0368A

TESTED BY D. WEBER REDUCED BY S. CAPPS DATE 11/12/92

LOCATION:

PAGE 2 OF 2

SAMPLE NUMBER	WET WT. + TARE	DRY WT. + TARE	TARE	SAMPLE DESCRIPTION	% MOISTURE
23B	1135.4	1049.4	221.0	BROWN GRAVELLY CLAYEY SAND	10.4

Woodward-Clyde Consultants

PLEASANT HILL LABORATORY

WATER CONTENT

PROJECT NAME QUANTEQ 9211056 PROJECT NO. 90C0368A

TESTED BY D. WEBER REDUCED BY S. CAPPS DATE 11/12/92
LOCATION: PAGE 1 OF 1

SAMPLE NUMBER	WET WT. + TARE	DRY WT. + TARE	TARE	SAMPLE DESCRIPTION	% MOISTURE
2B	1332.1	1217.6	225.5	BROWN GRAVELLY SILTY SAND	11.5
4B	1251.8	1134.7	221.5	GRAY BROWN GRAVELLY CLAYEY SAND	12.8
6B	1235.7	1140.1	223.1	BROWN CLAYEY SILTY SAND TO SANDY SILT	10.4
7B	1302.6	1208.3	221.5	BROWN CLAYEY SILTY SAND TO SANDY SILT	9.6
8B	1308.6	1211.5	221.0	BROWN GRAVELLY SILTY SAND	9.8
10B	1263.0	1145.8	218.8	GRAY BROWN SANDY CLAY WITH GRAVEL	12.6
12B	1381.6	1290.6	223.7	BROWN GRAVELLY CLAYEY SAND	8.5
13B	1150.3	1047.3	224.2	BROWN SANDY CLAY WITH GRAVEL	12.5
14B	1300.7	1216.7	217.2	GRAY BROWN SANDY CLAY WITH GRAVEL	8.4

CHANGE ORDER REQUEST

QUANTEQ Laboratories
3440 Vincent Road
Pleasant Hill, CA 945223

Phone (510) 930-9090

REPLY REQUESTED

QUANTEQ FAX (510) 930-0256

DATE/TIME OF CALL	11-19-92	CLIENT	Elizabeth Nixon
QUANTEQ REP.	Robin Byars	COMPANY	GeomaTrix
QUANTEQ PROJ. #	9211054, 55, 56	JOB #	1736.10
		COC #	Below

We hereby agree to make the change(s) specified below:

Additional Analysis - 4 day TAT
COC 3218 G21 2-4
COC 3216 B24 2-4
COC 3217 O22 0-2
COC 3220 L15 2-4, L22 0-2
COC 3221 O24 0-2

TCLP, Pb

Please authorize by signing below
& FAXing back (This page only)

ACCEPTED - The above specifications of this Change Order are satisfactory and are hereby accepted.

X Date of acceptance 11/19/92
X Signature Elizabeth Nixon

Quanteq
An Ecologics Company

Page 1 of 1

REQUEST FOR ANALYSIS/CHAIN OF CUSTODY

Reporting Information:
1. Client: Quanteq
Address: 3440 Vincent Rd.
Pleasant Hill, CA 94523
Contact: Denise Harrington
Alt. Contact:

Address Invoice To:
3. ①

Address Report To:
2. ①

Send Invoice To:
4. ①

Send Report To: 1 or 2 (Circle one)
Client project/P.O. #: P.O. 11555 / 9211054
Sample Team Member ('s)

Lab Job Number:
Lab Destination: WCC
Date Samples Shipped: hand deliver 11/9
Lab Contact: Sam Capps
Date Results Required: ASAP
Date Report Required:
Client Contact PH. No.: (510) 930-9090
Client Contact Fax No.: (510) 930-0256

Lab Number	Client Sample Identification	Air Volume	Date/ Time Collected	Sample Type *	Pres.	No. of Cont.	Type of Cont.	ANALYSIS % moisture		Homogenize + sieve complete sample to 10 mesh			Dry Sample						Comments/Inst., Hazards, etc.
	9211054 - 1B		11-5-92	8		1	baggie	X		X			X						
	3B							X		X			X						
	8B							X		X			X						
	11B							X		X			X						
	15B							X		X			X						
	16B							X		X			X						
	17B							X		X			X						
	19B							X		X			X						
	23B							X		X			X						
	24B							X		X			X						

Relinquished by: (Signature) Gina Gillespie	DATE 11-9-92	TIME 1050	Received by: (Signature)	DATE	TIME
Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)	DATE	TIME
Relinquished by: (Signature)	DATE	TIME	Received by: (Signature)	DATE	TIME
Method of Shipment			Lab Comments		

* Sample type (Specify): 1) 37 mm 0.8 Um MCEF 2) 25 mm 0.8 Um MCEF 3) 25 mm 0.4 Um polycarb. filter 4) PVC filter, diam. _____ pore size _____ 5) Charcoal tube 6) Silica gel tube 7) Water 8) Soil 9) Bulk Sample 10) Other _____ (11) Other _____

COPIES: WHITE - JOB FILE • YELLOW - PROJECT FILE • PINK - CLIENT

R-4,5-D

9211054

Chain-of-Custody Record

№ 3218

Date: 11 5 92

Page 3 of 6

Project No.: 1736.10

Samplers (Signatures): Steve Sanders

	Date	Time	Sample Number	EPA Method 8010	EPA Method 8020	EPA Method 8240	EPA Method 8270	TPH as gasoline	TPH as diesel	TPH as BTEX	~~TPH~~ as oil [1]	Total Pb 6010 [2]	% mois	Sieve 10 mesh	HOLD	TCLP Pb							Cooled	Soil (S) or water (W)	Acidified	Number of containers
01AB	11/5		G13 2-4								X	X	X	X									X	S		2
02AB			G21 0-2								X	X			*								X	S		2
03AB			G21 2-4								X	X	X	X		X							X	S		2
04AB			H4 0-2								X	X			*								X	S		2
05AB			H11 0-2								X	X			*								X	S		2
06AB			H11 2-4								X	X			*								X	S		2
07AB			H13 0-2								X	X			*								X	S		2
08AB			H13 2-4								X	X	X	X									X	S		2
09AB			H23 0-2								X	X			*								X	S		2
0AB			H23 2-4								X	X			*								X	S		2
1AB			I13 0-2								X	X	X	X									X	S		2
2AB	↓		I18 0-2								X	X			*								X	S		2

Turnaround time: 1 wk / 2 wk

Results to: Elizabeth Nixon

Total No. of containers: 24

REMARKS

Additional comments

① Homogenize sample / do not grind prior to testing (Jar)

② Grind & homogenize prior to testing (bag)

1 wk turnaround for total Pb 6010

2 wk turnaround for TPH as oil.

Relinquished by: Signature: Steve Sanders Printed name: STEVE SANDERS Company: GEOMATRIX	Date: 11-5-92 1700	Relinquished by: Signature: Neil Herrick Printed name: NEIL HERRICK Company: QUANTEQ	Date: 11-5-92 1700
Received by: Signature: Neil Herrick Printed name: NEIL HERRICK Company:	Time: 18:00	Received by: Orma Gillespie Signature: Printed name: Company: 11-5-92 1810	Time:

Relinquished by: Signature: Printed name: Company:	Date:
Received by: Signature: Printed name: Company:	Time:

Method of shipment: Lab Pickup

Laboratory comments and Log No.: 9211054

Geomatrix Consultants
100 Pine St. 10th Floor
San Francisco, CA. 94111
(415) 434-9400

R-4, D

9211054

Chain-of-Custody Record

№ 3219

Date: 11/5/92

Page 4 of 6

Project No.: 1732.10

Samplers (Signatures): Steve Sanders

	Date	Time	Sample Number	EPA Method 8010	EPA Method 8020	EPA Method 8240	EPA Method 8270	TPH as gasoline	TPH as diesel	TPH as BTEX	TPH as oil ①	Total Pb 6010 ②	% mois	Sieve 10 mesh	HOLD		TCLP-Pb						Cooled	Soil (S) or water (W)	Acidified	Number of containers
3AB	11/5		I18 2-4								X	X			*								X	S		2
14AB			I22 0-2								X	X			*		[illegible]						X	S		2
15AB			I22 2-4								X	X	X	X			*	due 12/2/92					X	S		2
16AB			J4 0-2								X	X	X	X									X	S		2
17AB			J18 0-2								X	X	X	X									X	S		2
18AB			J21 0-2								X	X			*								X	S		2
19AB			J21 2-4								X	X	X	X									X	S		2
20AB			J23 0-2								X	X			*								X	S		2
21AB			J23 2-4								X	X			*								X	S		2
22AB			K3 0-2								X	X			*								X	S		2
23AB			K3 2-4								X	X	X	X									X	S		2
24AB	↓		K8 0-2								X	X	X	X									X	S		2

Turnaround time: 1 wk / 2 wk

Results to: Elizabeth Nixon

Total No. of containers: 24

REMARKS

Additional comments

① Homogenize sample / do not grind prior to testing (Jar)

② Homogenize & grind prior to sampling (bag)

1 wk turnaround on total Pb 6010

2 wk turnaround on TPH as oil.

Relinquished by:
Signature: Steve Sanders
Printed name: STEVE SANDERS
Company: GEOMATRIX
Date: 17:00 11-5-92

Received by:
Signature:
Printed name: NEIL HERRICK
Company:
Time: 18:10

Relinquished by:
Signature:
Printed name: NEIL HERRICK
Company: QUANTERRA
Date: 17:00 11-5-92

Received by: Anna Gillespie
Signature:
Printed name:
Company: 11-5-92 1810
Time:

Relinquished by:
Signature:
Printed name:
Company:
Date:

Received by:
Signature:
Printed name:
Company:
Time:

Method of shipment: Lab Pickup

Laboratory comments and Log No.:

9211054

Geomatrix Consultants
100 Pine St. 10th Floor
San Francisco, CA. 94111
(415) 434-9400

K-4,5 D

9211056

Chain-of-Custody Record

№ 3220

Date: 11/5/92

Page 5 of 6

Project No.: 1736.1 (~~NOT 1736.12~~)

Samplers (Signatures): Steve Sanders

	Date	Time	Sample Number	EPA Method 8010	EPA Method 8020	EPA Method 8240	EPA Method 8270	TPH as gasoline	TPH as diesel	TPH as BTEX	TPH as oil ①	Total Pb 6010 ②	% Mois	Sieve 10 mesh	HOLD	TCLP Pb							Cooled	Soil (S) or water (W)	Acidified	Number of containers
1AB	11/5		K9 0-2								X	X			*								X	S		2
2AB	↓		K9 2-4								X	X	X	X									X	S		2
3AB			K15 0-2								X	X			*								X	S		2
4AB			K15 2-4								X	X	X	X									X	S		2
5AB			K21 0-2								X	X			*								X	S		2
6AB			K21 2-4								X	X	X	X									X	S		2
7AB			K24 0-2								X	X	X	X		*	>due 12/2/92						X	S		2
8AB			L12 0-2								X	X	X	X									X	S		2
9AB			L15 0-2								X	X			*								X	S		2
10AB			L15 2-4								X	X	X	X		X							X	S		2
11AB			L16 0-2								X	X			*								X	S		2
12AB	↓		L22 0-2								X	X	X	X		X							X	S		2

REMARKS

Additional comments

① Homogenize sample / do not grind prior to testing (Jar)

② Homogenize & grind prior to testing (bag)

1 wk turnaround for total Pb 6010

2 wk turnaround for TPH as oil.

Turnaround time: 1 wk / 2 wk

Results to: Elizabeth Nixon

Total No. of containers: 24

Relinquished by:
Signature: Steve Sanders
Printed name: STEVE SANDERS
Company: GEOMATRIX
Date: 11-5-92
17:00

Received by:
Signature:
Printed name: NEIL HERRICK
Company:
Time: 18:10

Relinquished by:
Signature:
Printed name: NEIL HERRICK
Company: QUANTEQ
Date: 17:00
11-5

Received by: Gina Gillespie
Signature:
Printed name:
Company: 11-5-92 1810
Time:

Relinquished by:
Signature:
Printed name:
Company:
Date:

Received by:
Signature:
Printed name:
Company:
Time:

Method of shipment: Lab pickup

Laboratory comments and Log No.:
9211056

Geomatrix Consultants
100 Pine St. 10th Floor
San Francisco, CA. 94111
(415) 434-9400

R-4,5-D

9211056

Chain-of-Custody Record

№ 3221

Date: 11/5/92

Page 6 of 6

Project No.: 1736.10

Samplers (Signatures): Steve Sanders

	Date	Time	Sample Number	EPA Method 8010	EPA Method 8020	EPA Method 8240	EPA Method 8270	TPH as gasoline	TPH as diesel	TPH as BTEX	TPH as oil ¹	total Pb 6010 ²	% Mois	Sieve 10 mesh	HOLD	TCLP Pb							Cooled	Soil (S) or water (W)	Acidified	Number of containers
13AB	11/5		M6 0-2								X	X	X	X									X	S		2
14AB	↓		O24 0-2								X	X	X	X		X							X	S		2
15AB	11/5		J18 2-4	rec'd not listed											*											

REMARKS

Additional comments

① Homogenize sample / do not grind prior to testing (Jar)

② Homogenize & grind prior to testing (bag)

1 wk turnaround on total Pb 6010

2 wk turnaround on TPH as oil.

Turnaround time: 1 wk / 2 wk

Results to: Elizabeth Nixon

Total No. of containers: 4

Relinquished by:
Signature: Steve Sanders
Printed name: STEVE SANDERS
Company: GEOMATRIX
Date: 11-5
17:00

Received by:
Signature:
Printed name: NEIL HERRICK
Company:
Time: 18:10

Relinquished by:
Signature: NEIL HERRICK
Printed name:
Company: QUANTEQ
Date:

Received by: Gina Gillespie
Signature:
Printed name:
Company: 11-5-92 1810
Time:

Relinquished by:
Signature:
Printed name:
Company:
Date:

Received by:
Signature:
Printed name:
Company:
Time:

Method of shipment: Lab pickup

Laboratory comments and Log No.: 9211056

Geomatrix Consultants
100 Pine St. 10th Floor
San Francisco, CA. 94111
(415) 434-9400

APPENDIX F

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
METHODS FOR EVALUATING SOLID WASTE
SW-846, CHAPTER NINE

CHAPTER NINE

SAMPLING PLAN

9.1 DESIGN AND DEVELOPMENT

The initial -- and perhaps most critical -- element in a program designed to evaluate the physical and chemical properties of a solid waste is the plan for sampling the waste. It is understandable that analytical studies, with their sophisticated instrumentation and high cost, are often perceived as the dominant element in a waste characterization program. Yet, despite that sophistication and high cost, analytical data generated by a scientifically defective sampling plan have limited utility, particularly in the case of regulatory proceedings.

This section of the manual addresses the development and implementation of a scientifically credible sampling plan for a solid waste and the documentation of the chain of custody for such a plan. The information presented in this section is relevant to the sampling of any solid waste, which has been defined by the EPA in its regulations for the identification and listing of hazardous wastes to include solid, semisolid, liquid, and contained gaseous materials. However, the physical and chemical diversity of those materials, as well as the dissimilarity of storage facilities (lagoons, open piles, tanks, drums, etc.) and sampling equipment associated with them, preclude a detailed consideration of any specific sampling plan. Consequently, because the burden of responsibility for developing a technically sound sampling plan rests with the waste producer, it is advisable that he/she seek competent advice before designing a plan. This is particularly true in the early developmental stages of a sampling plan, at which time at least a basic understanding of applied statistics is required. Applied statistics is the science of employing techniques that allow the uncertainty of inductive inferences (general conclusions based on partial knowledge) to be evaluated.

9.1.1 Development of Appropriate Sampling Plans

An appropriate sampling plan for a solid waste must be responsive to both regulatory and scientific objectives. Once those objectives have been clearly identified, a suitable sampling strategy, predicated upon fundamental statistical concepts, can be developed. The statistical terminology associated with those concepts is reviewed in Table 9-1; Student's "t" values for use in the statistics of Table 9-1 appear in Table 9-2.

9.1.1.1 Regulatory and Scientific Objectives

The EPA, in its hazardous waste management system, has required that certain solid wastes be analyzed for physical and chemical properties. It is mostly chemical properties that are of concern, and, in the case of a number of chemical contaminants, the EPA has promulgated levels (regulatory thresholds) that cannot be equaled or exceeded. The regulations pertaining to the management of hazardous wastes contain three references regarding the

TABLE 9-1. BASIC STATISTICAL TERMINOLOGY APPLICABLE TO SAMPLING PLANS FOR SOLID WASTES

Terminology	Symbol	Mathematical equation	(Equation)
• Variable (e.g., barium or endrin)	x	—	
• Individual measurement of variable	x_i	—	
• Mean of all possible measurements of variable (population mean)	μ	$\mu = \frac{\sum_{i=1}^{N} x_i}{N}$, with N = number of possible measurements	(1)
• Mean of measurements generated by sample (sample mean)	$\bar{x}$	Simple random sampling and systematic random sampling $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$, with n = number of sample measurements	(2a)
		Stratified random sampling $\bar{x} = \sum_{k=1}^{r} W_k \bar{x}_k$, with $\bar{x}_k$ = stratum mean and W_k = fraction of population represented by Stratum k (number of strata [k] range from 1 to r)	(2b)
• Variance of sample	s^2	Simple random sampling and systematic random sampling $s^2 = \frac{\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2/n}{n - 1}$	(3a)
		Stratified random sampling $s^2 = \sum_{k=1}^{r} W_k s_k^2$, with s_k^2 = stratum variance and W_k = fraction of population represent by Stratum k (number of strata [k] ranges from 1 to r)	(3b)

TABLE 9-1. (Continued)

Terminology	Symbol	Mathematical equation	(Equation)
• Standard deviation of sample	s	$s = \sqrt{s^2}$	(4)
• Standard error (also standard error of mean and standard deviation of mean) of sample	$s_{\bar{x}}$	$s_{\bar{x}} = \frac{s}{\sqrt{n}}$	(5)
• Confidence interval for μ[a]	CI	$CI = \bar{x} \pm t_{.20}\, s_{\bar{x}}$, with $t_{.20}$ obtained from Table 2 for appropriate degrees of freedom	(6)
• Regulatory threshold[a]	RT	Defined by EPA (e.g., 100 ppm for barium in elutriate of EP toxicity)	(7)
• Appropriate number of samples to collect from a solid waste (financial constraints not considered)	n	$n = \frac{t^2_{.20} s^2}{\Delta^2}$, with $\Delta = RT - \bar{x}$	(8)
• Degrees of freedom	df	$df = n - 1$	(9)
• Square root transformation	---	$X_i + 1/2$	(10)
• Arcsin transformation	---	Arcsin p; if necessary, refer to any text on basic statistics; measurements must be converted to percentages (p)	(11)

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[a] The upper limit of the CI for μ is compared with the applicable regulatory threshold (RT) to determine if a solid waste contains the variable (chemical contaminant) of concern at a hazardous level. The contaminant of concern is not considered to be present in the waste at a hazardous level if the upper limit of the CI is less than the applicable RT. Otherwise, the opposite conclusion is reached.

TABLE 9-2. TABULATED VALUES OF STUDENT'S "t" FOR EVALUATING SOLID WASTES

Degrees of freedom (n-1)[a]	Tabulated "t" value[b]
1	3.078
2	1.886
3	1.638
4	1.533
5	1.476
6	1.440
7	1.415
8	1.397
9	1.393
10	1.372
11	1.363
12	1.356
13	1.350
14	1.345
15	1.341
16	1.337
17	1.333
18	1.330
19	1.328
20	1.325
21	1.323
22	1.321
23	1.319
24	1.318
25	1.316
26	1.315
27	1.314
28	1.313
29	1.311
30	1.310
40	1.303
60	1.296
120	1.289
	1.282

---

[a] Degrees of freedom (df) are equal to the number of samples (n) collected from a solid waste less one.

[b] Tabulated "t" values are for a two-tailed confidence interval and a probability of 0.20 (the same values are applicable to a one-tailed confidence interval and a probability of 0.10).

sampling of solid wastes for analytical properties. The first reference, which occurs throughout the regulations, requires that representative samples of waste be collected and defines representative samples as exhibiting average properties of the whole waste. The second reference, which pertains just to petitions to exclude wastes from being listed as hazardous wastes, specifies that enough samples (but in no case less than four samples) be collected over a period of time sufficient to represent the variability of the wastes. The third reference, which applies only to ground water monitoring systems, mandates that four replicates (subsamples) be taken from each ground water sample intended for chemical analysis and that the mean concentration and variance for each chemical constituent be calculated from those four subsamples and compared with background levels for ground water. Even the statistical test to be employed in that comparison is specified (Student's t-test).

The first of the above-described references addresses the issue of sampling accuracy, and the second and third references focus on sampling variability or, conversely, sampling precision (actually the third reference relates to analytical variability, which, in many statistical tests, is indistinguishable from true sampling variability). Sampling accuracy (the closeness of a sample value to its true value) and sampling precision (the closeness of repeated sample values) are also the issues of overriding importance in any scientific assessment of sampling practices. Thus, from both regulatory and scientific perspectives, the primary objectives of a sampling plan for a solid waste are twofold: namely, to collect samples that will allow measurements of the chemical properties of the waste that are both accurate and precise. If the chemical measurements are sufficiently accurate and precise, they will be considered reliable estimates of the chemical properties of the waste.

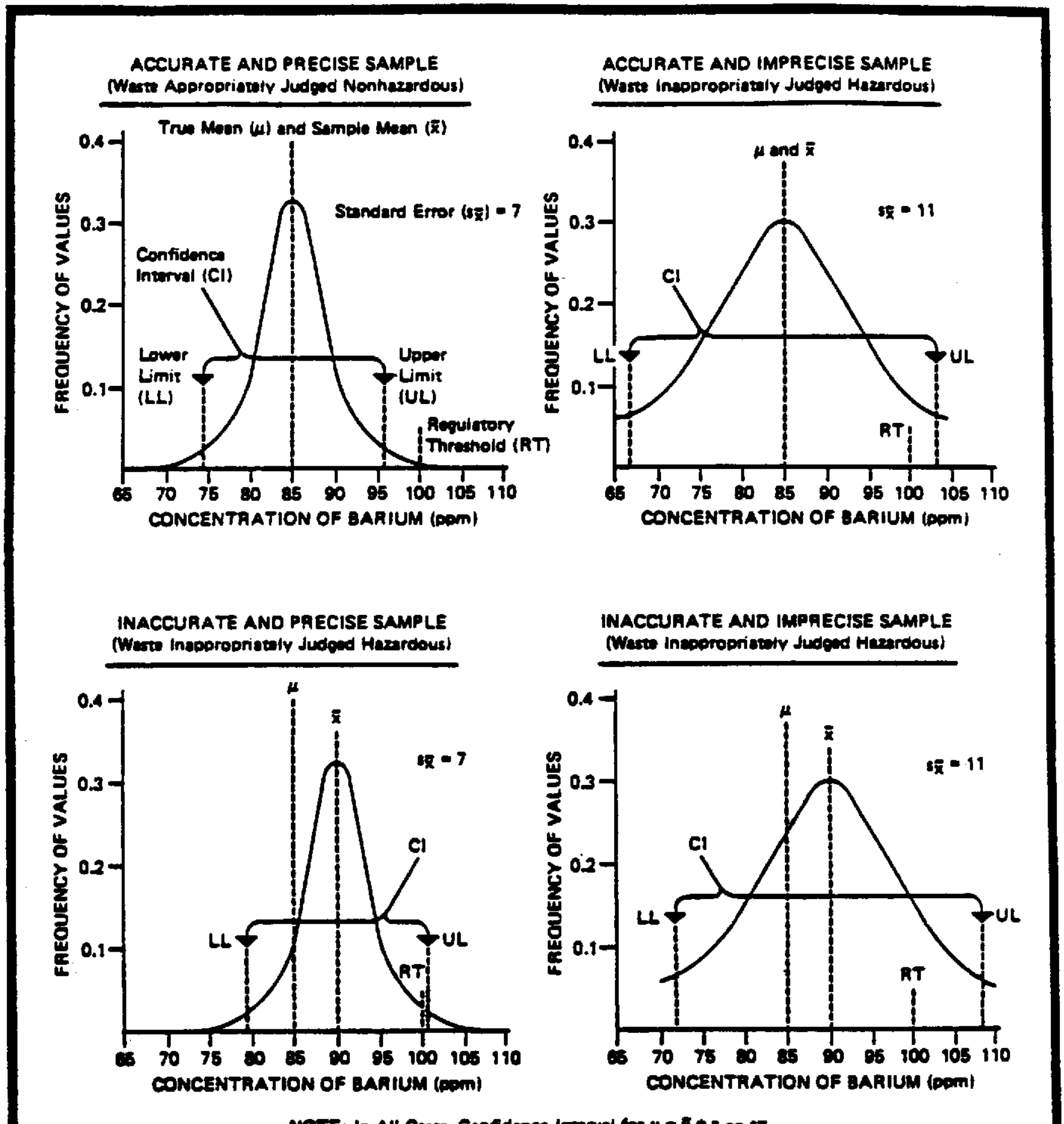
It is now apparent that a judgment must be made as to the degree of sampling accuracy and precision that is required to estimate reliably the chemical characteristics of a solid waste for the purpose of comparing those characteristics with applicable regulatory thresholds. Generally, high accuracy and high precision are required if one or more chemical contaminants of a solid waste are present at a concentration that is close to the applicable regulatory threshold. Alternatively, relatively low accuracy and low precision can be tolerated if the contaminants of concern occur at levels far below or far above their applicable thresholds. However, a word of caution is in order. Low sampling precision is often associated with considerable savings in analytical, as well as sampling, costs and is clearly recognizable even in the simplest of statistical tests. On the other hand, low sampling accuracy may not entail cost savings and is always obscured in statistical tests (i.e., it cannot be evaluated). Therefore, although it is desirable to design sampling plans for solid wastes to achieve only the minimally required precision (at least two samples of a material are required for any estimate of precision), it is prudent to design the plans to attain the greatest possible accuracy.

The roles that inaccurate and imprecise sampling can play in causing a solid waste to be inappropriately judged hazardous are illustrated in Figure 9-1. When evaluating Figure 9-1, several points are worthy of consideration. Although a sampling plan for a solid waste generates a mean concentration ($\bar{x}$) and standard deviation (s, a measure of the extent to which individual sample concentrations are dispersed around $\bar{x}$) for each chemical contaminant of concern, it is not the variation of individual sample concentrations that is of ultimate concern, but rather the variation that characterizes $\bar{x}$ itself. That measure of dispersion is termed the standard deviation of the mean (also, the standard error of the mean or standard error) and is designated as $s_{\bar{x}}$. Those two sample values, $\bar{x}$ and $s_{\bar{x}}$, are used to estimate the interval (range) within which the true mean (μ) of the chemical concentration probably occurs, under the assumption that the individual concentrations exhibit a normal (bell-shaped) distribution. For the purposes of evaluating solid wastes, the probability level (confidence interval) of 80% has been selected. That is, for each chemical contaminant of concern, a confidence interval (CI) is described within which μ occurs if the sample is representative, which is expected of about 80 out of 100 samples. The upper limit of the 80% CI is then compared with the appropriate regulatory threshold. If the upper limit is less than the threshold, the chemical contaminant is not considered to be present in the waste at a hazardous level; otherwise, the opposite conclusion is drawn. One last point merits explanation. Even if the upper limit of an estimated 80% CI is only slightly less than the regulatory threshold (the worst case of chemical contamination that would be judged acceptable), there is only a 10% (not 20%) chance that the threshold is equaled or exceeded. That is because values of a normally distributed contaminant that are outside the limits of an 80% CI are equally distributed between the left (lower) and right (upper) tails of the normal curve. Consequently, the CI employed to evaluate solid wastes is, for all practical purposes, a 90% interval.

9.1.1.2 Fundamental Statistical Concepts

The concepts of sampling accuracy and precision have already been introduced, along with some measurements of central tendency ($\bar{x}$) and dispersion (standard deviation [s] and $s_{\bar{x}}$) for concentrations of a chemical contaminant of a solid waste. The utility of $\bar{x}$ and $s_{\bar{x}}$ in estimating a confidence interval that probably contains the true mean (μ) concentration of a contaminant has also been described. However, it was noted that the validity of that estimate is predicated upon the assumption that individual concentrations of the contaminant exhibit a normal distribution.

Statistical techniques for obtaining accurate and precise samples are relatively simple and easy to implement. <u>Sampling accuracy is usually achieved by some form of random sampling</u>. In random sampling, every unit in the population (e.g., every location in a lagoon used to store a solid waste) has a theoretically equal chance of being sampled and measured. Consequently, statistics generated by the sample (e.g., $\bar{x}$ and, to a lesser degree, $s_{\bar{x}}$) are unbiased (accurate) estimators of true population parameters (e.g., the CI for μ). In other words, the sample is representative of the population. One of the commonest methods of selecting a random sample is to divide the



NOTE: In All Cases, Confidence Interval for $\mu = \bar{x} \pm t_{.20}\, s_{\bar{x}}$.

Figure 9-1.—Important theoretical relationships between sampling accuracy and precision and regulatory objectives for a chemical contaminant of a solid waste that occurs at a concentration marginally less than its regulatory threshold. In this example, barium is the chemical contaminant. The true mean concentration of barium in the elutriate of the EP toxicity test is 85 ppm, as compared to a regulatory threshold of 100 ppm. The upper limit of the confidence interval for the true mean concentration, which is estimated from the sample mean and standard error, must be less than the regulatory threshold if barium is judged to be present in the waste at a nonhazardous level.

population by an imaginary grid, assign a series of consecutive numbers to the units of the grid, and select the numbers (units) to be sampled through the use of a random-numbers table (such a table can be found in any text on basic statistics). It is important to emphasize that a haphazardly selected sample is not a suitable substitute for a randomly selected sample. That is because there is no assurance that a person performing undisciplined sampling will not consciously or subconsciously favor the selection of certain units of the population, thus causing the sample to be unrepresentative of the population.

Sampling precision is most commonly achieved by taking an appropriate number of samples from the population. As can be observed from the equation for calculating $s_{\bar{x}}$, precision increases ($s_{\bar{x}}$ and the CI for μ decrease) as the number of samples (n) increases, although not in a 1:1 ratio. For example, a 100% increase in the number of samples from two to four causes the CI to decrease by approximately 62% (about 31% of that decrease is associated with the critical upper tail of the normal curve). However, another 100% increase in sampling effort from four to eight samples results in only an additional 39% decrease in the CI. Another technique for increasing sampling precision is to maximize the physical size (weight or volume) of the samples that are collected. That has the effect of minimizing between-sample variation and, consequently, decreasing $s_{\bar{x}}$. Increasing the number or size of samples taken from a population, in addition to increasing sampling precision, has the secondary effect of increasing sampling accuracy.

In summary, reliable information concerning the chemical properties of a solid waste is needed for the purpose of comparing those properties with applicable regulatory thresholds. If chemical information is to be considered reliable, it must be accurate and sufficiently precise. Accuracy is usually achieved by incorporating some form of randomness into the selection process for the samples that generate the chemical information. Sufficient precision is most often obtained by selecting an appropriate number of samples.

There are a few ramifications of the above-described concepts that merit elaboration. If, for example, as in the case of semiconductor etching solutions, each batch of a waste is completely homogeneous with regard to the chemical properties of concern and that chemical homogeneity is constant (uniform) over time (from batch to batch), a single sample collected from the waste at an arbitrary location and time would theoretically generate an accurate and precise estimate of the chemical properties. However, most wastes are heterogeneous in terms of their chemical properties. If a batch of waste is randomly heterogeneous with regard to its chemical characteristics and that random chemical heterogeneity remains constant from batch to batch, accuracy and appropriate precision can usually be achieved by simple random sampling. In that type of sampling, all units in the population (essentially all locations or points in all batches of waste from which a sample could be collected) are identified, and a suitable number of samples is randomly selected from the population. More complex stratified random sampling is appropriate if a batch of waste is known to be nonrandomly heterogeneous in terms of its chemical properties and/or nonrandom chemical heterogeneity is known to exist from batch to batch. In such cases, the population is stratified to isolate the known sources of nonrandom chemical heterogeneity.

After stratification, which may occur over space (locations or points in a batch of waste) and/or time (each batch of waste), the units in each stratum are numerically identified, and a simple random sample is taken from each stratum. As previously intimated, both simple and stratified random sampling generate accurate estimates of the chemical properties of a solid waste. The advantage of stratified random sampling over simple random sampling is that, for a given number of samples and a given sample size, the former technique often results in a more precise estimate of chemical properties of a waste (a lower value of $s_{\bar{x}}$) than the latter technique. However, greater precision is likely to be realized only if a waste exhibits substantial nonrandom chemical heterogeneity and stratification efficiently "divides" the waste into strata that exhibit maximum between-strata variability and minimum within-strata variability. If that does not occur, stratified random sampling can produce results that are less precise than in the case of simple random sampling. Therefore, it is reasonable to select stratified random sampling over simple random sampling only if the distribution of chemical contaminants in a waste is sufficiently known to allow an intelligent identification of strata and at least two or three samples can be collected in each stratum. If a strategy employing stratified random sampling is selected, a decision must be made regarding the allocation of sampling effort among strata. When chemical variation within each stratum can be estimated with a great degree of detail, samples should be optimally allocated among strata, i.e., the number of samples collected from each stratum should be directly proportional to the chemical variation encountered in the stratum. When detailed information concerning chemical variability within strata is not available, samples should be proportionally allocated among strata, i.e., sampling effort in each stratum should be directly proportional to the size of the stratum.

Simple random sampling and stratified random sampling are types of probability sampling, which, because of a reliance upon mathematical and statistical theories, allows an evaluation of the effectiveness of sampling procedures. Another type of probability sampling is systematic random sampling, in which the first unit to be collected from a population is randomly selected, but all subsequent units are taken at fixed space or time intervals. An example of systematic random sampling is the sampling of a waste lagoon along a transect in which the first sampling point on the transect is 1 m from a randomly selected location on the shore and subsequent sampling points are located at 2-m intervals along the transect. The advantages of systematic random sampling over simple random sampling and stratified random sampling are the ease with which samples are identified and collected (the selection of the first sampling unit determines the remainder of the units) and, sometimes, an increase in precision. In certain cases, for example, systematic random sampling might be expected to be a little more precise than stratified random sampling with one unit per stratum because samples are distributed more evenly over the population. As will be demonstrated shortly, disadvantages of systematic random sampling are the poor accuracy and precision that can occur when unrecognized trends or cycles occur in the population. For those reasons, systematic random sampling is recommended only when a population is essentially random or contains at most a modest stratification. In such cases, systematic random sampling would be employed for the sake of convenience, with little expectation of an increase in precision over other random sampling techniques.

Probability sampling is contrasted with authoritative sampling, in which an individual who is well acquainted with the solid waste to be sampled selects a sample without regard to randomization. The validity of data gathered in that manner is totally dependent on the knowledge of the sampler and, although valid data can sometimes be obtained, authoritative sampling is not recommended for the chemical characterization of most wastes.

It may now be useful to offer a generalization regarding the four sampling strategies that have been identified for solid wastes. If little or no information is available concerning the distribution of chemical contaminants of a waste, simple random sampling is the most appropriate sampling strategy. As more information is accumulated for the contaminants of concern, greater consideration can be given (in order of the additional information required) to stratified random sampling, systematic random sampling, and, perhaps, authoritative sampling.

The validity of a CI for the true mean (μ) concentration of a chemical contaminant of a solid waste is, as previously noted, based on the assumption that individual concentrations of the contaminant exhibit a normal distribution. This is true regardless of the strategy that is employed to sample the waste. Although there are computational procedures for evaluating the correctness of the assumption of normality, those procedures are meaningful only if a large number of samples are collected from a waste. Because sampling plans for most solid wastes entail just a few samples, one can do little more than superficially examine resulting data for obvious departures from normality (this can be done by simple graphical methods), keeping in mind that even if individual measurements of a chemical contaminant of a waste exhibit a considerably abnormal distribution, such abnormality is not likely to be the case for sample means, which are our primary concern. One can also compare the mean of the sample ($\bar{x}$) with the variance of the sample (s^2). In a normally distributed population, $\bar{x}$ would be expected to be greater than s^2 (assuming that the number of samples [n] is reasonably large). If that is not the case, the chemical contaminant of concern may be characterized by a Poisson distribution ($\bar{x}$ is approximately equal to s^2) or a negative binomial distribution ($\bar{x}$ is less than s^2). In the former circumstance, normality can often be achieved by transforming data according to the square root transformation. In the latter circumstance, normality may be realized through use of the arcsine transformation. If either transformation is required, all subsequent statistical evaluations must be performed on the transformed scale.

Finally, it is necessary to address the appropriate number of samples to be employed in the chemical characterization of a solid waste. As has already been emphasized, the appropriate number of samples is the least number of samples required to generate a sufficiently precise estimate of the true mean (μ) concentration of a chemical contaminant of a waste. From the perspective of most waste producers, that means the minimal number of samples needed to demonstrate that the upper limit of the CI for μ is less than the applicable regulatory threshold (RT). The formula for estimating appropriate sampling effort (Table 9-1, Equation 8) indicates that increased sampling effort is generally justified as s^2 or the "$t_{.20}$" value (probable error rate) increases and as $\Delta(RT - \bar{x})$ decreases. In a well-designed sampling plan for a solid waste, an effort is made to estimate the values of $\bar{x}$ and s^2 before sampling is initiated. Such preliminary estimates, which may be derived from information pertaining to similar wastes, process engineering data, or limited analytical studies, are used to identify the approximate number of samples that must be collected from the waste. It is always prudent to collect a somewhat greater number of samples than indicated by preliminary estimates of $\bar{x}$ and s^2 since poor preliminary estimates of those statistics can result in an underestimate of the appropriate number of samples to collect. It is usually possible to process and store the extra samples appropriately until analysis of the initially identified samples is completed and it can be determined if analysis of the additional samples is warranted.

9.1.1.3 Basic Sampling Strategies

It is now appropriate to present general procedures for implementing the three previously introduced sampling strategies (simple random sampling, stratified random sampling, and systematic random sampling) and a hypothetical example of each sampling strategy. The hypothetical examples illustrate the statistical calculations that must be performed in most situations likely to be encountered by a waste producer and, also, provide some insight into the efficiency of the three sampling strategies in meeting regulatory objectives.

The following hypothetical conditions are assumed to exist for all three sampling strategies. First, barium, which has an RT of 100 ppm as measured in the EP elutriate test, is the only chemical contaminant of concern. Second, barium is discharged in particulate form to a waste lagoon and accumulates in the lagoon in the form of a sludge, which has built up to approximately the same thickness throughout the lagoon. Third, concentrations of barium are relatively homogeneous along the vertical gradient (from the water-sludge interface to the sludge-lagoon interface), suggesting a highly controlled manufacturing process (little between-batch variation in barium concentrations). Fourth, the physical size of sludge samples collected from the lagoon is as large as practical, and barium concentrations derived from those samples are normally distributed (note that we do not refer to barium levels in the samples of sludge because barium measurements are actually made on the elutriate from EP toxicity tests performed with the samples). Last, a preliminary study of barium levels in the elutriate of four EP toxicity tests conducted with sludge collected from the lagoon several years ago identified values of 86 and 90 ppm for material collected near the outfall (in the upper third) of the lagoon and values of 98 and 104 ppm for material obtained from the far end (the lower two-thirds) of the lagoon.

For all sampling strategies, it is important to remember that barium will be determined to be present in the sludge at a hazardous level if the upper limit of the CI for μ is equal to or greater than the RT of 100 ppm (Table 9-1, Equations 6 and 7).

9.1.1.3.1 Simple Random Sampling

Simple random sampling (Box 1) is performed by general procedures in which preliminary estimates of $\bar{x}$ and s^2, as well as a knowledge of the RT, for each chemical contaminant of a solid waste that is of concern are employed to estimate the appropriate number of samples (n) to be collected from the waste. That number of samples is subsequently analyzed for each chemical contaminant of concern. The resulting analytical data are then used to conclude definitively that each contaminant is or is not present in the waste at a hazardous concentration or, alternatively, to suggest a reiterative process, involving increased sampling effort, through which the presence or absence of hazard can be definitively determined.

In the hypothetical example for simple random sampling (Box 1), preliminary estimates of $\bar{x}$ and s^2 indicated a sampling effort consisting of six samples. That number of samples was collected and initially analyzed, generating analytical data somewhat different from the preliminary data (s^2 was substantially greater than was preliminarily estimated). Consequently, the upper limit of the CI was unexpectedly greater than the applicable RT, resulting in a tentative conclusion of hazard. However, a reestimation of appropriate sampling effort, based on statistics derived from the six samples, suggested that such a conclusion might be reversed through the collection and analysis of just one more sample. Fortunately, a resampling effort was not required because of the foresight of the waste producer in obtaining three extra samples during the initial sampling effort, which, because of their influence in decreasing the final values of $\bar{x}$, $s_{\bar{x}}$, $t_{.20}$, and, consequently, the upper limit of the CI -- values obtained from all nine samples -- resulted in a definitive conclusion of nonhazard.

9.1.1.3.2 Stratified Random Sampling

Stratified random sampling (Box 2) is conducted by general procedures that are similar to the procedures described for simple random sampling. The only difference is that, in stratified random sampling, values of $\bar{x}$ and s^2 are calculated for each stratum in the population and then integrated into overall estimates of those statistics, the standard deviation (s), $s_{\bar{x}}$, and the appropriate number of samples (n) for all strata.

The hypothetical example for stratified random sampling (Box 2) is based on the same nine sludge samples previously identified in the example of simple random sampling (Box 1) so that the relative efficiencies of the two sampling strategies can be fully compared. The efficiency generated through the process of stratification is first evident in the preliminary estimate of n (Step 2 in Boxes 1 and 2), which is six for simple random sampling and four for stratified random sampling. (The lesser value for stratified sampling is the consequence of a dramatic decrease in s^2, which more than compensated for a modest increase in Δ.) The most relevant indication of sampling efficiency is the value of $s_{\bar{x}}$, which is directly employed to calculate the CI. In the case of simple random sampling, $s_{\bar{x}}$ is calculated as 2.58 (Step 9 in Box 1), and, for stratified random sampling, $s_{\bar{x}}$ is determined to be 2.35 (Steps 5 and 7 in Box 2). Consequently, the gain in efficiency attributable to stratification is approximately 9% (0.23/2.58).

BOX 1. STRATEGY FOR DETERMINING IF CHEMICAL CONTAMINANTS OF SOLID WASTES ARE PRESENT AT HAZARDOUS LEVELS - SIMPLE RANDOM SAMPLING

Step	General Procedures

1. Obtain preliminary estimates of $\bar{x}$ and s^2 for each chemical contaminant of a solid waste that is of concern. The two above-identified statistics are calculated by, respectively, Equations 2a and 3a (Table 9-1).

2. Estimate the appropriate number of samples (n_1) to be collected from the waste through use of Equation 8 (Table 9-1) and Table 9-2. Derive individual values of n_1 for each chemical contaminant of concern. The appropriate number of samples to be taken from the waste is the greatest of the individual n_1 values.

3. Randomly collect at least n_1 (or $n_2 - n_1$, $n_3 - n_2$, etc., as will be indicated later in this box) samples from the waste (collection of a few extra samples will provide protection against poor preliminary estimates of $\bar{x}$ and s^2). Maximize the physical size (weight or volume) of all samples that are collected.

4. Analyze the n_1 (or $n_2 - n_1$, $n_3 - n_2$ etc.) samples for each chemical contaminant of concern. Superficially (graphically) examine each set of analytical data for obvious departures from normality.

5. Calculate $\bar{x}$, s^2, the standard deviation (s), and $s_{\bar{x}}$ for each set of analytical data by, respectively, Equations 2a, 3a, 4, and 5 (Table 9-1).

6. If $\bar{x}$ for a chemical contaminant is equal to or greater than the applicable RT (Equation 7, Table 9-1) and is believed to be an accurate estimator of μ, the contaminant is considered to be present in the waste at a hazardous concentration, and the study is completed. Otherwise, continue the study. In the case of a set of analytical data that does not exhibit obvious abnormality and for which $\bar{x}$ is greater than s^2, perform the following calculations with nontransformed data. Otherwise, consider transforming the data by the square root transformation (if $\bar{x}$ is about equal to s^2) or the arcsine transformation (if $\bar{x}$ is less than s^2) and performing all subsequent calculations with transformed data. Square root and arcsine transformations are defined by, respectively, Equations 10 and 11 (Table 9-1).

7. Determine the CI for each chemical contaminant of concern by Equation 6 (Table 9-1) and Table 9-2. If the upper limit of the CI is less than the applicable RT (Equations 6 and 7, Table 9-1), the chemical contaminant is not considered to be present in the waste at a hazardous concentration and the study is completed. Otherwise, the opposite conclusion is tentatively reached.

8. If a tentative conclusion of hazard is reached, reestimate the total number of samples (n_2) to be collected from the waste by use of Equation 8 (Table 9-1) and Table 9-2. When deriving n_2, employ the newly calculated (not preliminary) values of x and s^2. If additional $n_2 - n_1$ samples of waste cannot reasonably be collected, the study is completed, and a definitive conclusion of hazard is reached. Otherwise, collect extra $n_2 - n_1$ samples of waste.

9. Repeat the basic operations described in Steps 3 through 8 until the waste is judged to be nonhazardous or, if the opposite conclusion continues to be reached, until increased sampling effort is impractical.

Hypothetical Example

Step

1. The preliminary study of barium levels in the elutriate of four EP toxicity tests, conducted with sludge collected from the lagoon several years ago, generated values of 86 and 90 ppm for sludge obtained from the upper third of the lagoon and values of 98 and 104 ppm for sludge from the lower two-thirds of the lagoon. Those two sets of values are not judged to be indicative of nonrandom chemical heterogeneity (stratification) within the lagoon. Therefore, preliminary estimates of $\bar{x}$ and s^2 are calculated as:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{86 + 90 + 98 + 104}{4} = 94.50, \text{ and} \qquad \text{(Equation 2a)}$$

$$s^2 = \frac{\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2/n}{n - 1} \qquad \text{(Equation 3a)}$$

$$= \frac{35{,}916.00 - 35{,}721.00}{3} = 65.00.$$

2. Based on the preliminary estimates of $\bar{x}$ and s^2, as well as the knowledge that the RT for barium is 100 ppm,

$$n_1 = \frac{t_{.20}^2 s^2}{\Delta^2} = \frac{(1.638^2)(65.00)}{5.50^2} = 5.77. \qquad \text{(Equation 8)}$$

3. As indicated above, the appropriate number of sludge samples (n_1) to be collected from the lagoon is six. That number of samples (plus three extra samples for protection against poor preliminary estimates of $\bar{x}$ and s^2) is collected from the lagoon by a single randomization process (Figure 9-2). All samples consist of the greatest volume of sludge that

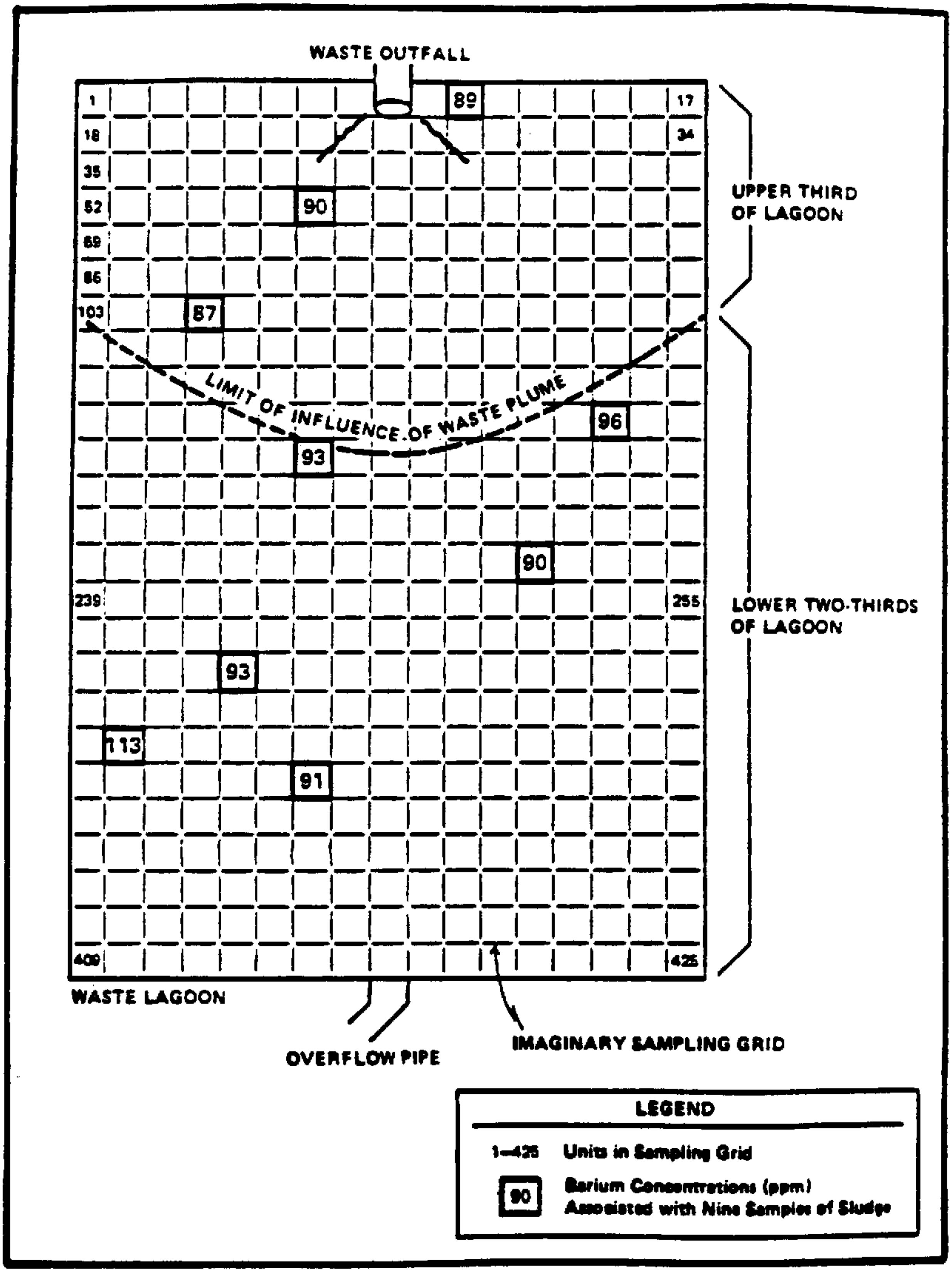


Figure 9-2.—Hypothetical sampling conditions in waste lagoon containing sludge contaminated with barium. Barium concentrations associated with samples of sludge refer to levels measured in the elutriate of EP toxicity tests conducted with the samples.

can be practically collected. The three extra samples are suitably processed and stored for possible later analysis.

4. The six samples of sludge (n_1) designated for immediate analysis generate the following concentrations of barium in the EP toxicity test: 89, 90, 87, 96, 93, and 113 ppm. Although the value of 113 ppm appears unusual as compared with the other data, there is no obvious indication that the data are not normally distributed.

5. New values for $\bar{x}$ and s^2 and associated values for the standard deviation (s) and $s_{\bar{x}}$ are calculated as:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{89 + 90 + 87 + 96 + 93 + 113}{6} = 94.67, \qquad \text{(Equation 2a)}$$

$$s^2 = \frac{\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2/n}{n - 1} \qquad \text{(Equation 3a)}$$

$$= \frac{54,224.00 - 53,770.67}{5} = 90.67,$$

$$s = \sqrt{s^2} = 9.52, \text{ and} \qquad \text{(Equation 4)}$$

$$s_{\bar{x}} = s/\sqrt{n} = 9.52/\sqrt{6} = 3.89. \qquad \text{(Equation 5)}$$

6. The new value for $\bar{x}$ (94.67) is less than the RT (100). In addition, $\bar{x}$ is greater (only slightly) than s^2 (90.67), and, as previously indicated, the raw data are not characterized by obvious abnormality. Consequently, the study is continued, with the following calculations performed with nontransformed data.

7. $$CI = \bar{x} \pm t_{.20} s_{\bar{x}} = 94.67 \pm (1.476)(3.89) \qquad \text{(Equation 6)}$$

$$= 94.67 \pm 5.74.$$

Because the upper limit of the CI (100.41) is greater than the applicable RT (100), it is tentatively concluded that barium is present in the sludge at a hazardous concentration.

8. n is now reestimated as:

$$n_2 = \frac{t^2_{.20}s^2}{\Delta^2} \; \frac{(1.476^2)(90.67)}{5.33^2} = 6.95. \qquad \text{(Equation 8)}$$

The value for n_2 (approximately 7) indicates that an additional ($n_2 - n_1 = 1$) sludge sample should be collected from the lagoon.

9. The additional sampling effort is not necessary because of the three extra samples that were initially collected from the lagoon. All extra samples are analyzed, generating the following levels of barium for the EP toxicity test: 93, 90, and 91 ppm. Consequently, $\bar{x}$, s^2, the standard deviation (s), and $s_{\bar{x}}$ are recalculated as:

$$\bar{x} = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{86 + 90 + \ldots + 91}{9} = 93.56 \,, \qquad \text{(Equation 2a)}$$

$$s^2 = \frac{\sum_{i=1}^{n} X_i^2 - (\sum_{i=1}^{n} X_i)^2/n}{n - 1} \qquad \text{(Equation 3a)}$$

$$= \frac{79{,}254.00 - 78{,}773.78}{8} = 60.03,$$

$$s = \sqrt{s^2} = 7.75, \text{ and} \qquad \text{(Equation 4)}$$

$$s_{\bar{x}} = s/\sqrt{n} = 7.75/\sqrt{9} = 2.58. \qquad \text{(Equation 5)}$$

The value for $\bar{x}$ (93.56) is again less than the RT (100), and there is no indication that the nine data points, considered collectively, are abnormally distributed (in particular, $\bar{x}$ is now substantially greater than s^2). Consequently, CI, calculated with nontransformed data, is determined to be:

$$CI = \bar{x} \pm t_{.20}s_{\bar{x}} = 93.56 \pm (1.397)(2.58) \qquad \text{(Equation 6)}$$

$$= 93.56 \pm 3.60.$$

The upper limit of the CI (97.16) is now less than the RT of 100. Consequently, it is definitively concluded that barium is not present in the sludge at a hazardous level.