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MCAS EL TORO
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OHM Remediation Services Corp.
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OHM TRANSMITTAL/DELIVERABLE RECEIPT

CONTRACT N68711-93-D-1459 **DOCUMENT CONTROL NO: SW1294**

TO:

Commanding Officer
Naval Facilities Engineering Command
Southwest Division
Mr. Ken Kennedy, Code 0232.KK
Building 131
1220 Pacific Highway
San Diego, California 92132-5187

Date: 11 Jan 96

D.O.: 0024

Location: El Toro, CA

FROM: _____ _____
Stewart Bornhoft, Program Manager Ginger James, Contracts Manager

DESCRIPTION OF ENCLOSURE: ULS Geophysical Survey at 15 UST sites and two IRP sites Final Report. Treatibility Study Report for Exsitu Bioremediation at El Toro. Draft Map Drawing of D. O. 24 UST Sites.

TYPE: Contract Deliverable ( ) D.O. Deliverable (X) Request for Change ( ) Other ( )

VERSION: Final **REVISION NO.:** 0

ADMIN RECORD: Yes (X) No ( ) Category ( ) Confidential ( )

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Letter of Transmittal

OHM Remediation Services Corp.
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2031 Main Street, Irvine, CA 92714
Phone: (714) 263-1146 Fax: (714) 263-1147

Irvine Office

To:
Ms. Lynn Hornecker, Code 1831.LMH
Remedial Project Manager
Naval Facilities Engineering Command
Southwest Division
1220 Pacific Highway
San Diego, CA 92132-5187

From:
Dhananjay Dave
Job No.: 17486
January 9, 1996

Project: **Remediation of Various UST Sites**
At Marine Corps Air Station, El Toro, California
Contract N68711-93-D-1459, D.O. 0024

DOCUMENT CONTROL NO: SW 1294

Dear Ms. Hornecker:

Attached is one copy of the following:

-ULS Geophysical Survey at 15 UST sites and two IRP sites Final Report.
-Treatability Study Report for Exsitu Bioremediation at El Toro.
-Draft Map Drawing of D.O. 24 UST sites

Copies are also being provided (under separate cover) to the following persons:

ROICC, MCAS El Toro, (Mr. Scott Kehe, and Joe Bucho, 1 copy)
MCAS El Toro, AC/S Environmental (Lt. Hope Katcharian, 1 copy)

If there is any problem with these documents, please contact me at 714-263-1146, ext. 303.

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JAN 10 1996

FEASIBILITY OF BIOREMEDIATION IN THE EX-SITU CLEAN-UP OF DIESEL FUEL AT THE MARINE CORPS AIR STATION EL TORO, CALIFORNIA

for

OHM Remediation
2031 Main Street
Irvine, CA 92714

Attn: Dhananjay Dave

by

W. T. Frankenberger, Jr.
J. L. Newcomb
Center for Environmental Microbiology
1660 Chicago Avenue, Suite M-2
Riverside, CA 92507

December 1995

EXECUTIVE SUMMARY

A treatability study was conducted to assess the feasibility of bioremediation in the clean-up of diesel fuel in soil collected from underground storage tanks at the Marine Corps Air Station (MCAS) El Toro, California. The soil was characterized in terms of pH, inorganic nitrogen (N), inorganic phosphorus (P), moisture content, total heterotrophic bacteria and the hydrocarbon-oxidizing population. The pH of the soil was 8.0, which is within the optimum pH range (7.0-8.5) for biodegradation of petroleum hydrocarbons. The ammonium-N content of the soil was 5.0 mg kg^{-1} and nitrate-N was 12.5 mg kg^{-1} giving a total available inorganic N content of 17.5 mg kg^{-1} soil. The inorganic P content was 8.7 mg kg^{-1} soil and the moisture content was 6.9% (wt/wt). The total recoverable petroleum hydrocarbon (TRPH) content as measured by EPA 418.1 was 75 mg of hydrocarbons kg^{-1} soil, which was spiked to 27,000 mg kg^{-1} soil. The total heterotrophic plate count was 2×10^7 colony-forming units g^{-1} soil and the hydrocarbon-oxidizing population was 5×10^4 most probable number g^{-1} soil.

A respirometry study (O_2 uptake) was conducted as an indirect measure of aerobic biodegradation of the diesel fuel. The sterile control showed a 1.8% decrease in O_2 content in the microcosm headspace with 20.2% O_2 remaining after 5 days of incubation. With the application of moisture alone, the O_2 content declined 5.6% from 21.0 to 15.4% O_2. The most effective amendment was with the addition of nutrients [200 mg N kg^{-1} as $(NH_4)_2SO_4$ and 75 mg P kg^{-1} as K_2HPO_4] to the contaminated soil, showing a 19.2% reduction in O_2 content after 5 days of incubation. Nitrogen appears to be the major limiting nutrient since the addition of N [100 mg N kg^{-1} as $(NH_4)_2SO_4$] alone resulted in a 19.3% decline in O_2. The addition of P (25 mg kg^{-1} as K_2HPO_4) to the contaminated soil had a similar effect as the moist only treatment with a 5.5% decline in the O_2 content.

Biodegradation of the diesel fuel was monitored in an open system where aeration would not be a limiting factor. The contaminated soil was maintained under moist conditions while mixed and incubated at ambient temperature (23°C ± 2°C) for six weeks. Treatments consisted of a sterile

control, a moist-only treatment, the application of nutrients [200 mg kg^{-1} N as $(NH_4)_2SO_4$ and 75 mg kg^{-1}P as K_2HPO_4] and the application of nutrients (N and P) in a 1% solution of Witconol SN-70 (alcohol ethoxylate [nonionic]) surfactant. The sterile control allowed an assessment of TRPH lost through volatilization and hindered biological degradation. The initial concentration of TRPH averaged 26,700 mg kg^{-1}. The sterile soil showed very little change in the TRPH level with variations between 25,000 and 29,000 mg kg^{-1} soil. The addition of water alone to keep the soil moist resulted in a 55% loss (29,000 to 13,000 mg kg^{-1}) in TRPH after 6 weeks of incubation. The application of nutrients [200 mg N kg^{-1} as $(NH_4)_2SO_4$ and 75 mg P kg^{-1} as K_2HPO_4] enhanced the biodegradation of the diesel fuel with a 62% decline (26,000 to 10,000 mg kg^{-1}) in TRPH. Treatment with nutrients (200 mg N kg^{-1} plus 75 mg P kg^{-1}) in a 1% Witconol SN-70 surfactant solution resulted in a 58% decrease (26,000 to 11,000 mg kg^{-1}) in TRPH at the end of the incubation period (6 weeks). It is obvious, from this study, that the addition of nutrients will promote the biodegradation of diesel fuel as confirmed by the respirometry study. Bioavailability of hydrocarbons does not appear to be a limiting factor since the addition of the surfactant did not stimulate biodegradation of the diesel fuel and since the degradation follows zero-order kinetics. Since the decline in TRPH is following a linear decrease in hydrocarbons over 6 weeks of incubation, one would expect a further decline in TRPH with continuing incubation. With the optimum treatment, the $T_{1/2}$ (half-live) was calculated at 33 days using the equation, $C_t = C_o - kt$.

INTRODUCTION

A bench-scale treatability study was conducted to assess the feasibility of bioremediation in the ex-situ clean-up of diesel fuel from former underground storage tanks located at the Marine Corps Air Station (MCAS), El Toro, California. It is well-known that soil microorganisms can naturally degrade petroleum hydrocarbons, however biodegradation rates can be dramatically stimulated by altering the environmental conditions such as adding nutrients, promoting aeration and maintaining moist conditions. Native soil microbiota can use petroleum hydrocarbons as a sole carbon and energy source for growth and proliferation, releasing innocuous products such as carbon dioxide (CO_2) and water (H_2O).

Generally, petroleum hydrocarbons contain about 85% carbon. With such a high load of carbon, this imbalance leads to deficiencies in other nutrients required for degradation. Nutrients which have been shown to stimulate biodegradation of petroleum hydrocarbons include nitrogen (N) and phosphorus (P). The addition of N and P as biostimulating agents can often more than double biodegradation rates. Aeration is another important factor because complete destruction of hydrocarbons requires oxygen for ring fission of the aromatic compounds and monoterminal (or subterminal) oxidation of the aliphatics. Moisture is needed to maintain the hydrocarbon-oxidizing microorganisms in a viable state.

Before a bioremediation approach is initiated in the field, it is important to obtain background information on the contaminated soil to optimize the conditions for biodegradation. For this program to be successful, basic information is needed such as the inventory residual hydrocarbon concentration, population density of the hydrocarbon-degrading microorganisms, various chemical and physical properties of the contaminated soil (pH, inorganic N, inorganic P, and moisture content) and the biodegradation potential with the application of nutrients. All contaminated sites vary in their potential for biodegradation, depending on the soil type, biological diversity, prevailing environmental factors, type of contamination, and amount of spillage. A bench-scale treatability study will assess the physical, chemical and biological properties of the

contaminated soil. This study provides a relative index on the natural, unamended biodegradation rates vs. accelerated rates upon the addition of biostimulating agents. Once these optimum conditions have been established through laboratory tests, biostimulation can be practiced on-site to initiate a bioremediation approach. These recommendations should reduce contamination in considerably less time and subsequently require less cost for maintenance of the remedial operation.

MATERIALS AND METHODS

Soil Characterization

The following methods were used for soil characterization: pH was determined by a glass electrode (soil:water ratio 1:2) (EPA 9045), NH_4-N and NO_3-N by steam distillation (Kenney and Nelson, 1982), inorganic P (orthophosphate) by the method of Olsen and Sommers (1982), moisture percentage by gravimetric determination (ASTM D2216) and total recoverable petroleum hydrocarbons (TRPH) by EPA 418.1.

The biological analyses included an enumeration of the total native heterotrophic microbiota and the hydrocarbon-oxidizing microorganisms capable of using diesel fuel as a sole carbon and energy source. Total heterotrophic plate counts were performed using the spread-plate method with the medium consisting of Bacto Plate Count Agar (Difco Laboratories, Detroit, MI) (Method 9215C [*Standard Methods for the Examination of Water and Wastewater*, 18th edition, American Public Health Association, American Water Works Association, Water Environment Federation, 1992]). The plates were prepared in duplicate and incubated at ambient temperatures (23°C $\pm$ 2°C) up to three days. Microbial colonies were counted and reported as the number of colony-forming units (cfu) per gram of soil.

Hydrocarbon-degrading microorganisms were enumerated using the most probable number method (mpn) (Alexander, 1982). The medium consisted of Bushnell-Haas medium (0.2 g $MgSO_4 \cdot 7H_2O$, 0.02 g $CaCl_2$, 1.0 g K_2HPO_4, 1.0 g KH_2PO_4, 1.0 g NH_4NO_3 and 0.05 g $FeCl_3$),

and 1 liter of distilled water. The medium (10 ml) was pipetted into test tubes and autoclaved for 20 min at 121°C and 19 psi. Diesel (200 µl) was pipetted into each test tube to serve as the sole carbon and energy source for the hydrocarbon-degrading microorganisms. Serial dilutions in sterile tap water were performed on the contaminated soil and 100 µl of each dilution were added to test tubes containing the medium and diesel fuel. The inoculated test tubes were incubated at ambient temperatures (23°C ± 2°C) for 7 days. To each of the incubated test tubes, 100 µl of a solution of iodonitrotetrazolium violet (INT) and N,N dimethyl-formamide was added to test for the presence of dehydrogenase activity. The tubes were incubated in the dark overnight, and then scored for the presence of a violet dye (the reduction of INT [clear to light yellow] to INT formazan [INTF] [violet]). The hydrocarbon-oxidizing population was determined from Cochran's most probable number table (Cochran, 1950) and reported as the most probable number (mpn) per gram of soil.

Respirometry Study

Biodegradation of the diesel fuel was assessed by monitoring the O_2 uptake by the contaminated, spiked (27,000 mg diesel kg^{-1}) soil subjected to different treatments. Twenty grams of contaminated soil were added to 40-ml glass vials. The soil moisture was maintained at field capacity. The following treatments were applied to the contaminated soil: a sterile control (autoclaved for 5 hours at 121°C and 19 psi); application of water alone; treatment with biostimulating agents consisting of N [100 mg N kg^{-1} as $(NH_4)_2SO_4$] or P (50 mg P kg^{-1} as K_2HPO_4); and the combination of N and P (50 mg N plus 25 mg P kg^{-1} soil; 100 mg N plus 50 mg P kg^{-1} soil; and 200 mg N plus 75 mg P kg^{-1} soil). The vials were capped with 70% ethanol disinfected mininert valves (Dynatech, Baton Rouge, LA) and incubated statically at ambient temperature (23°C ± 2°C) up to 5 days.

Oxygen uptake was determined by gas chromatography (GC) by withdrawing a 1-ml headspace sample with a gas-tight series pressure Lok® gas syringe (Alltech, Deerfield, IL). The GC analysis was performed on a Hewlett Packard Model 5890 connected to a Hewlett Packard

3390A integrator. Samples were separated on a Supelco (Bellefonte, PA) 60/80 Carboxen 1000 column. The peaks were detected by thermal conductivity (TC). The operational conditions were as follows: column temperature, 35°C; initial time, 5.0 min; rate, 20.0°C min^{-1}; final temperature, 225°C; injection temperature, 225°C; detector temperature, 225°C; and carrier gas (He) at 30 ml min^{-1}. The amount of O_2 detected was determined by use of standards (Scott Specialty Gases, San Bernardino, CA). The detection limit for O_2 is 0.1% using GC-TCD. The vials remained closed throughout incubation.

Decline in Total Recoverable Petroleum Hydrocarbons

U.S. EPA Method 418.1 (U.S. Environmental Protection Agency, 1983) was used to determine the decline in total recoverable petroleum hydrocarbons (TRPH) at 0, 2, 4 and 6 week intervals. The contaminated soil was placed into 12" x 14" pans at a depth of 3". Treatments consisted of (i) a sterile control (autoclaved for 5 hours at 121°C and 21 psi), (ii) the application of water alone, (iii) added nutrients [200 mg N kg^{-1} as $(NH_4)_2SO_4$ and 75 mg P kg^{-1} as K_2HPO_4], and (iv) added nutrients [200 mg N kg^{-1} as $(NH_4)_2SO_4$ and 75 mg P kg^{-1} as K_2HPO_4] in a 1% solution of Witconol SN-70 surfactant. Witconol SN-70 was obtained from Witco Corporation (Houston, Texas). This surfactant is an alcohol ethoxylate (nonionic) which is biodegradable and does not cause soil dispersion.

The sterile autoclaved control allowed an assessment of the TRPH lost through abiotic reactions. The non-sterile soils were maintained daily under moist conditions. The mesocosms were incubated at ambient temperature (23°C $\pm$ 2°C) for 6 weeks. Soils (non-sterile) were mixed daily to maintain aerated conditions.

For sampling, a grid was established over the soil and a random composite sample was taken from five locations within each mesocosm. This composite sample was then analyzed for TRPH by the 418.1 method. Soil samples were extracted with 1,1,2-trichloro-1,2,2-trifluoroethane (freon). Interferences were removed from extraction with silica gel to account for biogenic components. The detection limit for measurement of TRPH in soils by 418.1 is 5 mg kg^{-1}.

RESULTS AND DISCUSSION

Physical and Chemical Properties of the Contaminated Soils

The physical and chemical properties of the contaminated soil were characterized in terms of pH, inorganic N (NH_4-N and NO_3-N) , orthophosphate-P, moisture content and TRPH (Table 1). The pH of the soil was 8.0, which falls within the optimum pH range (7.0-8.5) for biodegradation of petroleum hydrocarbons. The inorganic N content was 5.0 mg NH_4-N kg^{-1} and 12.5 mg NO_3-N kg^{-1} soil. The inorganic P content (orthophosphate-P) was 8.7 mg kg^{-1} soil. The moisture content was 6.9% (wt/wt). The average TRPH content of the unspiked contaminated soil was 75 mg diesel kg^{-1} soil.

Table 1. Physical and chemical properties of the contaminated (unspiked) soil .

Parameters	Results
pH	8.0
Inorganic nitrogen	
NH_4-N (mg kg^{-1} soil)	5.0
NO_3-N (mg kg^{-1} soil)	12.5
Inorganic phosphorus	
orthophosphate-P (mg kg^{-1} soil)	8.7
Moisture content (%)	6.9
Total recoverable petroleum hydrocarbons (mg kg^{-1} soil)	75

Enumeration of Bacteria

The total heterotrophic plate count of the bulk soil at the onset of this investigation was 2 x 10^7 colony-forming units (cfu) g^{-1} soil. The hydrocarbonoclastic microbial population was 5 x 10^4 most probable number (mpn) g^{-1} soil (Table 2).

Table 2. Enumeration of total heterotrophic and hydrocarbon-oxidizing microorganisms.

Parameters	Microbial Populations
Total heterotrophic microorganisms (cfu* g^{-1} soil)	2 x 10^7
Hydrocarbon-oxidizing population (mpn** g^{-1} soil)	5 x 10^4

* cfu, colony-forming units
** mpn, most probable number

Respirometry

The aerobic biodegradability of an organic compound can be determined directly by measuring the disappearance of the chemical over time or indirectly by measuring oxygen (O_2) consumption. The consumption of O_2 was used to determine the most effective biostimulating agent to enhance biodegradation of the diesel fuel. During incubation, the vials remained closed so that the O_2 consumed could be monitored. The contaminated, spiked soil was exposed to various treatments including autoclaving (a sterile control); the addition of water only (unamended); N alone; P alone; and the combined application of N and P at varying concentrations. A sterile control was used to monitor abiotic uptake of O_2.

The sterile control showed a 1.8% decrease in O_2 content with 20.2% O_2 remaining in the headspace of the microcosm after 5 days incubation. This decrease in O_2 was attributed to abiotic

processes (Fig. 1). The O_2 content in the headspace of the moist only treatment declined 5.6% from 21.0 to 15.4% O_2. Upon the addition of N [100 mg N kg^{-1} as $(NH_4)_2SO_4$], the O_2 content declined 19.3% (21.0 to 1.7% O_2) indicating that N is a limiting nutrient in the contaminated soil. The addition of P (25 mg P kg^{-1} as K_2HPO_4) to the contaminated soil resulted in a 5.5% decline in O_2 comparable to the moist only soil. The combined application of N and P at various concentrations enhanced the degradation of diesel fuel as evidenced by a large decline in O_2 content. The combined application of N and P that resulted in the largest decrease in O_2 was 200 mg N plus 75 mg P kg^{-1} soil, showing a 19.2% reduction in O_2 in the headspace after 5 days of incubation (21.0 to 1.8% O_2). The addition of 100 mg N plus 50 mg P kg^{-1} soil promoted a 15.5% decrease in O_2 content (21.0 to 5.5% O_2), while 50 mg N plus 25 mg P kg^{-1} soil resulted in a 13.3% decline (21.0 to 7.7% O_2). It is evident from this study that N is the major limiting nutrient for biodegradation of diesel fuel in the soil.

Degradation of Total Recoverable Petroleum Hydrocarbons

Biodegradation of total recoverable petroleum hydrocarbons (TRPH) was monitored in an open system where aeration would not be a limiting factor. The contaminated soil was well-homogenized and spiked to 27,000 mg diesel fuel kg^{-1} soil. The treatments consisted of (i) a sterile control, (ii) a moist only treatment, (iii) the application of nutrients [200 ppm N as $(NH_4)_2SO_4$ and 75 ppm P as K_2HPO_4] and (iv) the addition of nutrients (N and P) in a 1% surfactant (Witconol SN-70) solution. Surfactants increase the concentration of a hydrophobic compound in the aqueous phase by solubilization. Colloidal aggregates (micelles) form at a critical surfactant concentration (CMC), providing increased solubilization or emulsification of the hydrophobic compound present. Increasing the compound concentration in the aqueous phase potentially increases its availability for microbial attack or removal by other remediation treatments.

The non-sterile soils were maintained under moist conditions, well-mixed and incubated at ambient temperature (23°C $\pm$ 2°C) for 6 weeks. Subsamples were taken from each mesocosm and

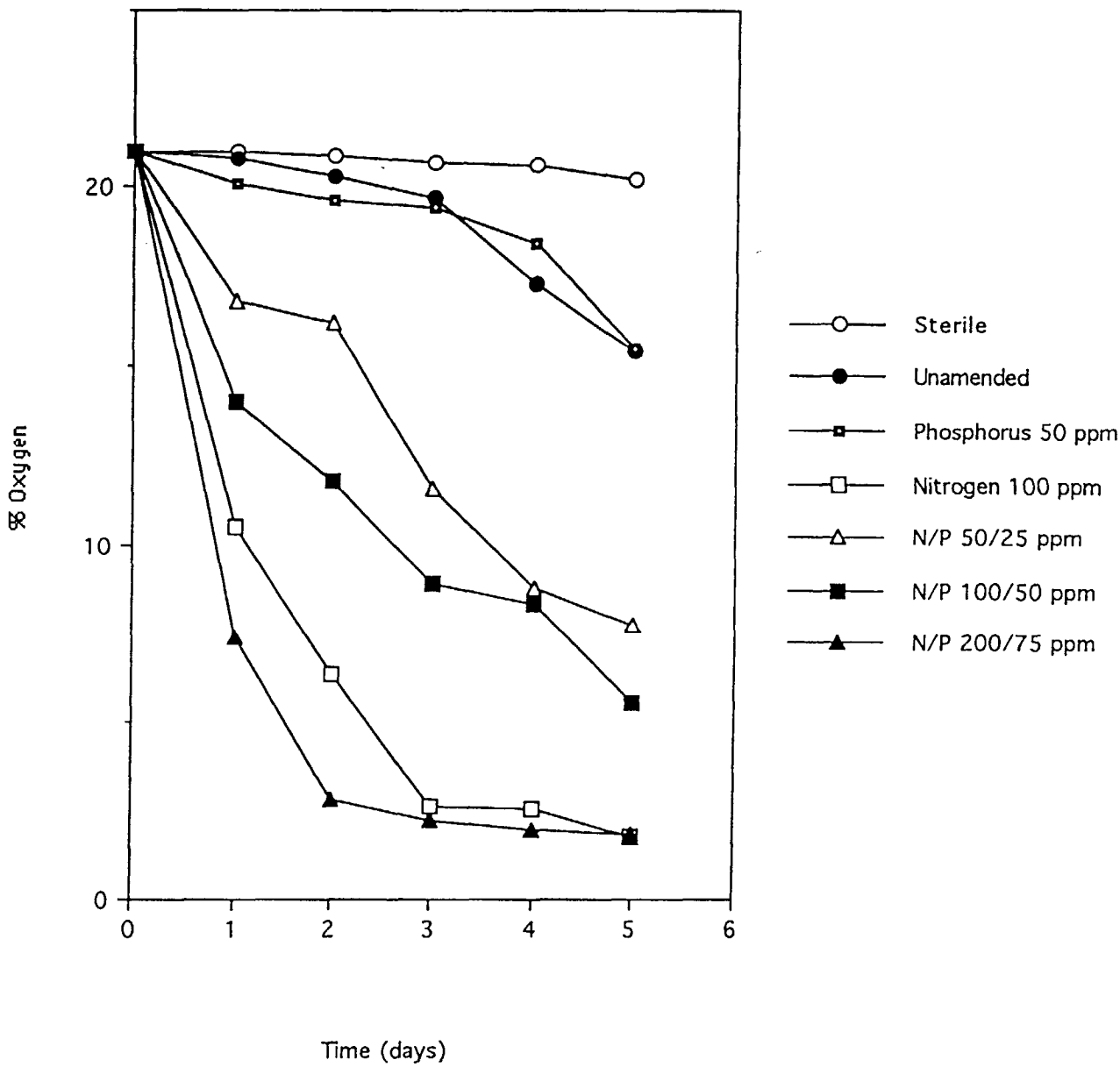

Fig. 1. Consumption of oxygen in the contaminated soil subject to biostimulating treatments.

analyzed for TRPH by the EPA Method 418.1. The results indicate that the sterile control did not decline in TRPH during the 6-week incubation period. With the application of water alone, TRPH steadily decreased over time (Fig. 2). After 6 weeks, approximately 55% of the TRPH was removed from the contaminated soil upon the addition of water alone. With an initial concentration of 26,000 mg TRPH kg^{-1} soil, the amount remaining after 6 weeks was 13,000 mg TRPH kg^{-1} soil. The application of nutrients (200 mg N kg^{-1} and 75 mg P kg^{-1}) enhanced biodegradation of diesel fuel with a decline of 62% (26,000 to 10,000 mg kg^{-1}) after 6 weeks of incubation. The addition of nutrients (N and P) in a 1% surfactant (Witconol SN-70) solution resulted in a 58% decline in TRPH, from 26,000 to 11,000 mg kg^{-1} soil. From these results, it is evident that the application of nutrients [particularly $(NH_4)_2SO_4$] will enhance the biodegradation of diesel fuel as confirmed by the respirometry study. Bioavailability of hydrocarbons does not appear to be a limiting factor since the addition of the surfactant did not stimulate biodegradation of the diesel fuel and since biodegradation follows zero-order kinetics. With a linear decrease in hydrocarbons over 6 weeks of incubation, one would expect further a decline in TRPH with continuing incubation.

CONCLUSIONS AND RECOMMENDATIONS

This benchscale treatability study was conducted to assess the feasibility of *ex situ* bioremediation of diesel fuel in soil contaminated near underground storage tanks located at the Marine Corps Air Station, El Toro, California. The contaminated soil was characterized in terms of chemical, physical and biological properties. The soil had a pH of 8.0, which is within the optimum pH range (pH 7.0-8.5) for biodegradation of petroleum hydrocarbons. The residual inorganic N and inorganic P content of the soil is well below the available nutrients needed to enhance the biodegradation of diesel fuel. The moisture content (6.9% wt/wt) was also below field capacity. The bacterial population was at a relatively high level consisting of 10^7 cfu when cultivated on rich carbon sources and the hydrocarbon oxidizing population consisted of 10^4 mpn g^{-1} soil when enriched on diesel fuel.

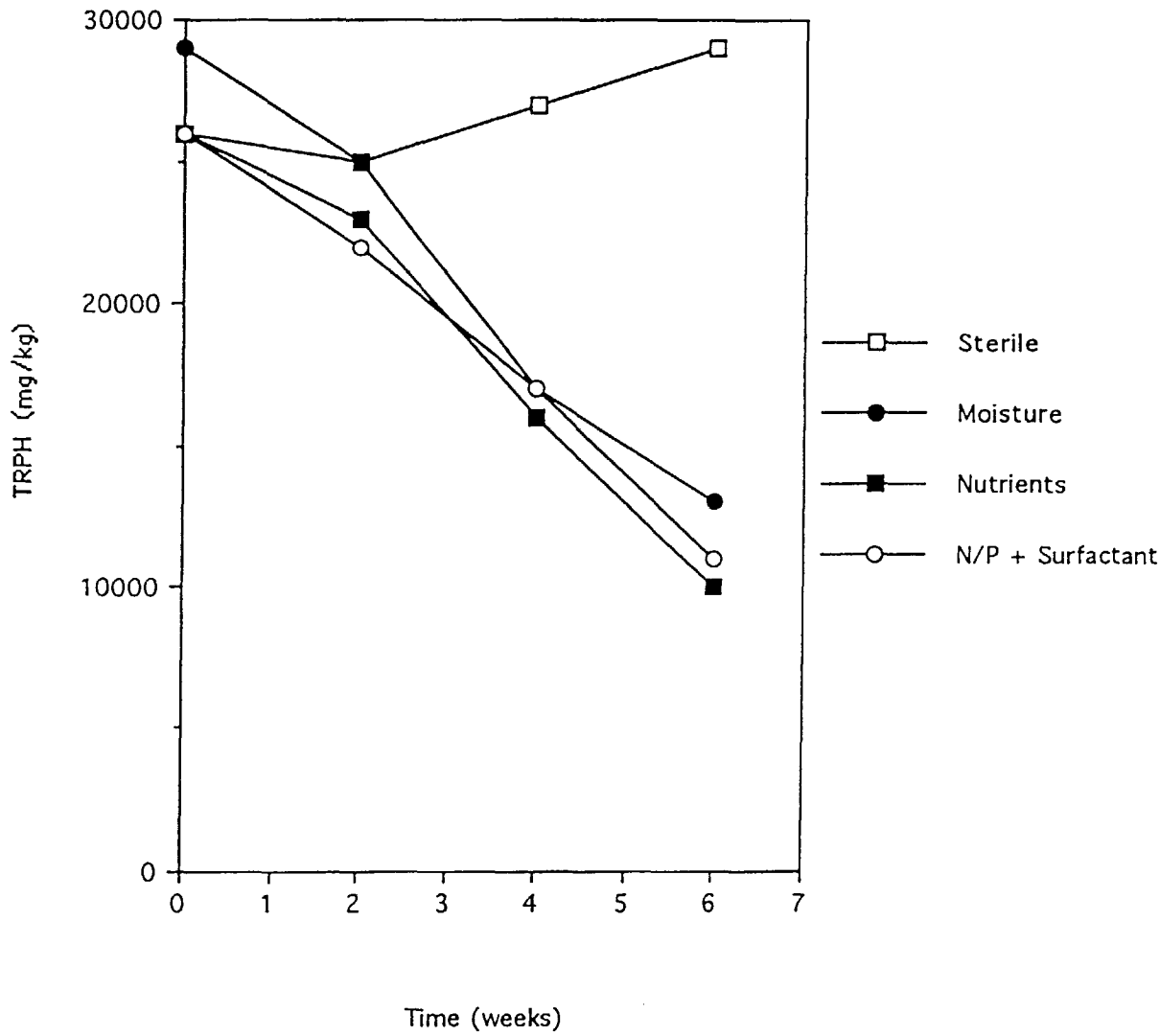

Fig. 2. Decline in TRPH upon the addition of moisture, nutrients and a surfactant.

A respirometry study was conducted to determine the most effective amendment that would enhance biodegradation of the diesel fuel. The sterile control indicated that abiotic processes had very little contribution in O_2 uptake. The application of moisture alone and P as K_2HPO_4 to the contaminated soil resulted in a 5.5% decline in O_2 content within the headspace of the microcosms. The most effective amendment to promote biodegradation of the diesel fuel after 5 days of incubation was with nitrogen as $(NH_4)_2SO_4$. Approximately 19% of the available O_2 was consumed after 5 days of incubation with the N treatment alone. The combination of N and P also confirmed that N was a limiting factor with high uptake of O_2 from the headspace of the microcosm.

Biodegradation of diesel fuel was monitored in an open system where aeration would not be a limiting factor. The contaminated soil (27,000 mg TRPH kg^{-1} soil) was maintained under moist conditions while mixed and incubated at 23°C for 6 weeks. The sterile control indicated that TRPH was not lost through volatilization. With the addition of water to maintain field capacity, as much as 55% of the diesel fuel was lost after 6 weeks of incubation. The addition of nutrients (N and P) stimulated biodegradation moreso with a 62% decline in TRPH, whereas the addition of a surfactant combined with the nutrients did not enhance the biodegradation rate over that of nutrients alone. It is obvious from this study that the addition of nutrients, particularly N, will enhance biodegradation of diesel fuel as confirmed by the respirometry study. Since the decline in TRPH is following a linear decrease in hydrocarbons over 6 weeks of incubation, one would expect a further decrease in TRPH with continuing incubation. With the optimum treatment, the $T_{1/2}$ (half-live) was calculated at 33 days using the equation ($C_t = C_o - kt$).

This treatability study indicates that *ex situ* bioremediation of diesel fuel can be a very successful operation at the Marine Corps Air Station in El Toro, California. It is highly recommended that the soil be excavated and mixed with N and P fertilizers (200 mg N kg^{-1} plus 75 mg P kg^{-1}) to accelerate the degradation of hydrocarbons at this site. The soil should be well mixed to provide adequate aeration for complete destruction of the hydrocarbons via ring fission of the aromatic compounds and oxidation (mono- and subterminal) of the aliphatics. The soil should

be kept under moist conditions at approximately field capacity (10-12% by weight) to maintain a viable population of the hydrocarbon-oxidizing population. The addition of N and P, moisture and well-mixed (aeration) will promote the degradation of diesel fuel by the indigenous soil microorganisms.

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APPENDIX

CENTER FOR ENVIRONMENTAL MICROBIOLOGY, INC.

1660 CHICAGO AVE., SUITE M-2 • RIVERSIDE, CA 92507 • (909) 788-0808 • FAX (909) 788-0346

DATA SHEET

Client: OHM Remediation
2031 Main St.
Irvine, CA 92714

Project: Feasibility of bioremediaiton in the *ex-situ* clean-up of diesel fuel at the Marine Corps Air Station El Toro, California

Sample: soil

Study: Physical and chemical properties of the contaminated soil.

Analyses	Results
pH	8.0
Inorganic nitrogen	
NH_4-N (mg kg^{-1} soil)	5.0
NO_3-N (mg kg^{-1} soil)	12.5
Inorganic phosphorus	
orthophosphate-P (mg kg^{-1} soil)	8.7
Moisture content (%)	6.9
Total recoverable petroleum hydrocarbons (mg kg^{-1} soil)	75

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DATA SHEET

Client: OHM Remediation
2031 Main St.
Irvine, CA 92714

Project: Feasibility of bioremediaiton in the *ex-situ* clean-up of diesel fuel at the Marine Corps Air Station El Toro, California

Sample: soil

Study: Enumeration of total heterotrophic and hydrocarbon-oxidizing microorganisms.

Units: Colony-forming units (cfu) per gram of soil or most probable number (mpn) per gram of soil

Analyses	Results
Total Heterotrophic microorganisms (cfu g^{-1} soil)	2×10^7
Hydrocarbon-oxidizing microorganisms (mpn g^{-1} soil)	5×10^4

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DATA SHEET

Client: OHM Remediation
2031 Main St.
Irvine, CA 92714

Project: Feasibility of bioremediaiton in the *ex-situ* clean-up of diesel fuel at the Marine Corps Air Station El Toro, California

Sample: soil

Study: Respirometry study as an indirect measure of aerobic degradation of the diesel fuel.

Units: % O_2

	Time of incubation (days)					
Sample	T=0	T=1	T=2	T=3	T=4	T=5
Sterile	21.0	21.0	20.9	20.7	20.6	20.2
Moisture alone	21.0	20.8	20.3	19.7	17.3	15.4
Phosphorus (50 mg kg^{-1})	21.0	20.0	19.6	19.4	18.4	15.5
Nitrogen (100 mg kg^{-1})	21.0	10.5	6.3	2.6	2.5	1.7
Nitrogen/Phosphorus (50/25 mg kg^{-1})	21.0	16.8	16.2	11.6	8.8	7.7
Nitrogen/Phosphorus (100/50 mg kg^{-1})	21.0	14.0	11.8	8.9	8.3	5.5
Nitrogen/Phorphorus (200/75 mg kg^{-1})	21.0	7.5	2.8	2.2	1.9	1.8

CENTER FOR ENVIRONMENTAL MICROBIOLOGY, INC.

1660 CHICAGO AVE., SUITE M-2 • RIVERSIDE, CA 92507 • (909) 788-0808 • FAX (909) 788-0346

DATA SHEET

Client: OHM Remediation
2031 Main St.
Irvine, CA 92714

Project: Feasibility of bioremediaiton in the *ex-situ* clean-up of diesel fuel at the Marine Corps Air Station El Toro, California

Sample: soil

Study: EPA 418.1 Total recoverable petroleum hydrocarbons

Units: mg kg^{-1}

	Time of incubation (weeks)			
Sample	T=0	T=2	T=4	T=6
Sterile	26000	25000	27000	29000
Moisture alone	29000	25000	17000	13000
Nutrient amended	26000	23000	16000	10000
Nutrients + Surfactant	26000	21000	17000	11000

December 29, 1995

Mr. Dhananjay Dave
OHM Remediation Services Corporation
2031 Main Street
Irvine, Ca 92714

Subject: Field Documentation Report
Utility Location and Pit Delineation Survey
Former UST Sites, MCAS, El Torro

Reference: Job No. 17486
PO No. 1016272

Gentlemen:

A representative of ULS Services Company was present at the referenced sites on and between the dates December 5 through December 18, 1995 to perform underground utility location/clearance surveys and former tank pit delineation work at 18 former UST or IRP sites **(GS-1 through GS-18)** designated by a OHM representative in the field. OHM field staff determined the location of former UST(s)/Pit locations based on location maps. Pit locations were marked in the field by OHM staff. An approximate 100 by 100 square foot survey zone around the reported pit location was surveyed for the presence of utilities and detectable potential interferences at each site. Pit delineation work was performed at and around the reported location chosen by OHM.

METHODS

Utility Detection Survey

Analog Electromagnetic methods were used and include: Electromagnetic Pipe and Cable Location (EMPCL) and Electromagnetic Induction Metal Detection (EMIMD). Conductive Utility Clearance Work was accomplished utilizing EMPCL methods which include passive, ground induction, and connection modes. A high watt signal generator with multi-frequency receiver was used. In addition, EMIMD air to ground induction mode was employed to detect broad metal mass anomalies that may be reflective of potential USTs not reported or known to exist. A bar suspended transmitter and receiver type unit was utilized. Observed EM line signals (utilities) and metal mass anomalies were painted on the ground surface and field drawings were prepared for OHM personnel as well as CAD drawing enclosed with this report **(Figures 1 through 18).**

METHODS (continued)

Pit Delineation Work

Ground Penetrating Radar (GPR) and Electromagnetic Induction Metal Detection (EMIMD) methods were employed. EMIMD was utilized at each site to determine the presence of relative high conductive anomalies in the soil materials, resulting from metallic tank residue which may include rust particles, metal shaving, soil staining, or other potential metal debris left from the tanks and associated piping. These materials when present within surrounding less conductive soil materials may be detectable. GPR transects were run over EMIMD anomalies observed and over reported pit locations where EMIMD anomalies were not observed. GPR data resolution is highly dependent upon soil material conductivity. Generally silty clayey type soil which is relatively high in conductivity lends itself to very poor to no data resolution; whereas silty to sandy or gravelly soils have good data resolution.

FINDINGS

Site GS-1 UST 364-B

Site GS-1 Survey Zone is a topographically flat area near the southwest corner Building 364 (**Figure 1**). Ground surface consists of low cut grass. There is no depression or soil staining on the surface present. There are no other physical UST related features such as vent pipe risers,etc present. Utilities are observed trending through the survey zone and include a natural gas pipe, steam pipes, and a unknown utility (**Figure 1**). OHM field representative requested that pit delineation work be postponed at this site.

Site GS-2 USTs 78 and 80

Site GS-2 Survey Zone is a topographically flat area east of Building 276 (**Figure 2**). Ground surface consists of sparse low cut grass and weeds. Numerous rodent borough activity is present at the surface. Soil appears to be of a silty clayey type. There are some depressions. There are no soil staining on the surface present other than the sparse grassy areas. There are no other physical UST related features such as vent pipe risers,etc present.

There are no utilities observed trending through the survey zone other than a sewer pipe that trends north-south through the zone as observed from sewer manhole inspection and alignment. A small metal mass anomaly approximately one by 17 feet long is observed in the southwest corner of the survey zone near reported pit UST 78.

Site GS-2 USTs 78 and 80 (continued)

Results of the EMIMD survey and GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No metal residue anomaly(s) nor GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data.

Site GS-3 UST 276

Site GS-3 Survey Zone is a topographically flat area south of Building 276 near the southeast corner (**Figure 3**). Ground surface consists of very sparse low cut grass and weeds to a light grayish brown soil material that appears to be of a silty clayey type. There is a slight depression in the soil that extends northward onto the side walk next to the building wall. There are no soil staining on the surface present other than the sparse grassy areas. The pit location is located next to the end of the building that appears to be a former boiler, utility, or power room. There are no other physical UST related features such as vent pipe risers,etc present.

There are a couple utilities observed trending through the survey zone. These include natural gas and a unknown utility. A small approximate two by four foot EMIMD metal mass anomaly is observed next to the reported pit location.

Results of the EMIMD survey and GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No metal residue anomaly(s) nor GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data.

Site GS-4 UST 58

Site GS-4 Survey Zone is a topographically flat area east of Building 28 within a alcove section of the building (**Figure 4**). Ground surface consists of low cut grass and concrete sidewalk. There are no obvious depressions in the soil. There are no soil staining on the surface present. The reported pit location is located next to the building that appears to be a former boiler, utility, or power room. There are visible steel piping inside the building floor trench that trend outward to the building wall towards the pit location.

There are several utilities observed trending next to the east side of the survey zone and some within the survey zone. There are EM line signal anomalies observed leading from the wall, where the visible piping is located, outward to the pit location where they terminate. A single EM line signal is observed leading from the pit location eastward into the parking lot, approximately 32 feet away, where the line signal terminates. A remote fill pipe is reported to exist in this location. Utilities observed outside the east side of the survey zone include: natural gas, electric,

Site GS-4 USTs 58 (continued)

water, and overhead lines. A strong EMIMD metal mass anomaly is observed within the entire alcove area surrounding the pit location, which is lacking the observed metal-mass anomaly.

Results of the EMIMD metallic soil residue survey within the pit location where the strong EMIMD anomaly exists is non-conclusive. GPR transect profile data collected from from transect profiles run over the pit area exhibit a very sharp and distinct vertical contact between the observed edge of the strong EMIMD anomaly and the reported pit area where the strong EMIMD anomaly is lacking **(Figure A)**. There does not appear to be any other GPR reflector patterns indicating disturbed pit excavation activity.

The results from the work, including the physical piping observations inside the building, suggest that the former pit has been cut out within a existing grass and soil covered concrete steel reinforced slab located throughout the alcove area.

Site GS-5 USTs 63 A and 63 B

Site GS-5 Survey Zone is a topographically mounded near the southeast corner of the existing day care center building (**Figure 5**). Ground surface consists of low cut grass. Some rodent borough activity is present at the surface. Soil appears to be of a silty clayey type. There are no depressions. There are no soil staining on the surface present . There are no other physical UST related features such as vent pipe risers,etc present. There are some utilities observed trending through the survey zone and include a sewer pipe and a natural gas pipe.

Results of the GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data. Results of the EMIMD metallic residue survey indicate some low-non uniform anomalies within the area.

OHM field staff has determined that this location may be incorrect and is pending a determination based on further information. The low strength EMIMD anomaly observed may be indicative of building demolition materials left beneath the existing surface or may reflect former UST residue materials.

Site GS-6 UST 328

Site GS-6 Survey Zone is a topographically flat area east of Building 28 within a alcove section of the building (**Figure 6**). Ground surface consists of space low cut grass. There is a slight are no obvious depressions in the surface where it is very sparse to soil covered. There is no soil staining on the surface present. Soil color on the surface is a light gray. The reported pit location is located next to the building that appears to be a former boiler, utility, or power room. There are visible steel piping inside the building floor trench that trend outward to the building wall towards the pit location.

There are a couple utilities observed trending within the survey zone and include: natural gas and water. A second natural gas valve is located next to the building wall near the reported pit. There is no EM line signal observed trending from this valve and the piping trend is not known.

Results of the EMIMD metallic soil residue survey within the pit location is non-conclusive. GPR transect profile data collected from from transect profiles run over the pit area exhibit a very sharp and distinct vertical contact between the observed edge of the soil covered depression area and the sparse low cut grass area **(Figure B)**. Choppy vertical parabolic spike reflector pattern is also observed indicating likely disturbed pit excavation materials. The results from the GPR survey work, including the physical piping observations inside the building, suggest that the former pit is verified.

Site GS-7 UST 78(Alternate Location)

Site GS-7 Survey Zone is a topographically flat area in the vicinity of the southeast corner of Building 276 in a open area (**Figure 7**). This location was chosen By OHM field staff based on additional maps provided to them by the NAVY. Ground surface consists of space low cut grass. Numerous rodent borough activity is present at the surface in the area. There is a slight depression in the surface where it is very sparse to soil covered. There is some possible soil staining on the surface present. Soil color on the surface is a light gray to tan and appears to be somewhat relatively sandy. There is a sewer pipe trending north-south through the survey zone as observed from sewer manhole inspection and alignment.

Results of the EMIMD metallic soil residue survey within the pit location is non-conclusive. GPR transect profile data collected from from transect profiles run over the pit area exhibit a very sharp and distinct vertical contact between the observed edge of the soil covered depression area and the sparse low cut grass area **(Figure C)**. Choppy vertical parabolic spike reflector pattern is also observed indicating likely disturbed pit excavation materials. Horizontal reflector patterns are observed to either side of the choppy-vertical patterns indicating likely relatively undisturbed soil materials surrounding the pit. The results from the GPR survey work suggest that the former pit may be verified. This conclusion is based on the assumption that the reported tank and pit location is correct based on the drawings and location chosen by OHM field staff.

Site GS-8 UST 327

Site GS-8 Survey Zone is a topographically flat area where former building 327 existed north of West Marine Drive. The site is in a open area (**Figure 8**). Ground surface consists of low cut grass and weeds. There are no depressions. There are no soil staining on the surface present other than a sparse grass area where the grass is dead. There are no physical UST related features such as vent pipe risers,etc present.

There are no conductive utilities observed trending through the survey zone. there are irrigation sprinkler heads located throughout the area that are reported to be fed via PVC piping. Location of this piping is not known. A large EMIMD metal-mass anomaly approximately 10 by 45 feet is observed trending north-south.

Results of the GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data. Results of the EMIMD metallic residue survey indicate scattered low-non uniform anomalies scattered throughout the general widespread area indicating the likely presence of building and foundation materials left in the ground.

Site GS-9 UST 1B

Site GS-9 Survey Zone is a topographically flat area east of a small office building. Number is unknown (**Figure 9**). Ground surface consists of low cut grass. Some rodent borough activity is present at the surface. Soil appears to be of a silty clayey type. There are no depressions. There are no soil staining on the surface present . There are no other physical UST related features such as vent pipe risers,etc present. There is a single natural gas pipe utility observed trending through the survey zone. A person from the building came outside and indicated that a tank was removed from the general location.

Results of the GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data.

Results of the EMIMD metallic residue survey indicate a low-EM signal anomaly approximately 16 by 21 feet near the building. Grass and soil materials within the anomaly appear to be less competent and compress at the surface when compared to surrounding grass and soil areas. The results from the EMIMD survey work suggest that the former pit may be verified. This conclusion is based on the assumption that the reported tank and pit location is correct based on the drawings and location chosen by OHM field staff.

Site GS-10 UST 24

Site GS-10 Survey Zone is a topographically flat area in a open space in the vicinity of the northwest corner of Building 241(**Figure 10**). Ground surface consists of low cut grass. Rodent borough activity is present at the surface. Soil appears to be of a silty clayey type. There are no depressions. There are some soil-vegitation staining on the surface present . There are no other physical UST related features such as vent pipe risers,etc present. There are no utilities observed within the survey zone.

Results of the GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data.

Results of the EMIMD metallic residue survey indicate a low-EM signal anomaly approximately 28 by 28 feet in general location with the vegitation staining. The results from the EMIMD survey work suggest that the former pit may be verified. This conclusion is based on the assumption that the reported tank and pit location is correct based on the drawings and location chosen by OHM field staff.

Site GS-11 UST 241

Site GS-11 Survey Zone is within topographically flat area along the east side of Building 241 (**Figure 11**). Ground surface consists of asphalt. There is a rectangular asphalt patch approximately 12 by 16 feet located approximately 23 feet from the building wall.

A PVC pipe is reported to exist trending north-south through the survey zone, approximately 16 feet from the wall. A single EM line signal is observed trending from the gas valve at the building wall northward along the wall and out of the survey zone. A single EM line signal is observed trending from the wall and lead into the asphalt patch area where it terminates.

Results of the EMIMD metallic soil residue survey within the pit location is non-conclusive. GPR transect profile data collected from from transect profiles run over the asphalt patch area exhibit a very sharp and distinct vertical contact between the observed edge of the asphalt patch and surrounding faded asphalt **(Figure D)**. Choppy vertical parabolic spike reflector pattern is also observed indicating likely disturbed pit excavation materials. Horizontal reflector patterns are observed to either side of the choppy-vertical patterns indicating likely relatively undisturbed soil materials surrounding the pit. The results from the GPR survey work, the asphalt patch, and EM line signal terminating within the patch suggest that the former pit may be verified. This conclusion is based on the assumption that the reported tank and pit location is correct based on the drawings and location chosen by OHM field staff.

Site GS-12 UST 35

Site GS-12 Survey Zone is a topographically flat area north of a Building 35 (**Figure 12**). Ground surface consists of low cut grass. There are no depressions. There are no soil staining on the surface present . There are no other physical UST related features such as vent pipe risers,etc present. There is a single natural gas pipe utility observed trending through the survey zone.

Results of the GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data.

Results of the EMIMD metallic residue survey indicate a low-EM signal anomaly approximately 14 by 14 feet near the building. The results from the EMIMD survey work suggest that the former pit may be verified. This conclusion is based on the assumption that the reported tank and pit location is correct based on the drawings and location chosen by OHM field staff.

Site GS-13 UST 33

Site GS-13 Survey Zone is a topographically flat area north of Building 33 (**Figure 13**). Ground surface consists of low cut grass. There are no depressions. There are no soil staining on the surface present . There are no other physical UST related features such as vent pipe risers,etc present. There is a single natural gas pipe utility observed trending through the survey zone.

Results of the GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data.

Results of the EMIMD metallic residue survey indicate a low-EM signal anomaly approximately 13 by 24 feet near the building. The results from the EMIMD survey work suggest that the former pit may be verified. This conclusion is based on the assumption that the reported tank and pit location is correct based on the drawings and location chosen by OHM field staff.

Site GS-14 UST 243

Site GS-14 Survey Zone is within topographically flat area along the south side of Building 243 (**Figure 14**). Ground surface consists of low cut grass. There is a depression in the grass which is very sparse to soil covered. Soil is a sandy material.

A single EM line signal is observed trending from the gas valve at the building along the wall from east to west. A sewer clean out exists next to the building wall. Trend direction of the sewer pipe is not known.

Results of the EMIMD metallic soil residue survey within the pit location is non-conclusive. GPR transect profile data collected from from transect profile run over the sandy depression area exhibits a very sharp and distinct vertical contact between the observed edge of the asphalt patch and surrounding faded asphalt **(Figure E)**. Choppy vertical parabolic spike reflector pattern is also observed indicating likely disturbed pit excavation materials. Horizontal reflector patterns are observed to either side of the choppy-vertical patterns indicating likely relatively undisturbed soil materials surrounding the pit. The results from the GPR survey work suggest that the former pit may be verified. This conclusion is based on the assumption that the reported tank and pit location is correct based on the drawings and location chosen by OHM field staff.

Site GS-15 UST 105A

Site GS-15A Survey Zone is a topographically flat area near the northwest corner of Building 105A (**Figure 15**). Ground surface consists of low cut grass. There is some rodent borough activity. There are no depressions. There are no soil staining on the surface present . There are no other physical UST related features such as vent pipe risers,etc present. A natural gas pipe is observed trending north-south along the west side of the survey zone. Another unknown utility is observed trending from the building wall and tees trending north and south.

Results of the GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data. Results of the EMIMD metallic residue survey were non-conclusive at this site.

Site GS-15.1 UST 105A

Site GS-15A Survey Zone is a topographically flat area near the northweat corner of Building 105A (**Figure 15A**). Ground surface consists of low cut grass. There is some rodent borough activity. There are no depressions. There are no soil staining on the surface present . There are no other physical UST related features such as vent pipe risers,etc present. There are no utilities observed, other than overhead lines.

Results of the GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data.

Results of the EMIMD metallic residue survey indicate a low-EM signal anomaly approximately 9 by 22 feet near the building. The results from the EMIMD survey work suggest that the former pit may be verified. This conclusion is based on the assumption that the reported tank and pit location is correct based on the drawings and location chosen by OHM field staff.

Site GS-16 Tank Farm 2

Site GS-16 Survey Zone is a topographically flat open area next to the aircraft area southeast of Building 241(**Figure 16**). Ground surface consists of light brown silty clay -clayey silt material which has recently been graded. There are no other physical UST related features such as vent pipe risers,etc present. A drain pipe trends north-south through the west side. A fire hydrant pipe also trends southward near the southwest section of the survey zone. Two other EM line signal anomalies are observed trending east-west within the middle sections of the survey zone. these line signal terminate at both ends, indicating they may be abandoned. No significant metal masses were observed within the survey zone. Eight circular USTs were reported to have been removed from this site.

Results of the GPR survey were non-conclusive at this site due to possible high conductive soils throughout the general area. No GPR transect profile reflector patterns indicating disturbed pit excavation activity could be determined from the data. Results of the EMIMD metallic residue survey were non-conclusive at this site.

GS-17 IRP SITE 15-1 AST 15

Site GS-17 Survey Zone is a topographically flat open area enclosed compound area in the vicinity of the southwest corner of Building 29(**Figure 17**). Ground surface consists of light brown to dark tan silty clay -clayey silt material. A sewer manhole is located near the east side of the survey zone. Piping trends north-south as observed from manhole inspection. GPR and EMIMD metallic residue surveys were not performed at this site since it is reported as a Above Ground Storage (AST) tank site.

GS-18 IRP SITE 19

Site GS-18 Survey Zone is a topographically flat area located between a drainage culvert that drains towards the southwest and a concrete pavement area. This site is located next to a Jet Fuel remote fill area(**Figure 18**). Ground surface consists of soil materials. Fiberglass fuel piping is reported to trend southwest-northeast along the top of the culvert bank. Electric and water may also trend in this same direction. A stormdrain also trends east to west across the survey zone. ewer manhole is located near the east side of the survey zone. GPR and EMIMD metallic residue surveys were not performed at this site since it is not reported as a UST pit site.

SUMMARY - Pit Delineation

Of the 19 sites surveyed, nine(9) pit areas were verified with GPR and/or EM Induction. Two(1) sites were found to be in the incorrect location by OHM field staff and a alternate location was not determined for one of these sites. Three(3) sites were not applicable (n/a) as they were AST sites. One of these n/a sites, althoug a UST pit site, was removed from further GPR work by OHM field staff. The remaining Five (5) sites were non-conclusive with respect to GPR or EM Induction. Of these five non-conclusive sites, two had very good historical UST drawings which correlated with the existing buildings. A tabulation is listed below:

Site No.	UST/PIT/AST No.	Survey Results	Fig No
GS-1	364 B	n/a	1
GS-2	78 & 80	non-conclusive	2
GS-3	276	non-conclusive (good UST location map)	3
GS-4	58	verified	4
GS-5	63A & 63B	incorrect location per OHM (no alt)	5
GS-6	328	verified	6
GS-7	78 (Alt)	verified	7
GS-8	327	non-conclusive	8
GS-9	1B	verified	9
GS-10	24	verified	10
GS-11	241	verified	11
GS-12	35	verified	12
GS-13	33	verifed	13
GS-14	243	verified	14
GS-15	105A	incorrect location	15
GS-15.1	105A (alt)	verified	15A
GS-16	Tank Farm 2	non-conclusive (good UST location map)	16
GS-17	IRP AST 15	n/a	17
GS-18	IRP SITE 19	n/a	18

Note: Verification by GPR and or EM Induction is based on assumption that UST Pit location chosen by OHM field staff is correct.

LIMITATIONS

This utility survey work was performed to industry standards, however, not all utilities, conductive or non-conductive may be detected and observed due to known or unknown variables. Multiple methods and sweeps as well as visual methods are employed. It is advisable to exhaust all other sources of information before intrusive work begins. This may include PC/Navy review of site, additional utility drawing review, and Underground Service Alert notification.

GPR and EMIMD results are very dependent upon soil conditions and data obtained as well as observations may vary from site to site. It is not always feasible to obtain useful data. Interpretations made here are based on past experience and typical response of these methods to similar scenarios associated with this site work. Other interpretations may be possible. These interpretations are based on the assumption that the reported and marked out UST pit locations by OHM field staff, based on Navy drawings, are correct. Additional historical UST drawings and location in the field may be needed.

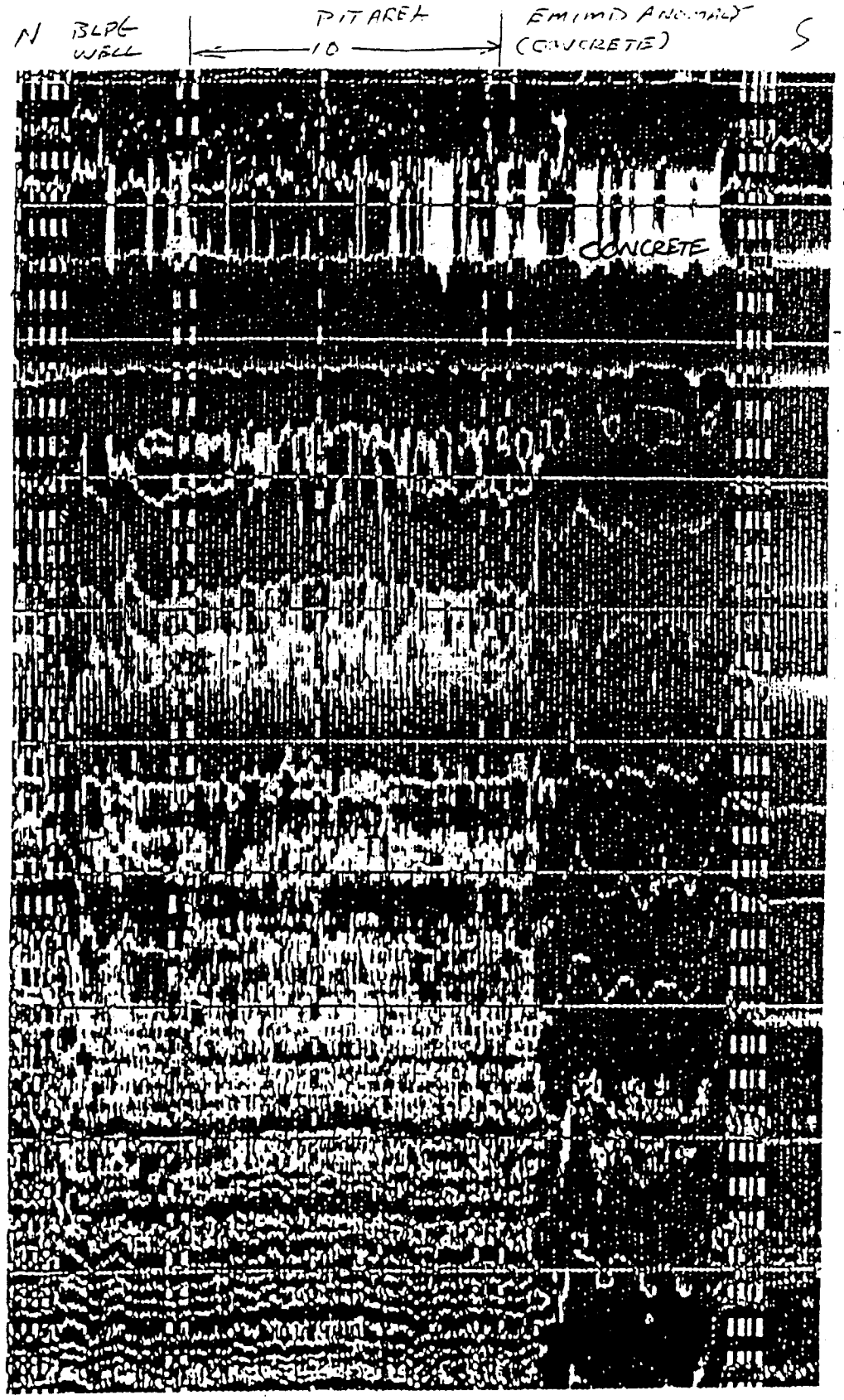
If you have any questions about this report please contact me at (619) 459-8598 or (800) 528-8206.

Sincerely,
ULS Services Company

Michael Benedict
Director Western and
Pacific Regions

OHM
MCAS, EL TORO
Site 58 GS 4

R=200
GAIN 6-0-5



11 Dec. 95
MB ULS

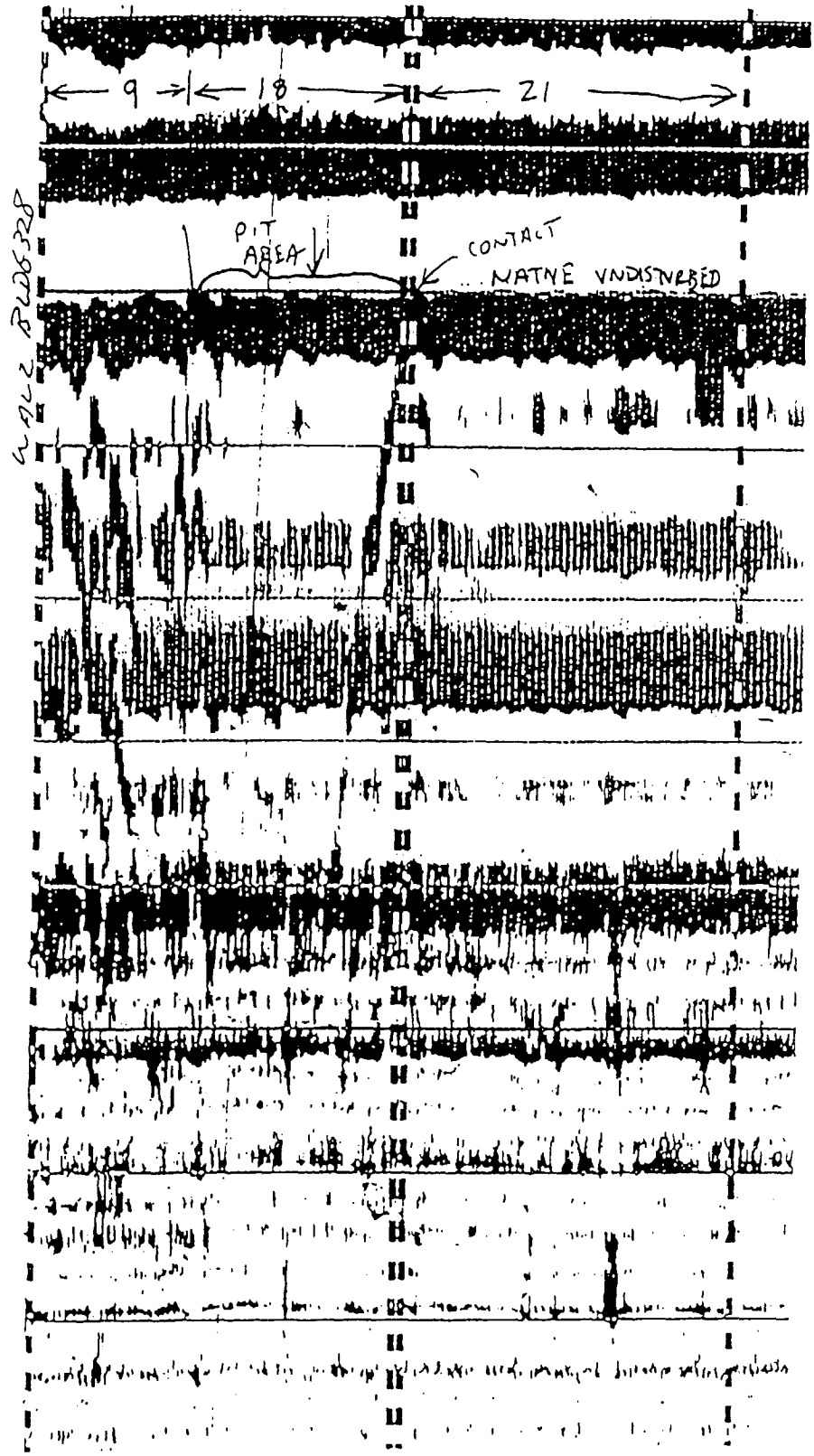
FIGURE A. GPR Transect Across Reported Former UST Pit Location
UST 58, Site GS 4.

ULS SERVICES COMPANY
SPECIALIZED SERVICES FOR ENVIRONMENTAL AND CONSTRUCTION ENGINEERING

W to E

OHM
MCAS, EL TORO
UST 328

Site GS-6
R=224 ns
GAIN= 5-3-4

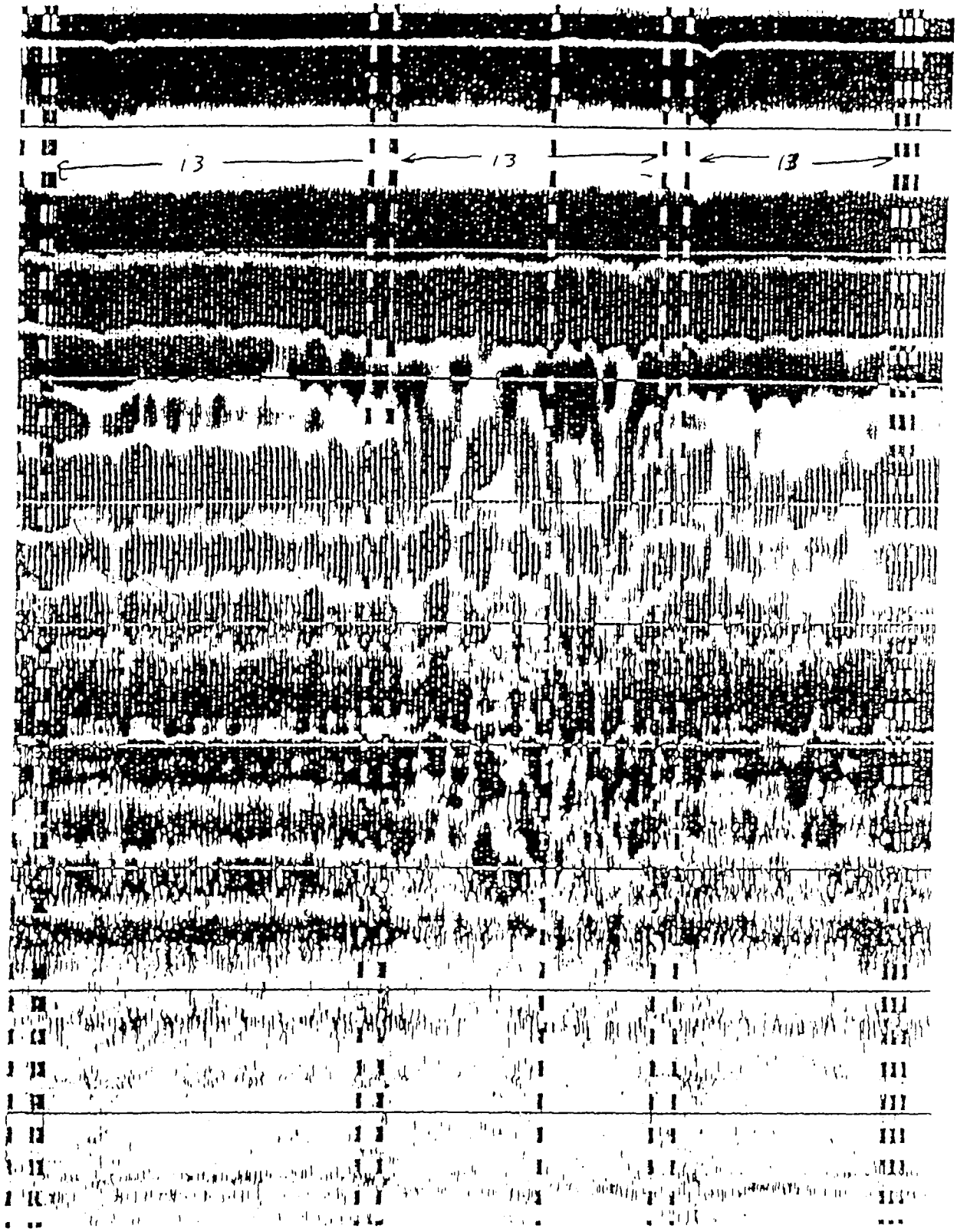


11 Dec. 95
MB ULS

FIGURE B. GPR Transect Across Reported Former UST Pit Location
UST 328, Site GS 6.

ULS SERVICES COMPANY
SPECIALIZED SERVICES FOR ENVIRONMENTAL AND CONSTRUCTION ENGINEERING

MCAS, EL TORO
UST 78 GS-7
(Aux 2)
R= 175
G= 3-3-5



12 Dec. 95
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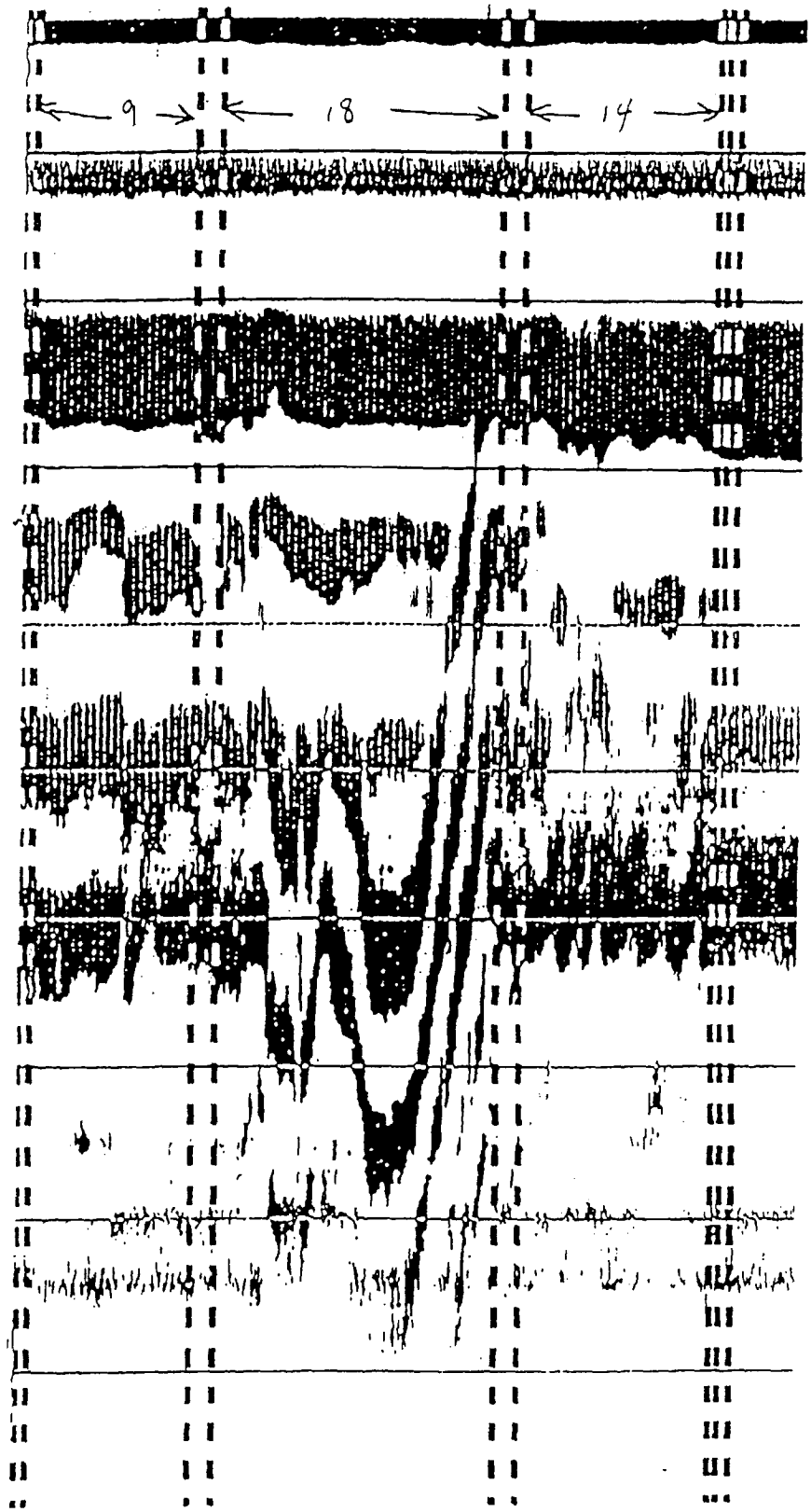
FIGURE C. GPR Transect Across Reported Former UST Pit Location
UST 78, Site GS 7.

ULS SERVICES COMPANY
SPECIALIZED SERVICES FOR ENVIRONMENTAL AND CONSTRUCTION ENGINEERING

MCAS, EL TORO
UST 241 GS-11
GPR TRANSECT
R=160 ns
GAIN= 3-3-3



12 Dec. 95
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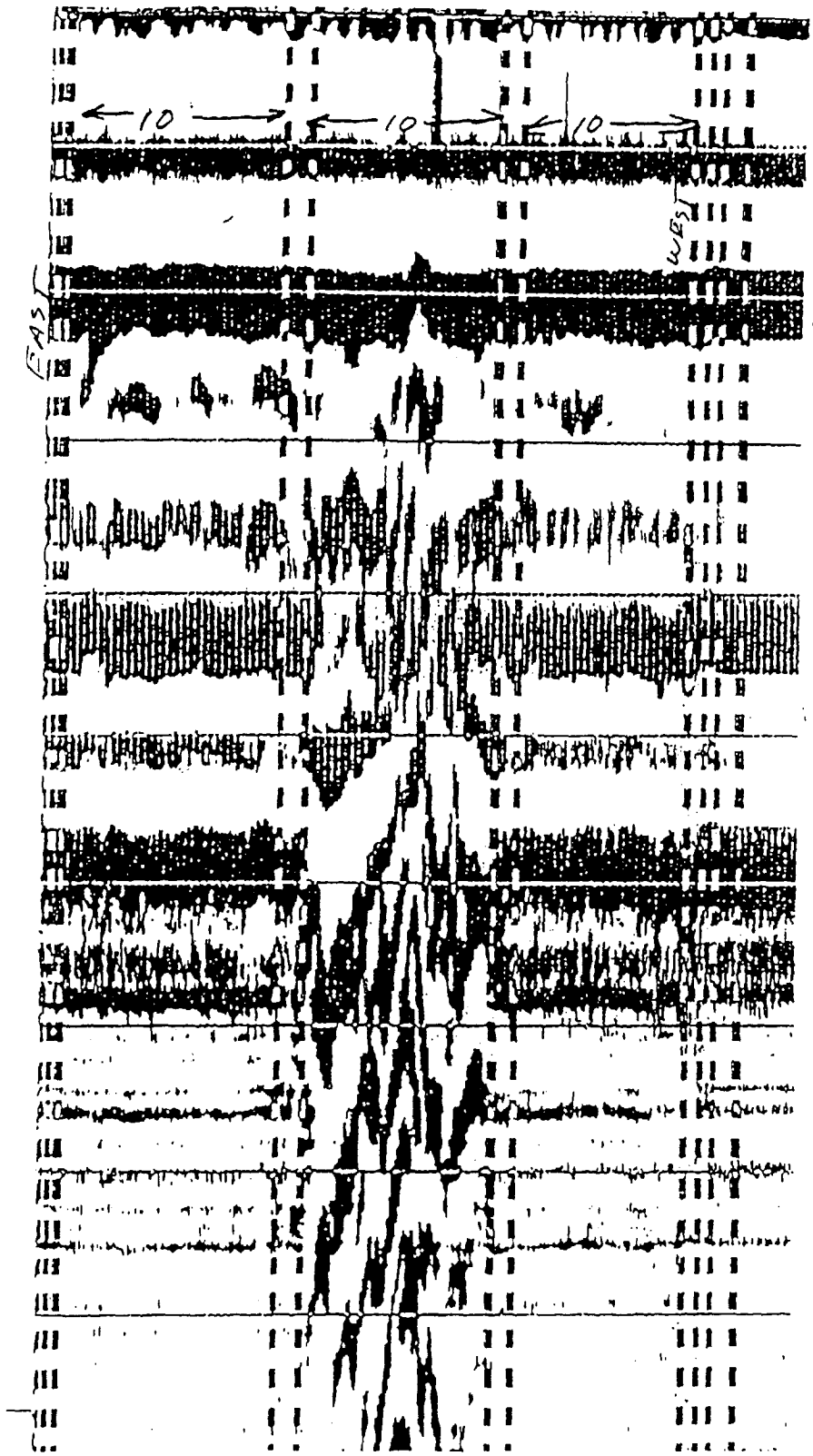
FIGURE D. GPR Transect Across Reported Former UST Pit Location
UST 241, Site GS11

ULS SERVICES COMPANY
SPECIALIZED SERVICES FOR ENVIRONMENTAL AND CONSTRUCTION ENGINEERING

OHM
MCAS, EL TORO
UST 243 SITE GS 14

GPR TRANSECT E-W

R= 240 ns
GAIN= 3-4-5



12 Dec. 95
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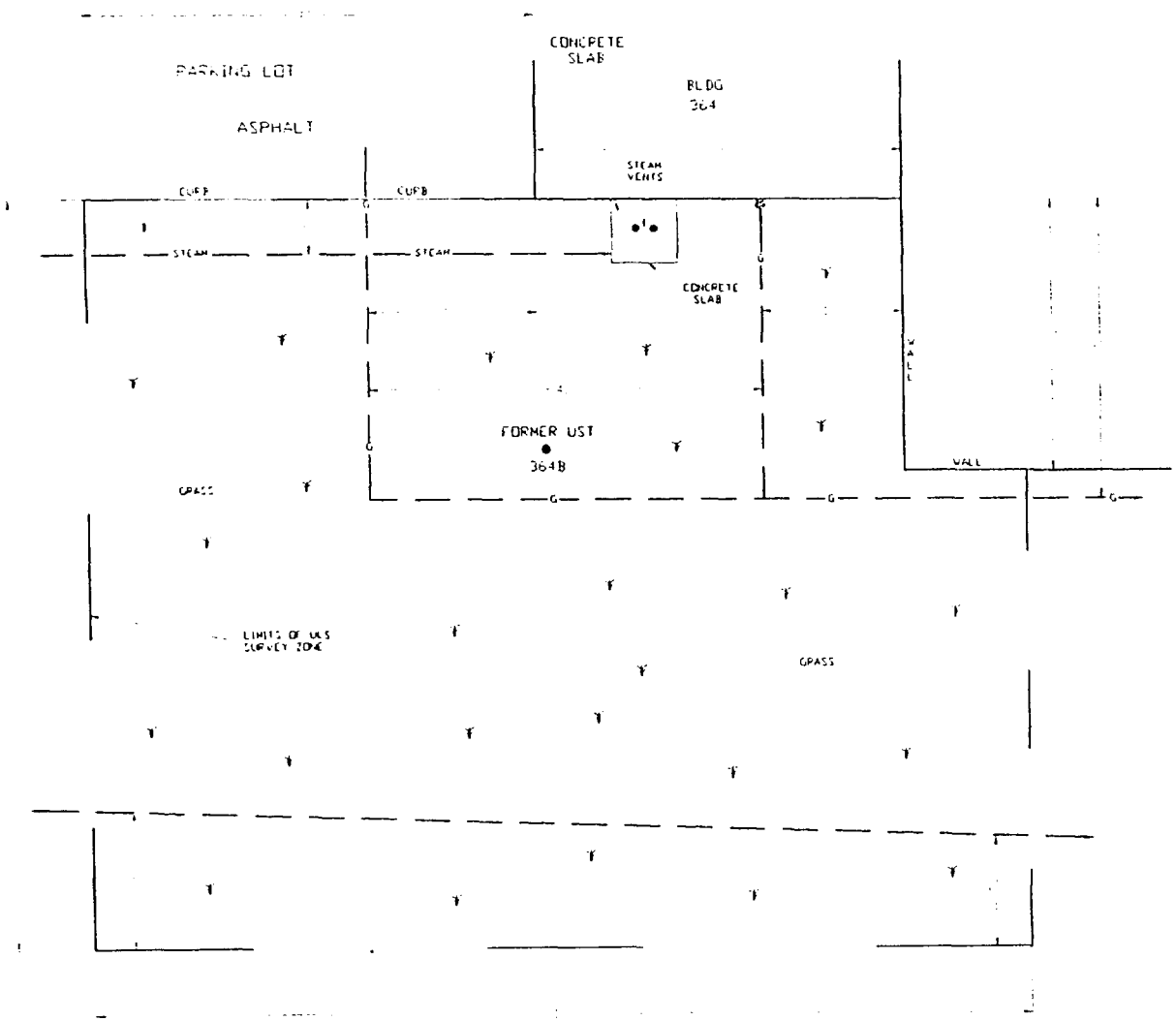
FIGURE E. GPR Transect Across Reported Former UST Pit location UST 243, Site GS 14.

ULS SERVICES COMPANY
SPECIALIZED SERVICES FOR ENVIRONMENTAL AND CONSTRUCTION ENGINEERING



N

PLAN

PROPORTIONAL

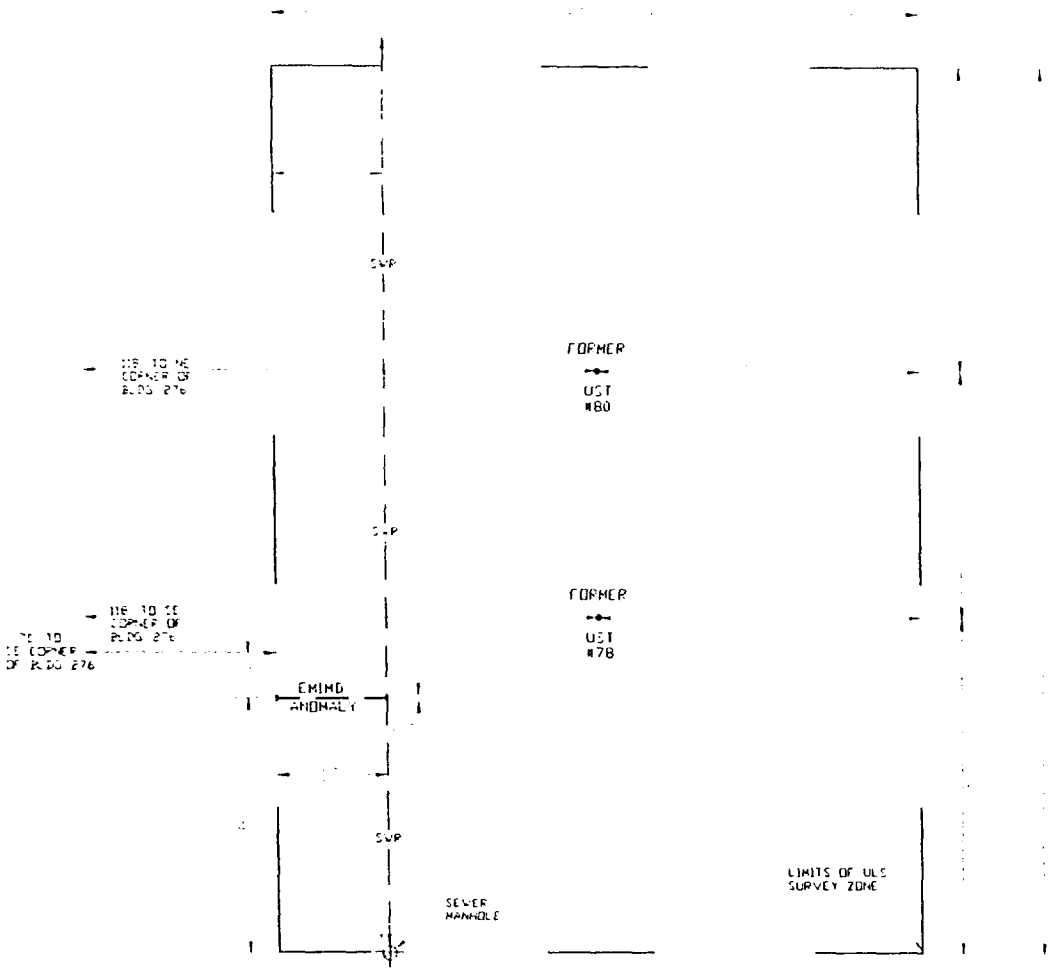
NOT TO SCALE

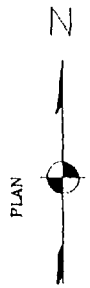
DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
- STRONG
- WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MM CHECKED BY: MB DATE: 12-05-96	UTILITY LOCATION SURVEY SITE GS-01 UST 364-B	
	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 1





PROPORTIONAL

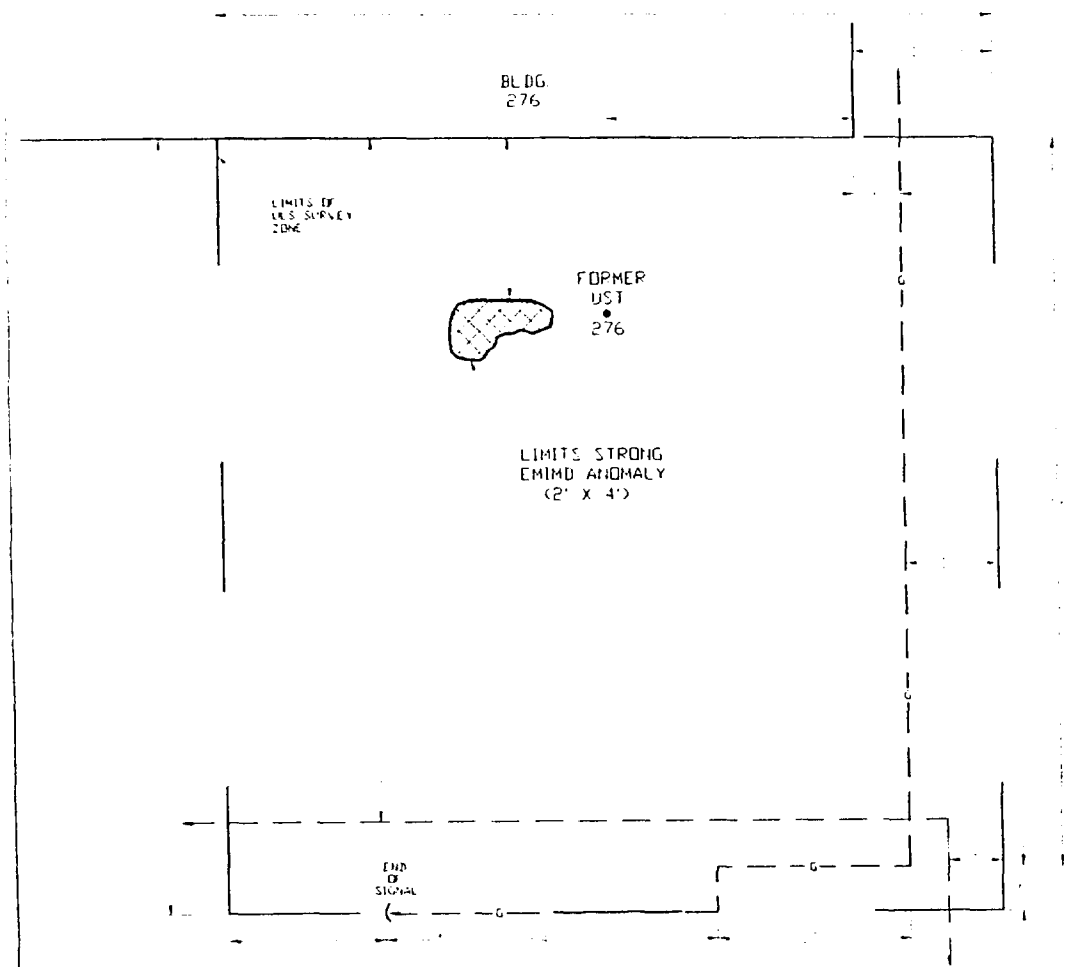
NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
  - STRONG
  - WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MM	UTILITY LOCATION SURVEY SITE GS-02 UST's 78/80	
CHECKED BY: MB DATE 10-05-96	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 2



PROPORTIONAL

NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

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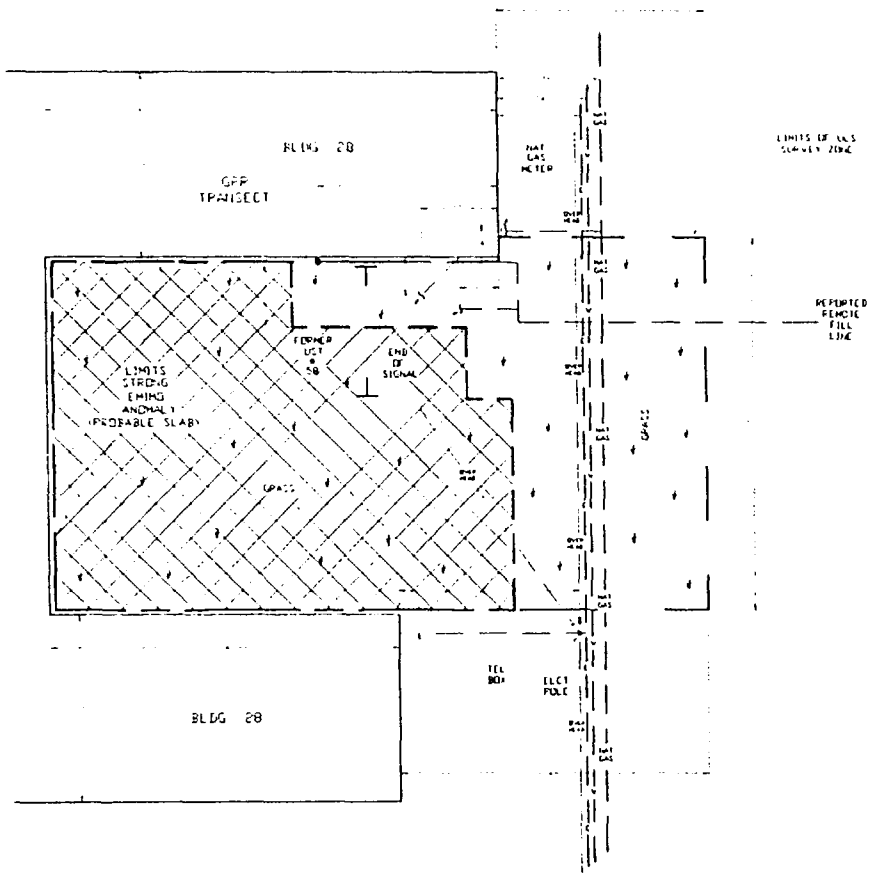
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
- STRONG
- WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SV CAD BY: NN	UTILITY LOCATION SURVEY SITE GS-03 UST 276	
CHECKED BY: NB DATE: 12-06-96	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 3



PROPORTIONAL

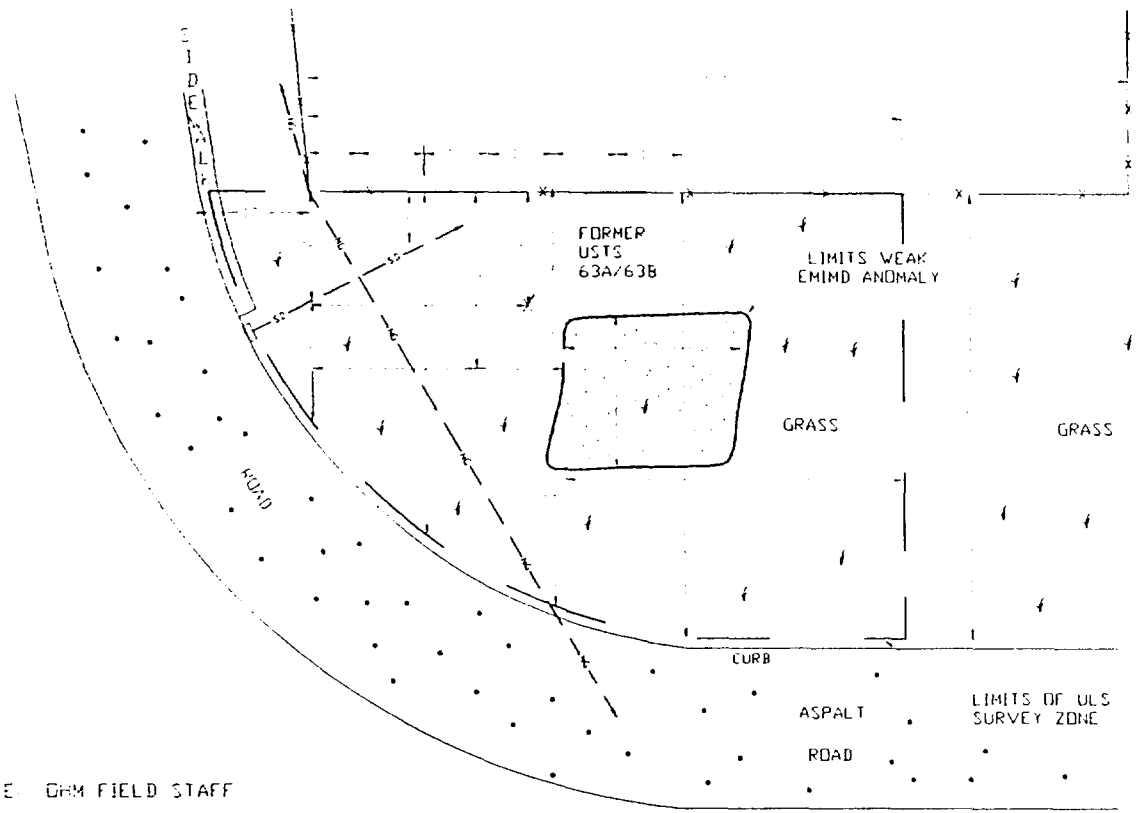
NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
  - STRONG
  - WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW	UTILITY LOCATION SURVEY	
CAD BY: MM	SITE GS-04 UST 58	
CHECKED BY: MB	PROJECT NO. 17486	FIG. NO. 4
DATE: 18-7-95	PO NO. 1016272	



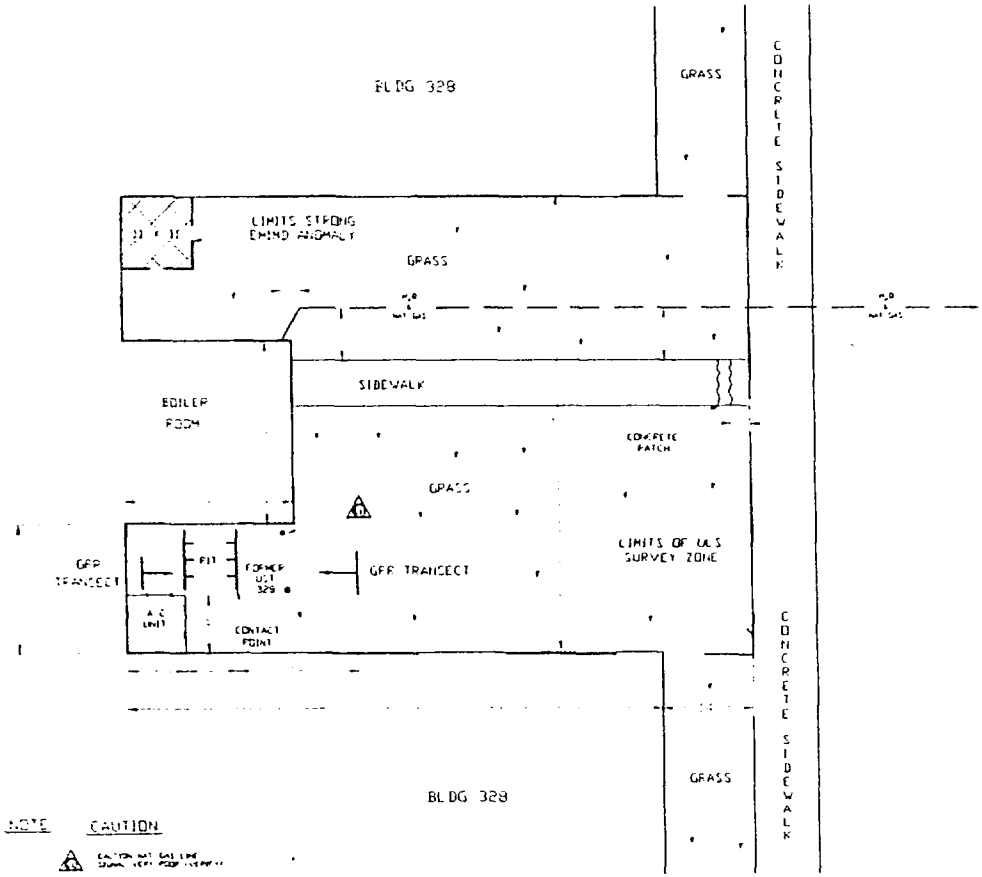
NOTE: OHM FIELD STAFF
HAS DETERMINED THIS AREA TO
BE INCORRECT FORMER UST AREA.

PROPORTIONAL
NOT TO SCALE
DIMENSIONS SHOWN ARE APPROXIMATE

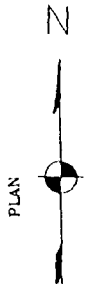
EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
  - STRONG
  - WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MN	UTILITY LOCATION SURVEY SITE GS-5 UST 63A/63B	
CHECKED BY: MB DATE: 12-07-96	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 5



NOTE CAUTION

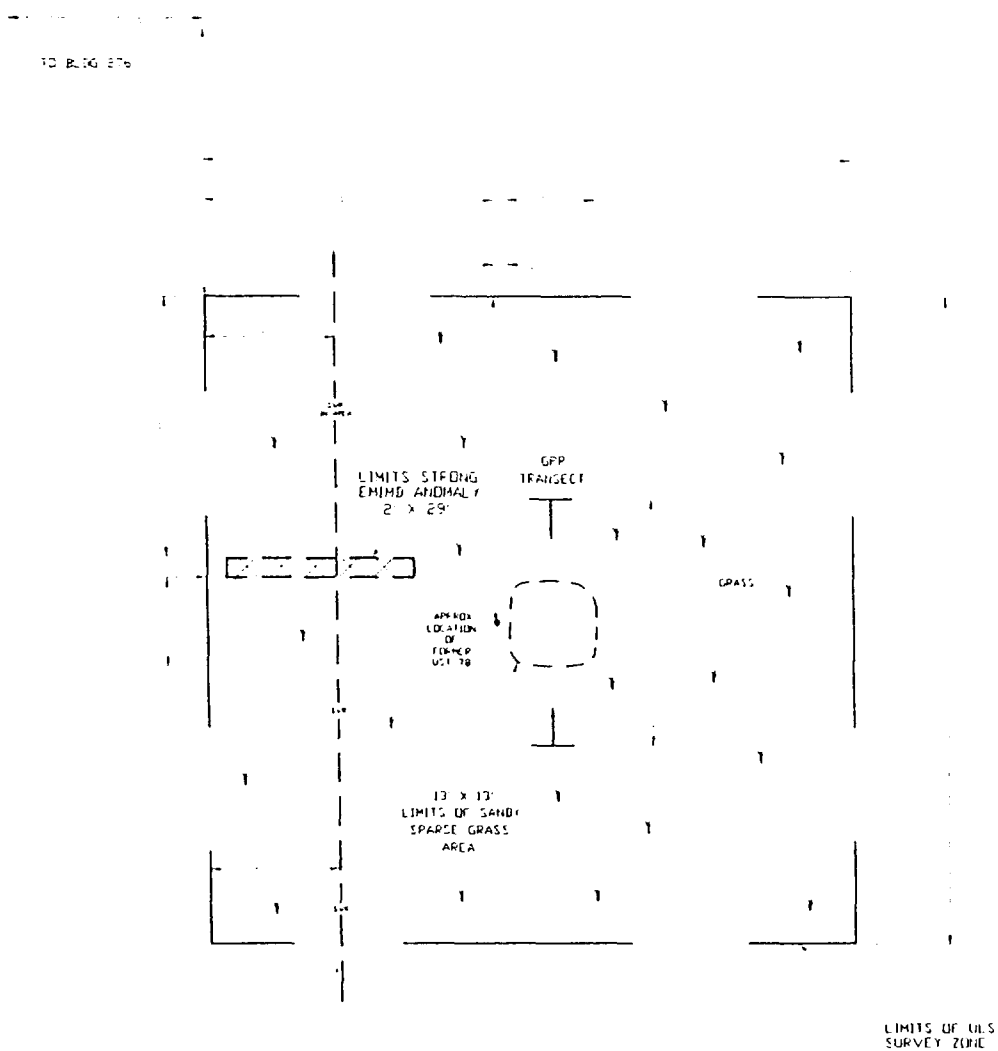


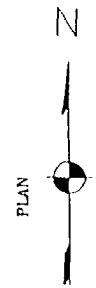
PROPORTIONAL
NOT TO SCALE
DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
- STRONG
- WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW	UTILITY LOCATION SURVEY	
CAD BY: MM	SITE GS-06 UST 328	
CHECKED BY: MB	PROJECT NO. 17486	FIG. NO. 6
DATE: 12-08-96	PO NO. 1016272	





PROPORTIONAL

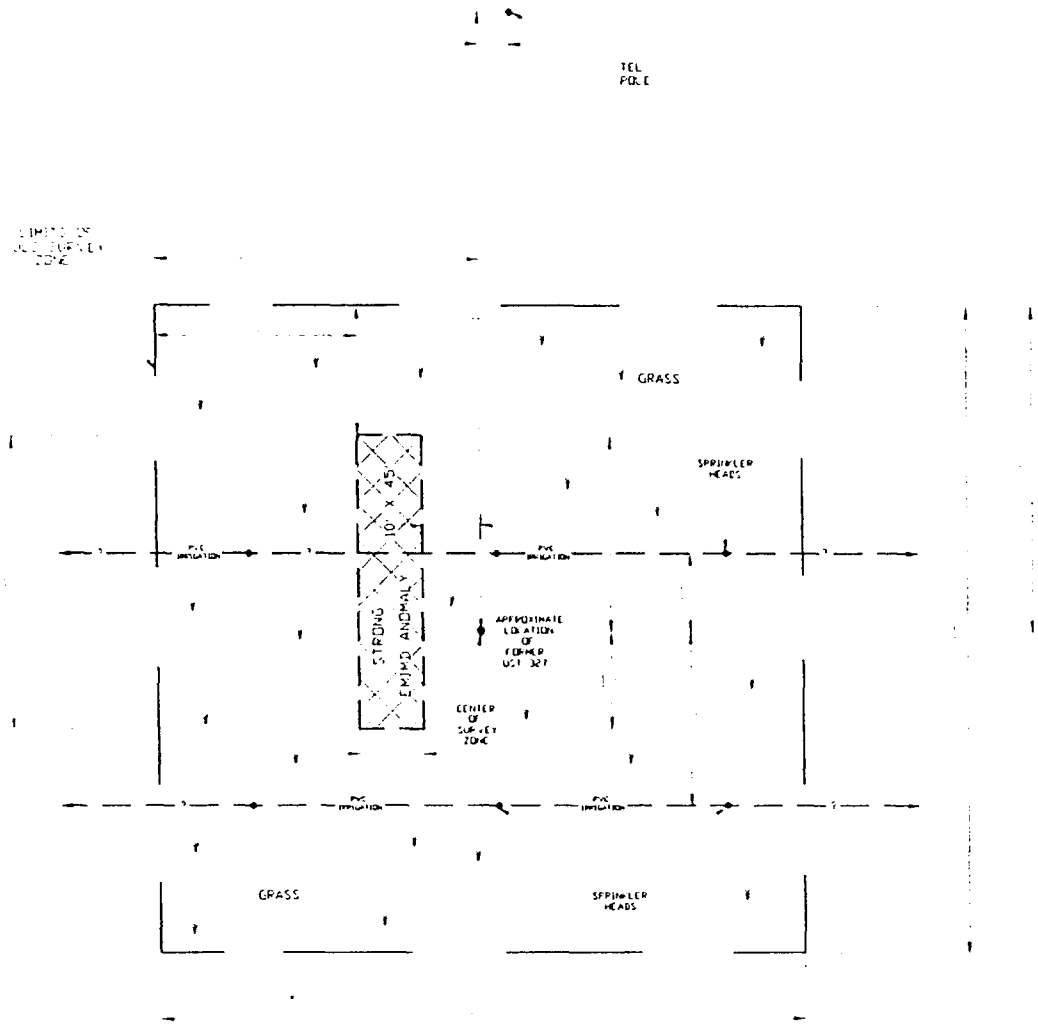
NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
- STRONG
- WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MM	UTILITY LOCATION SURVEY SITE GS-7 UST 78	
CHECKED BY: MB DATE: 12-11-95	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 7



CAUTION: PVC SPRINKLER LINE TREND UNKNOWN

PROPORTIONAL

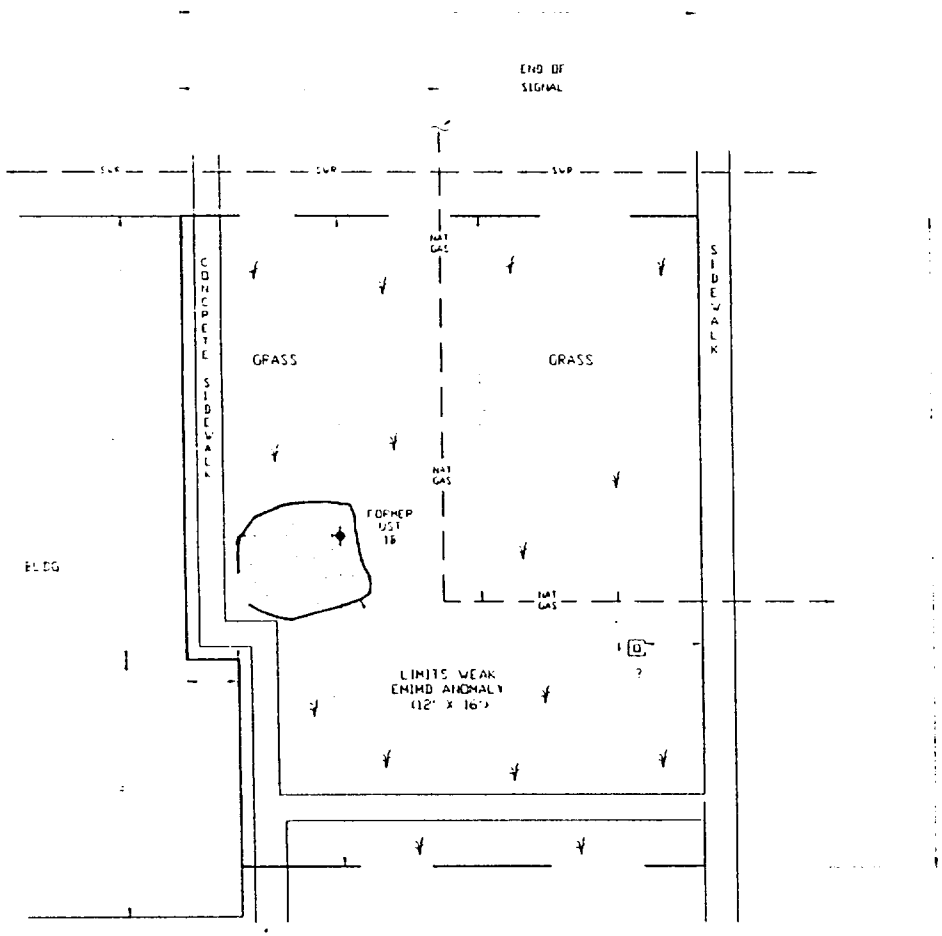
NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
  - STRONG
  - WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MM CHECKED BY: MB DATE: 12-11-95	UTILITY LOCATION SURVEY SITE GS-8 UST 327	
	PROJECT NO. 17466 PO NO. 1016272	FIG. NO. 8



PROPORTIONAL

NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
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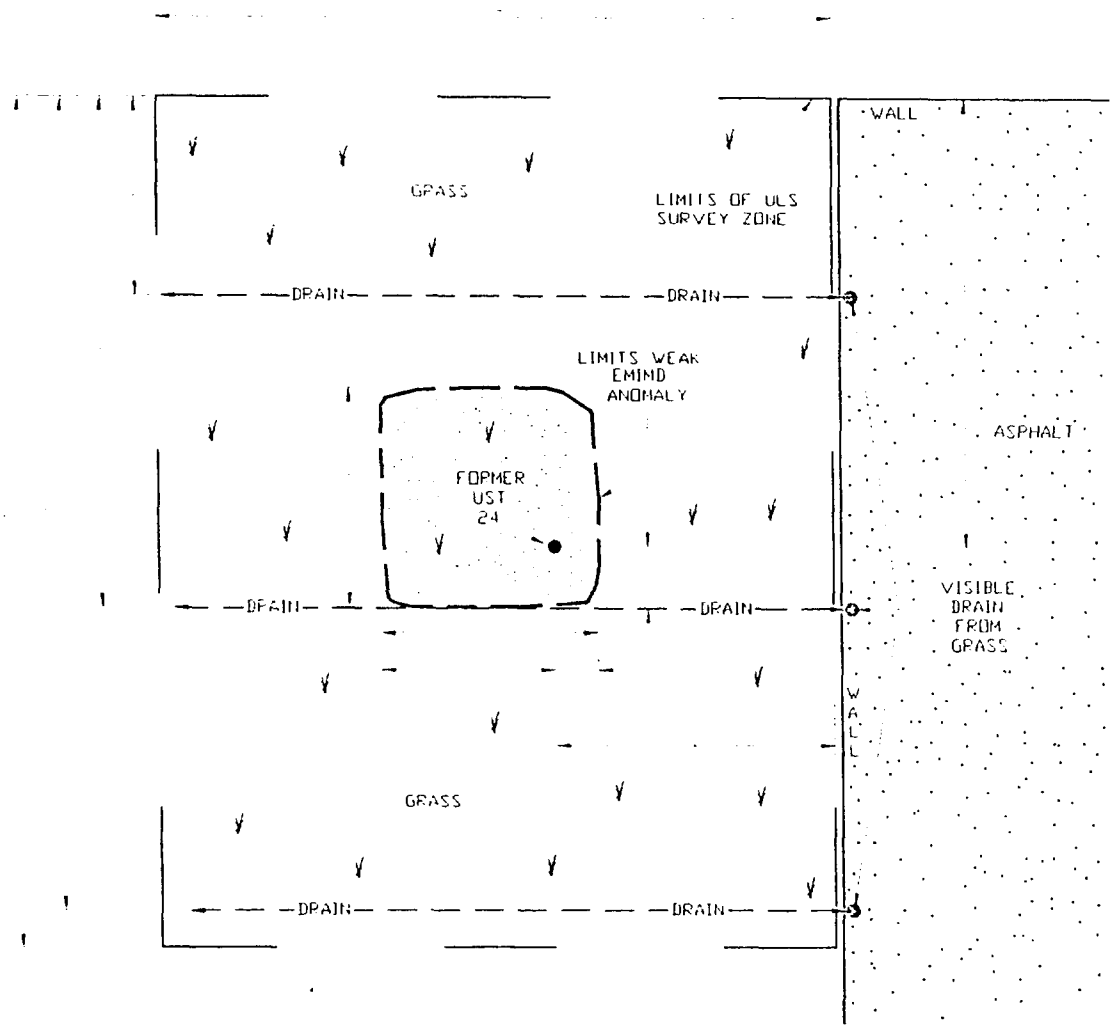
- WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MN	UTILITY LOCATION SURVEY SITE GS-09 UST 1B	
CHECKED BY: MB DATE: 12-11-96	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 9



PROPORTIONAL

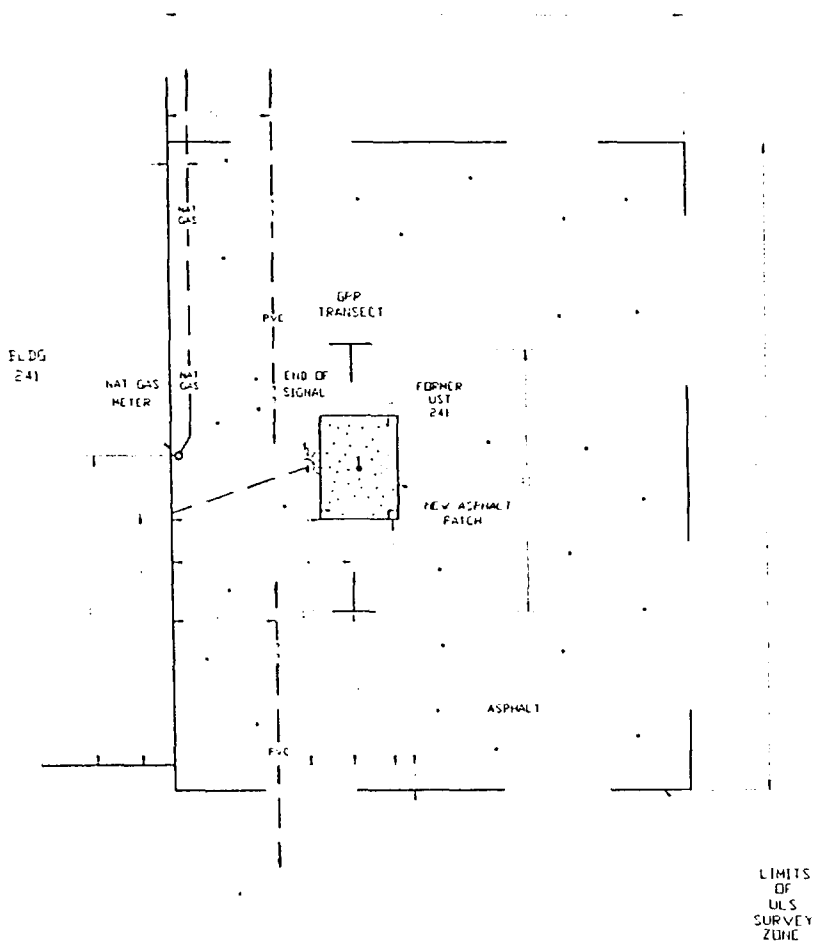
NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
  - STRONG
  - WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MM	UTILITY LOCATION SURVEY SITE GS-10	
CHECKED BY: MB DATE: 10-11-96	PROJECT NO. 17486 PO NO. 1010272	FIG. NO. 10



PROPORTIONAL

NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

AST's & ABOVE GROUND STRUCTURES & BLDGS.

ABOVE GROUND PIPING AND UTILITIES

ULS SURVEY ZONE

FENCE

UNDER GROUND PIPING AND UTILITIES

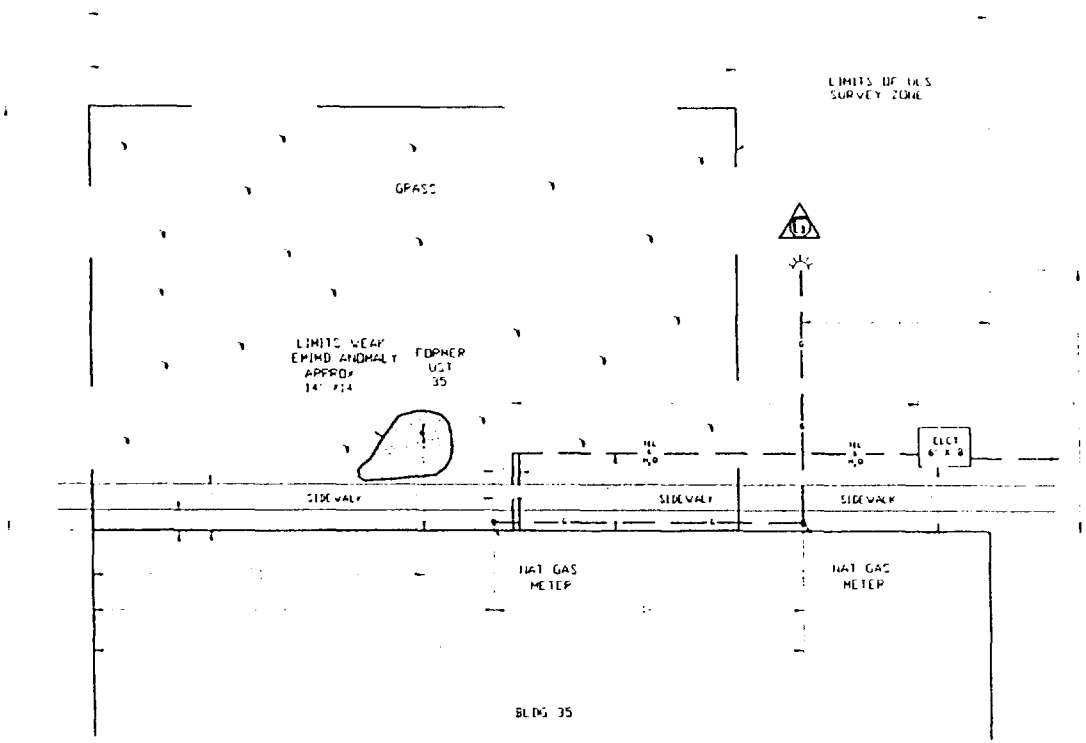
ANOMALIES AND UNDER GROUND STRUCTURES :

STRONG

WEAK

EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: NM	UTILITY LOCATION SURVEY SITE GS-11 UST 241	
CHECKED BY: MB DATE: 12-13-96	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 11



NOTE: CAUTION

CAUTION NAT. GAS LINE SIGNAL VERY POOR (VERIFY)

PROPORTIONAL

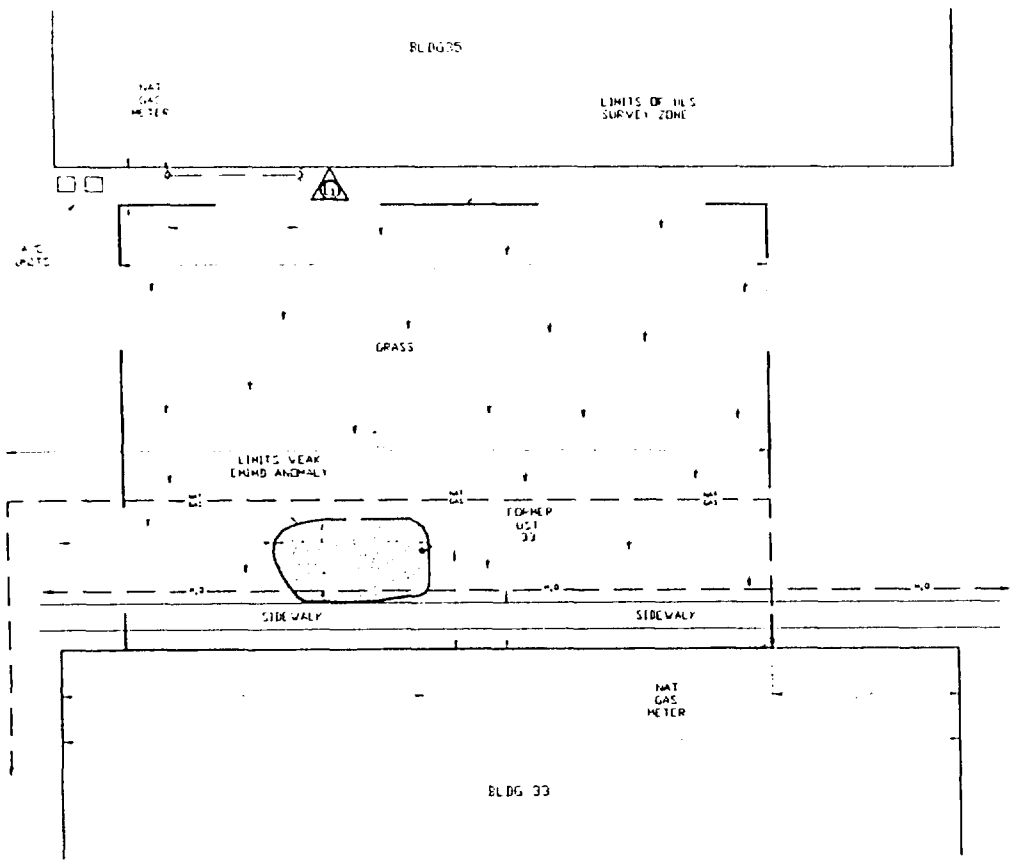
NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
  - STRONG
  - WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.	
ULS SERVICES CO.	MCAS EL TORRO
DRAWN BY: SW CAD BY: NM CHECKED BY: NB DATE: 12-13-95	UTILITY LOCATION SURVEY SITE GS-12 UST 35
	PROJECT NO. 17466 PO NO. 1016272 — FIG. NO. 12



NOTE: CAUTION

CAUTION NAT GAS LINE SIGNAL VERY POOR (VERIFY)

N

PLAN

PROPORTIONAL

NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
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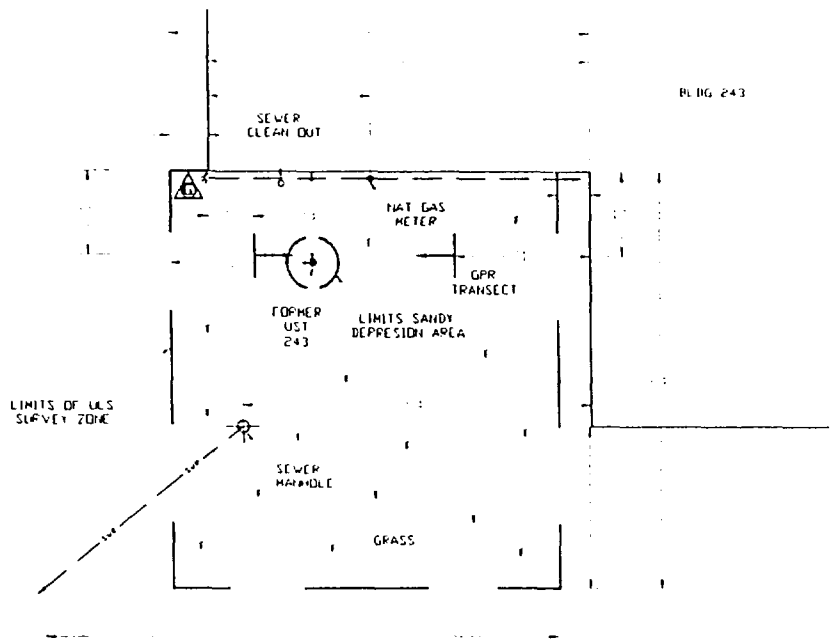
- WEAK
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: NM	UTILITY LOCATION SURVEY SITE GS-13 UST 33	
CHECKED BY: MB DATE: 12-13-96	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 13



PROPORTIONAL

NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

- AST's & ABOVE GROUND STRUCTURES & BLDGS.
- ABOVE GROUND PIPING AND UTILITIES
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- FENCE
- UNDER GROUND PIPING AND UTILITIES
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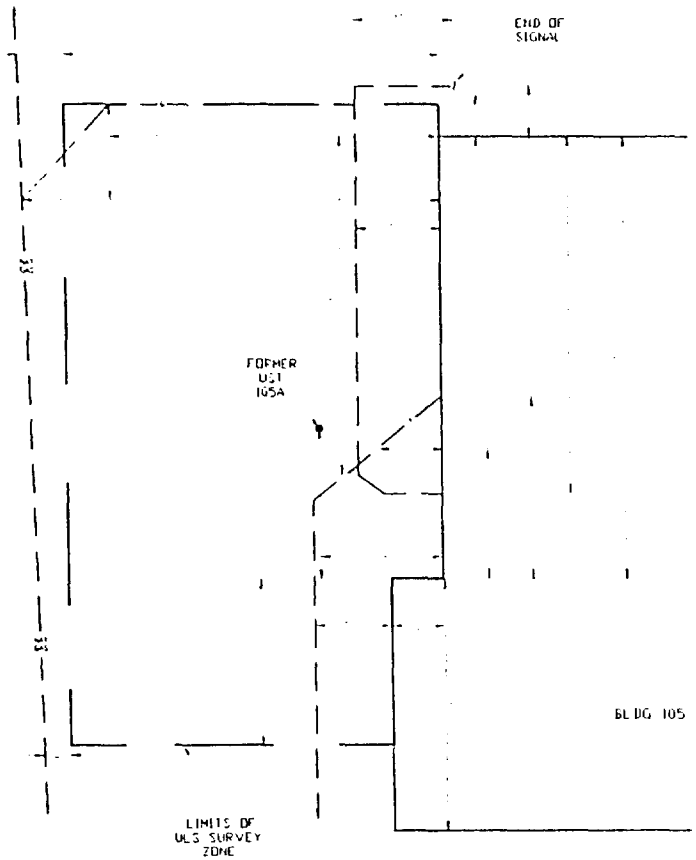
NOTE: CAUTION

CAUTION NAT GAS LINE SIGNAL VERY POOR (VERIFY)

SEWER LATERALS FROM CLEANOUT NOT FOUND

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW	UTILITY LOCATION SURVEY SITE GS-14 UST 243	
CAD BY: MM		
CHECKED BY: MB	PROJECT NO. 17486	FIG. NO. 14
DATE: 10-13-95	PO NO. 1010272	



NOTE OHM FIELD STAFF
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PROPORTIONAL
NOT TO SCALE
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EXPLANATION

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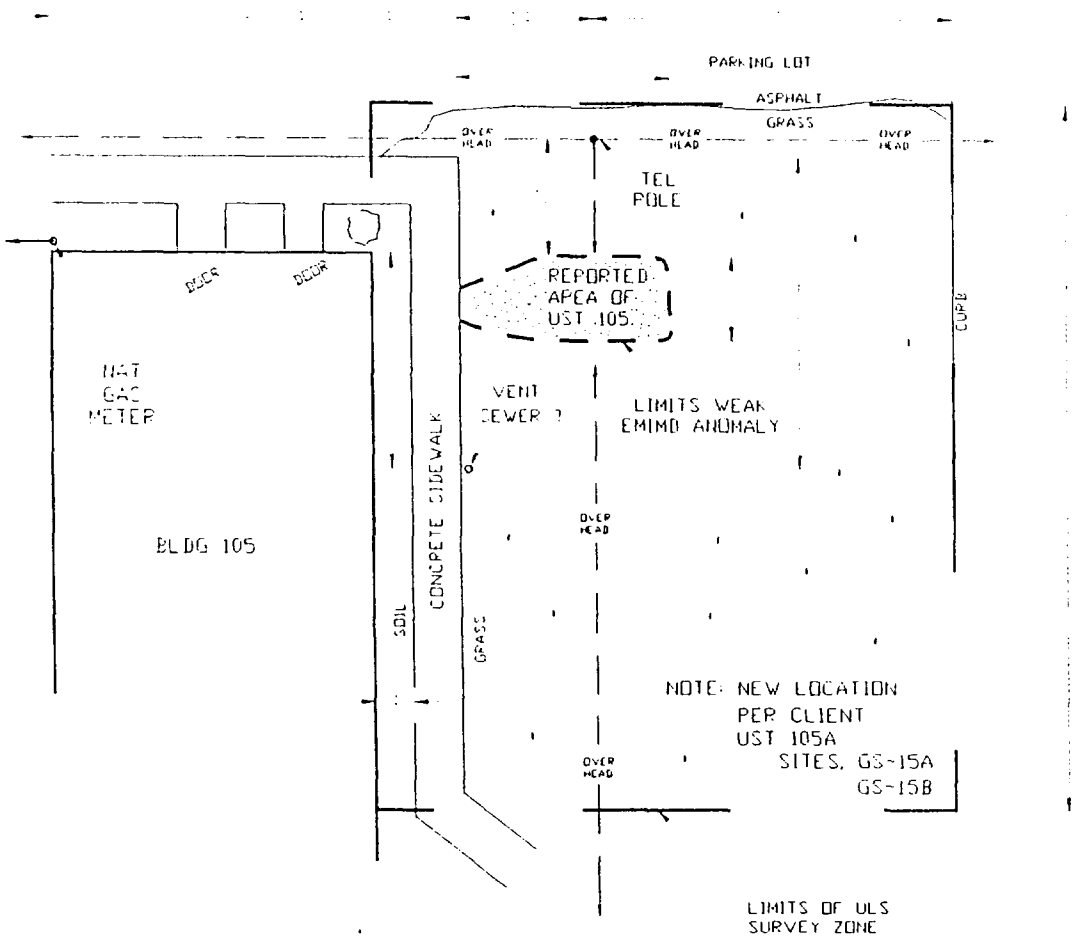
OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SV CAD BY: MM CHECKED BY: MB DATE: 12-13-95	UTILITY LOCATION SURVEY SITE GS-15 UST 105A	
	PROJECT NO. 17488 PO NO. 1016272	FIG. NO. 15



PROPORTIONAL

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EXPLANATION

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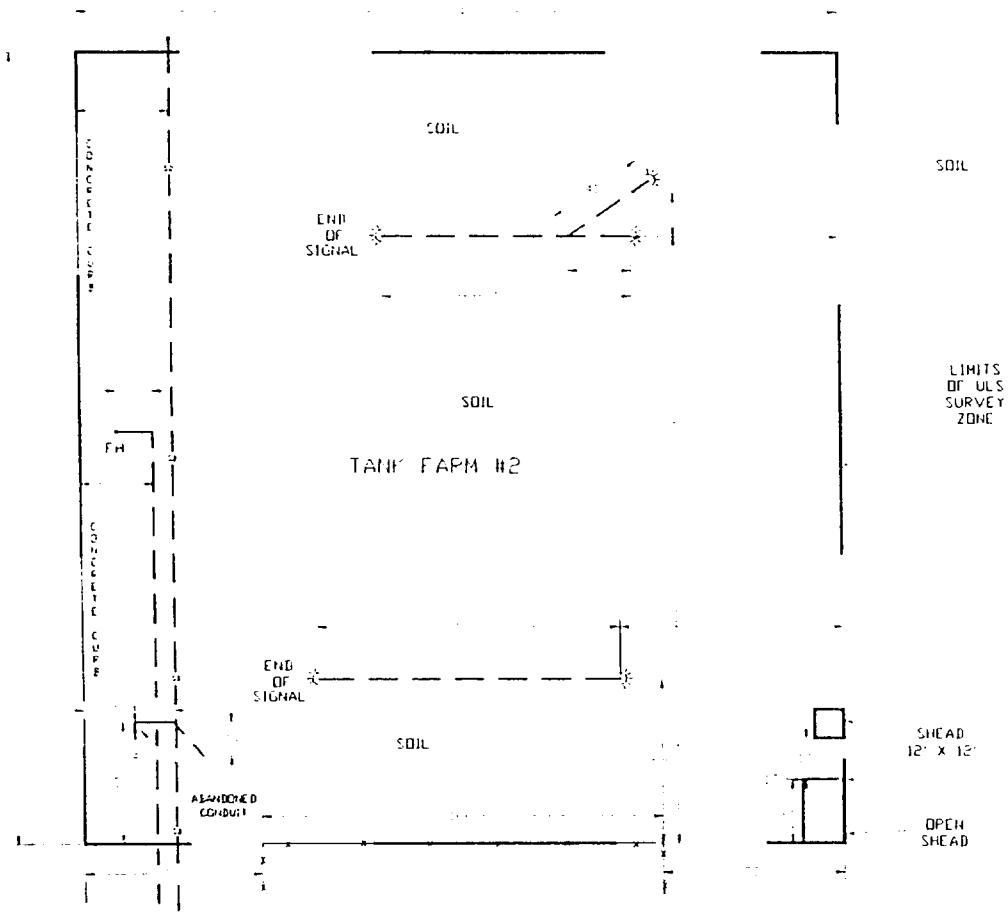
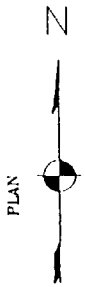
OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MN CHECKED BY: NB DATE: 12-14-95	UTILITY LOCATION SURVEY SITE GS-15.1 UST 105A	
	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 15A





PROPORTIONAL

NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

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- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
- ANOMALIES AND UNDER GROUND STRUCTURES :
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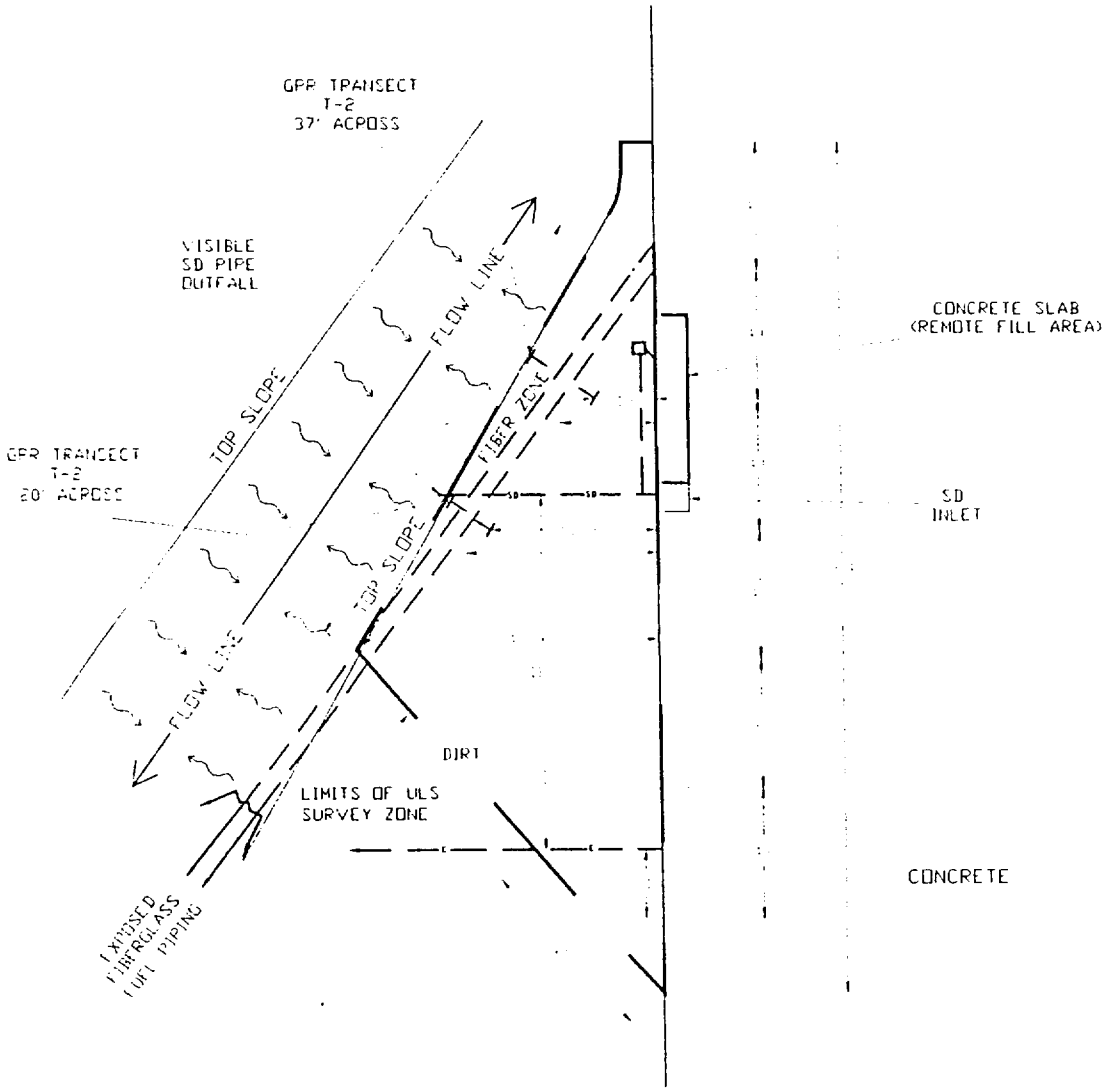
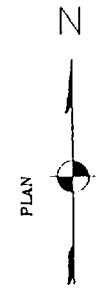
- EDGE OF GROUND, CURB, OR ASPHALT AND CONCRETE PAVEMENT

OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW	UTILITY LOCATION SURVEY	
CAD BY: MM	SITE GS-16 FORMER TANK FARM #2	
CHECKED BY: MB	PROJECT NO. 17486	FIG. NO. 16
DATE: 12-14-95	PO NO. 1016272	





PROPORTIONAL

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DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

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- ABOVE GROUND PIPING AND UTILITIES
- ULS SURVEY ZONE
- FENCE
- UNDER GROUND PIPING AND UTILITIES
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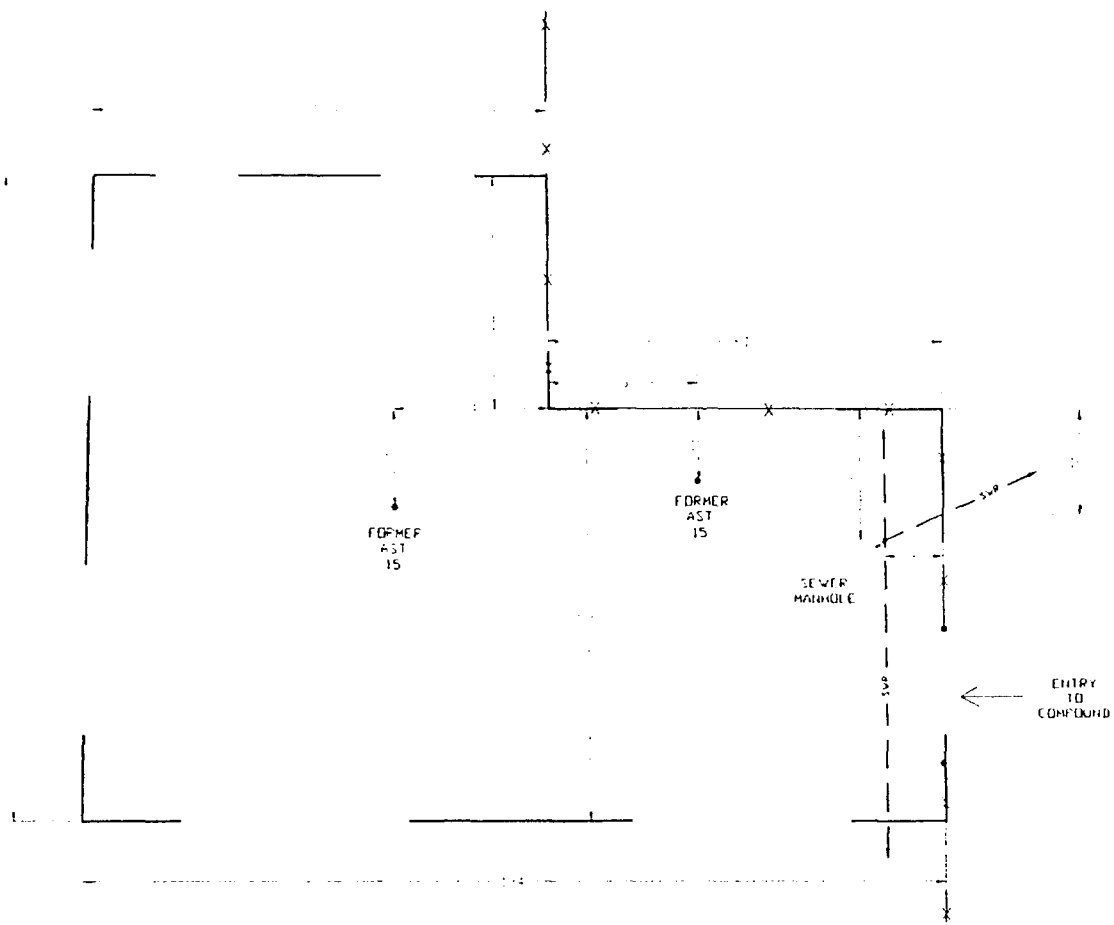
OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MN CHECKED BY: MB DATE: 12-18-96	UTILITY LOCATION SURVEY SITE GS-18	
	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 18



PROPORTIONAL

NOT TO SCALE

DIMENSIONS SHOWN ARE APPROXIMATE

EXPLANATION

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OHM REMEDIATION SERVICES CORP.		
ULS SERVICES CO.	MCAS EL TORRO	
DRAWN BY: SW CAD BY: MM CHECKED BY: MB DATE: 12-15-95	UTILITY LOCATION SURVEY SITE GS-17 AST 15	
	PROJECT NO. 17486 PO NO. 1016272	FIG. NO. 17