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Chapter II and III

RESOURCE CONSERVATION AND RECOVERY ACT PART B PERMIT APPLICATION

Navajo Refining Company
Artesia, New Mexico

Submitted To
U. S. Environmental Protection Agency
Dallas, Texas

Submitted By
Navajo Refining Company
Artesia, New Mexico

Prepared By
URS Engineers
Metairie, Lousiana

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Chapter II-1

North Colony Landfarm

270.20 Specific Part B information requirements for land treatment facilities

Except as otherwide provided in 264.1, owners and operators of facilities that use land treatment to dispose of hazardous waste must provide the following additional information:

a. A description of plans to conduct a treatment demonstration as required under 264.272. The description must include the following information;
  1. The waste for which the demonstration will be made and the potential hazardous constituents in the waste;
  2. The data sources to be used to make the demonstration (e.g., literature, laboratory data, field data, or operating data);
  3. Any specific laboratory or field test that will be conducted, including:
    i. The type of test (e.g., column leaching, degradation);
    ii. Materials and methods, including analytical procedures;
    iii. Expected time for completion;
    iv. Characteristics of the unit that will be simulated in the demonstration, including treatment zone characteristics, climatic conditions, and operating practices.

b. A description of a land treatment program, as required under 264.271. This information must be submitted with the plans for the treatment demonstration, and updated following the treatment demonstration. The land treatment program must address the following items:
  1. The wastes to be land treated;
  2. Design measures and operating practices necessary to maximize treatment in accordance with 264.273(a) including:
    i. Waste application method and rate;
    ii. Measures to control soil pH;
    iii. Enhancement of microbial or chemical reactions;
    iv. Control of moisture content;
  3. Provisions for unsaturated zone monitoring including:
    i. Sampling equipment, procedures, and frequency;
    ii. Procedures for selecting sampling locations;
    iii. Analytical procedures;
    iv. Chain of custody control;
    v. Procedures for establishing background values;
    vi. Statistical methods for interpreting results;
    vii. The justification for any hazardous constituents recommended for selection as principal hazardous constituents, in accordance with the criteria for such selection in 264.278(a);
  4. A list of hazardous constituents reasonably expected to be in, or derived from, the wastes to be land treated based on waste analysis performed pursuant to 264.13;
  5. The proposed dimensions of the treatment zone;

c. A description of how the unit is or will be designed, constructed, operated, and maintained in order to meet the requirements of 264.273. This submission must address the following items:
  1. Control of run-on;
  2. Collection and control of run-off;

3. Minimization of run-off of hazardous constituents from the treatment zone;
4. Management of collection and holding facilities associated with run-on and run-off control systems;
5. Periodic inspection of the unit. This information should be included in the inspection plan submitted under 270.14(b)(5);
6. Control of wind dispersal of particulate matter, if applicable;

d. If food-chain crops are to be grown in or on the treatment zone of the land treatment unit, a description of how the demonstration required under 264.276(a) will be conducted including:

1. Characteristics of the food-chain crop for which the demonstration will be made.
2. Characteristics of the waste, treatment zone, and waste application method and rate to be used in the demonstration;
3. Procedures for crop growth, sample collection, sample analysis, and data evaluation;
4. Characteristics of the comparison crop including the location and conditions under which it was or will be grown;
5. If food-chain crops are to be grown, and cadmium is present in the land-treated waste, a description of how the requirements of 264.276(b) will be complied with;
6. A description of the vegetative cover to be applied to closed portions of the facility, and a plan for maintaining such cover during the post-closure care period, as required under 264.280(a)(8) and 264.280(c)(2). This information should be included in the closure plan and, where applicable, the post-closure care plan submitted under 270.14(b)(13);
7. If ignitable or reactive wastes will be placed in or on the treatment zone, an explanation of how the requirements of 264.281 will be complied with;
8. If incompatible wastes, or incompatible wastes and materials, will be placed in or on the same treatment zone, an explanation of how 264.282 will be complied with.

Chapter II-I

North Colony Landfarm

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I. Treatment Demonstration

The 264.272 technical standards require Navajo to demonstrate that hazardous constituents contained in wastes applied to the landfarm area can be completely degraded, transformed or immobilized in the treatment zone. The treatment demonstration for the petroleum wastes applied to the landfarm is based on the existing literature detailing the degradation and immobilization of oily refinery wastes during the land treatment process as supported by operating data collected by Navajo during the interim status period.

A. Wastes Generated at the Refinery

The North Colony landfarm is an existing land treatment facility operating under interim status. Hazardous wastes from various refinery processes are landfarmed. A list of landfarmed wastes is contained in Table II-1-1.

1. Slop Oil Emulsion Solids (EPA number K049)

Navajo generates slop oil emulsion solids as a result of oil recovery occurring in slop tanks. Slop oil emulsion solids include the slurry and oil removed from slop tanks. Slop oil tanks are cleaned on an as needed basis, estimated to occur a maximum of twice per year. A representative sample of this waste has been obtained for detailed analyses. Additional samples will be obtained when the waste is generated and analyzed for selected parameters. Following removal of these materials from tankage, they are landfarmed in accordance with 40 CFR Part 264, Subpart M.

2. Heat Exchanger Bundle Cleaning Sludge (EPA number K050)

Navajo generates heat exchanger bundle cleaning sludge during routine maintenance operations. Heat exchanger bundle cleaning sludge includes the residue from the cooling water system generated when the heat exchangers are serviced or the tower basins cleaned. Heat exchangers are serviced whenever the buildup of solids and sludge limits heat transfer, estimated to occur a maximum of twice per year.

Table II-1-1

Landfarmed Refinery Wastes

Name of Waste	Waste Source	Waste Generation (tons/year)	Frequency of Generation	EPA Hazardous Waste Number
Slop Oil Emulsion Solids	Slop Tanks	160	0-2/yr	K049
Heat Exchanger Bundle Cleaning Sludge	Solids from Exchangers, Cooling Tower Basins	40	0-2/yr	K050
Primary Oil/Solids/Water Separation Sludge	Oil/Water Separators	400	1-2/yr	K051
Leaded Tank Bottoms	Storage Tanks	5	1/10 yr	K052
Kerosene Filter Clay	Kerosene Treater	5	1/5 yr	Nonhazardous, D001
Tank Bottoms	Storage Tanks	40	1/10 yr	Nonhazardous, D001
Spill Contaminated Materials	Spills	40	0-2/yr	Nonhazardous, D001

Note: The annual waste generation figures are based on refinery estimates. The quantity of wastes generated could include substantial quantities of water along with sludges, solids and oil. Physical waste characteristics and the sporadic nature of waste generation events make an estimate of the annual tonnage of waste virtually meaningless. The kerosene filter clay, tank bottoms and spill contaminated materials would generally be considered nonhazardous, although there may be isolated instances where the wastes or waste mixtures may be considered hazardous due to the characteristic of ignitability (i.e., the liquid or semisolid waste sample may have a flashpoint below 140°F).

Residual solids are manifested to the North Colony landfarm and cleaning wash waters are discharged to the Navajo sewer system, although mixtures of wastewater and heat exchanger solids are exempt from the presumption of hazard by federal definition (261.3(a)(2)(iv)(C)). Representative samples of heat exchanger solids and cooling tower basin sludge have been obtained for detailed analyses, and additional samples will be obtained when the waste is generated and analyzed for selected parameters. These wastes are landfarmed in accordance with 40 CFR Part 264, Subpart M on an as generated basis.

3. Primary Oil/Solids/Water Separation Sludge (EPA number K051)

Navajo generates primary oil/solids/water separation sludge from the primary wastewater treatment processes at the refinery. Generation sources are refinery oil/water separators in the North and South Divisions. Primary oil/solids/water separation sludge include the BS&W, waste oil and sludge from the oil/water separators. Separation sludge is generated when oil/water separators are cleaned, estimated to occur once or twice a year. Representative samples of sludges removed from these separation devices have been obtained for detailed analyses, and additional samples will be obtained when the waste is generated and analyzed for selected parameters. Once removed from the wastewater treatment unit, the sludges are landfarmed in accordance with 40 CFR Part 264, Subpart M.

4. Leaded Tank Bottoms (EPA number K052)

Leaded tank bottoms include sludges and solids from gasoline storage tanks. The lead contaminated solids are considered to be generated when they are removed from product storage facilities. Leaded tank bottoms are generated when leaded gasoline tanks are cleaned, estimated to occur once every ten years. No leaded gasoline tank has been cleaned since 1975. A representative sample of the waste will be obtained when generated and detailed analyses conducted. Thereafter, a representative sample of waste will be analyzed for selected parameters. Once generated, the leaded tank bottoms are managed as hazardous wastes in accordance with 40 CFR Part 264, Subpart M.

5. Unlisted Wastes (EPA number D001)

A variety of other wastes are generated at the refinery which may exhibit hazardous characteristics, including kerosene filter clay, tank bottoms, spilled hydrocarbons and spill contaminated materials. In general, these wastes are not considered hazardous because the flash point of liquid and semisolid samples is above 140°F, although there may be isolated instances where the contaminating hydrocarbon (such as in the case of unleaded gasoline bottoms) might have a flash point below 140°F. However, there is no prescribed test method for establishing the characteristic of ignitability for a solid material such as contaminated soil from a gasoline spill, so these type wastes are considered nonhazardous. Liquid and semisolid samples of wastes, such as unleaded tank bottoms, will be analyzed with Pensky-Martens or Setaflash closed cup methods to establish whether the material has a flashpoint below 140°F and therefore exhibits the characteristic of ignitability. If hazardous, the waste will be sent to the North Colony landfarm, otherwise it will be applied to the Truck Bypass landfarm.

Kerosene filter clay is the diatomaceous earth medium through which kerosene is filtered to remove color particles. While the kerosene itself has a flash point below 140°F, there is no prescribed test method to establish the ignitability characteristic of a solid material, so the filter clay may be considered nonhazardous by present definition. Kerosene filter clay is generated when the clay filtration medium no longer effectively removes color particles, estimated to occur every 5 years. No kerosene clay has been generated in the last 2 years.

Tank bottoms is the generic term for all BS&W, oil, slurry and sludges removed from crude oil, intermediate and unleaded product storage tanks. These wastes have widely varying characteristics and may, in some instances, be considered hazardous due to the characteristic of ignitability. Tank bottoms are generated whenever tankage is cleaned, assumed to occur once every ten years. Tanks storing kerosene and lighter materials may accumulate sludges exhibiting the characteristic of ignitability. The majority of the tank bottoms will be nonhazardous as the tanks storing heavier petroleum fractions with flash points above 140°F tend to accumulate solids, while lighter petroleum products tend to be free of residual solids.

Spill contaminated materials include water and debris contaminated with petroleum. These residues are generated in response to refinery spill events and vary widely in characteristics although there may be some instances where the materials are ignitable. Spills are estimated to occur a maximum of twice per year, although the frequency of generation cannot truly be estimated.

Navajo has determined that the unlisted wastes should not be classified as hazardous by EPA definition, except possibly in isolated instances. Oily refinery wastes which potentially exhibit the characteristic of ignitability will be analyzed with Pensky-Martens or Setaflash closed cup methods for flashpoint. If the flashpoint is below 140°F, a detailed analysis will be conducted on a representative sample of the initial waste. Additional wastes will be analyzed for selected parameters. Once removed from product storage, the sludges will be landfarmed in accordance with 40 CFR Part 264, Subpart M.

The listed hazardous wastes, slop oil emulsion solids, heat exchanger sludge, primary oil/solids/water separation sludge and leaded tank bottoms have been classified as hazardous due to the presence of chromium and lead in other refinery waste samples analyzed by the Environmental Protection Agency. However, analytical results from Navajo waste sources suggest these metals are not present in sufficient quantities for the wastes to be considered hazardous. In general, it is the oil content, rather than concentration of metals, which dictates the waste application rate and operational considerations for land treatment. Navajo generates large quantities of predominantly oily rather than metal bearing wastes. It is the organic rather than the inorganic constituents which are of relatively greater importance in evaluating the treatment program, given the characteristics of refinery wastes, the operational parameters involved in landfarming and the relative proportion of wastes generated by Navajo.

The hazardous constituents listed in 40 CFR 261, Appendix VIII which might potentially be present in each of the oily waste streams include low concentrations of the metals arsenic, chromium, copper, lead, nickel, and vanadium; selected volatile organic compounds such as benzene, ethylbenzene and toluene; polynuclear aromatic compounds such as anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(ghi) perylene, chrysene, fluoranthene, naphthalene, phenanthrene, and pyrene; low concentrations of chlorinated hydrocarbons such as 1,2-dichloroethylene, hexachloroethane, hexachlorocyclopentadiene, 1,1,2,2-tetrachloroethane, tetrachloroethylene, trichloroethylene; phthalate esters such as bis (2-ethylhexyl) phthalate and diethylphthalate and miscellaneous compounds such as phenolic compounds, cyanide soluble salts and complexes, and sulfides. These and other Appendix VIII compounds may be present in trace or insignificant concentrations.

B. Wastes for the Treatment Demonstration

The separator sludge is the largest volume waste stream generated on a regular basis at the refinery. In that this waste is generated from the separation of oil from the wastewater stream, the impact of all the refinery processes should be reflected in the waste analysis. The separator sludge should contain the same constituents as the slop oil emulsion solids in that the slop oil is recovered from the oil/water separator. The separator sludge should contain the same hazardous constituents as the tank bottoms or spill contaminated materials in that the petroleum present in tank bottoms or spill contaminated materials are also present in the separator sludge. Heat exchanger sludge and leaded tank bottoms are expected to contain chromium and lead in relatively greater concentrations than the separator sludge. However, these wastes are generated on a very sporadic basis and in relatively small quantities. The expected quantity of metal bearing wastes is much less than the oily wastes, and the immobilization of metals is relatively well documented in properly operated land treatment facilities.

Samples of slop oil solids, separator sludge and heat exchanger solids have been collected and are being analyzed for the potential hazardous constituents which may reasonably be expected to be present. Analytical results will be presented in Table II-1-2. The other potentially hazardous wastes applied to the landfarm will be analyzed when generated, as discussed in the Waste Analysis Plan contained in Chapter I-3. It should be emphasized that the other oily wastes might reasonably be expected to contain the same hazardous constituents, and the metal bearing wastes would reasonably be expected to contain the same hazardous constituents although elevated concentrations of lead and chromium are expected.

C. Data Sources

The treatment demonstration consists of a review of the literature supplemented by operational information. The transformation, mobility, volatility and toxicity of waste constituents applied to the treatment zone are discussed. The literature cited in the bibliography provided the necessary data base to establish fate mechanisms, operational procedures and application rates for oily refinery wastes. Based on the literature and characteristics of oily refinery wastes, a monitoring program has been established to ensure the expected degradation and immobilization of hazardous constituents is occurring. Soil and soil pore liquid samples are collected and analyzed for select metals and organics. Further, operational procedures identify additional

Table II-1-2
Waste Characterization
Common Refinery Wastes

	Slop Oil Emulsion Solids	Primary Oil Separation Sludge		Heat Exchanger Sludge	
		North Division	South Division	Exchanger Solids	Tower Basin Solids
Trace Elements					
Arsenic					
Chromium					
Copper					
Lead					
Nickel					
Vanadium					
Volatile Organic Compounds					
Benzene					
Ethylbenzene					
Toluene					
Polynuclear Aromatic Compounds					
Anthracene					
Benzo(a)anthracene					
Benzo(a)pyrene					
Benzo(ghi)perylene					
Chrysene					
Fluoranthene					
Naphthalene					
Phenanthrene					
Pyrene					
Chlorinated Hydrocarbons					
1,2 Dichloroethylene					
Hexachloroethane					
Hexachlorocyclopentadiene					
1,1,2,2 Tetrachloroethane					
Tetrachloroethylene					
Trichloroethylene					
Phthalate Esters					
Bis(2-ethylhexyl)phthalate					
Diethylphthalate					
Miscellaneous Compounds					
Phenols					
Cyanides					
Sulfides					

monitoring conducted to maximize immobilization, through pH control, and degradation, through fertilizer application, irrigation and soil aeration. Results of the monitoring program established by Navajo are presented to supplement the available literature for the treatment demonstration.

The monitoring program developed under interim status standards tracked the chromium and lead content in soil and soil pore liquid samples. A much more comprehensive monitoring program has been developed to maximize the degradation and immobilization of hazardous constituents within the treatment zone. On a quarterly basis, soil cores are obtained and analyzed for concentration of metals and organics at 6 inch intervals from the land surface to a depth of 36 inches. The results of the initial sampling program are included as the operational data substantiating the literature review. Soil sampling locations for the October (first quarter) data collection effort are shown in Figure II-1-1.

II. Treatment Demonstration Results

A. Organic Constituents

1. Literature Review

The oily wastes must be demonstrated to degrade in the treatment zone at a sufficiently rapid rate that degradation rather than volatilization, leaching or runoff is the controlling loss mechanism within the landfarm. A review of the literature indicates landfarming of oily wastes is a viable treatment option because the soil provides a natural environment for degradation of waste materials through physical, chemical and biological processes. Soil microorganisms are primarily responsible for inducing the chemical changes in the decomposition process. Bacteria, filamentous fungi, yeasts and actinomycetes can digest and use natural hydrocarbons. Although hydrocarbons provide carbon and energy for microorganisms, rapid degradation of organic compounds also requires an adequate supply of oxygen, moisture and nutrients within the treatment zone. The oil is assimilated in the production of a biomass and aerobic end products, carbon dioxide and water, are produced.

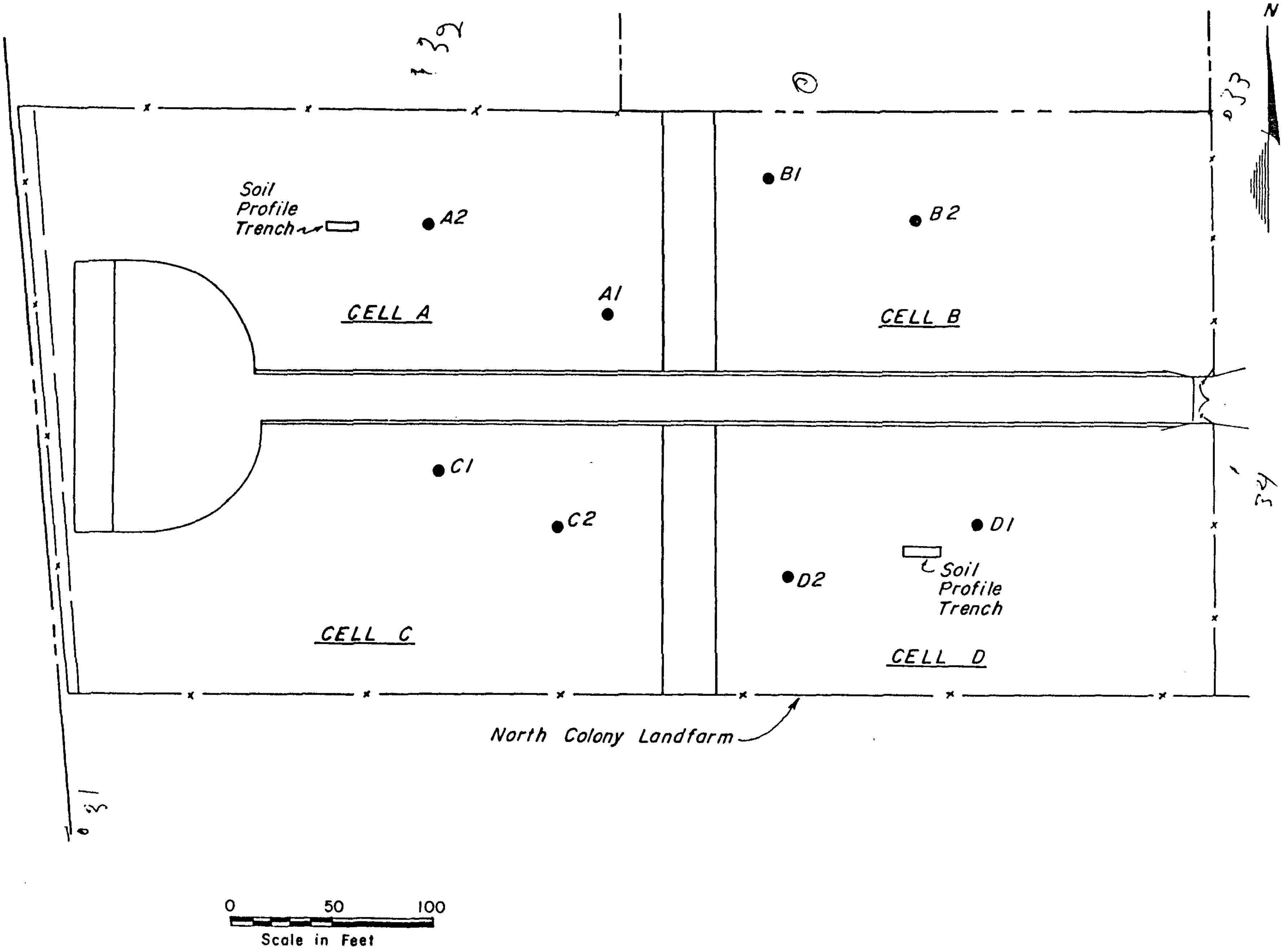


FIGURE II-1-1
TREATMENT DEMONSTRATION
SOIL SAMPLING LOCATIONS

For oily refinery wastes, the aliphatic and aromatic hydrocarbons are the two most prevalent organic compounds. Perry and Cerniglia (1973) ranked aliphatic and aromatic hydrocarbons from most to least biodegradable as straight chain alkanes (C_{12} - C_{18}), gases (C_2 - C_4), straight chain alkanes (C_5 - C_9), branched alkanes (up to C_{12}), straight chain alkenes (C_3 - C_{11}), branched alkenes, aromatics and cycloalkanes. Straight chain aliphatic hydrocarbons are relatively easily assimilated while branched chain paraffins and cycloparaffins decompose slowly. Aromatic hydrocarbons, particularly those of high molecular weight, are decomposed slowly. The bacterial cells and undestroyed cyclic portion of aromatic hydrocarbons are ultimately destroyed, albeit slowly by the combined effect of a mixed population of soil microbes. Anaerobic digestion of organic matter is more complex than aerobic destruction, and certain hydrocarbons undergo little degradation in an anaerobic environment. Essential mineral nutrients are necessary for rapid biodegradation, particularly nitrogen (as ammonia or nitrate) and phosphorus (as soluble phosphates). Soil pH exerts a marked impact on microbial activity and should be maintained near 7 (neutral). Moisture, temperature and soil waste contact also affect degradation rates.

Land treatability of organic constituents is discussed in general terms by class of organic constituents. Aliphatic hydrocarbons are commonly found in oily refinery wastes. The degradability of these open chain alkanes, alkenes, alkynes and their cyclic analogs is dependent on the molecular weight, vapor pressure, water solubility, number of double bonds, degree of branching and whether the compound has an open chain or cyclic configuration. Straight chain alkanes are more easily degraded than branched chain alkanes of the same molecular weight. The degradation rate decreases with the number and size of alkyl groups as well as the number of double bonds or presence of a benzene group. Straight or branched open chain aliphatics degrade much more rapidly than their cyclic analogs. Cycloalkane and its derivatives are very difficult to degrade.

While aliphatic hydrocarbons are amenable to degradation in a landfarm environment, a long term accumulation of recalcitrant decomposition byproducts may occur. Kincannon (1972) determined one major byproduct of oil decomposition is naphthenic acid, which may degrade slowly in soil (Overcash and Pal, 1979).

Other loss mechanisms for aliphatic hydrocarbons include runoff, leaching and volatilization. Runoff and leaching are generally thought to be minimal due to low water solubility (Raymond et al., 1976). Volatilization can be a significant loss mechanism for low molecular weight aliphatics (Wetherold et al., 1981). The waste volatility is the most important factor affecting emission levels. Emission rates were found to increase with increasing ambient humidity, soil temperature and soil moisture and decrease with increased depth of subsurface injection. Emission rates were found to be greatest within 30 minutes of land application.

Aromatic hydrocarbons are cyclic compounds with multiple double bonds and include monoaromatic compounds such as benzene, nitrobenzene and ethylbenzene and polyaromatic compounds such as naphthalene and anthracene. The decomposition rate of aromatic compounds is very compound specific, although general trends suggest the decomposition rate decreases as the number of fused rings in the compound increases and the decomposition rate increases as the water solubility of the compound increases. In order of increasing degradability, Fedorak and Westlake (1981) ranked the aromatic constituents of crude oil as naphthalene and 2-methylnaphthalene; methylnaphthalene; dimethylnaphthalene, dibenzothiophene and phenanthrene; C_3-naphthalenes; methylphenanthrenes; and C_2-phenanthrenes. A short term accumulation of aromatic hydrocarbons is expected due to the formation of aromatic hydrocarbons from the decomposition of aliphatic hydrocarbons.

Organic acids and halogenated organics may also occur in refinery oily wastes, although they are relatively less prevalent than aliphatic or aromatic hydrocarbons. Organic acids are organic constituents with phenolic or carboxylic acid functional groups. Organic acids are relatively volatile and leachable, although degradation can be relatively rapid under favorable environmental conditions, particularly at lower application rates. Halogenated organics span the range of degradability, leachability and volatility. Chlorinated benzene derivatives are, as a group, less degradable, volatile and leachable than their chlorinated aliphatic counterparts. Halogenated organics are fairly resistant to biodegradation.

2. Operational Data

Soil samples taken at 6 inch intervals for the land surface to a depth of 36 inches were obtained from 8 locations within the 4 acre landfarm. Samples were prepared by Soxhlet extraction procedures, and analyzed by gas chromatographic techniques. Idealized GC curves for samples taken at increasing depths are shown in Figure II-1-2. The area under the curve is directly correlative with the concentration of organic constituents. The location of the peak (on the time scale) provides an indication of the type of organic constituent. The area under the curve is equivalent to the concentration of the cumulative organic constituents, both hazardous and nonhazardous. The idealized curves in Figure II-1-2 are intended to demonstrate that in a properly operated landfarm, the concentration of organic matter should decrease with increasing depth due to biodegradation, and the GC curves should shift to the left with increasing depth due to the transformation of higher molecular weight compounds to lighter decomposition byproducts.

The peak area has been plotted as a function of depth for each soil sample analyzed, as shown in Figure II-1-3. Samples from landfarm plots B, C and D are in the process of being analyzed, and data are expected by December 2. The existing data indicates the peak area drops substantially from a high in surficial soils to a low at a depth of 36 inches. In one of the soil cores in landfarm plot A, the peak area drops at a soil depth of 12 to 18 inches, and the rises at a soil depth of 18 to 30 inches. This data indicates there is an accumulation zone for organics at an 18 to 30 inch soil

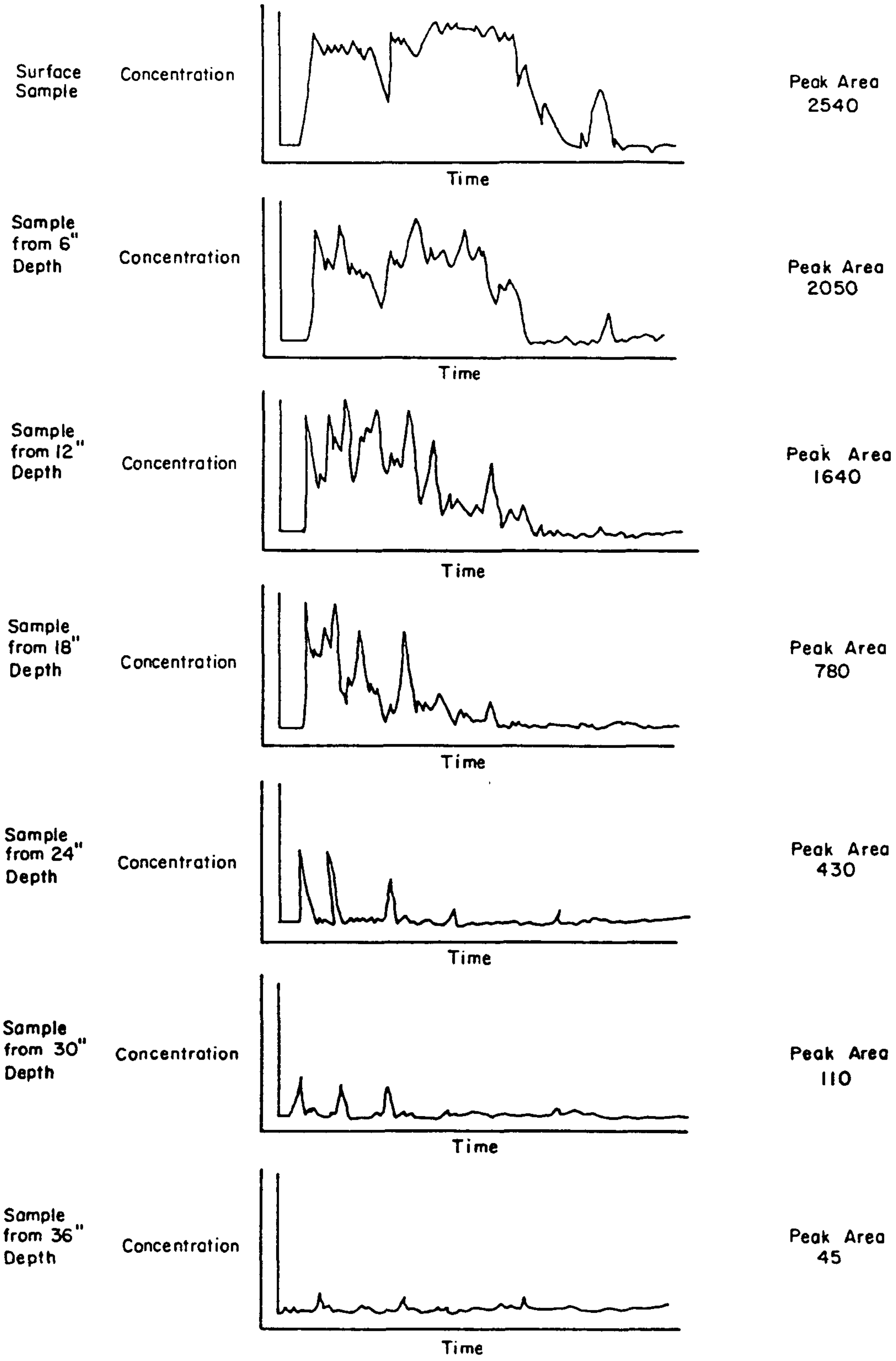


FIGURE II-1-2
TREATMENT DEMONSTRATION
IDEALIZED GC CURVES WITH
INCREASING DEPTH

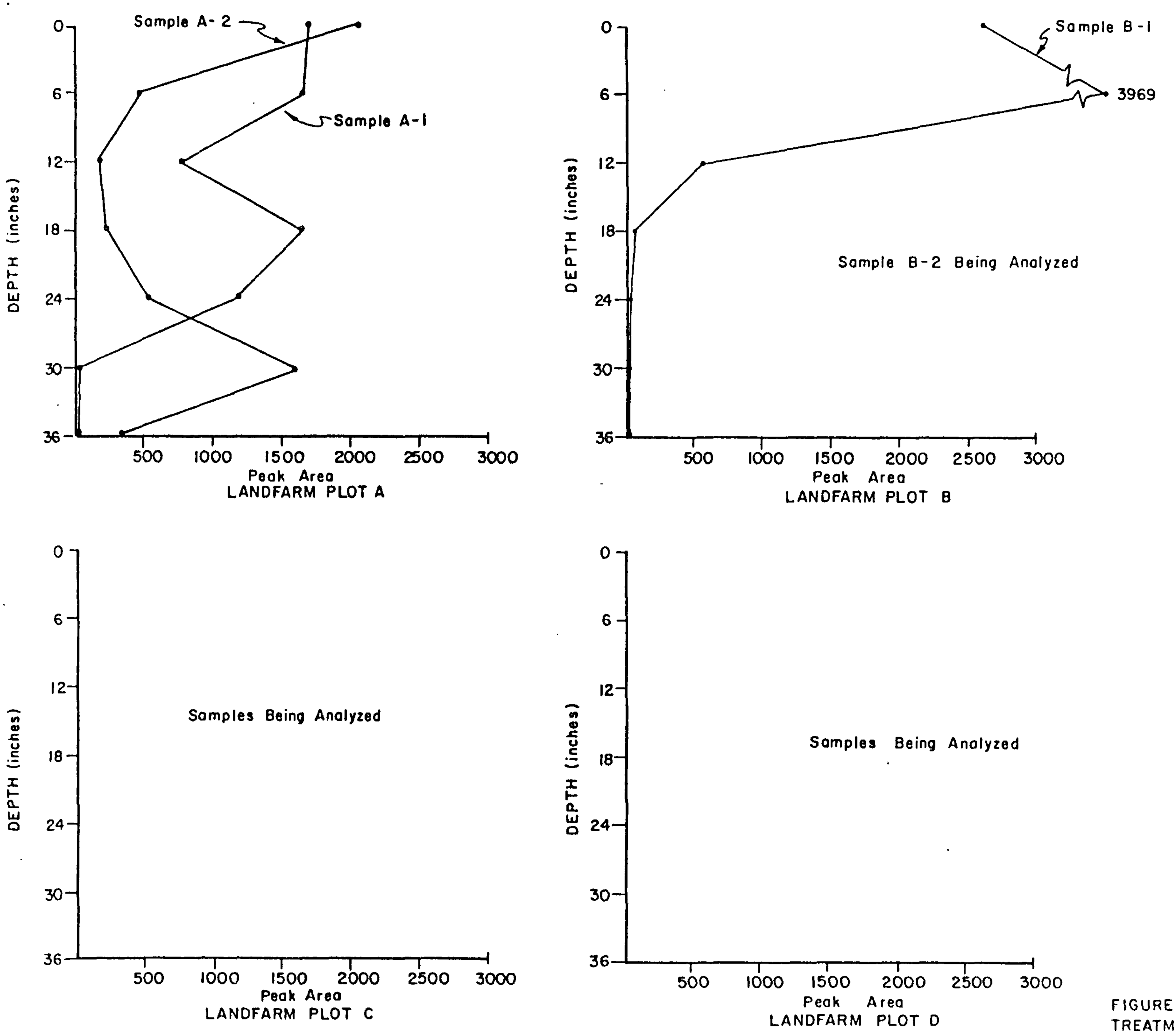


FIGURE II-1-3
TREATMENT DEMONSTRATION
SOIL ORGANIC PROFILE

depth. In that aerobic degradation or organic constituents is expected to occur very slowly at this depth, the data indicates this landfarm plot is a candidate for deep plowing to bring the organic layer closer to the land surface. Soil amendments to maintain desirable pH, nutrient and water levels should be added and the landfarm plot allowed to lie fallow until the organic matter has degraded. It should be emphasized, however, that while biodegradation may not be occurring at the optimum rate, organic constituents do seem to be contained within the treatment zone.

Specific compounds will be analyzed by a GC/MS in order to identify the compounds present. The contract laboratory is expected to have completed their analyses by December 30.

B. Metals

I. Literature Review

Petroleum refinery wastewater treatment sludges generally have metal concentrations lower than those found in municipal sewage sludge. However, the tetraethyl lead in leaded gasoline and chromates in heat exchanger sludge results in the generation of small volume metal bearing refinery waste streams. The mobility and toxic effect of metals is largely determined by its chemical form. For land treatment, the soil pH, redox potential and mineralogy together with metal compound present in the waste stream establishes the fate of metals added to the soil. Metals may be present as insoluble precipitates such as sulfates, carbonates or hydroxides, sorbed or chelated organic complexes, sorbed on exchange sites in either the waste or soil, or in solution in soil pore water. If the metal is insoluble at the normal pH of soil, it will not be present in appreciable amounts in the soil solution and thus not readily absorbed by plants or leached. As long as the metal is strongly sorbed or chelated, it will have low potential for plant uptake and leaching. Immobilization of metals may occur as long as the loading rates are not excessive and proper soil conditions such as soil pH are maintained. Generalized guidelines for maximum metal accumulations in soil and loading rates are presented in Table II-1-3. The type and level of metals present will dictate specific requirements.

Arsenic research has focused on the anions arsenate and arsenite. The cycling of arsenic in the environment is dominated by soil sorption, although leaching and volatilization may also occur. Immobilization of arsenic increases with increased soil pH and increased clay, aluminum and iron content. Arsenic precipitation by iron and aluminum oxides or calcium reduces the potential for leaching. Saturated soils tend to solubilize arsenic from ferric arsenate or arsenite to the more mobile arsines or methyl arsines. Reduction of arsenic under saturated soil conditions can also result in volatilization. However, research by Woolson (1977) has indicated only 1 to 2% of arsenate applied at a rate of 10 ppm was volatilized as dimethyl arsine after 160 days. The toxicity of arsenic results from the interaction with sulhydral groups or SH radicals of some enzymes. Inorganic arsenic is much more toxic than the organic forms which are more easily and rapidly eleminated by animals. Arsenic has been shown to be phytotoxic at soil application rates between 200 and 1000 kg/ha (Overcash and Pal, 1979).

In aerobic soils, hexavalent chromium is converted to less toxic trivalent chromium, which is quite immobile (Overcash and Pal, 1979). Trivalent chromium precipitates readily with carbonates, hydoxides and sulfides, which reduces the leaching potential. Such precipitation reactions are favored at a pH greater than 6. Hexavalent chromium, chromate or dichromate is toxic and mobile in soils. Soluble chromium salts (sulfates and nitrates) are much more toxic than insoluble chromium salts (oxides and phosphates). Almost 100% retention of chromiun has been documented by Wentink and Edzel (1972).

Immobilization of copper in soils is dependent on soil pH. The soil should be maintained at 6.5 or more to ensure the predominance of insoluble forms of copper. Copper forms stable complexes with soil organic matter particularly when the iron and

Table II-1-3

Maximum Metal Accumulation and Loading Rates

Element	Metal Content of Native Soils[1]		Suggested Maximum Metal Accumulations[2]	Suggested Metal Loadings[3]
	Common Range (mg/kg)	Average (mg/kg)	(mg/kg)	(kg/ha-30 cm)
Ag	0.01-5	0.05		400
Al	10,000-300,000	71,000		
As	1-50	5	300	
Au	n.g.	1		4000
B	2-100	10		
Ba	100-3,000	430		2000
Be	0.1-40	6	50	
Cd	0.01-0.7	0.06	3	
Co	1-40	8	200	
Cr	1-1,000	100	1000	
Cu	2-100	30	250	
Hg	0.01-0.3	0.03		40
La	1-5,000	30		2000
Li	5-200	20	250	
Mg	600-6,000	5,000		
Mn	20-3000	600	1000	
Mo	0.2-5	2	5	
Ni	5-500	40	100	
Pb	2-200	10	1000	
Rb	50-500	10		
Sb	2-10	not given	1000	
Se	0.1-2	0.3	5	
Sn	2-200	10		
Sr	50-1000	200		40
V	20-500	100	500	
Zn	10-300	50	500	
Zr	60-2,000	300		4000

1. Trace element content of soils extracted from Table 6.46 of Hazardous Waste Land Treatment, SW-874.

2. Suggested maximum metal accumulations in soil based on current literature extracted from Table 6.47 of Hazardous Waste Land Treatment, SW-874. Higher levels may be acceptable if it can be demonstrated that the ultimate vegetative cover is metal tolerant.

3. Suggested metal loadings for metals with less well defined information extracted from Table 6.52 of Hazardous Waste Land Treatment, SW-874. Values given should be used as preliminary guide.

manganese oxide concentration is low. However, the loss of organic matter through decomposition reduces the effectiveness of this retention mechanism. A column study (Emmerich et al., 1982) revealed 94% of copper applied was retained in the soil. Overcash and Pal (1979) suggest metal loadings of 125 to 500 kg/ha, depending on soil cation exchange capacity.

Divalent lead is present in soils as lead sulfates, hydroxides and carbonates depending on soil pH. The availability of lead in soils is related to moisture content, soil pH, organic matter content and the concentration of calcium and phosphate. Under saturated soil conditions, naturally occurring lead becomes reduced and mobile. Under the conditions of high pH, cation exchange capacity and available phosphorus, lead is less soluble and thus more strongly adsorbed. Lead toxicity in plants is uncommon, found only in acid soils. Concentrations up to 1000 ppm total lead can safely accumulate without phytotoxicity.

Nickel in soil associates with the oxide and hydroxide ligands and is precipitated as nickel hydroxyoxides at alkaline pH. In an anaerobic system, nickel may be reduced to lower oxidation states and precipitate as nickel carbonate or sulfide. In a column study (Emmerich et al., 1982), 94% of the nickel applied was recovered indicating essentially no nickel leached below the depth of incorporation. Liming of soil can greatly reduce nickel toxicity, not only by increasing soil pH, but by introducing calcium which is apparently antagonistic to nickel uptake. Soil accumulation rates of 100 ppm appear acceptable based on phytotoxicity and microbial toxicity.

Vanadium may be incorporated into clay minerals and is associated with aluminum oxides. Vanadium may be present as a divalent cation or oxidized anion, bound to soil organic matter or organic waste constituents.

2. Operational Data

Soil samples taken at 6 inch intervals from the land surface to a depth of 36 inches were obtained from 8 locations within the 4 acre landfarm. Samples were prepared by an acid digestion procedure, and analyzed by atomic absorption methods to establish the concentration of lead, chromium, copper, nickel and arsenic. The values for arsenic in cores A-1, A-2, B-1 and B-2 are in the process of being confirmed, and verified values for all 8 cores will be available by December 2. The concentration of these elements as a function of depth have been plotted for each soil sample, as shown in Figure II-1-4 through II-1-11. The mean metal concentration at each soil depth and within each soil core is shown in Table II-1-4. This data suggests the concentration of nickel and arsenic do not vary substantially with depth or across the landfarm. However, lead and chromium, and to a lesser extent copper, vary both with depth and laterally across the landfarm. The concentration of lead and chromium is greatest in the upper 12 to 24 inches of soil, dropping to less than 50 mg/kg below 24 inches in all soil cores but A-2. In soil core A-2, there appears to be a zone of accumulation as evidenced by profiles of both organics and metals at the 30 inch depth. The concentration of copper is greatest in the upper 12 inches of soil, dropping to less than 30 mg/kg below this depth in all soil cores but A-2. This data indicates metals are immobilized within the upper 36 inches of soil.

III. Land Treatment Program

The land treatment program identifies the operational procedures which will be employed in the management of oily refinery sludges. The oily materials are applied and tilled into the landfarm plots as generated. Application rates do not exceed prescribed limits. Surficial soils will be tested annually to identify the soil amendments necessary to adjust pH and nutrient levels to maximize microbial action. Unsaturated zone monitoring is conducted to demonstrate the effectiveness of the treatment program. Soil and soil pore liquid samples will be collected and analyzed for selected metals and base neutral organics.

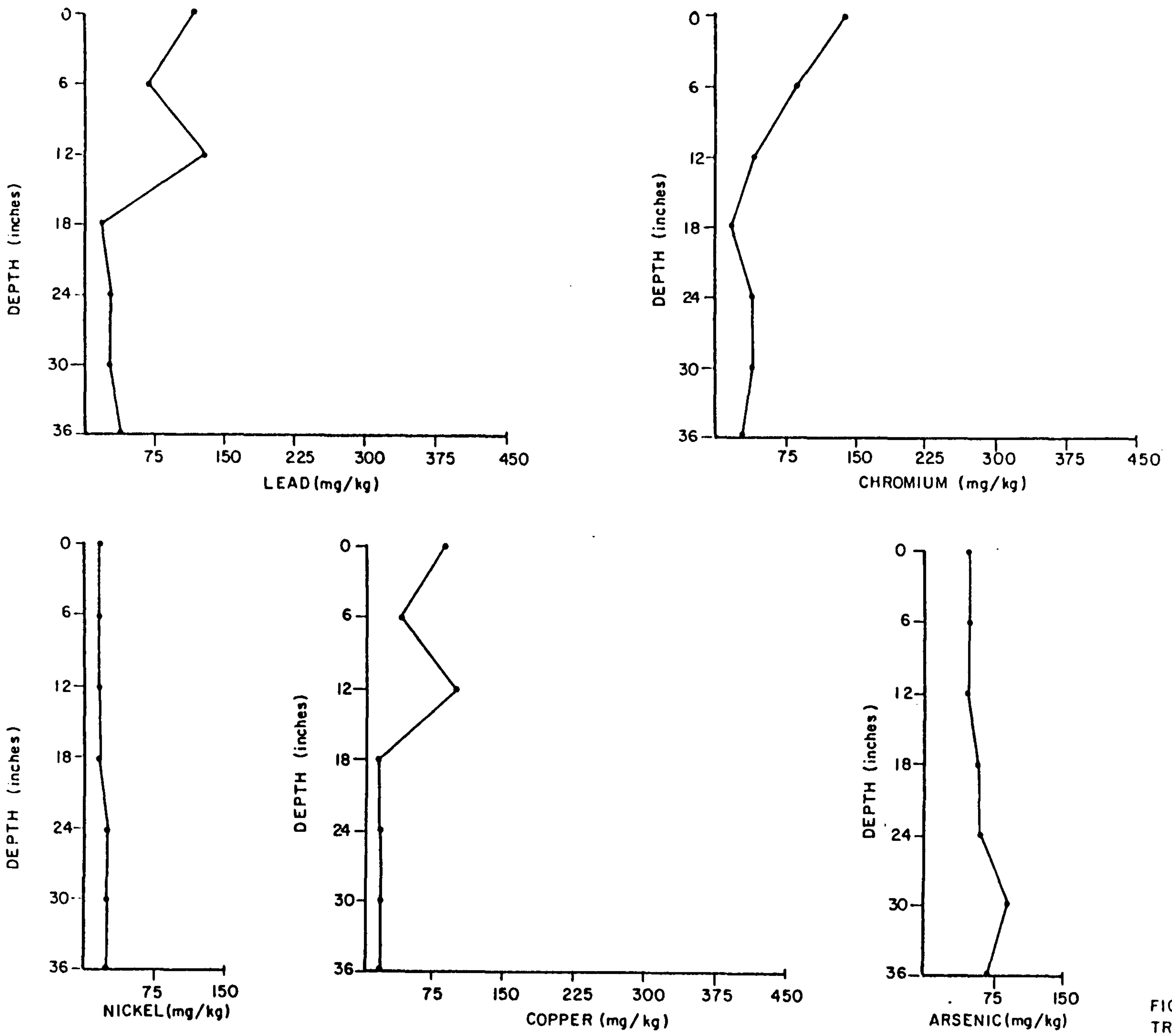


FIGURE II-1-4
TREATMENT DEMONSTRATION
SAMPLE A-1
SOIL METALS PROFILE

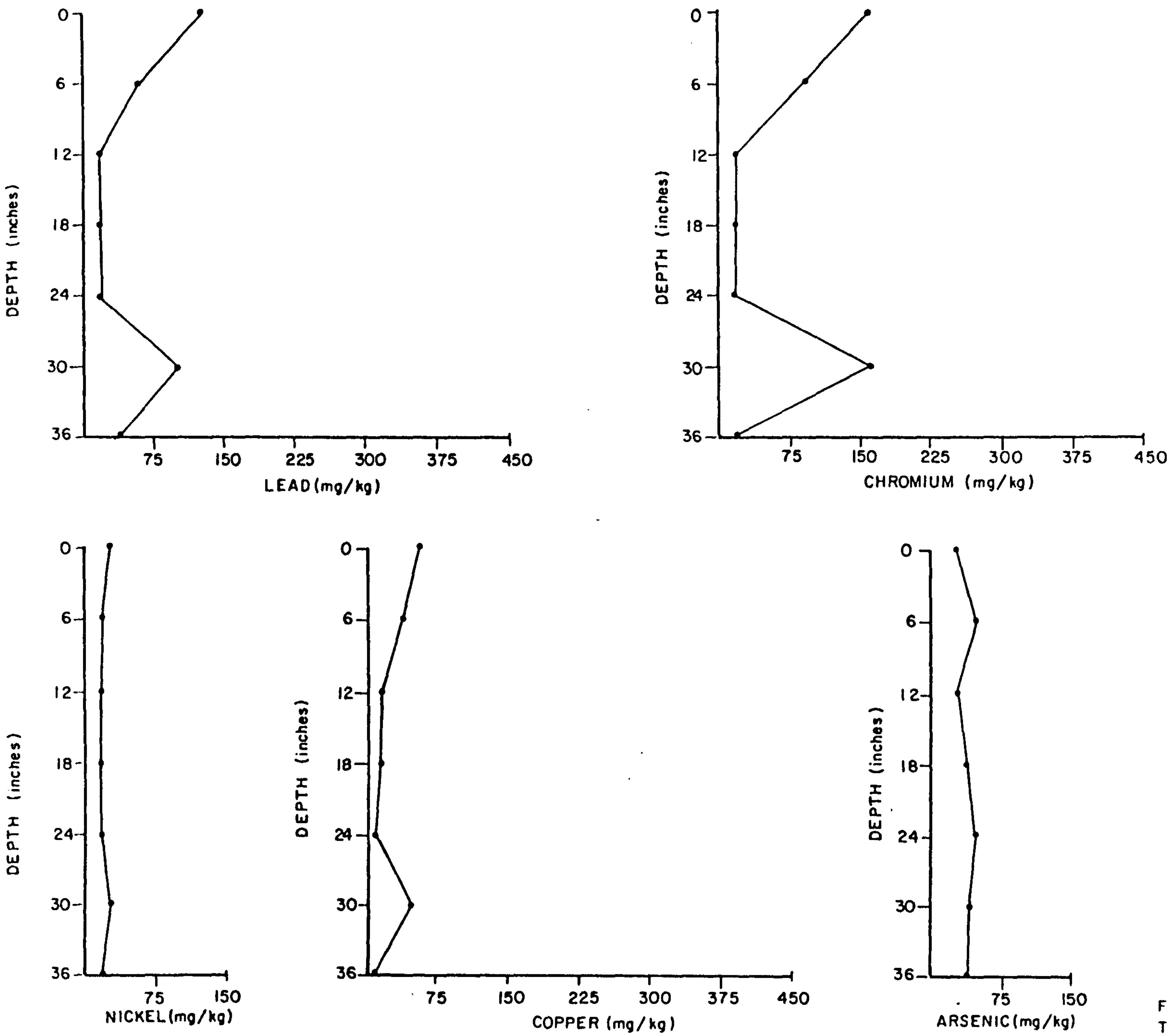


FIGURE II-1-5
TREATMENT DEMONSTRATION
SAMPLE A-2
SOIL METALS PROFILE

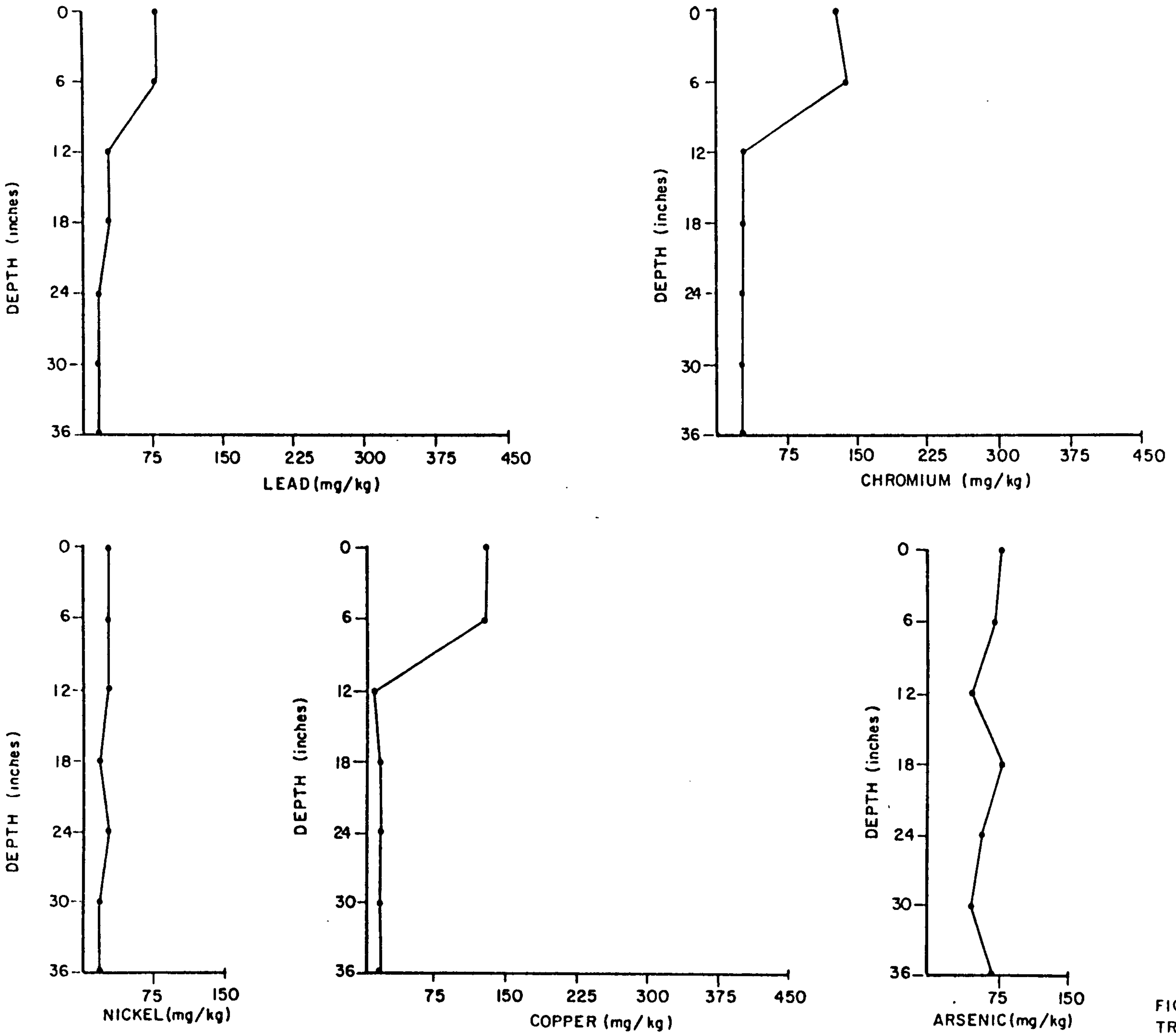


FIGURE II-1-6
TREATMENT DEMONSTRATION
SAMPLE B-1
SOIL METALS PROFILE

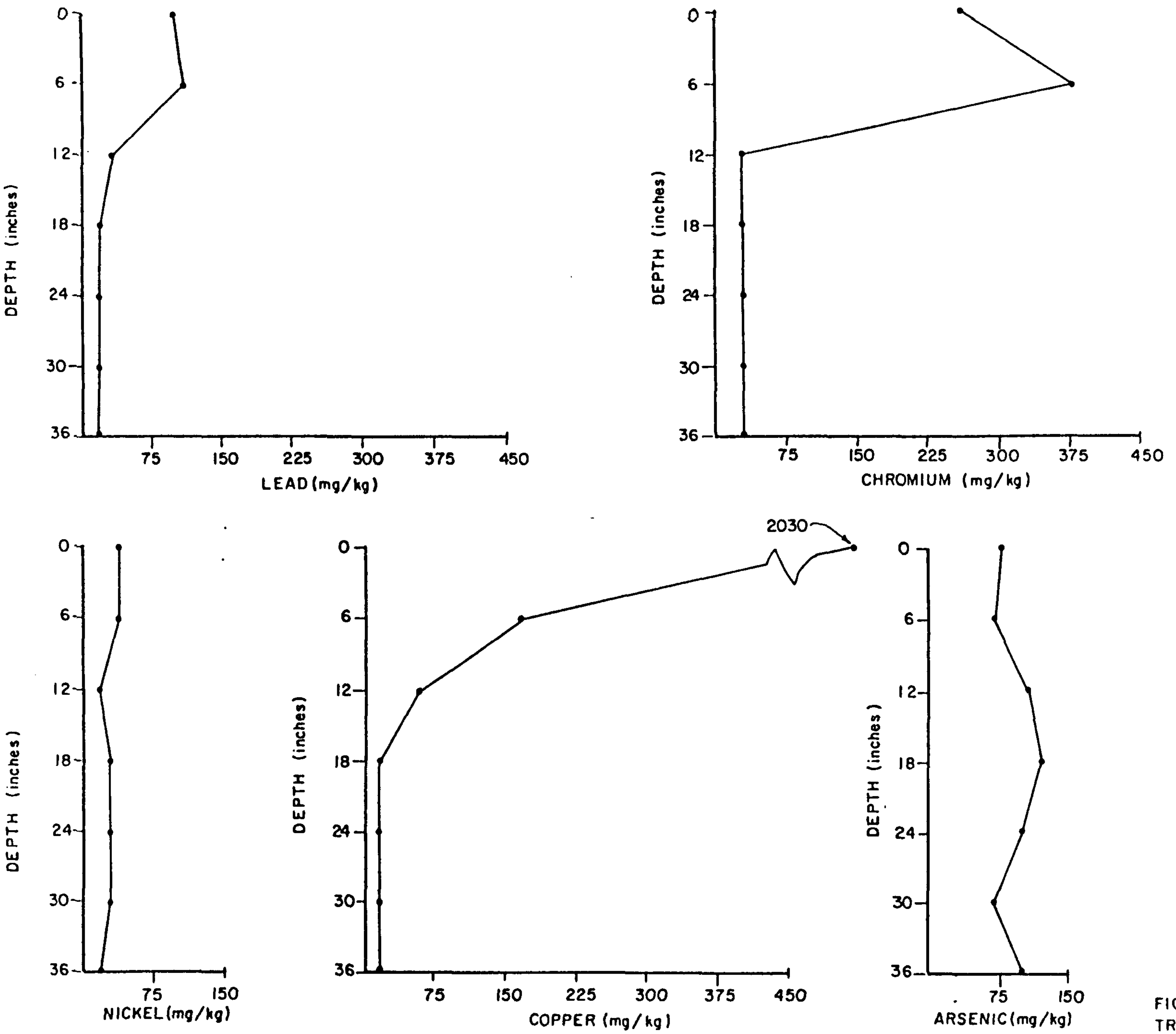


FIGURE II-1-7
TREATMENT DEMONSTRATION
SAMPLE B-2
SOIL METALS PROFILE

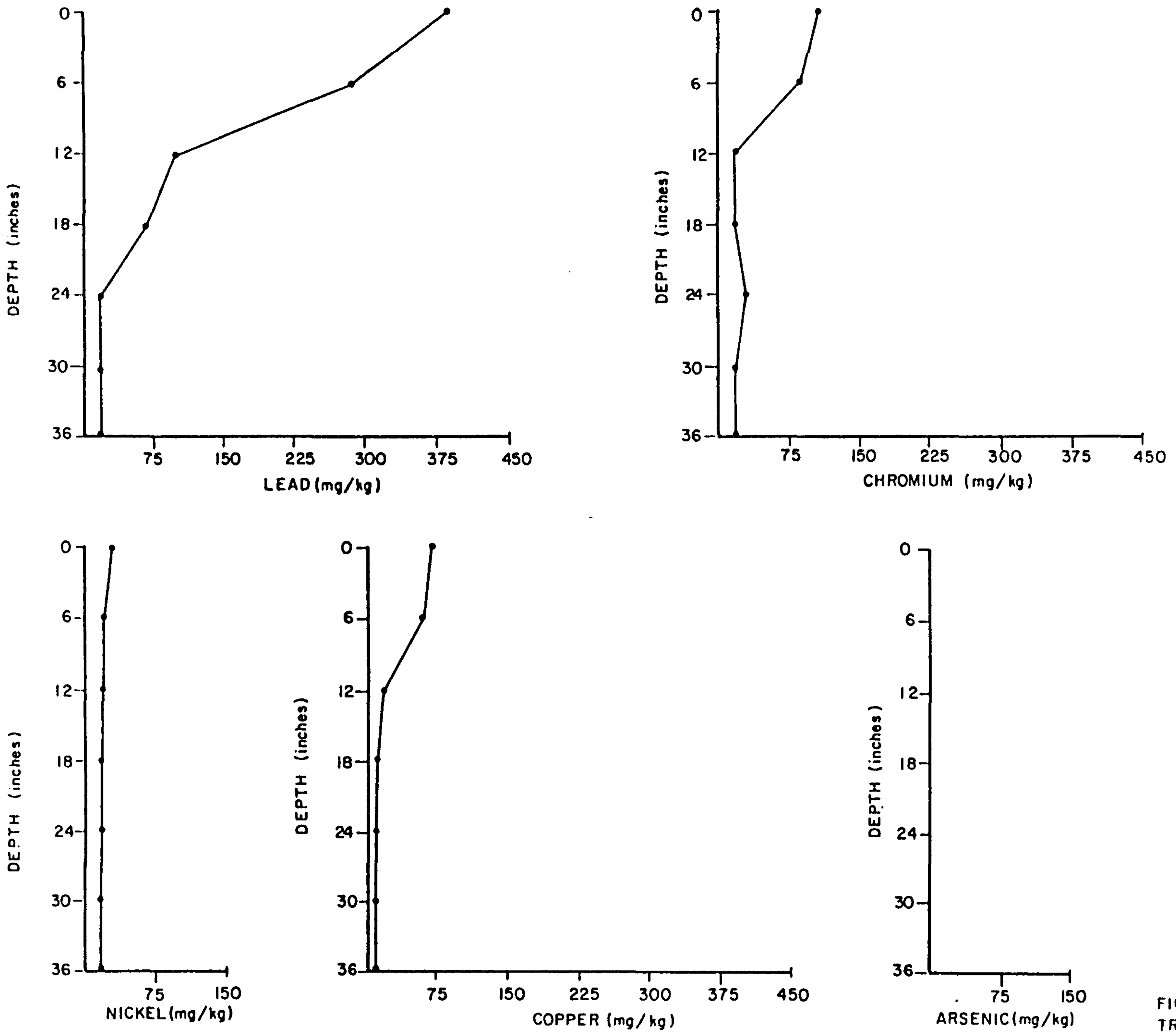


FIGURE II-1-8
TREATMENT DEMONSTRATION
SAMPLE C-1
SOIL METALS PROFILE

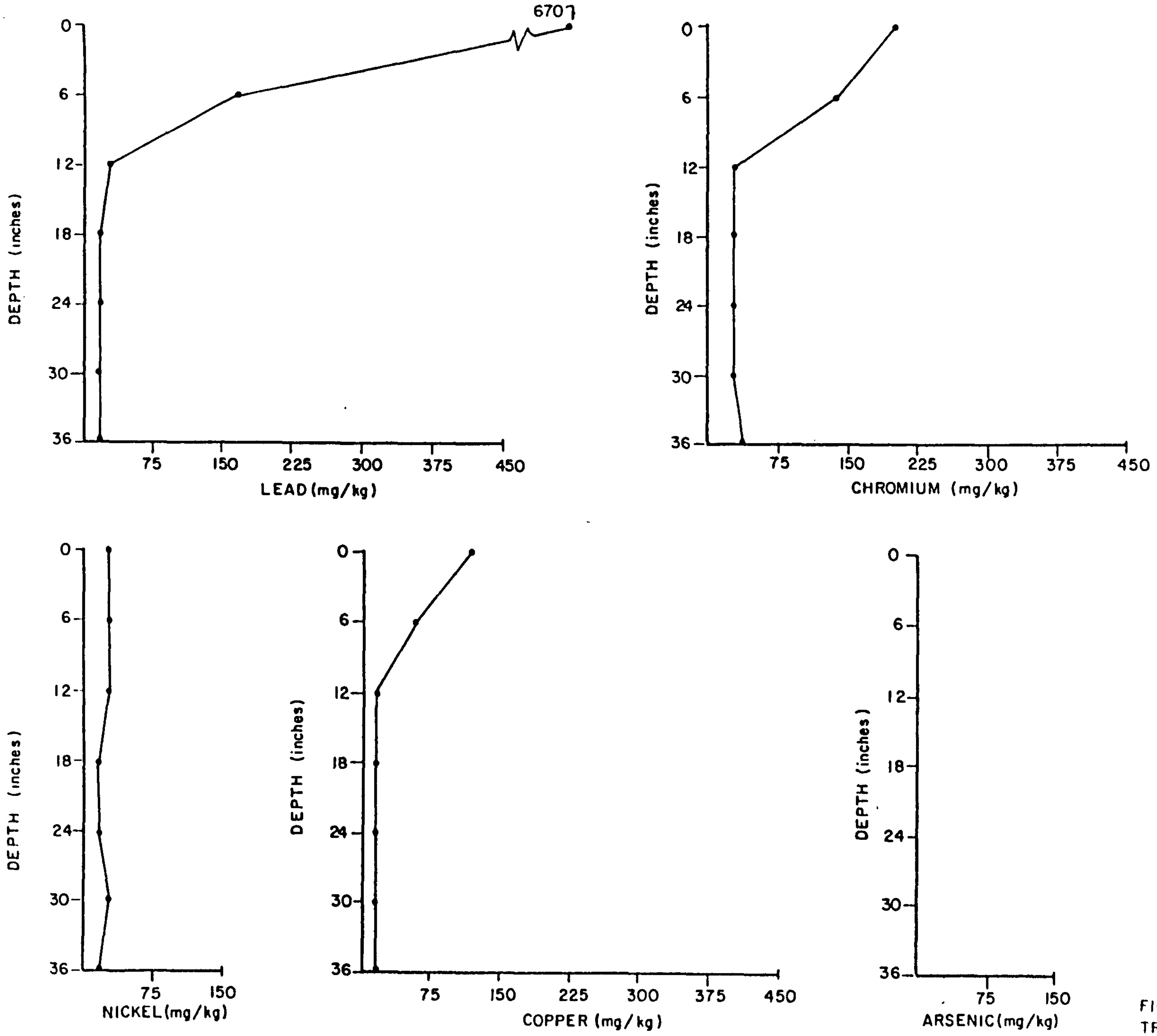


FIGURE II-1-9
TREATMENT DEMONSTRATION
SAMPLE C-2
SOIL METALS PROFILE

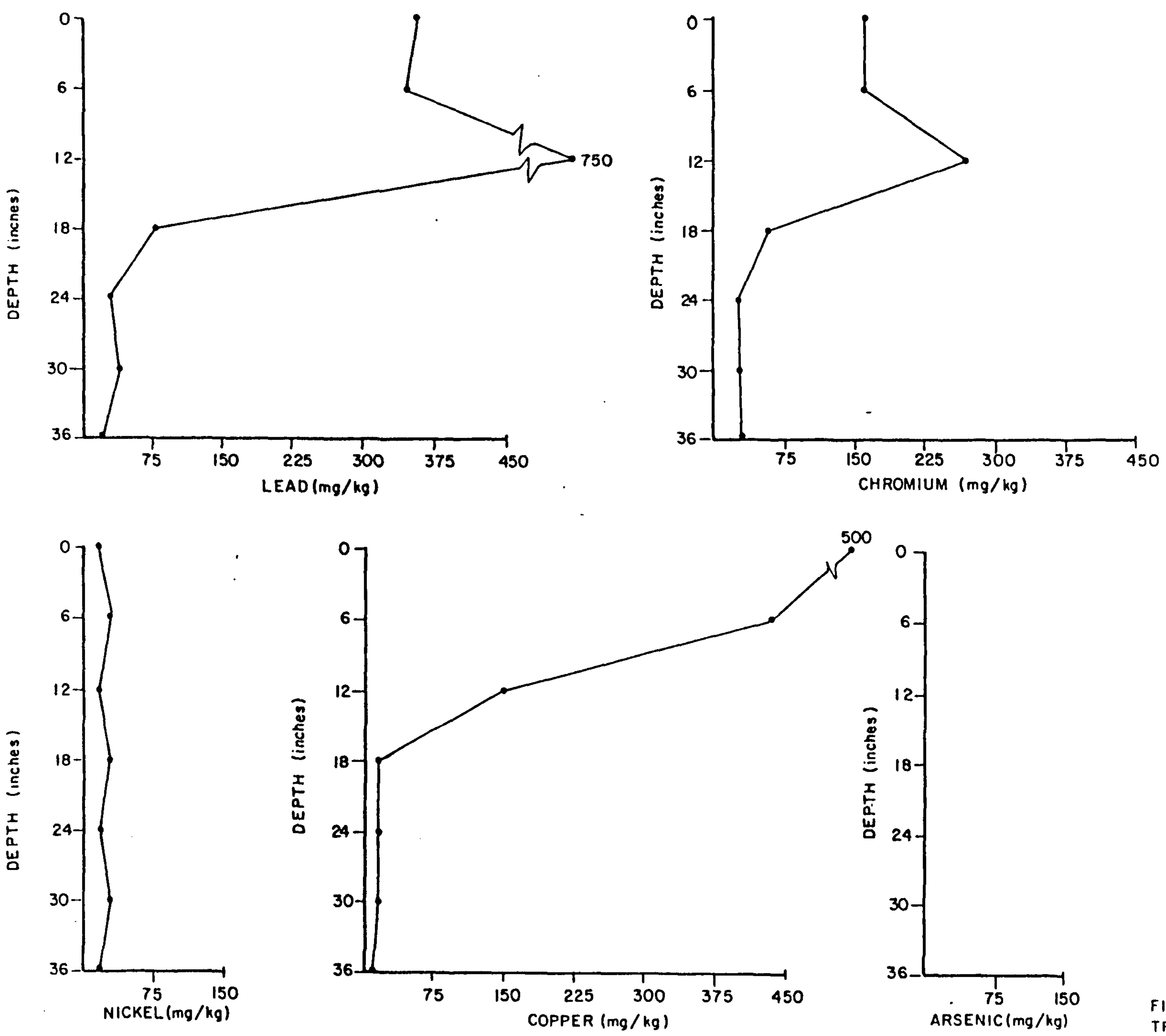


FIGURE II-1-10
TREATMENT DEMONSTRATIO
SAMPLE D-1
SOIL METALS PROFILE

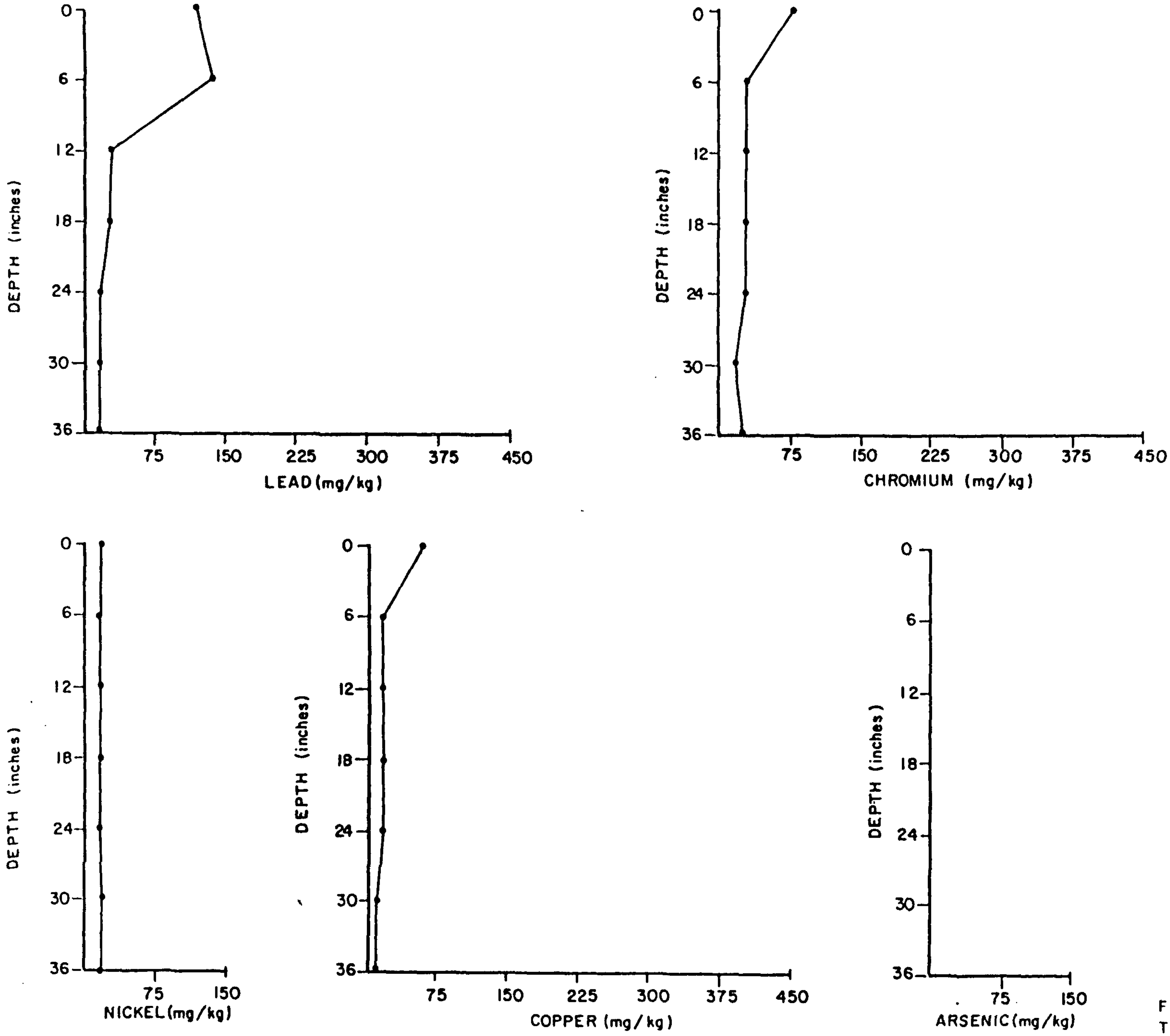


FIGURE II - 1 - 11
TREATMENT DEMONSTRATIO
SAMPLE D-2
SOIL METALS PROFILE

Table II-1-4

Mean Metal Content of Soils
(all values in mg/kg)

Concentration as a Function of Depth

Soil Depth (inches)	Lead	Chromium	Nickel	Copper	Arsenic
0	250	160	30	380(150)*	
6	160	140	30	120	
12	140	60	20	50	
18	40	30	20	20	
24	20	30	20	20	
30	30	50	30	20	
36	20	30	20	20	
Concentration within each Soil Core					
A-1	60	60	20	40	60
A-2	60	70	20	30	40
B-1	40	60	30	50	70
B-2	50	110	30	330(50)*	90
C-1	130	40	20	30	
C-2	140	70	30	40	
D-1	230	110	20	170	
D-2	60	40	20	20	

* Unusually high value of 2030 mg/kg reported for surficial soil from boring B-2. Figure in parentheses excludes this value from the data base.

A. Wastes

The wastes applied to the North Colony landfarm are listed below.

Wastes Applied to North Colony Landfarm
(tons/year)

	Average	Range
Slop Oil Emulsion Solids	100	0-160
Heat Exchanger Bundle Cleaning Sludge	30	0-40
Primary Separation Sludge	300	200-400
Leaded Tank Bottoms	0	0-5
Miscellaneous Oily Wastes	0	0-85

1. Characteristics

The slop oil emulsion solids and primary oil/solids/water separation sludge are relatively large volume waste streams generated once or twice a year. The heat exchanger sludge and leaded tank bottoms constitute small volume waste streams generated on an intermittent basis. Miscellaneous oily wastes are generated on a very sporadic basis. The physical characteristics of the oily waste streams may vary greatly.

Waste Variability

Characteristic	Estimated Range of Waste Variability (%)
Phase	
Water	15-99
Oil	5-40
Solids	1-15
Organics	
Aliphatic or Paraffinic Alkanes	15-30
Cycloparaffinic cycloalkanes, naphthenes	30-50
Aromatic Benzenes and Polynuclear Series	5-20
Asphaltic Asphaltenes, Heterocyclic Compounds	2-15
Metals	<1

2. Application Rates

The literature indicates soils have a great capacity for decomposing oily materials and significant quantities of waste can be applied without serious ill effects. Soils do have upper limits as to how much refinery wastes may be applied without producing anaerobic conditions which result in a reducing environment and an accumulation of odors and phytotoxic substances. Based on studies conducted by Cresswell (1977) in Oklahoma, annual degradation rates of 7 to 16 g oil/kg soil with an average 8.5 g/kg are possible. Overcash and Pal (1979) cite a wide range of oil decomposition rates from their literature review and suggest an annual degradation rate of 3.6% (36 g/kg) of soil weight under optimal conditions. Assuming acceptable application rates are in the range of 8.5 to 36 g oil/kg soil, an average 10% oil content of applied waste and a total landfarm area of 3.68 acres, acceptable loading rates range from 340 to 1440 tons/year. The 690 tons of hazardous waste generated annually are within the acceptable range of application rates, provided fertilizer additions and cultivation practices are adequate. A summary of calculations for the capacity and application rates of oily refinery sludges in the North Colony landfarm is presented in Table II-1-5.

The application, rate and capacity limits for trace elements are shown in Table II-1-6. The landfarm life based on trace element loading is shown in Table II-1-7. The theoretical design life of the landfarm based on trace element loading is a minimum of 110 years. This exercise demonstrates the importance of the oil content of landfarmed wastes relative to the concentration of metals present in establishing application rates and operational procedures. While the metal content of soils will be analyzed regularly to ensure the maximum recommended accumulation rate is not exceeded, the application rate of oil to landfarm plots is of greater importance.

3. Waste Application

Oily refinery wastes are collected from the various generation points by a vacuum truck with a capacity of 30 bbl. The vacuum truck discharges the sludges onto the land surface. Wastes are evenly allocated into each of the four landfarm plots. Records are maintained of the waste source, amount and area of application for each waste load. Landfarm plots are tilled within 2 weeks of waste application and thereafter on a monthly basis.

Table II-1-5

North Colony Landfarm

Oil Application Rates

North Colony Landfarm Area:	3.68 usable acres 160,300 square feet
Average Landfarm Plot Area:	4 landfarm plots 40,075 sq ft average plot area
Soil Mass of North Colony Landfarm:	assume 100 lb/cf soil density assume 6 in depth of incorporation 8,015,040 lb or 3,643,200 kg
Soil Mass per Landfarm Plot:	assume 100 lb/cf soil density assume 6 in depth of incorporation 2,003,750 lb or 910,800 kg
Oil Content of Truckload:	assume 30 bbl/load assume 10% oil assume 8 lb/gal average density 1008 lb oil or 458 kg oil

Landfarm Capacity
Based on 8.5 g oil/kg soil

$$\frac{0.0085 \text{ kg oil}}{\text{kg soil-year}} \quad \frac{3{,}643{,}200 \text{ kg soil}}{\text{landfarm}} \quad \frac{2.2 \text{ lb}}{\text{kg}} \quad = \quad \frac{68130 \text{ lb oil}}{\text{year}}$$

$$\frac{68{,}130 \text{ lb oil}}{\text{year}} \quad \frac{100 \text{ lb waste}}{10 \text{ lb oil}} \quad \frac{\text{ton}}{2000 \text{ lb}} \quad = \quad 340 \text{ tons waste/year}$$

Based on 36 g oil/kg soil

$$\frac{.036 \text{ kg oil}}{\text{kg soil-year}} \quad \frac{3{,}643{,}200 \text{ kg soil}}{\text{landfarm}} \quad \frac{2.2 \text{ lb}}{\text{kg}} \quad = \quad 288{,}540 \text{ lb oil/year}$$

$$\frac{288{,}450 \text{ lb oil}}{\text{year}} \quad \frac{100 \text{ lb waste}}{10 \text{ lb oil}} \quad \frac{\text{ton}}{2000 \text{ lb}} \quad = \quad 1440 \text{ tons waste/year}$$

Application Rate
Based on 8.5 g oil/kg soil

$$\frac{0.0085 \text{ kg oil}}{\text{kg soil-year}} \quad \frac{910{,}800 \text{ kg soil}}{\text{plot}} \quad \frac{\text{truckload}}{458 \text{ kg oil}} \quad = \quad 17 \text{ truckloads/year/plot}$$

Based on 36 g oil/kg soil

$$\frac{0.036 \text{ kg oil}}{\text{kg soil-year}} \quad \frac{910{,}800 \text{ kg soil}}{\text{plot}} \quad \frac{\text{truckload}}{458 \text{ kg oil}} \quad = \quad 72 \text{ truckloads/year/plot}$$

Table II-1-6

Trace Elements
Application, Rate and Capacity Limits

Waste Constituent	Application Limit (lb/acre)	Rate Limit (lb/acre/yr)	Capacity Limit (lb/acre)	Comments
Arsenic	175-880	--	1300	Toxic to plants at application rates between 200 and 1000 kg/ha; Maximum soil accumulation of 300 mg/kg
Chromium	--	--	4355	Maximum soil accumulation of 1000 mg/kg
Copper	--	--	1090	Maximum soil accumulation of 250 mg/kg
Lead	--	--	4355	Maximum soil accumulation of 1000 mg/kg without phytotoxicity
Nickel	--	--	435	Maximum soil accumulation of 100 mg/kg based on phytotoxicity and microbial toxicity
Vanadium	--	--	2175	Maximum soil accumulation of 500 mg/kg

Source: Hazardous Waste Land Treatment, SW-874

Table II-1-7

Landfarm Life
Based on Trace Element Loading

	Capacity Limit (lb/acre)	Cumulative Landfarm Application (lb)	Waste Concentration (mg/kg)	Cumulative Waste Application (tons)	Landfarm Life (yr)
Arsenic	1,300	4,810	10	240,450	350
Chromium	4,355	16,030	50	160,300	230
Copper	1,090	4,010	5	400,800	580
Lead	4,355	16,030	25	320,600	465
Nickel	435	1,605	10	80,150	115
Vanadium	2,175	8,015	10	400,750	580

Note: "Capacity Limit" is calculated by multiplying the maximum recommended soil accumulation (as ratio of element to soil) for each trace element by soil density (estimated at 100 lb/cf), the square footage in an acre (43,560 sq ft) and the zone of incorporation (the upper 1 ft of soil)

"Cumulative Landfarm Application" is calculated by multiplying capacity limit (in lb/acre) by usable landfarm area (in acres)

"Waste Concentration" is conservative estimate based on analysis of representative waste samples

"Cumulative Waste Application" is calculated by dividing the cumulative landfarm application for each element (in pounds) by average concentration (as weight ratio of element to soil) and correcting for tons (2000 lb/ton)

"Landfarm Life" is calculated by dividing the maximum cumulative waste application (in tons) by estimated average annual waste application (in tons/year).

B. Operational Procedures

Operational procedures to encourage degradation and immobilization of hazardous constituents include pH control, nutrient addition and soil aeration. These methods are designed to optimize treatment process occurring in the soil system.

1. pH Control

The existing information suggests the soil in the landfarm area tends to be alkaline, although the addition of oily wastes to the soil should tend to depress soil pH. Soil pH will be monitored annually, and will be maintained in the range of 7 to 9. A soil scientist is in the process of identifying soil pH and making recommendations as to pH control.

2. Nutrient Levels

The action of the microbial population can be enhanced by addition of selected soil nutrients. The level of the nutrients nitrogen, phosphorus and potassium are of concern, and will be analyzed on an annual basis. Fertilizer application rates may be selected on the basis of these results.

Overcash and Pal (1979) state 50 ppm N and 20 ppm P will sustain oil degradation by microbial action. A Soil Scientist is in the process of evaluating landfarm soils and nutrient deficiencies, and will make recommendations to maximize microbial action.

3. Soil Aeration

Monthly tilling of the landfarm plots increases the soil to oil contact, aerates the soil, improves soil moisture and hastens the mineralization of organics. The decomposition of oily wastes has long term beneficial effects on soil physical properties. An increase in water holding capacity and available water and a decrease in wind dispersal losses have been noted.

4. Soil Moisture

Soil moisture should be maintained in the 50 to 70% of available water capacity to maximize biodegradation. The soil scientist evaluating the landfarm will establish the available water capacity in each landfarm plot as well as the existing water content. It may be necessary to irrigate the landfarm in order to maintain sufficiently high water content. As currently envisioned, refinery effluent may be piped to the landfarm and spray nozzles installed to irrigate the land surface. Plots will be irrigated during periods when soil moisture drops below 50% as evidenced by in situ moisture monitors, tests on soil samples or soil textural analysis.

C. Unsaturated Zone Monitoring

An unsaturated zone monitoring system has been established in the North Colony landfarm in accordance with interim status standards. The unsaturated zone monitoring system provides subsurface data used to define the treatment zone in the landfarm. A comprehensive monitoring program, in accordance with 264.278, is being established to determine the quality of the soil-pore liquid and the chemical make-up of the soil in and below the treatment zone. The results of the monitoring program will then being used to evaluate the capacity of the soil to attenuate hazardous constituents in the oily wastes applied to the land surface.

1. Lysimeter Installation

Two soil core samples were obtained in the North Colony landfarm and suction lysimeters were installed in the open borings. The locations of the existing landfarm lysimeters are shown in Figure II-1-12. Two 6 in diameter soil core samples were collected at one foot intervals using a coring device attached to the drilling rig. These core samples were analyzed to determine both the thickness of the treatment zone and the chemical make-up of the soil below the treatment zone. Approximately 1 cubic liter of soil was collected from each zone and analyzed for chromium, lead and arsenic. These parameters were selected based on initial waste characterization data.

Suction lysimeters (Soilmoisture Equipment Corporation, Model 1900) were installed in the open borings excavated by the core sampling work. The lysimeter sampling cup was placed below the apparent treatment zone, approximately 5 ft, to

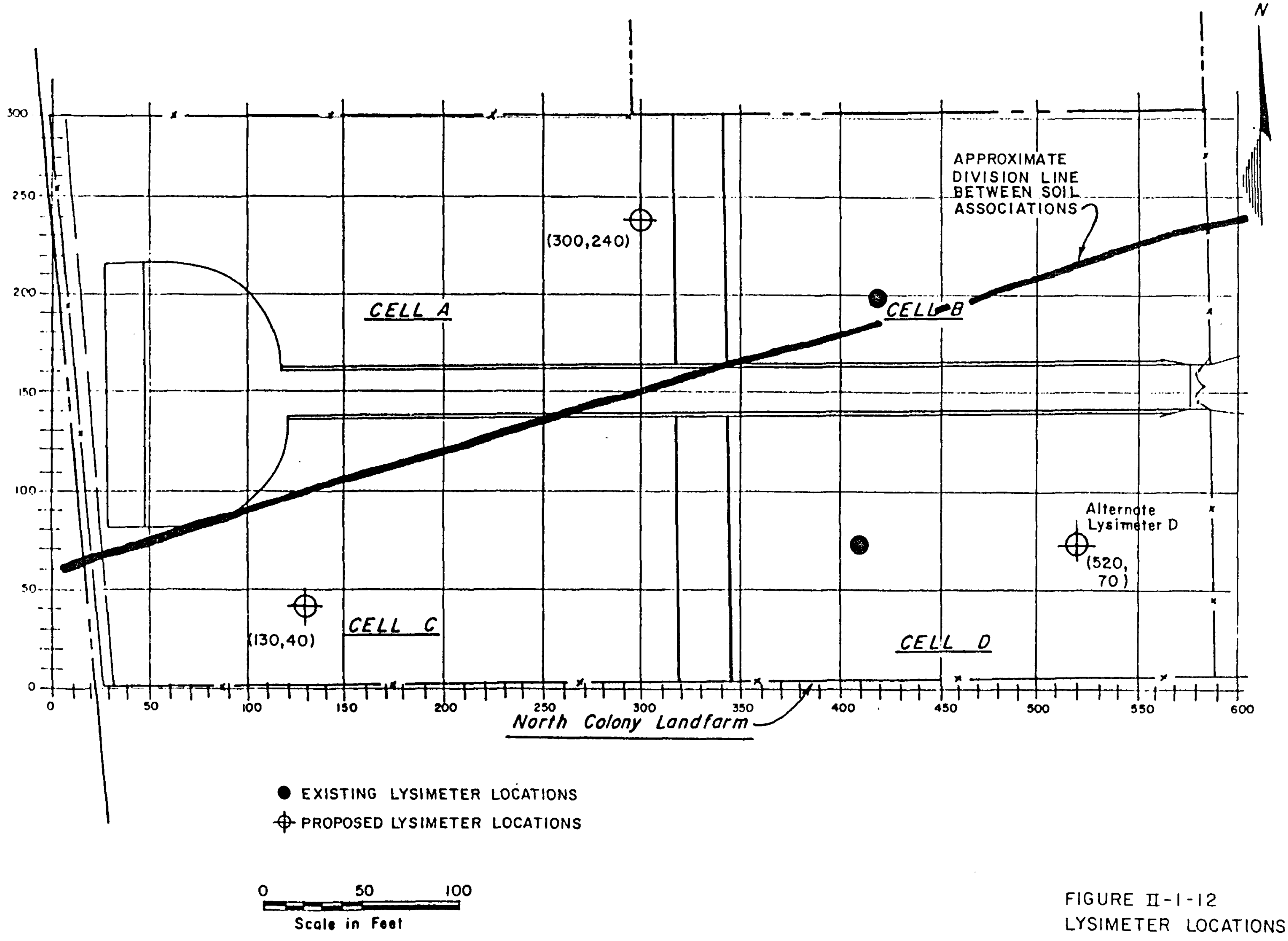


FIGURE II-1-12
LYSIMETER LOCATIONS

collect soil pore liquid passing through the treatment zone. A slurry of grade sand and natural material was used to backfill around the lysimeter to ground level.

Navajo plans to have one functional lysimeter in each landfarm plot. In that there are two soil series (as indicated by the Soil Scientist, not the SCS report) each covering roughly half of the landfarm area, there will be two lysimeters per uniform area. Existing lysimeter B is still functional. No sample has been recovered by lysimeter D on the last two attempts. Unless the lysimeter can be made functional, a new lysimeter will be installed in cell D. New lysimeters will be installed in cells A and C.

The proposed location of soil pore liquid samplers have been randomly selected in accordance with the RCRA Guidance Document. A grid was developed for the landfarm, and potential coordinates of the proposed lysimeters drawn for a random number table. The proposed locations of lysimeters are shown in Figure II-1-12. The type of lysimeter to be installed is currently being reviewed. Soilmoisture lysimeter model numbers 1900 and 1920 are being considered.

2. Lysimeter Sampling and Analysis

Soil pore liquid samples will be obtained on a quarterly basis after waste applications or significant rainfall events. The soil water sampling procedures are discussed in Appendix II-5-1. Soil pore liquid samples will be collected, transported and analyzed in house. Chain of custody control procedures will be employed. Each sample will be labelled with the sample number, name of sampler, date and the time of collection and sampling point. Laboratory log books are maintained which specify the sampler, name, date and time of collection, sampling procedures, analytical procedures, analyst and date and time of analysis.

Soil pore liquid samples will be analyzed for selected hazardous constituents in the base neutral extractable organic fraction. A qualitative analysis of the base neutral extractable organics will be obtained by gas chromatography.

3. Soil Sampling and Analysis

A soil auger will be employed to collect soil samples on a semiannual basis. Sampling locations will be randomly selected by the following procedure. A grid has been superimposed over the landfarm as shown in Figure II-1-13. Sampling locations will be established by extracting coordinates from a random number table until one sampling location has been identified within each cell.

Soil samples will be obtained from the surface and at 6 inch intervals from the soil core. Each subsample will be homogenized and prepared for laboratory analysis. A quantitative analysis will be conducted for the metals chromium and lead. Soil will be prepared by acid digestion procedure followed by analysis by AA. A qualitative analysis will be conducted for the base neutral extractable organic fraction. The soil will be prepared by a soxhlet extraction procedure followed by GC analysis. The metals content and peak area will be plotted as a function of depth to verify the immobilization and degradation processes occurring within the landfarm.

4. Recordkeeping

Soil and soil pore liquid analyses will be conducted on a quarterly basis. Sampling will be conducted after waste applications or significant rainfall events, if possible. Data will be recorded on an example form as shown in Table II-1-8.

D. Treatment Zone

The treatment zone consists of the upper 5 ft of soil in the North Colony landfarm. The base of the treatment zone is 12 ft above the shallow water table which occurs at a depth approximately 17 ft below the land surface.

1. Soil Survey

The Navajo refiney is located on the interface of the Reagan-Upton and Reeves-Gypsum Land-Cottonwood associations as shown in Figure II-1-14. The Reagan Upton association are loamy soils which consist of deep to shallow soils on gently undulating plains and in the broader valleys mainly west of the Pecos River. The Pima soils, also

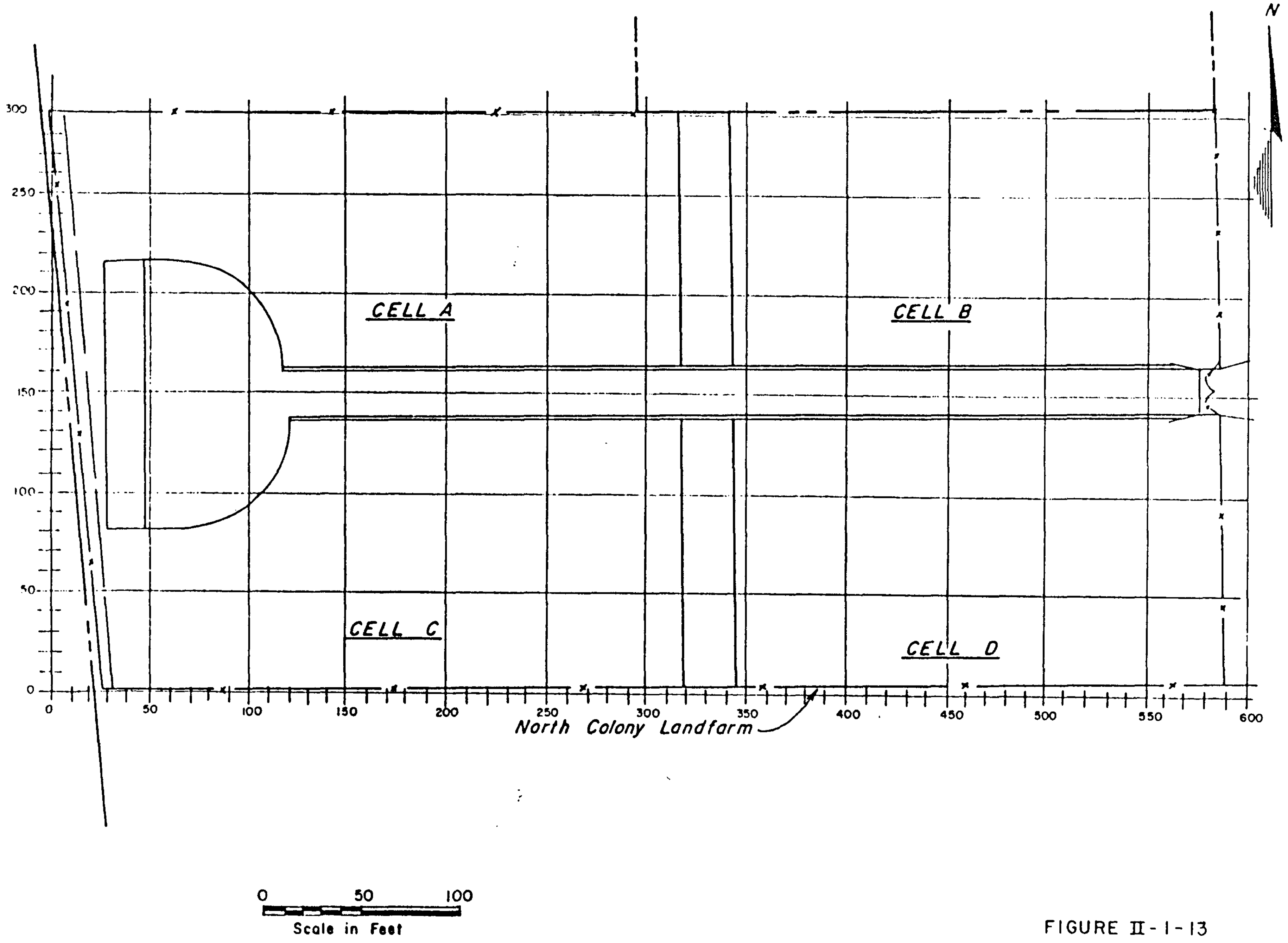
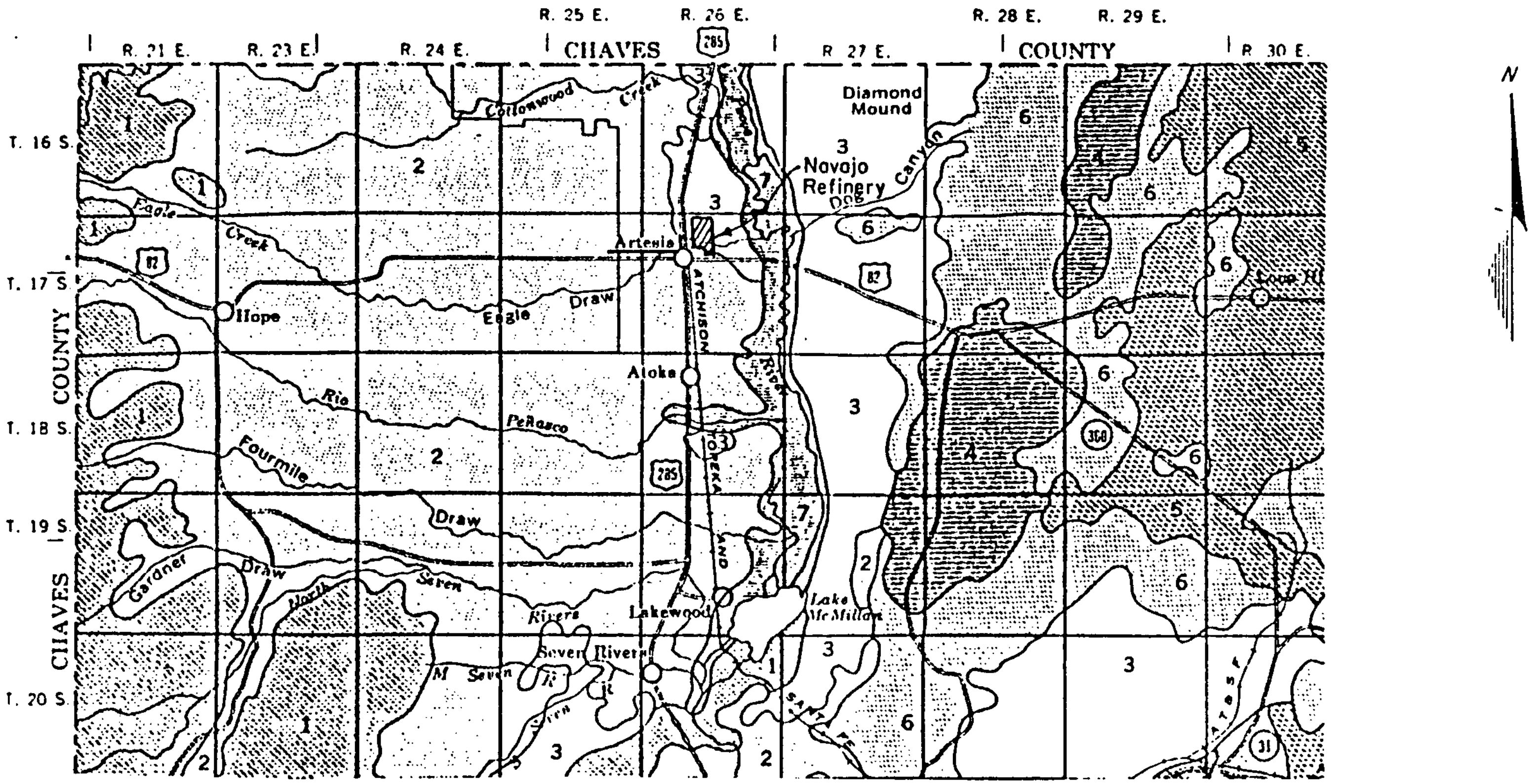


FIGURE II-1-13
SOIL SAMPLING LOCATIONS

Table II-1-8

Unsaturated Zone Monitoring
Example Record Form

		Soil Samples		
		Metal Content (mg/kg)		Base Neutral Extractables
Cell	Sampling Depth (in)	Chromium	Lead	Peak Area
A	0			
Sampling Date	6			
______	12			
Last Waste	18			
Application	24			
______	30			
Lysimeter Sample	36			
Base Neutral Extractables				
(Peak Area)				
______				
B	0			
Sampling Date	6			
______	12			
Last Waste	18			
Application	24			
______	30			
Lysimeter Sample	36			
Base Neutral Extractables				
(Peak Area)				
______				
C	0			
Sampling Date	6			
______	12			
Last Waste	18			
Application	24			
______	30			
Lysimeter Sample	36			
Base Neutral Extractables				
(Peak Area)				
______				
D	0			
Sampling Date	6			
______	12			
Last Waste	18			
Application	24			
______	30			
Lysimeter Sample	36			
Base Neutral Extractables				
(Peak Area)				
______				



SOIL ASSOCIATIONS

1	Limestone rock land-Ector association: Rock land and very shallow, stony and rocky, loamy soils over limestone; on hills and mountains
2	Reagan-Upton association: Loamy, deep soils and soils that are shallow to caliche; from old alluvium
3	Reeves-Gypsum land-Cottonwood association: Loamy soils that are very shallow to moderately deep over gypsum beds, and Gypsum land
4	Kimbrough-Stegall association: Loamy soils that are very shallow to moderately deep to caliche; from old alluvium
5	Kermit-Berino association: Sandy, deep soils from wind-worked mixed sand deposits
6	Simona-Pajarito association: Sandy, deep soils and soils that are shallow to caliche; from wind-worked deposits
7	Arno-Harkey-Anthony association: Loamy, deep soils from recent mixed alluvium

May 1969

Scale 1:506880

1 0 1 2 3 4 5 6 7 8 Miles

Source: Soil Survey, Eddy Area, New Mexico, USDA, 1971.

FIGURE II-1-14
GENERAL SOIL MAP
NAVAJO REFINERY
URS ENGINEERS

in the association, occur on flood plains developed in silty alluvium. The soils are moderately dark colored, calcareous, loamy and are moderately deep over Caliche. The Reeves-Gypsum land - Cottonwood association are loamy soils which consist of gently undulating soils on plains and low hills, and on gypsum land. Reeves soils are moderately deep, light colored and loamy and occur in swales and drainageways. Karro soils, also in this association, occur on high terraces or flats developed on alluvium. These soils are deep, limy and lightly colored. Soils in the North Colony landfarm consist of the Karro loam (Kr), Pima silt loam (Pe), and Reeves loam (Ri) as shown in Figure II-1-15. Estimated properties and characteristics are presented in Table II-1-9 and analytical data for selected profiles is shown in Table II-1-10.

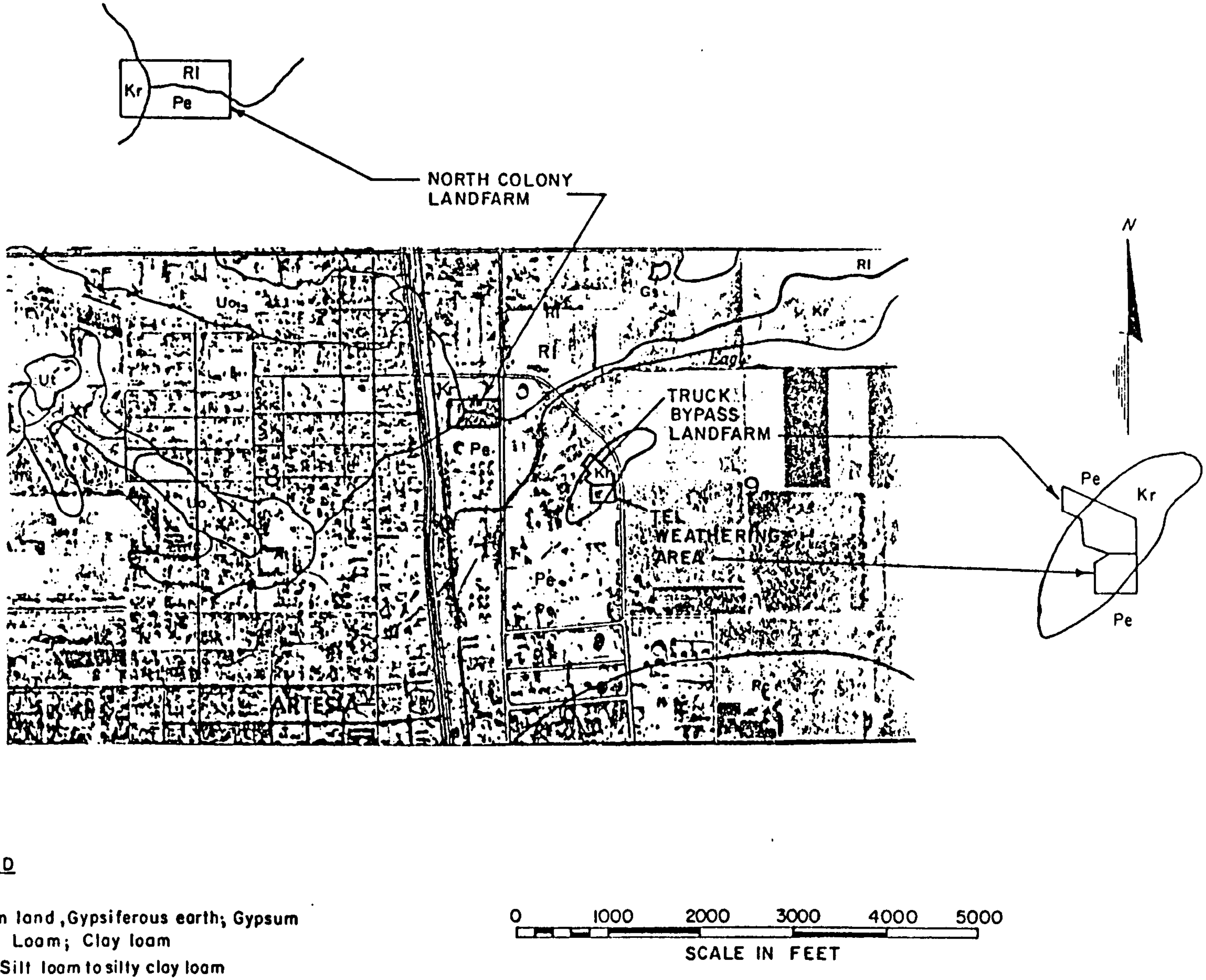
The **Karro** series consists of light-colored, strongly calcareous, loamy soils that developed in deep, old alluvium derived from calcareous, sedimentary rocks. These soils are enriched by lime absorbed from ground water or left by runoff from adjacent limy uplands.

Soils of the Karro series typically have a surface layer of light brownish-gray loam about 10 inches thick. The next layer, about 10 inches thick, consists of very pale brown loam. The substratum is very pale brown and pink clay loam that extends to a depth of more than 60 inches. Calcium carbonate has accumulated at a depth of about 46 inches.

These soils are highly susceptible to wind erosion if the plant cover is seriously depleted or if cultivated areas are left bare. Permeability is moderate. The water-holding capacity is high. The organic-matter content is low.

The **Pima** series consists of deep, well-drained, moderately dark colored, calcareous soils that developed in alluvium derived from limestone. These soils occur on flood plains of narrow drainageways.

Soils of the Pima series typically are light brownish-gray silt loam in the upper 3 inches. Below this brown or light-brown silty clay loam that extends to a depth of 60



LEGEND

Gs - Gypsum land, Gypsiferous earth; Gypsum
Kr - Karro, Loam; Clay loam
Pe - Pima, Silt loam to silty clay loam
Rc - Reagan, Loam and light clay loam
Rl - Reeves, Heavy loam and light clay loam; Gypsum

Source. Soil Survey, Eddy Area, New Mexico, USDA, 1971.

FIGURE II-1-15
SOIL SURVEY
NAVAJO REFINERY
URS REFINERY

TABLE II-1-9

ESTIMATED PROPERTIES AND CHARACTERISTICS

Soil series and map symbols	Depth to bedrock, hard caliche, or gypsum inches	Depth from surface inches	Classification		Permeability	Available water capacity	Reaction	Electrical conductivity (Ec × 10³) Mmho./cm. at 25° C.
			USDA texture	Unified				
					Inches per hour	Inches per inch of soil	pH	
Karro: KA, Kl, Kr, Ku, Kv	More than 60.	0-20	Loam	ML-CL	0.8-2.5	0.16-0.18	7.9-8.4	4.0-10.0
		24-60	Clay loam	CL	0.8-2.5	0.18-0.20	7.9-8.4	8.0-15.0
Pima: PM, Pe, Pn, Pv	More than 60.	0-60	Silt loam to silty clay loam	CL	0.2-0.8	0.18-0.20	7.4-7.8	0-4.0
Reeves: RG, RM, Rl, Rn, Rt (For Reagan part of RM, see Reagan series; for Gypsum land part of RG, see Gypsum land.)	Soft or hard gypsum at a depth of 10 to 36 inches.	0-32	Heavy loam and light clay loam.	CL	0.8-2.5	0.17-0.19	7.4-7.8	4.0-8.0
		32	Gypsum.					

Source: Soil Survey, Eddy Area, New Mexico, USDA, 1971

TABLE II-1-10

ANALYTICAL DATA FOR SELECTED PROFILES

Soil type, location of sample, and sample number	Horizon	Depth	Texture	Organic carbon	Nitrogen	Electrical conductivity	$CaCO_3$ equivalent	Gypsum	Cation exchange capacity	Extractable cations		Saturation extract soluble cations				Moisture at saturation	Saturation extract soluble sodium	Ex-chang able sodiu
										Na	K	Na	K	Ca	Mg			
				Pct.	*Pct.*	*Ec × 10³ Mmhos./cm. at 25° C.*	*Pct.*	*Pct.*	*Meq./100 gm.*	*Meq./100 gm.*	*Meq./100 gm.*	*Meq./liter*	*Meq./liter*	*Meq./liter*	*Meq./liter*	*Pct.*	*Meq./100 gm.*	*Meq./gm*
Karro loam: Location: At the center of the E½NW¼SE¼, sec. 7, T. 21 S., R. 28 E. (Sample No. S56NMex-8-21-(1-6); laboratory No. 309-314)	Ap	0-10	Loam.....	.74	.106	9.5	23.4	2.2	12.3	2.8	.8	49.6	1.5	31.0	13.9	32	1.6	1
	AC	10-20	Loam.....	.52	.091	10.0+	28.7	2.1	12.2	3.8	.8	71.3	1.5	29.4	15.2	38	2.7	1
	C1	20-46	Clay loam.	.36	.083	10.0+	29.4	1.2	11.3	4.3	.9	81.6	2.0	35.9	24.8	37	3.1	1
	C2ca	46-60	Clay loam.	.34	.062	10.0+	38.6	.7	10.2	3.2	.9	67.4	2.2	40.4	25.3	36	2.4	
	C3ca	60-90	Clay loam.	.20	.037	9.0	46.6	.4	8.6	2.0	.4	29.7	1.2	27.9	21.0	37	1.1	
Reeves loam: Location: 800 feet E. and 100 feet S. of the NW. corner of sec. 21, T. 23 S., R. 27 E. (Sample No. S57NMex-8-7-(1-4); laboratory No. 355-359)	Ap	0-8	Heavy loam....	.60	.102	5.0	22.5	1.2	19.9	1.3	.7	9.0	.1	32.4	9.4	40	.4	.
	AC	8-15	Clay loam......	.51	.096	5.0	30.1	2.0	20.5	1.1	.7	9.9	.1	31.7	9.6	42	.4	.
	C1ca	15-23	Clay loam......	.31	.064	6.0	43.8	2.6	17.6	3.5	.5	24.9	.1	29.1	13.4	43	1.1	2.
	C2cs	23-32	Light clay loam; many crystals of gypsum.	.12	.033	6.1	22.3	31.3	13.0	1.4	.2	20.8	.9	29.4	17.4	62	1.1	.
	Rcs	32	Gypsum															

Source: Soil Survey, Eddy Area, New Mexico, USDA, 1971.

inches or more. These soils are subject to periodic flooding, and the floodwaters leave a small amount of deposition. Gullies form if the plant cover is seriously depleted. Runoff is slow. Permeability is moderately slow in the subsoil. The water-holding capacity is high.

The Reeves series consists of light-colored, well-drained, calcareous soils that are shallow to moderately deep over gypsiferous earth or rocks. These soils developed in old alluvium derived from sedimentary rocks. They are nearly level to gently sloping. Soils of the Reeves series typically have a plow layer of pale-brown heavy loam about 8 inches thick. The next layer, about 7 inches thick, is pale-brown clay loam, about 8 inches thick, that is enriched by calcium carbonate. Below this is a layer of white clay loam, about 9 inches thick, that is heavily enriched by gypsum and calcium carbonate. Hard, gypsiferous bedrock is at a depth of 32 inches.

These soils are uneroded or only slightly eroded. Runoff is slow. Permeability is moderate, and the water-holding capacity is low to moderate. The intake rate is moderate. The organic-matter content is low, and fertility is moderate.

2. Soil Sampling

A soil scientist has conducted a soil sampling and analysis program at the North Colony landfarm. In addition to standard investigative procedures, the Soil Scientist has been requested to ascertain the soil pH, cation exchange capacity and nutrient (nitrogen, phosphorus and potassium) levels in the zone of incorporation. He is expected to provide Navajo with recommendations to enhance microbial activity. His soil description report is due November 18, 1983, although soil analyses will not be complete until December 23, 1983.

IV. Design, Construction, Operation and Maintenance

A. Surface Water Control

The North Colony landfarm is surrounded by a dike constructed up to 3 ft above grade. The elevation of this dike is above the base flood elevation which should prevent inundation during the 100 yr flood. The dike is designed to contain rainwater impacting the landfarm area, preventing surface water runon and runoff. The rainwater is impounded and allowed to either infiltrate into the soil or evaporate. There is no need to construct separate stormwater control and storage facilities given the climate and operational procedures.

The arid climate of Artesia controls soil moisture in the North Colony landfarm. Climatic data is tabulated in Table II-1-11. As can be seen, the average annual precipitation is 12.4 inches and the average annual pan evaporation is 112.75 inches. It is estimated that one year in ten will have less than 6.4 inches of rainfall and one year in ten will have more than 18.1 inches of rainfall. The 10 year minimum and maximum monthly rainfall amounts reflect the amount recorded in any one month of a dry or wet year. These monthly minimum and maximum rainfall amounts are not additive in establishing the 10 year minimum and maximum precipitation on an annual basis (i.e., 12 consecutive months of extremes in precipitation is not statistically representative of a 10 year period). The sum of the 10 year minimum and maximum monthly precipitation amounts is 1.7 and 28.2 inches, as opposed to the 10 year minimum and maximum precipitation amounts of 6.4 and 18.1 inches, respectively. An average of 23 days in one year will have 0.1 inches or more rainfall, and 15 days in one year will have 0.5 inches or more rainfall.

Several water balances for the landfarm have been developed as shown in Tables II-1-12 and II-1-13. Several assumptions were employed in generating these water balances. The precipitation amounts have been corrected to reflect the amount of rainfall within the diked area (4.26 acres) as infiltrating the usable landfarm area (3.68 acres). The waste is considered to have an average 85% water content. Evaporation is estimated to be 70% of the Class A pan evaporation rate. For evenly distributed waste application, there is a negative amount of storage required in both average and wet years.

Table II-1-11

Climatic Data

	Precipitation Data					
		One Year in 10 Will Have		Average Number of Days With		
	Average Total (in)	Less Than (in)	More Than (in)	0.1 in. or more (days)	0.25 in. or more (days)	Evaporation (in)
January	0.44	0.005	0.9	1	1	4.44
February	0.37	0.005	1.0	1	1	5.75
March	0.46	0.005	1.1	1	1	9.51
April	0.54	0.005	1.3	1	1	12.04
May	1.76	0.4	3.4	3	2	14.14
June	1.33	0.1	3.1	2	1	14.79
July	1.56	0.6	2.5	3	2	13.65
August	1.60	0.2	3.1	3	2	12.68
September	1.94	0.2	5.8	3	2	10.13
October	1.61	0.2	3.3	3	1	7.17
November	0.35	0.005	0.7	1	1	4.54
December	0.47	0.005	1.9	1	1	3.91
TOTAL	12.43	6.4	18.1	23	15	112.75

Source: Soil Survey, Eddy Area, New Mexico; Soil Conservation Service, March 1971

Table II-1-12

Water Balance
Average Year - Evenly Distributed Waste Application
(all values in inches)

	Precipitation	Water In Waste	Evaporation	Percolation	Change in Storage	Cumulative Storage
September	2.25	0.12	7.1	0	-4.73	-4.73
October	1.86	0.12	5.0	0	-3.02	-7.75
November	0.41	0.12	3.2	0	-2.67	-10.42
December	0.54	0.12	2.7	0	-2.04	-12.46
January	0.51	0.12	3.1	0	-2.47	-14.93
February	0.43	0.12	3.9	0	-3.35	-18.28
March	0.53	0.12	6.7	0	-6.05	-24.33
April	0.63	0.12	8.4	0	-7.65	-31.98
May	2.04	0.12	9.9	0	-7.74	-39.72
June	1.54	0.12	10.4	0	-8.74	-48.46
July	1.81	0.12	9.6	0	-7.67	-56.13
August	1.85	0.12	8.9	0	-6.93	-63.06
TOTAL	14.40	1.44	78.9	0	-63.06	

Table II-1-13

Water Balance
Wet Year - Evenly Distributed Waste Application
(all values in inches)

	Precipitation	Water In Waste	Evaporation	Percolation	Change in Storage	Cumulative Storage
September	6.71	0.12	7.1	0	-0.27	-0.27
October	3.82	0.12	5.0	0	-1.06	-1.33
November	0.81	0.12	3.2	0	-2.27	-3.60
December	2.20	0.12	2.7	0	-0.38	-3.98
January	1.04	0.12	3.1	0	-1.94	-5.92
February	1.16	0.12	3.9	0	-2.62	-8.54
March	1.27	0.12	6.7	0	-5.31	-13.85
April	1.50	0.12	8.4	0	-6.78	-20.63
May	3.94	0.12	9.9	0	-5.84	-26.47
June	3.59	0.12	10.4	0	-6.69	-33.16
July	2.89	0.12	9.6	0	-6.59	-39.75
August	3.59	0.12	8.9	0	-5.19	-44.94
TOTAL	32.52	1.44	78.9	0	-44.94	

The average net precipitation minus evaporation is shown in Table II-1-14 for average, wet and dry years. As can be seen, evaporation exceeds precipitation in each month for each scenario. The amount of water in the waste generated over a period of one year is estimated to be a total of 1.4 inches, if spread evenly over the usable landfarm area. The total amount of waste generated in one year could be applied to the landfarm in one application in any month of an average or dry year. In a wet year, single waste applications may not be suitable in the months of September, October or December, although single waste applications would be possible in the remaining nine months without active runoff control because ponding is not expected.

B. Wind Dispersal

The incorporation of wastes into the soil results in a long term improvement in soil characteristics. The increase in organic matter and water holding capacity results in a decreased potential for wind dispersal as compared to native soils.

C. Inspection Plan

The landfarm is inspected weekly and after storms. The active portions of the landfarm are visually inspected for proper spreading and incorporation procedures, the dikes are inspected for any evidence of seepage or structural damage and the security devices are inspected for any signs of corrosion or damage. More details of the inspection plan are contained in Chapter I-5.

V. Food Chain Crops

Navajo has no plans to grow food chain crops on the landfarm during either the active life or the post closure care period.

VI. Closure

On an annual basis during the normal operating life of these landfarm Navajo analyzes samples of surficial soils for pH and nutrients. Soil amendments in the form of lime and fertilizer are then incorporated into the soil to maintain pH and nutrient levels within the desired ranges. Prior to the final waste application, soils will be

Table II-1-14

Average Net Precipitation Minus Evaporation
(all values in inches)

	Average Year	Wet Year	Dry Year
September	-4.85	-0.39	-6.87
October	-3.14	-1.18	-4.77
November	-2.79	-2.39	-3.20
December	-2.16	-0.50	-2.70
January	-2.59	-2.06	-3.10
February	-3.47	-2.74	-3.90
March	-6.17	-5.43	-6.70
April	-7.77	-6.90	-8.40
May	-7.86	-5.96	-9.44
June	-8.86	-6.81	-10.28
July	-9.67	-6.71	-8.91
August	-7.05	-5.31	-8.67
TOTAL	-64.50	-46.38	-76.94

analyzed to establish whether soil amendments are necessary. If necessary, soil additives will be incorporated into the treatment zone to prepare the landfarm to receive wastes. Once the refinery has ceased operation, all accumulated waste will be removed from the points of generation using standard Navajo waste removal procedures. These wastes will then be applied to the landfarm plots along with any spent wash waters generated as a result of decontamination of the drum storage area and waste handling equipment. Navajo will till the treatment zone as soon as possible after the final application of wastes to the treatment zone. Navajo will continue normal operating practices, i.e., till the treatment zone, add fertilizer, maintain pH and control soil moisture, during the 90 days following the last waste application. The inspection schedule, preparedness and prevention precautions and contingency and security considerations pertaining to the land treatment facilities will remain in effect as a part of standard landfarm operations at closure.

Unsaturated zone monitoring will be conducted at the land treatment facility during closure activities. The results of unsaturated zone monitoring will be used in conjunction with inspection results to determine when sufficient treatment has occurred to discontinue tilling and to establish a vegetative cover. Three months after the final waste application, soil and soil pore liquid samples will be obtained in accordance with the unsaturated zone monitoring plan established for the facility. If the soil pore liquid monitoring results do not indicate the presence of hazardous constituents, soil pore monitoring will be discontinued. Navajo does not anticipate conducting soil-pore liquid monitoring for more than 90 days following the last application of wastes. If soil core monitoring does not indicate the presence of metals at levels in excess of phytotoxic concentrations, the tilling of landfarm plots will be discontinued. Soil core monitoring however will continue through closure and the post-closure care period. Once it has been determined that no further tilling or other soil disturbance is necessary for sufficient treatment of wastes, Navajo will establish a vegetative cover over the landfarm plots. Potential candidates for vegetative cover include Russian Thistle and Johnson Grass as these native species require little or no maintenance to thrive. Once this cover has been established, the land treatment facility will be considered to be closed.

VII. Special Considerations

A. Ignitable and Reactive Wastes

The oily refinery wastes applied to the landfarm are generally not considered ignitable or reactive. However, even if an isolated waste shipment exhibited the characteristics of ignitability or reactivity, once applied to the land surface and incorporated into the surficial soils, the wastes should not be considered ignitable or reactive.

B. Incompatible Wastes

The various oily refinery wastes applied to the North Colony landfarm are not incompatible, so no special handling procedures are necessary.

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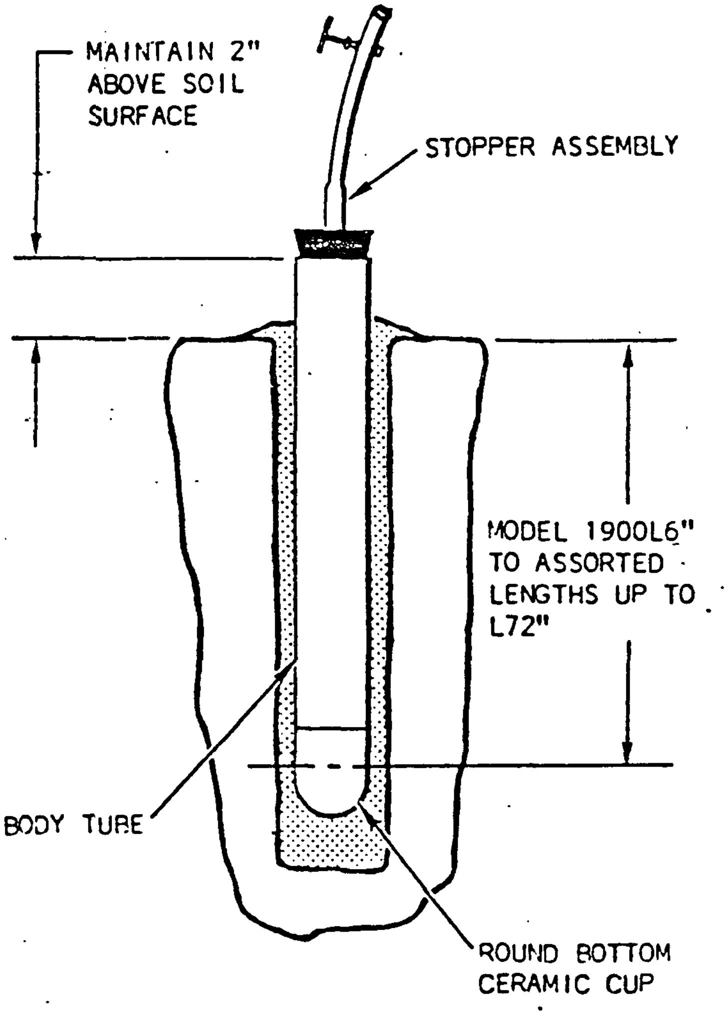
APPENDIX II-1-1

Operating Instructions for the Soil Water Sampler

Rec'd 11-1-82

OPERATING INSTRUCTIONS for the
Model 1900
SOIL WATER SAMPLER



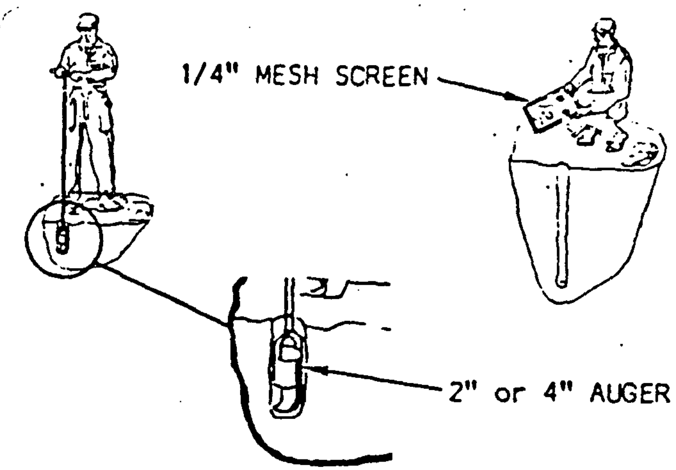
SITE LOCATION

The Model 1900 Soil Water Sampler can be installed in any location. The sampler can be installed in well drained soil or in areas where the water table is above the sampling depth. The surface area directly above the sampler should not be covered in any manner that would interfere with the normal percolation of soil moisture down to the depth of the sampler.

The samplers are normally installed vertically in the soil. However, they can be installed at an angle if this is necessary to reach some otherwise inaccessible point.

The samplers are available in various stock lengths for installation at depths up to 6 ft. Extra length samplers can be provided on special order, if this is necessary. However, for depths greater than 6 ft. it is normally less expensive to use the Model 1920 Pressure-Vacuum Soil Water Sampler.

The Model 1900 Soil Water Sampler has been designed so that the body tube of the sampler projects 2" above the soil surface when the sampler is installed to the proper depth, as shown in the figure to the left.

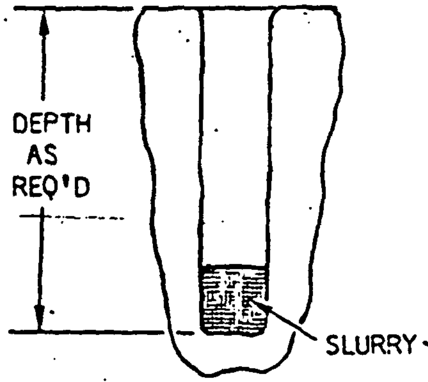


CORING THE HOLE

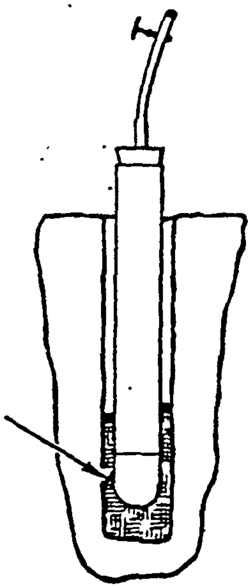
In rock-free uniform soils at shallow depths, use a 2" screw or bucket auger for coring the hole.

If the soil is rocky, a 4" auger should be used. The soil should then be sifted through a 1/4" mesh screen to free it of pebbles and rocks. This will provide a reasonably uniform backfill soil for filling in around the soil water sampler. The Model 230 Series Soil Augers can be used for this purpose.

INSTALLATION OF SOIL WATER SAMPLER USING A SOIL SLURRY



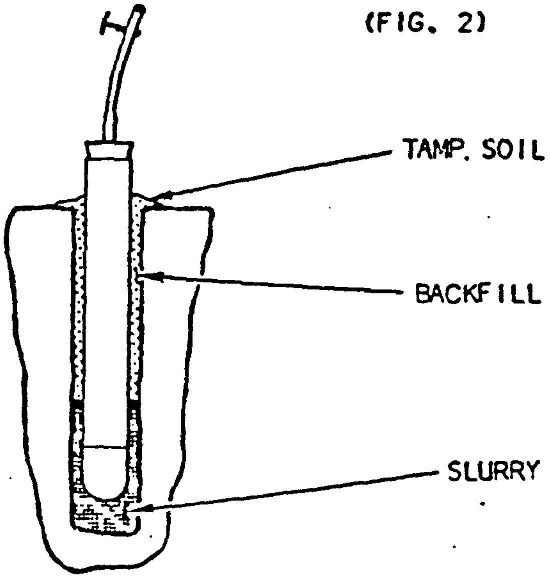
(FIG. 1)



(FIG. 2)

(Fig. 1) After the hole has been cored, mix a substantial quantity of soil from the bottom of the hole with water to make a slurry which has a consistency of cement mortar. This slurry is then poured down to the bottom of the cored hole to insure a good soil contact with the porous ceramic cup.

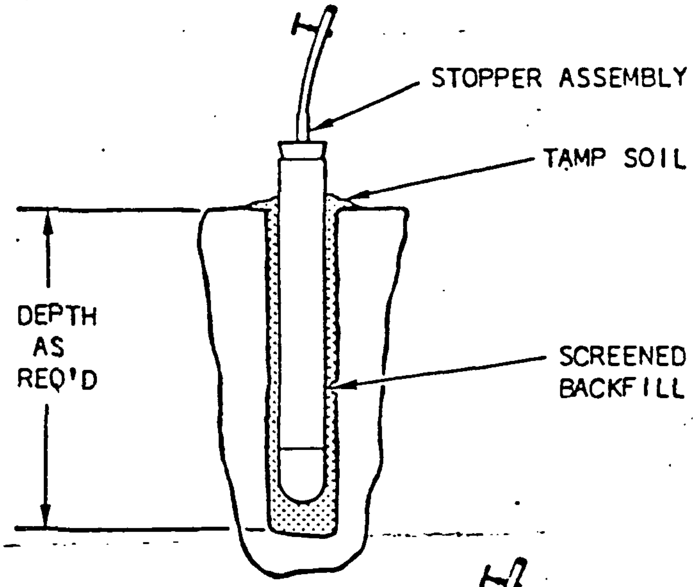
(Fig. 2) Immediately after the slurry has been poured, push the soil water sampler down into the hole so that the porous ceramic cup is completely embedded in the soil slurry.



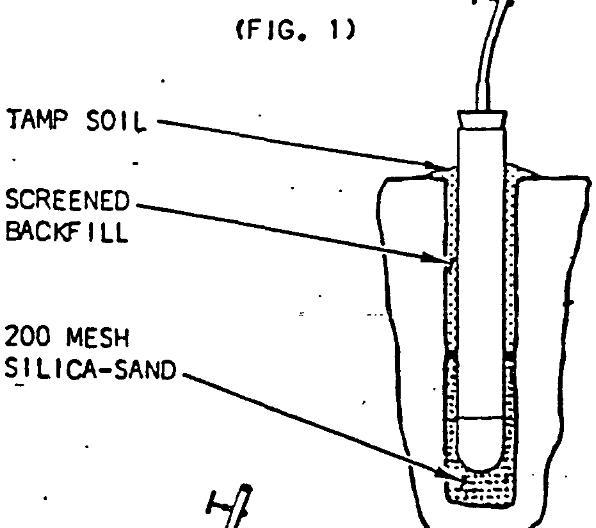
(FIG. 3)

(Fig. 3) Backfill the remaining area around the soil water sampler, tamping soil firmly, to prevent surface water from running down the cored hole. Backfill hole with native soil free of pebbles and rocks.

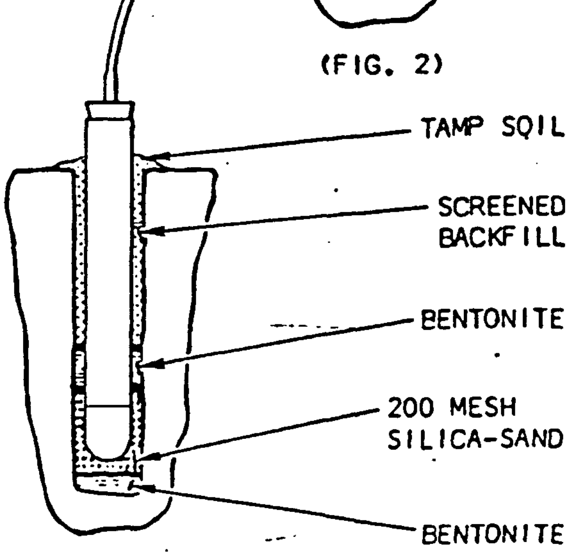
ADDITIONAL METHODS OF INSTALLING THE SOIL WATER SAMPLER



(FIG. 1)



(FIG. 2)



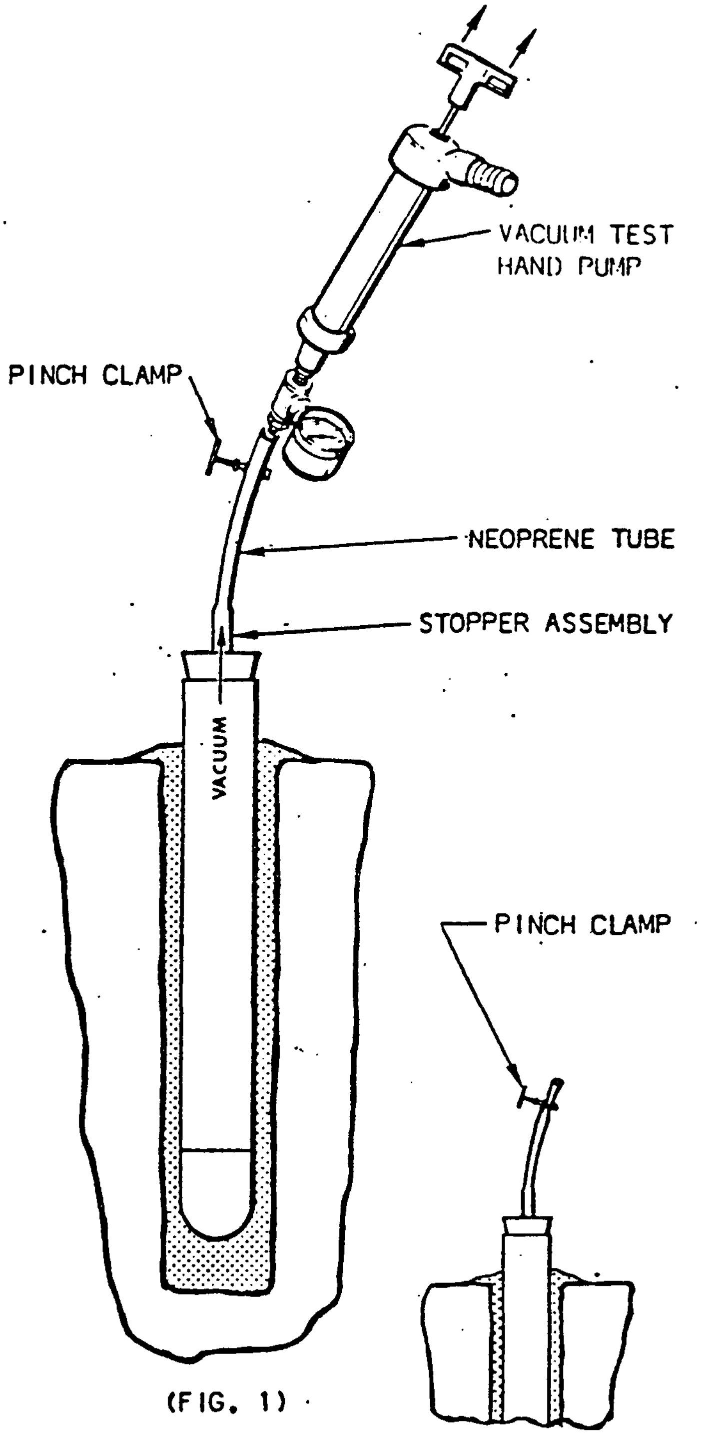
(FIG. 3)

(Fig.1) Core hole to desired depth, insert soil water sampler and backfill the hole with native soil, tamping continuously to insure good soil contact with the porous ceramic cup and complete sealing of the cored hole.

(Fig.2) Core hole to desired depth, pour in a small quantity of crushed 200 mesh pure silica-sand of almost talcum powder consistency (commercially available under trade names of Super-Sil and Silica Flour). Insert soil water sampler and pour another layer of the 200 mesh silica-sand at least six inches deep around cup of the soil water sampler. Backfill the hole with soil free of pebbles and rocks, tamping continuously with a long metal rod to insure against surface water channeling down between the soil and the body tube of the sampler.

(Fig. 3) Core hole to desired depth, pour in a small quantity of wet bentonite clay. This will isolate the sampler from the soil below. Pour in a small quantity of 200 mesh silica-sand and insert soil water sampler. Pour another layer of 200 mesh silica-sand at least six inches deep around the cup of the soil water sampler. Again, add a small quantity of bentonite as a plug to further isolate the ceramic cup and guard against possible channeling of water down the hole. Backfill the remainder of the hole with native soil free of pebbles and rocks tamping continuously with a long metal rod.

There are other methods of installing the soil water sampler that may be used, largely dictated by the type of soil you are concerned with and the tools available. The primary concern in any method of installation is that the porous cup of the sampler be in tight, intimate contact with the soil, so that soil moisture can move readily from the pores of the soil through the pores in the ceramic cup and into the soil water sampler.



(FIG. 1)

(FIG. 2)

COLLECTING SOIL WATER SAMPLE

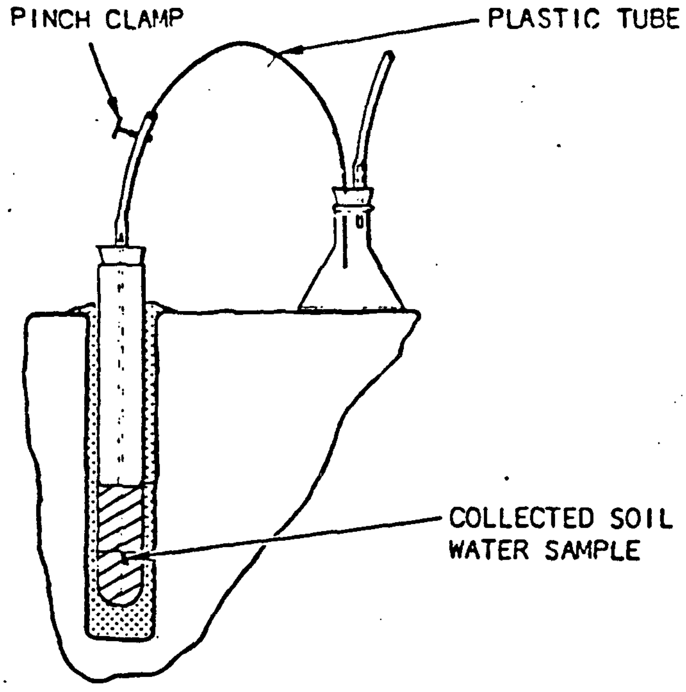
After the soil water sampler has been installed in the field, the accessory items as shown on page 6 are used for collecting a soil water sample.

(Fig.1) To collect a sample, the pinch clamp on the stopper assembly is opened. The serrated tube fitting on the end of the vacuum dial gauge adapter is then inserted into the neoprene tube of the stopper assembly. The vacuum hand pump is then stroked until a vacuum of perhaps 60 centibars (18" of mercury) is created within the sampler, as read out on the vacuum dial gauge.

(Fig.2) The pinch clamp is then closed securely to seal the sampler under vacuum. The hand pump can then be removed for other uses. The sampler is allowed to set for a period of time under vacuum.

The vacuum within the sampler causes the moisture to move from the soil, through the porous ceramic cup, and into the sampler. The rate at which the soil solution will collect within the sampler depends on the capillary conductivity of the soil, the soil suction value within the soil (as measured with tensiometers), and the amount of vacuum that has been created within the sampler. In moist soils of good conductivity, at field capacity (10 to 30 centibars of soil suction as read on a tensiometer), substantial soil water samples can be collected within a few hours. Under more difficult conditions it may require several days to collect an adequate sample.

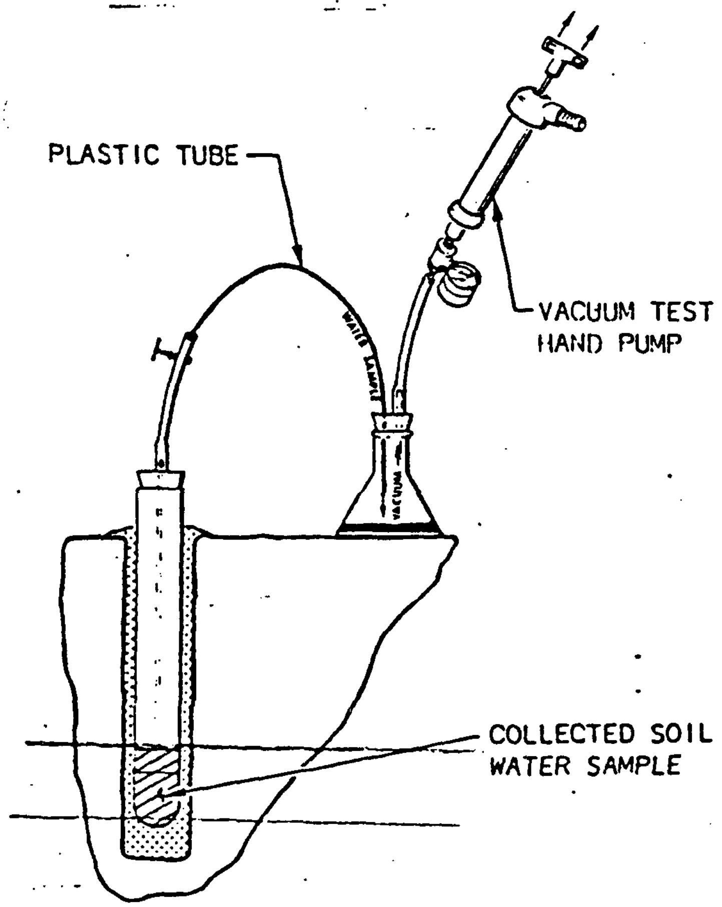
In general, vacuums of 50 to 85 centibars (15" to 25" of mercury) are normally applied to the soil water sampler. In very sandy soils it has been noted, however, that very high vacuums applied to the soil water sampler seem to result in slower rate of collection of the sample than lower applied vacuums. It is our feeling that in these coarse, sandy soils, the high vacuum within the sampler may deplete the moisture in the immediate vicinity of the porous ceramic cup and hence reduce the capillary conductivity, which creates a barrier to the flow of moisture to the cup under these circumstances. In loams and gravelly clay loams, users have reported collection of 300 to 500 ml of solution over a period of a day with applied vacuum of 15" of mercury (50 centibars) when soils are at field capacity. On waste water disposal sites, some users have obtained up to 1500 ml of sample within 24 hours after cessation of irrigation with 1" to 2" waste water on sandy or clay loam soil.



(FIG. 3)

(Fig.3) To remove the soil water sample from the sampler, a simple assembly is usually made up consisting of a small diameter (3/32" O.D. or less) plastic tube, a two-hole rubber stopper, a flask or bottle, as shown.

The pinch clamp on the sampler is opened and the small diameter plastic tube is inserted into the end of the neoprene tube on the stopper assembly and pushed down until it reaches the bottom of the sampler.



(FIG. 4)

(Fig.4) The vacuum hand pump is then connected to the other hole in the stopper. Stroking the hand pump creates a vacuum within the bottle or flask which in turn sucks the sample up from the sampler and into the collection bottle or flask.

If it is more convenient, the stopper assembly can be removed from the sampler so that the collected sample can be removed with a pipette or other means. However, repeated removal and replacement of the rubber stopper assembly can disturb the seal between the soil and the body tube of the sampler, particularly on shallow units.

Subsequent samples are collected by again creating a vacuum within the sampler and following the steps as outlined above.

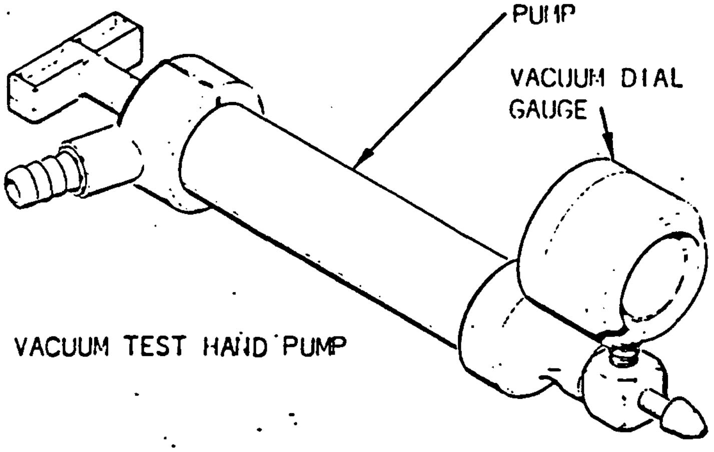
MAINTENANCE

There are no maintenance requirements for the soil water samplers other than protecting the exposed end of the body tube and the stopper assembly from physical damage. The end of the neoprene tube on the stopper assembly should be covered or plugged to prevent debris from entering the tube and later contaminating the sample.

Freezing conditions will not damage the samplers. The samplers are normally left permanently in place throughout the year.

ACCESSORY ITEMS FOR OPERATION OF THE SOIL WATER SAMPLER

1900K1 SERVICE KIT CONSISTING OF:



TUBING

1/16" O.D. X 1/64" WALL NYLON TUBE

5/64" O.D. X 1/64" WALL NYLON TUBE

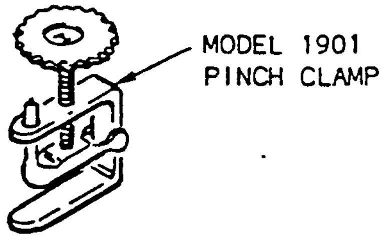
3/32" O.D. X 1/64" WALL NYLON TUBE

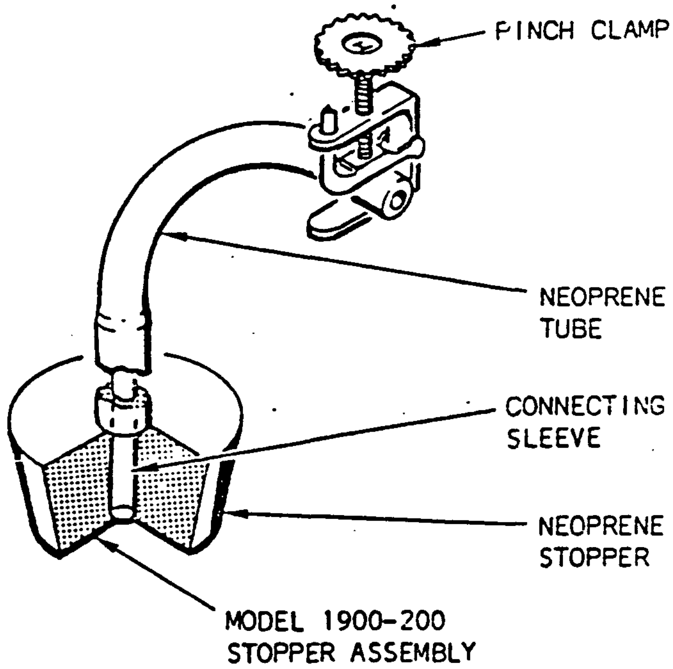
3/16" I.D. X 1/8" WALL NEOPRENE TUBE

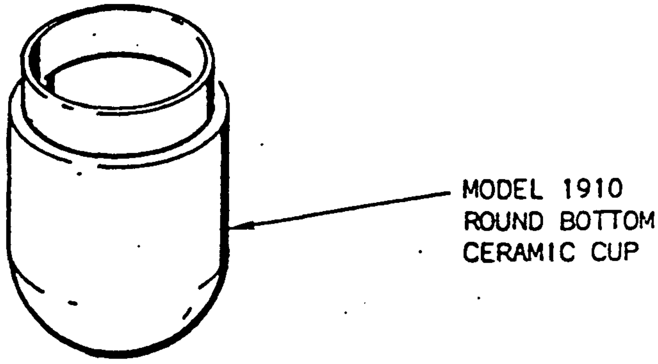
(ORDER NUMBER OF FEET REQUIRED)

NOTE:
ALL ACCESSORY ITEMS ARE AVAILABLE FROM SOILMOISTURE EQUIPMENT CORP.

REPLACEMENT ITEMS FOR THE SOIL WATER SAMPLER





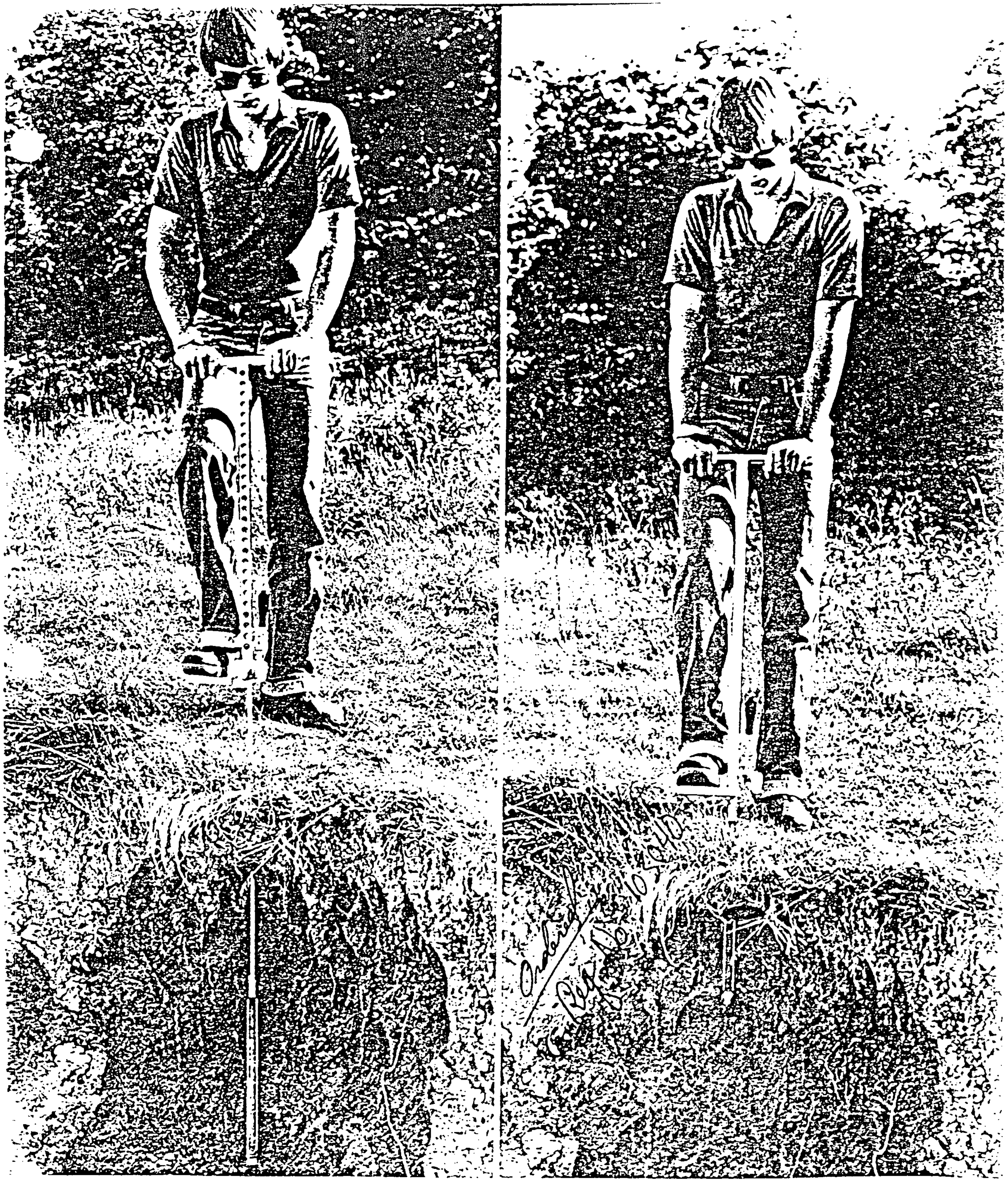


SOILMOISTURE EQUIPMENT CORP. P.O. BOX 30025, SANTA BARBARA, CALIF. 93105 U.S.A.

Phone no 505-964-3525 5-2-83

APPENDIX II-1-2

JMC Soil Investigation Equipment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JMC SOIL INVESTIGATION EQUIPMENT

Catalog No. 6

II-1-50

CLEMENTS ASSOCIATES, INC.
JMC Soil Investigation Equipment
R.R. No. 1; Box 162 A
Newton, Iowa 50208 U.S.A.
Phone: (515) 792-8285

Dear Customer;

I am delighted to present our latest catalog to you. In it you will find some new items; The JMC Conventional T-Handle; The JMC Turf Specialist System; and The JMC bucket Augers for setting neutron probe access tubes.

Our equipment is the finest made. It is easiest to use. It takes the most accurate samples. It will last the longest and in the long run will be the least expensive.

Here is what a few of our customers say about JMC Soil Investigation Equipment:

> .."We have had excellent success with the JMC equipment we have. The first unit has survived 2½ years with no problems at all."--Irrigation Engineer,North Dakota.
>
> .."We used it in heavy clay soils and had no trouble with it plugging as the probes with removable tips do." ---Soil Scientist,Iowa.
>
> .."After cutting wood the day before,I was grateful for the Backsaver Handle."--Soil Scientist,Indiana.
>
> .."Based on a trial period,I feel the JMC equipment is so superior to other equipment. We would be very pleased to use them for soil mapping next year."--Soil Scientist, Iowa.

I look forward to hearing from you soon.

Sincerely,

James M Clements
James M.Clements
dvc

ITEM 1, BACKSAVER HANDLE

If you are doing deep soil sampling from 18 inches (46 cm) to 46 inches (117 cm), the Backsaver Handle and JMC Sampling Tubes can save you a lot of work. Whether you are mapping soils, taking fertility samples, checking the depth of the water table, planting moisture sensing equipment or performing some other type of subsurface investigation, you will find the Backsaver Handle and JMC Sampling tubes get the job done faster, easier and more accurately than any other hand operated equipment.

The Backsaver Handle is a revolutionary piece of hand operated soil investigation equipment. It has three features which no other handle for a soil sampling tube has: (1) The Backsaver Handle eliminates bending over to "pull" the core out of the ground. (2) The soil sampling tube is pushed into the ground by foot pressure. (3) A special cleaning device is mounted on the side of the Backsaver Handle. Many serious back injuries have resulted from "pulling" a soil sampling tube. With a conventional hand grip and rod combination the hand grip becomes closer to the ground with each successive section of the core that is pulled. The force required to pull the core can be more than 300 pounds, with the average being about 80 to 90 pounds. A person can most safely produce the greatest lifting force by using his legs. No matter from what depth the section of the core is being pulled the hand grip of the Backsaver Handle is at the ideal height so that one never has to bend over and lift with his back.

A soil sampling tube fitted with a conventional rod and hand grip is forced into the ground by pushing downward on the hand grip. Shoulder, wrist and arm injuries can result, particularly when working with hard ground conditions. A big advantage to the Backsaver Handle is that you can use all of your body weight to force the tube into the ground by stepping on the foot pedal. No more sore arms and shoulders. No more jumping on the handle to force the tube into the ground.

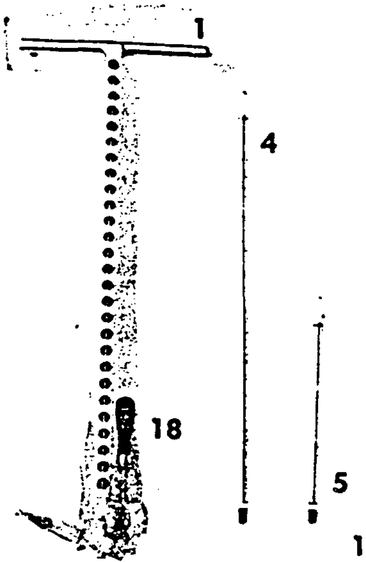
The Backsaver Handle and JMC Sampling Tubes are of a superior quality to any hand operated soil investigation equipment made. The Backsaver Handle is made of strong, lightweight, square tubing with a hand grip of round steel tubing. Viewing holes are spaced along the front to enable one to see the depth to which he has sampled. All parts are chrome plated and each Backsaver Handle comes equipped with a Special Cleaner.

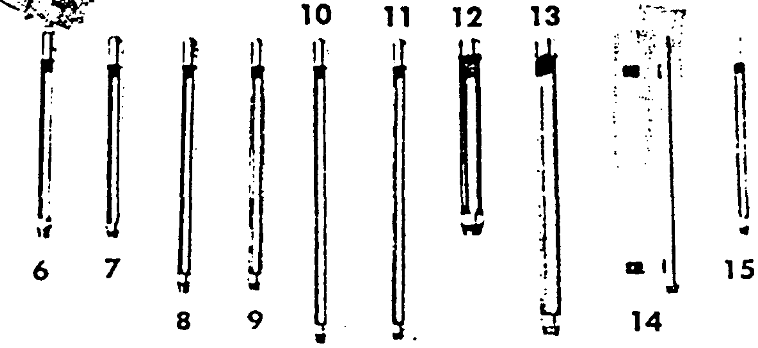
U.S. Patent Nos.
4, 106, 576; 4, 098, 360
Canadian Patent No. 1, 092, 389

Actual weight of Backsaver Handle with Cleaner 5.75 lbs. (2.61 kg.).

Actual weight of Backsaver Handle, Special Cleaner, and 18" Tube 6.63 lbs. (3.01 kg.).

All of the JMC Sampling Tubes pictured at lower left, Items 6 through 15, can be used with the Backsaver Handle.





SOME OF THE BACKSAVER HANDLE USERS ARE: Soil Conservation Service, Forest Service, City Engineers, Lumber and Paper Companies, Fertilizer Dealers, City Sanitarians, Farmers, Departments of Transportation, Irrigators, Farm Management Services, Environmental Consultants, Land Developers, Ecologists, Fruit Growers, Department of Nuclear Energy, Paleontologists, Truck Gardens, Archaeologists, Seed Companies, Nurseries, Agricultural Chemical Companies, Agricultural Consultants, Golf Course Maintenance Companies, Civil Engineers, Coal Mines, Coal Mining Land Reclamation Companies, Health Department, Extension Service, Geological Surveys, Science Teachers, Earthmoving Contractors, Vocational Agriculture Instructors, Agriculture Research Service, Department of Army, National Park Service, Department of Environmental Quality.

ITEM 2. BACKSAVER N-3 HANDLE.

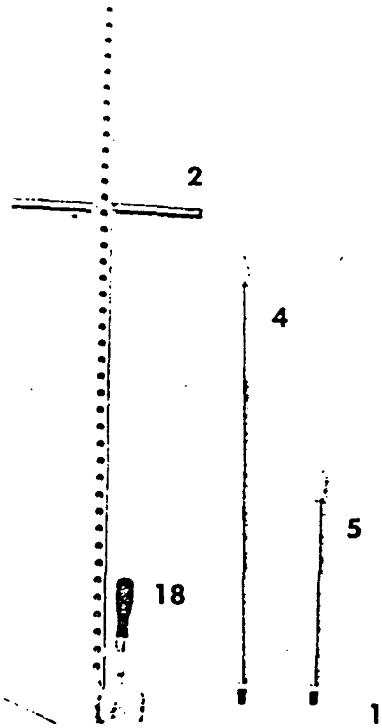
Do you sample deeper than 46 inches (116 cm)? Then this is the Handle for you. It will sample to a depth of 66" (168 cm), when using an 18" (45.7 cm). JMC Sampling Tube. This time and work saving Handle is an extended version of our Backsaver Handle. It has the same quality features: viewing holes to check the depth you have obtained, a waist level hand grip, foot pedal and a Special Cleaner. All steel parts are chrome plated for corrosion and abrasion resistance.Either of the Extensions (Item 4 or 5) may be used as well as all the tubes pictured (Items 6-15). GIVE YOUR BACK SOME REST FROM STRAINING AT THOSE "DEEP" SAMPLES, USE THE JMC BACKSAVER N-3 HANDLE.

Actual weight of backsaver N-3 Handle with Cleaner 8.28 lbs. (3.75 kg.).

Actual weight of Backsaver N-3 Handle, Cleaner, and 18" Tube 9.16 lbs. (4.15 kg.).

WHO USES THE JMC BACKSAVER N-3 HANDLE?

The Soil Conservation Service, Health Departments, Civil Engineers, Land Developers, Department of Army, National Park Service, City Engineers, and Ecologists are a few.



ITEMS 4 AND 5. ROD EXTENSIONS.

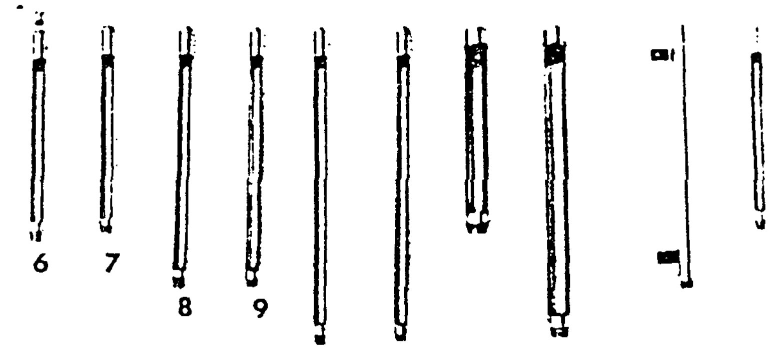
If you need to go just a little farther than our JMC Backsaver or N-3 Handles will allow, then you'll need one or more of the Rod Extensions. Many of the Backsaver Handles and Backsaver N-3 Handle users have one or two Rod Extensions thus enabling them to sample to depths of 8 to 10 feet (244 cm to 305 cm). JMC Rod Extensions are made of high strength steel and available in 26 inch (66 cm) and 13 inch (33 cm) lengths. The Rods are completely chrome plated for wear and corrosion resistance. The position of the open face of the sampling tube to the front of the probe handle can easily be adjusted by means of a locking nut.

ITEM 4. JMC ROD EXTENSION, 26" (66 cm).

Actual weight 1.56 lbs. (.71 kg.).

ITEM 5. JMC ROD EXTENSION, 13" (33 cm).

Actual weight .81 lbs. (.37 kg.).



ITEM 3, BACKSAVER N-2 HANDLE.

For "plow layer" sampling there is no comparing the ease of operating the Backsaver N-2 Handle and JMC Sampling tube to the difficulty of using other sampling equipment. You push the JMC Sampling Tube into the ground by stepping on the foot pedal of the N-2. No more sore arms and shoulders. No more jumping on the handle to force the tube into the ground. Under hard ground conditions the Backsaver N-2 Handle and JMC Sampling Tube may be the difference between getting a good sample or not getting any sample. The hand grip of the N-2 is at a comfortable level so that it is not necessary to bend over during sampling.

The N-2 is designed for shallow or "plow layer" soil sampling. It does not telescope. An N-2 with a 15" JMC Sampling Tube will sample to a depth of 15". Each N-2 Handle comes equipped with a "Special Cleaner" mounted on the side.

Power equipment is nice to have but it is very expensive and not always easy to transport it to those "back 20 acres" that need to be sampled. The N-2 is sturdy, durable, and easily carried on foot, tractor, pickup, or combine. Instead of waiting until after the crops are harvested fields can be sampled while crops are growing. Areas that are not producing well can be easily identified and sampled with the N-2. It is impossible to sample during the growing season with power equipment.

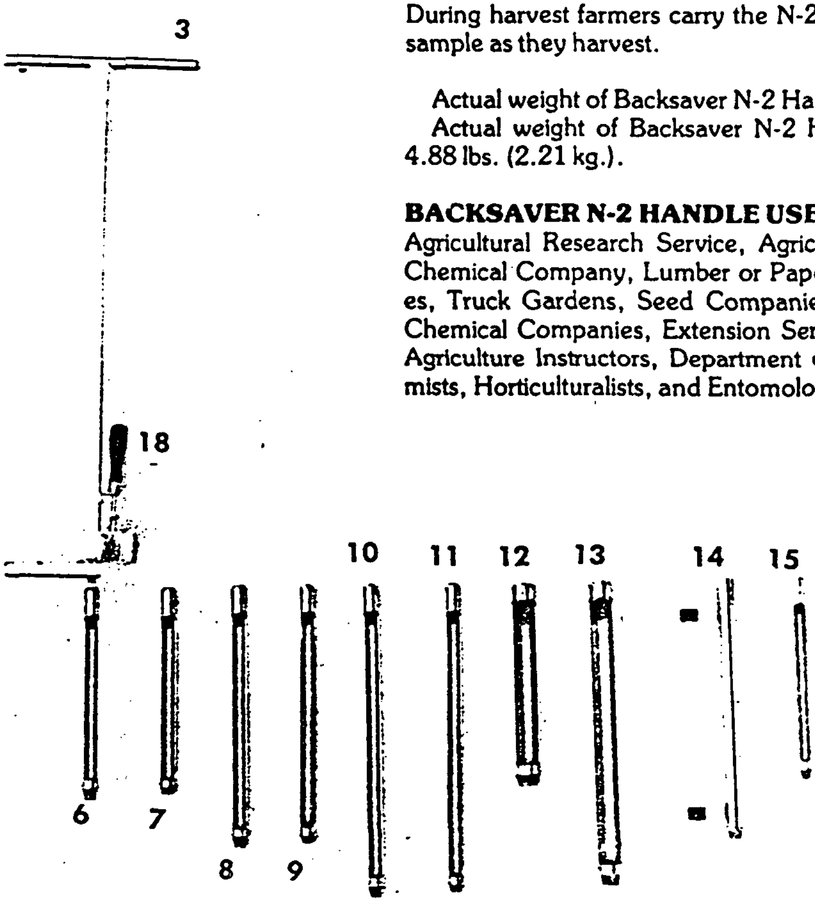
During harvest farmers carry the N-2 with them on the tractor or combine and sample as they harvest.

Actual weight of Backsaver N-2 Handle with Cleaner 4 lbs. (1.81 kg.).

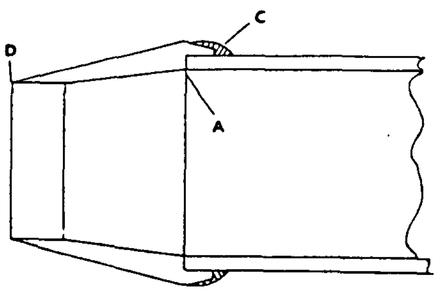
Actual weight of Backsaver N-2 Handle, Cleaner and 18" Sampling Tube 4.88 lbs. (2.21 kg.).

BACKSAVER N-2 HANDLE USERS:

Agricultural Research Service, Agricultural Consultants, Forest Service, Dow Chemical Company, Lumber or Paper Companies, Farm Management Services, Truck Gardens, Seed Companies, Nurseries, Farmers, Fertilizer Dealers, Chemical Companies, Extension Service, Earth Science Teachers, Vocational Agriculture Instructors, Department of Army, National Park Service, Agronomists, Horticulturalists, and Entomologists.

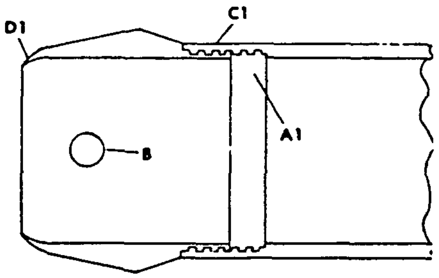


U.S. Patent No. 4, 106, 576
Canadian Patent No. 1, 092, 389

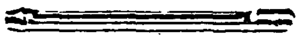


JMC

FIG. 3



OTHERS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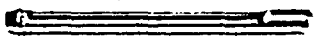
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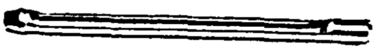
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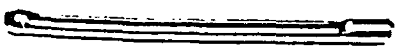

9

WHY JMC SAMPLING TUBES ARE BETTER.

- JMC Sampling Tubes are made of DOM steel tubing which is a great deal stronger than the mechanical tubing used by our competitors.
- Smooth interior surface of the JMC Tube (A) does not collect debris which causes the sample to jam inside the tube. The internal threads used to attach "screw on" tips leave a rough groove (A1) for the core to catch upon. The core also tends to drag and catch on the drilled hole (B) found in the "screw on" tip.
- The end of the tube portion of the sampling tube with a screw on tip (C1) "bells" out and allows the tip to come off. The tip of the JMC Sampling Tube is permanently welded on (C) and can not be lost.
- Cutting edge (D) of JMC tip is sharp and "wears sharp while the cutting edge of the screw on tip is blunt. Once the rolled edge at D1 wears smooth, the sample tends to jam because the core is the same diameter as the inside of the sampling tube.
- The tips on JMC Sampling tubes are made of a high strength alloy steel which is hardened to resist breakage and abrasion.
- All of the JMC Sampling Tubes will fit on any of the Backsaver Handles.
- The JMC Sampling Tube will consistently cut an undisturbed core which can be easily removed from the tube.

ITEMS 6 THROUGH 11, SMALL DIAMETER JMC SAMPLING TUBES.

A large variety of people use these tubes because of the superior performance that JMC Sampling Tubes give. The tips of JMC Sampling Tubes are designed to give the easiest penetration of any hand operated equipment. There are two styles of tips: Wet, for moist or wet soils; Dry, for hard dry conditions. The tubes come in three lengths— 12" (30.5 cm), 15"(38.1 cm), and 18" (45.7 cm). The Wet Tip cuts a diameter of 11/16" (17 mm) and the Dry Tip cuts a ¾" (19 mm) diameter core. You will be delighted at how easily the core of soil is removed from the JMC Sampling Tube. In most cases it will only be necessary to rotate the open side of the tube so the core rolls out of the tube. The bright chrome plating creates a smooth surface to cradle the undisturbed core as it is pulled from the ground.

ITEM NO. 6, JMC SAMPLING TUBE 12" WET TIP, SMALL DIAMETER

Actual weight .69 lbs. (.31 kg.).

ITEM NO. 7, JMC SAMPLING TUBE, 12" DRY TIP, SMALL DIAMETER

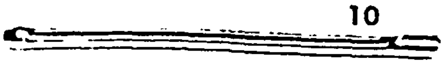
Actual Weight .69 lbs. (.31 kg.).

ITEM NO. 8, JMC SAMPLING TUBE, 15" WET TIP, SMALL DIAMETER.

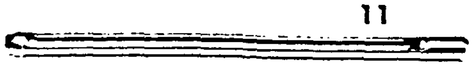
Actual weight .75 lbs. (.34 kg.).

ITEM NO. 9, JMC SAMPLING TUBE, 15" DRY TIP, SMALL DIAMETER.

Actual Weight .75 lbs. (.34 kg.).

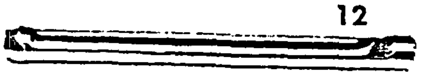


ITEM NO. 10. JMC SAMPLING TUBE. 18" WET TIP, SMALL DIAMETER.
Actual weight .88 lbs. (.40 kg.).

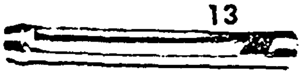


ITEM NO. 11. JMC SAMPLING TUBE. 18" DRY TIP, SMALL DIAMETER.
Actual weight .88 lbs. (.40 kg.).

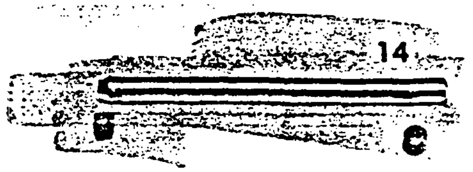
ITEMS 12 AND 13. JMC SAMPLING TUBES 1¼" (3.2 cm) DIAMETER.
The JMC Large Diameter (1¼ or 3.2 cm) Sampling Tubes are used for field demonstrations to large groups or any time a large volume of soil is needed. As with all JMC Sampling Tube tips, the "wears" sharp feature makes them far superior to any other large diameter sampling tubes. The socket end is welded to the tube, as is the tip. Neither will come off. The Heat-Treated tips are more resistant to breakage and abrasion. The entire tube is chrome plated for protection against corrosion and ease of cleaning. Our Large Diameter Tubes come in two lengths, 12" (30.5 cm) and 18" (45.7 cm).



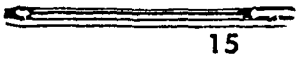
ITEM 12. JMC SAMPLING TUBE. 1¼" x 12".
Actual weight 1.37 lbs. (.62 kg.).



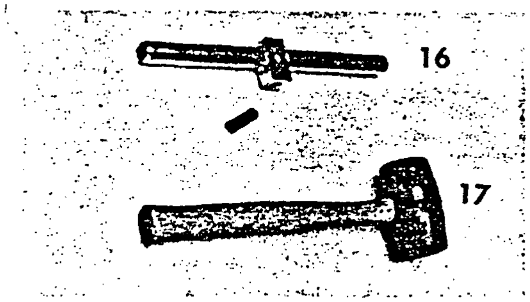
ITEM 13. JMC SAMPLING TUBE. 1¼" x 18".
Actual weight 1.69 lbs. (.77 kg.).



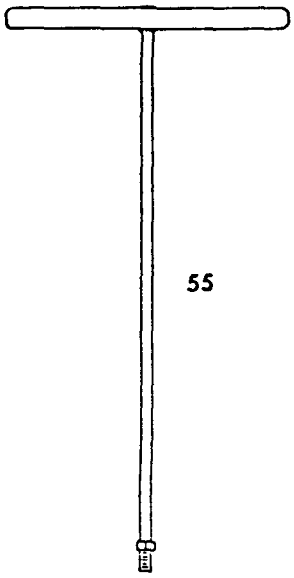
ITEM 14. JMC "O" CONTAMINATION TUBE.
Testing for residues? Then our "O" Contamination Tube is the tube for you. The soil core is contained in a removable rigid acetate liner. The sample can not receive surface contamination since it is completely enclosed within the acetate liner. The diameter of the core is .90 inch. Ten liners and twenty caps are supplied with the tube. The caps make it possible to cap the core for transporting to the office or laboratory. The liners may be washed and reused. Extra sets may be ordered as well. This can be a very important tool in Soil Survey work as well as Chemical Residue Studies. A heat shrink tube is being developed for the "O" Contamination Tube. It will make it possible to run water percolation tests on cores taken with the "O" Contamination Tubes.
Actual weight of Tube and one liner 1.88 lbs. (.85 kg.).



ITEM 15. JMC MOISTURE METER TUBE.
Setting soil moisture meters? Then this tube will be the one to use. The hole produced by this tube is .88 inch (2.2 cm) in diameter, the exact size required for optimum contact on many moisture sensing devices such as ones manufactured by the Irrometer Company. It can be used as a soil sampler, too. The core diameter is .56 inches (1.4 cm). It comes 12" (30.5 cm) long. The materials and construction are the same type used in other JMC Tubes; DOM steel tubing, smooth interior surface. The welded tip "wears" sharp, and is heat treated. The entire tube is chrome plated.
Actual weight .75 lbs. (.34 kg.).



WHO USES THE JMC SAMPLING TUBES?
Soil Conservation Service, Agricultural Research, Agricultural Consultants, Geologists, Archaeologists, Forest Service, Lumber and Paper Companies, Sanitarians, Civil Engineers, Farm Management Services, Land Developers, Fruit Growers, Truck Gardens, Seed Companies, Farmers, Irrigators, Fertilizer Dealers, Chemical Companies, Environmental Consultants, Golf Course Maintenance Companies, Coal Mining Companies, Coal Mining Land Reclamation Companies, Earth Science Teachers, Vocational Agricultural Teachers, The Department of Nuclear Energy, National Park Service, Agronomists, Horticulturists, Entomologists, Meteorologists, and Climatologists are a few of the many people who are pleased with our product.



[illegible] HANDLE

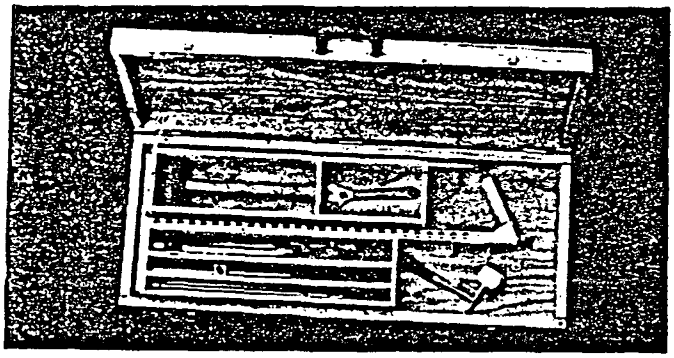
[illegible] ...tions? Then use [illegible] JMC Rod Extensions [illegible] Handle), and any [illegible] 15), you'll be able to [illegible] depth by striking the [illegible] as item 17. The hand grip [illegible] the center section is solid steel [illegible] The handle combines econo- [illegible] for extremely difficult sampling [illegible] page 6.

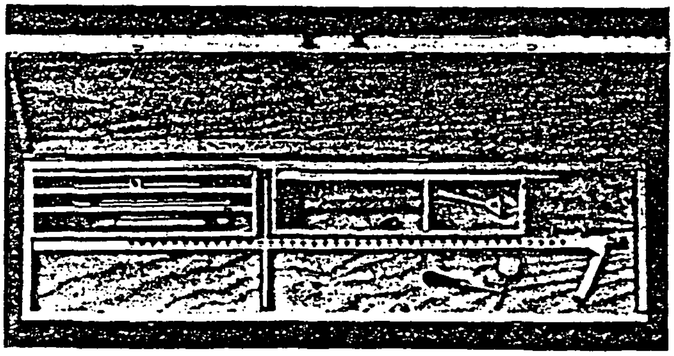
[illegible] (.51 kg.).

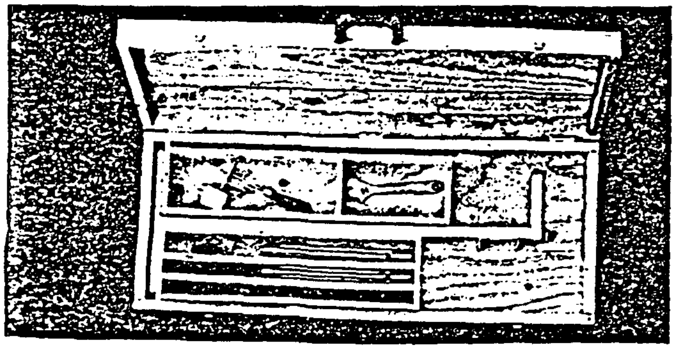
ITEM 17. DYALON MALLET.

[illegible] that retains its shape, absorbs those arm aching [illegible] not injure the JMC T-Handle. If you intend to [illegible] Handle then you'll need this mallet. It is made of [illegible] urethane—a tough and abrasive resistant substance. The [illegible] head is uniquely molded onto a hickory handle in a manner which makes the head integral with the handle. It absolutely can not loosen or come off. It will outperform any other soft faced mallet. Once you try one, you'll have to agree.

Actual weight 1.81 lbs. (.82 kb.). See picture on page 6.







ITEM 18. SPECIAL CLEANER.

Many have skinned and scraped their hands and fingers while trying to clean out sampling tubes. The JMC Special Cleaner will eliminate this painful experience. It is designed to clear the sampling tube of soil and apply a thin film of vegetable oil to the inside and outside of the sampling tube. (See "Cleaning of the soil sampling tube.") A JMC Special Cleaner comes with each JMC Handle but they may be purchased separately, as well.

Actual weight .38 lbs. (.17 kg.).

ITEM 19. JMC BACKSAVER HANDLE SAMPLING KIT.

This kit provides the Soil Scientist or Consultant with the equipment needed for sampling to depths of nearly eight feet. The case is made of exterior plywood and mahogany to provide a convenient and durable container for transporting and storing the Backsaver Handle and accessories. The equipment includes: 1— Backsaver Handle/Cleaner. 1— case, 2— 26" Rod Extensions, 1— 15" Dry Tip Sampling Tube, 1— 15" Wet Tip Sampling Tube, 1— 12" T-Handle, 1— Mallett, 1— 1¼" x 12" Sampling Tube, and 1— universal wrench.

Actual weight 28 lbs. (12.7 kg.)

ITEM 20. JMC BACKSAVER HANDLE SAMPLING KIT WITHOUT CARRYING CASE.

Same as Item No. 19 without case & universal wrench.

Actual weight 14.7 lbs. (6.7 kg.)

ITEM 21. JMC BACKSAVER N-3 HANDLE SAMPLING KIT.

This kit provides the Soil Scientist or Consultant with the equipment needed for sampling to depths of nearly ten feet. The case is made of exterior plywood and mahogany to provide a convenient and durable container for transporting and storing the N-3 and accessories. The equipment includes: 1— Backsaver N-3 Handle/Cleaner, 1— case, 2— 26" Rod Extensions, 1— 15" Dry Tip Sampling Tube, 1— 15" Wet Tip Sampling Tube, 1— 12" T-Handle, 1— Mallet, 1— 1¼" x 12" Sampling Tube, 1— universal wrench.

Actual weight 38 lbs. (17.2 kg.)

ITEM 22. JMC BACKSAVER N-3 HANDLE SAMPLING KIT WITHOUT CARRYING CASE.

Same as Item No. 21 without case & universal wrench.

Actual weight 17.2 lbs. (7.8 kg.).

ITEM 23. JMC BACKSAVER N-2 HANDLE SAMPLING KIT.

This kit provides the Scientist, Consultant, Fertilizer Dealer or Farmer with the equipment needed for "plow layer" soil sampling. The case is made of exterior plywood and mahogany to provide a convenient and durable container for transporting and storing the Backsaver N-2 Handle and accessories. The equipment includes: 1— N-2 Handle/Cleaner, 1— case, 1— 12" Wet Tip Sampling Tube, 1— 12" Dry Tip Sampling Tube, 1— universal wrench.

Actual weight 19 lbs. (8.6 kg.).

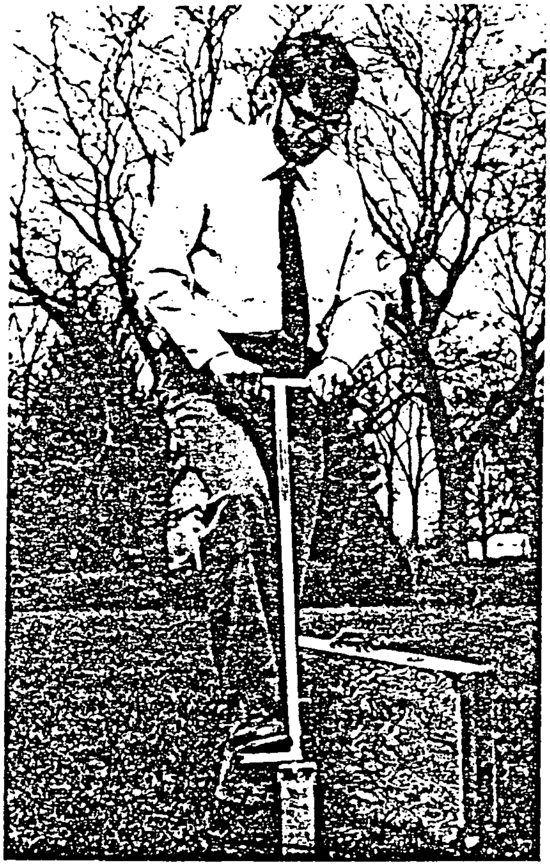
ITEM 55. JMC CONVENTIONAL HANDLE

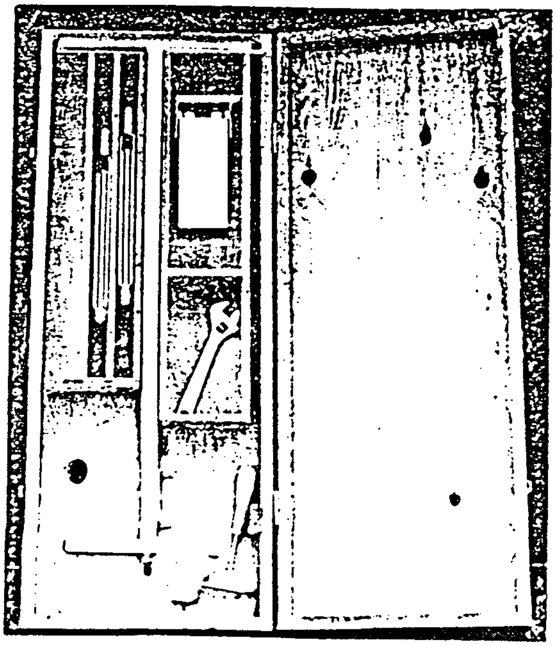
This Handle is for use in areas where the ground is soft. The handgrip is 12" wide and the rod is 24" long, and is made of the same high strength steel as our 26" extensions. It can be used with any of the JMC Sampling tubes. It is not to be pounded with a mallet.

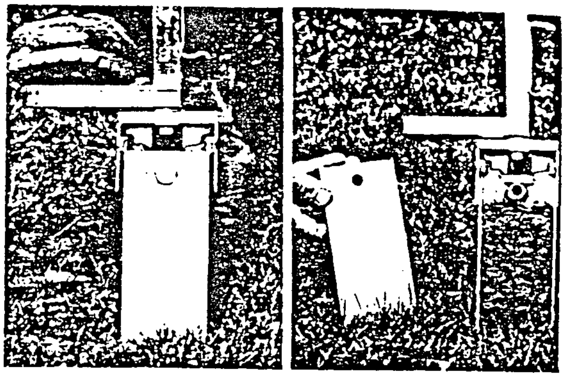
Actual weight 2 lbs. (.91 kg).

Introducing The JMC Turf Specialist System

Here is the equipment that you as a professional turf specialist need for taking accurate soil and turf samples.







N-2 Handle with JMC Turf Sampler **ITEM 51**

JMC Turf Sampler:

For many years professional turf specialist have recognized the value of taking profiles of turf for checking problem areas due to soil conditions, wetness, disease and insects. The JMC Turf Sampler lets you easily take a 7/8" x 3" profile section for examination and just as easily replace it in its original position. This is a great tool for demonstrating to others what the turf problems are below the surface of the ground.

JMC Greens Sampler:

Sampling greens has been a problem until now. Our other soil sampling equipment took an accurate sample but left a hole in the green that was too large to "heal over". The JMC Greens Sampler takes an accurate sample to a 6 inch depth and leaves only a ½" hole. It is constructed of DOM steel tubing with a hardened steel cutting tip.

JMC Greens Sampler

ITEM 52

JMC Turf Specialist Sampling System

The complete system consists of: 1-Backsaver N-2 Handle with Special Cleaner; 1-JMC Turf Sampler; 1-Handle with Greens Sampler; 1-JMC Sampling Tube, 12" Wet Tip; 1 JMC Sampling Tube, 12" Dry Tip; 1-Carrying Case; 1-universal wrench. All of the equipment in the JMC System is made of the highest quality materials and chrome plated to resist abrasion and corrosion. JMC Soil Investigation Equipment has been preferred by professional Soil Scientists for many years.

Case and Equipment

ITEM 53

HOW DOES THE BACKSAVER HANDLE WORK

Procedure used to pull a soil core with a sampling tube equipped with the "Backsaver Handle" or the "Backsaver N-3 Handle."

(1) Steady the soil probe in a nearly vertical position by grasping the handgrip with both hands. Force the sampling tube into the soil by stepping firmly on the footstep.

(2) Remove the first section of the core by pulling upward on the handgrip. Empty the sampling tube and clean. (see "cleaning of the soil sampling tube")

(3) Place the sampling tube in the original hole and push into the soil until the footstep is within an inch or two of the surface of the ground.

(4) While maintaining a slight pressure on the footstep pull upward on the handgrip, until the footstep has been elevated 6 to 8 inches above the surface of the ground.

(5) Maintain a slight upward pressure on the handgrip and step downward on the footstep. The footstep now grips the rod and the sampling tube can be pushed into the soil until the footstep is within 1 or 2 inches above the ground.

(6) Steps 4 and 5 are repeated until the sampling tube is full. The depth of penetration can be determined by the position of the rod end which can be seen through the viewing holes in the side of the square portion of the Backsaver Handle. It is important not to push the sampling tube into the soil to a depth that exceeds the holding capacity of the tube as this jams the sample and can make removal from the ground extremely difficult.

(7) Remove the full sampling tube by lifting upward on the handgrip. After the sampling tube has been elevated 6 to 8 inches, push downward on the handgrip returning the footstep to within 1 to 2 inches of the surface of the ground.

(8) Empty the sampling tube and clean.

(9) Steps 3 through 8 are repeated until the desired depth is reached.

Procedure used to pull a soil core with a sampling tube equipped with the "Backsaver N-2 Handle."

Same as steps 1 and 2 above.

Cleaning of the soil sampling tube

Proper cleaning of the sampling tube insures two things:

(1) Greatly reduced lifting pressures.

(2) A better soil core.

First, clear the trough portion of the sampling tube by inserting part A (fig. 2) into the exposed sample and pulling part A along the length of the trough.

Second, remove the end plug from the sampling tube by placing part B over the end of the plug and pulling on the handle of the cleaner.

Third, after the sampling tube is clear of soil, use part C of the probe cleaner as follows: Apply a thin film of vegetable oil to the inside of the sampling tube using the C-2 portion of the special cleaner. Use the C-1 portion to apply a thin film to the outside. Work a film of oil into the tip using one's fingers. The nylon mesh covered sponge, part C, should be filled with vegetable oil each day. We recommend vegetable oil because it is harmless to the skin and washes off easily with soap and water. Once every week or two the sponge should be washed thoroughly using a liquid detergent.

JMC Backsaver Handles & JMC Sampling Tubes are marketed by:
CLEMENTS ASSOCIATES, INC. R.R. 1 • Box 162-A,
NEWTON, IOWA 50208
Phone (515) 792-8285
Printed in U.S.A.

STEP 1

STEP 5

STEP 7

FIG. 1

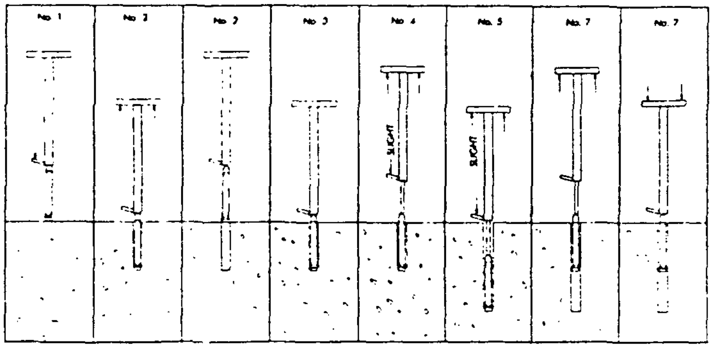
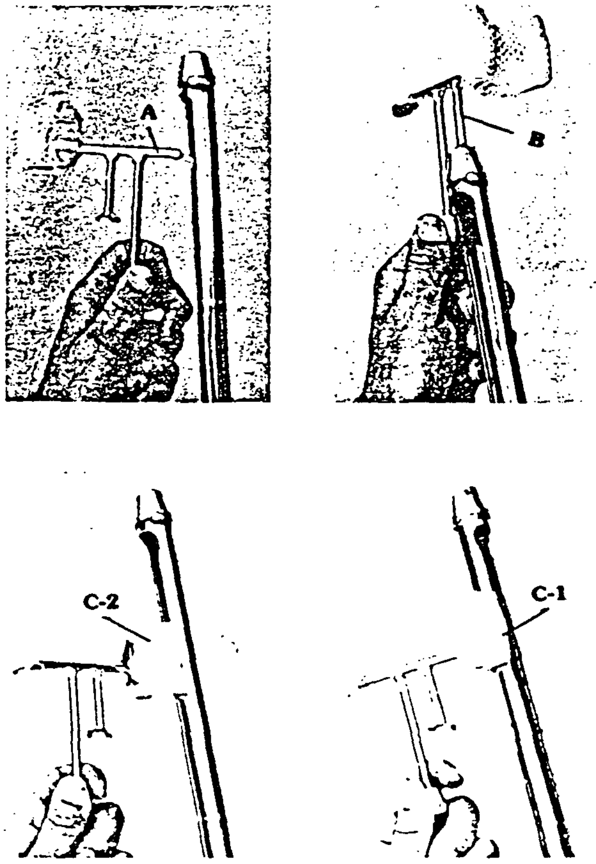


FIG. 2



ITEM 25, JMC AUGER HAND GRIP.

This lightweight Hand Grip is 16" (40.6 cm) long and made of the same high quality tubing with chrome plating as the JMC Sampling Tubes. You will need one of these to use your JMC Mud or Bucket Auger.

Actual weight 1.37 lbs. (.62 kg.).

ITEMS 26 AND 27, AUGER EXTENSIONS.

These lightweight extensions are made from strong, smooth tubing with a straight thread and flat shoulder joint which will not split. This is a joint that holds but comes uncoupled easily for disassembly. Both the 34" (Item 26) and the 45" (Item 27) are chrome plated for easier care.

ITEM 26, JMC AUGER EXTENSION 34" (86.4 cm)

Actual weight 2.31 lbs. (1.05 kg.)

ITEM 27, JMC AUGER EXTENSION 45" (114.3 cm)

Actual weight 2.97 lbs. (1.35 kg.)

ITEM 28, JMC MUD AUGER

If you sample peat, muck, extremely wet soils or soils with fragments too large for sampling tubes, the JMC Mud Auger may be the instrument you need. It is made of case hardened steel. The entire auger is chrome plated to resist corrosion and wear. A Hand Grip and two different lengths of Extensions are available. *Extensions may be hooked together for greater depths.*

Actual weight 1.75 lbs. (.79 kg.).

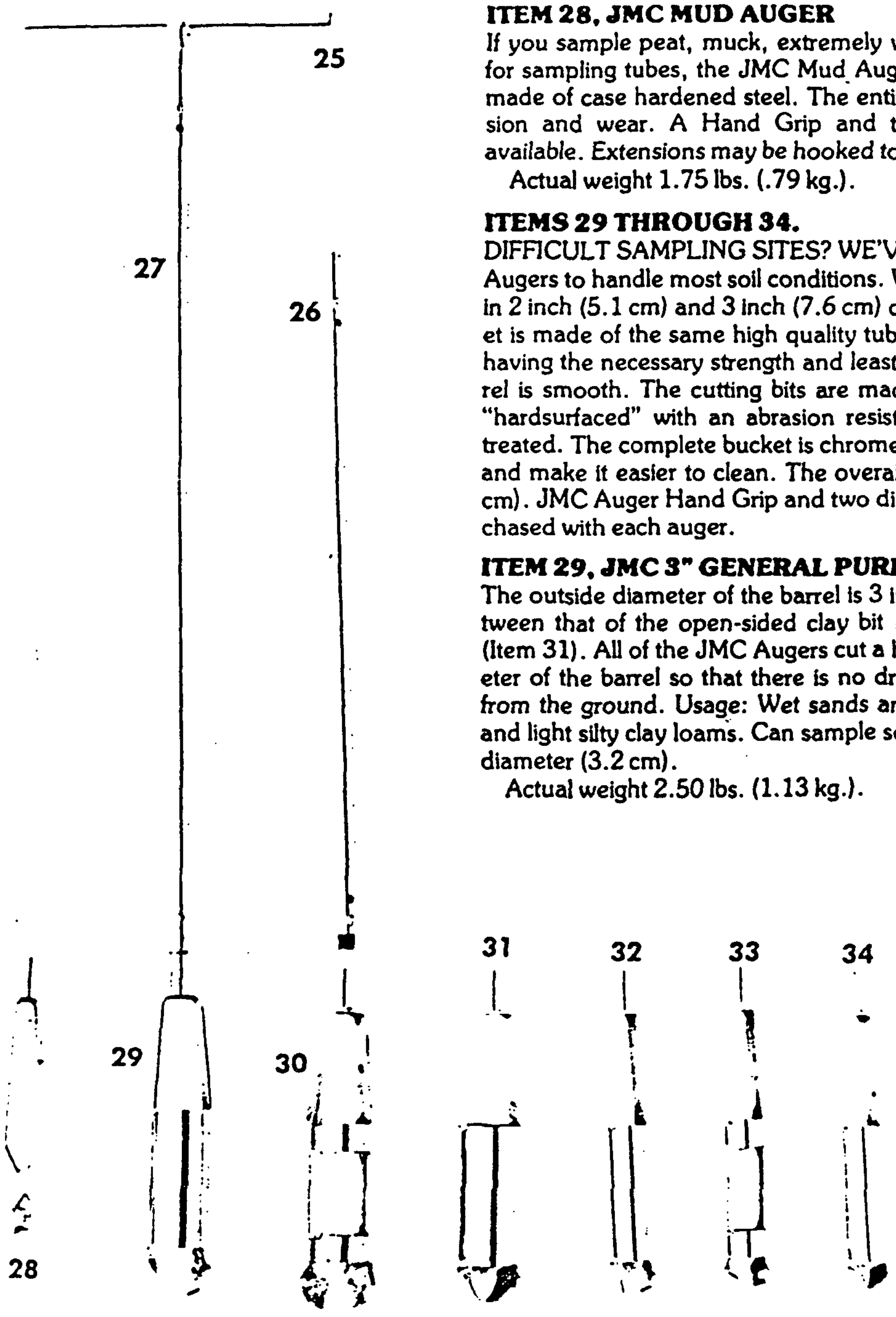
ITEMS 29 THROUGH 34.

DIFFICULT SAMPLING SITES? WE'VE GOT THE ANSWER! A line of Bucket Augers to handle most soil conditions. We manufacture 3 types of bucket augers in 2 inch (5.1 cm) and 3 inch (7.6 cm) diameters. The barrel portion of the bucket is made of the same high quality tubing as the JMC Sampling tubes. Besides having the necessary strength and least amount of weight, the inside of the barrel is smooth. The cutting bits are made of an alloy steel. The cutting edge is "hardsurfaced" with an abrasion resistant alloy. The entire cutting bit is heat treated. The complete bucket is chrome plated to prevent corrosion, resist wear, and make it easier to clean. The overall length of the bucket is 16 inches (40.6 cm). JMC Auger Hand Grip and two different lengths of Extensions may be purchased with each auger.

ITEM 29, JMC 3" GENERAL PURPOSE BUCKET AUGER.

The outside diameter of the barrel is 3 inches. The angle of the cutting bits is between that of the open-sided clay bit (Item 30) and the closed-sided sand bit (Item 31). All of the JMC Augers cut a hole slightly larger than the outside diameter of the barrel so that there is no drag on the bucket as it is being removed from the ground. Usage: Wet sands and gravels, dry or damp silts, silt loams, and light silty clay loams. Can sample soils with some fragments up to 1.25 inch diameter (3.2 cm).

Actual weight 2.50 lbs. (1.13 kg.).



JMC MUD AND BUCKET AUGERS ARE USED BY:

Soil Conservation Service, Civil Engineers, Environmental Consultants, Coal Mining Companies, Department of Army and The National Park Service.

ITEM 30, JMC 3" OPEN-SIDED CLAY BUCKET AUGER.
Instead of the closed barrel the sides have been removed so that the sample can be pushed sideways to empty the bucket. The angle of the cutting bits is very aggressive to enable it to penetrate hard clays. Usage: Wet silts, silt loams, damp to wet silty clays, and clays. Can sample soils with some fragments up to 1.25 inch diameter (3.2 cm). See picture on page 9.

Actual weight 2.25 lbs. (1.02 kg.).

ITEM 31, JMC 3" SAND BUCKET AUGER.
It is a closed-sided bucket auger. The cutting bit is the least aggressive of the three types of augers that we manufacture. The two cutting bits nearly touch. This allows the bucket to hold dry sands. Usage: Dry to wet sands and gravels, dry silts, and silt loams. Can sample soils with some fragments up to .75 inch diameter (1.9 cm). See picture on Page 9.

Actual weight 2.50 lbs. (1.13 kg.).

ITEM 32, JMC 2" GENERAL PURPOSE BUCKET AUGER.
The outside diameter of the barrel is 2 inches. The angle of the cutting bits is between that of the open-sided clay bit (Item 33) and the closed-sided sand bit (Item 34). All of the JMC Augers cut a hole slightly larger than the outside diameter of the barrel so that there is no drag on the bucket as it is being removed from the ground. Usage: Wet sands and gravels, dry or damp silts, silt loams, and light silty clay loams. Can sample soils with some fragments up to .75 inch diameter (1.9 cm). See picture on page 9.

Actual weight 1.88 lbs. (.85 kg.).

ITEM 33, JMC 2" OPEN-SIDED CLAY BUCKET AUGER.
Instead of the closed barrel the sides have been removed so that the sample can be pushed sideways to empty the bucket. The angle of the cutting bit is very aggressive to enable it to penetrate hard dry clays. Usage: Wet silts, silt loams, damp to wet silty clay loams, dry to wet silty clays, and clays. Can sample soils with some fragments up to 1.00 inch diameter (2.5 cm). See picture on page 9.

Actual weight 1.75 lbs. (.79 kg.).

ITEM 34, JMC 2" SAND BUCKET AUGER.
It is a closed-sided bucket auger. The cutting bit is the least aggressive of the three types of augers that we manufacture. The two cutting bits nearly touch. This allows the bucket to hold dry sands. Usage: Dry to wet sands and gravels, dry silts and silt loams. Can sample soils with some fragments up to .50 inch diameter (1.3 cm). See picture on page 9.

Actual weight 1.88 lbs. (.85 kg.).

ITEM 35, JMC MUD AUGER, HAND GRIP AND 34" EXTENSION.

Actual weight 5.43 lbs. (2.46 kg.).

ITEM 36, JMC MUD AUGER, HAND GRIP AND 45" EXTENSION.

Actual weight 6.09 lbs. (2.76 kg.).

ITEM 37, JMC BUCKET AUGER (SPECIFY WHICH AUGER WHEN ORDERING), HAND GRIP, AND 34" EXTENSION.

Actual weight—Add weights listed for each item.

ITEM 38, JMC BUCKET AUGER (SPECIFY WHICH AUGER WHEN ORDERING), HAND GRIP, AND 45" EXTENSION.

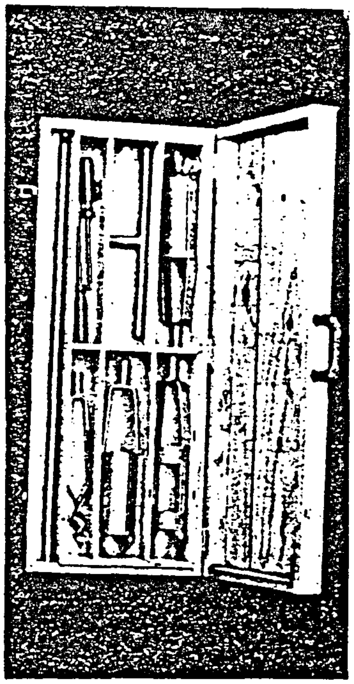
Actual weight—Add weights listed for each item.

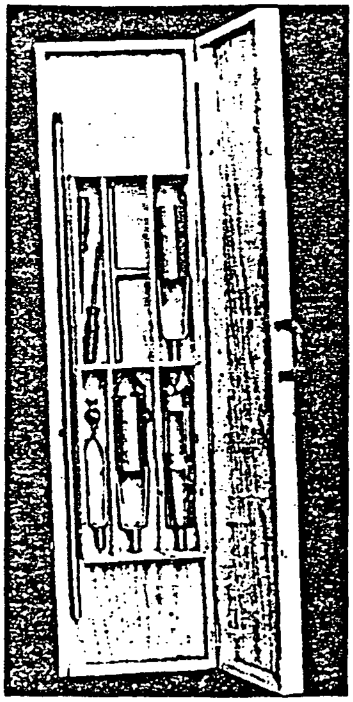
ITEM 50, JMC ACCESS TUBE BUCKET AUGER. 2" CUT
This auger is designed to produce the precise diameter hole for setting 2" diameter access tubes for neutron probes. The outside diameter of the barrel is 1¾ inches. The cutting bits cut a hole exactly 2" in diameter and give a "tight fit" for 2" diameter access tubes. Because the hole is slightly larger than the outside diameter of the barrel there is no drag on the bucket as it is being removed from the ground.

Actual weight 1.75 lbs. (.79 kg).

ITEM 54, JMC ACCESS TUBE BUCKET AUGER, 2 3/8" CUT
This auger is designed to produce the precise diameter hole for setting 2 3/8" diameter access tubes for neutron probes. The outside diameter of the barrel is 2 inches. The cutting bits cut a hole exactly 2 3/8" in diameter and give a "tight fit" for 2 3/8" diameter (2" PVC pipe) access tubes. Because the hole is slightly larger than the outside diameter of the barrel there is no drag on the bucket as it is being removed from the ground.

Actual weight 1.88 lbs. (.85 kg).





ITEM 39. JMC AUGER KIT WITH 34" EXTENSIONS.
This kit provides the Soil Scientist or Geologist with a complet set of augers to sample under nearly all types of soil conditions. The case is made of exterior plywood and mahogany to provide a convenient and durable container for transporting and storing the augers and accessories. The equipment includes: 1— case, 1— Auger Hand Grip, 2— 34" Extensions, 1— Mud Auger, 1— General Purpose Bucket Auger, 1— Clay Auger, 1— Sand Auger and 2— tools to disassemble extensions. NOTE: Specify **DIAMETER** of auger when ordering.

ITEM 40. JMC AUGER KIT WITH 34" EXTENSIONS, WITHOUT CARRYING CASE.
Same as Item No. 39 without case & tools to disassemble.
Actual weight 15 lbs. (6.8 kg.).

ITEM 41. JMC AUGER KIT WITH 45" EXTENSIONS.
This kit provides the Soil Scientist or Geologist with a complete set of augers to sample under nearly all types of soil conditions. The case is made of exterior plywood and mahogany to provide a convenient and durable container for transporting and storing the augers and accessories. The equipment includes: 1— case, 1— Auger Hand Grip, 2— 45" Extensions, 1— Mud Auger, 1— General Purpose Bucker Auger, 1— Clay Auger, 1— Sand Auger and 2— tools to disassemble extensions. NOTE: Specify **DIAMETER** of auger when ordering.
Actual weight 35 lbs. (15.9 kg.).

ITEM 42. JMC AUGER KIT WITH 45" EXTENSIONS, WITHOUT CARRYING CASE.
Same as Item No. 41 without case & tools to disassemble.
Actual weight 16.3 lbs. (7.4 kg.)

ITEM 43. JMC FOOT PEDAL (NOT PICTURED).
It is a replacement part for the Backsaver Handle and the Backsaver N-3 Handle.

ITEM 44. JMC SPRING (NOT PICTURED).
It is a replacement part for the Backsaver Handle and the Backsaver N-3 Handle.

ITEM 45. PUSH ROD FOR BACKSAVER HANDLE (NOT PICTURED).
It is a replacement part for the Backsaver Handle.

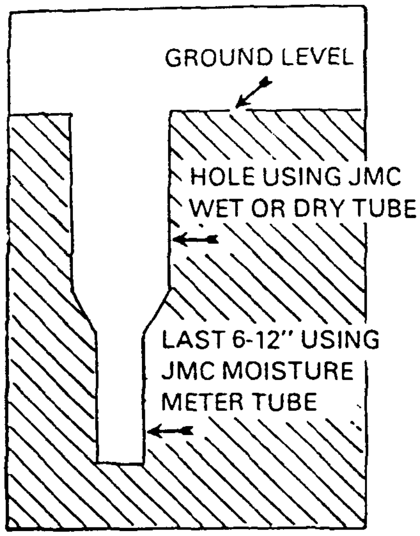
ITEM 46. PUSH ROD FOR BACKSAVER N-3 HANDLE (NOT PICTURED).
It is a replacement part for the Backsaver N-3 Handle.

ITEM 47. JMC 20 ACETATE LINERS/40 CAPS (FOR "O" TUBES) (NOT PICTURED).

ITEM 48. JMC 5 (o) RINGS, 2 PINS (REPLACE PARTS "O" TUBES) (NOT PICTURED).

ITEM 49. JMC THREAD ADAPTER (NOT PICTURED).
This is used to connect two female threads and is necessary to connect the assembly described in Item 16.

JMC Backsaver Handles & JMC Sampling Tubes are marketed by:
CLEMENTS ASSOCIATES, INC., P.O. Box 398, GRINNELL, IOWA 50112
Phone (515) 236-5511 or (515) 792-8285



Directions for seting moisture sensors using the JMC Moisture Meter Tube, Item 15, page 7.

Use the Backsaver Handle equipped with a small diameter, wet or dry tipped tube to dig the hole to within 6-12" of the desired setting depth for the meter. Use the Backsaver Handle with the JMC Moisture Meter Tube to form the last 6-12". This allows the sensor to be easily slipped to within 6-12" of the desired depth and then pressed into its final position assuring good soil contact.

How to monitor soil moisture by 'feel'

REPRINTED BY PERMISSION FROM MARCH, 1981, ISSUE OF IRRIGATION AGE.

Even without expensive and accurate monitoring systems, farmers can still get a "feel" for how much water is in the soil. Just grab a handful and squeeze.

While not in the same league as a neutron probe or a tensiometer, experienced hands can come pretty close to knowing if there is stress danger to the crop.

Regardless of your scheduling method the best yields and most efficient water use is obtained when moisture in the major root zone is not depleted more than about 50%. It is also important to begin watering well ahead of the 50% mark so no part of the field will be stressed.

To estimate moisture by hand, use Table 1 to compare the feel and appearance of several soil samples taken from the root zone. With experience a fairly accurate determination can be made.

TABLE 1: GUIDE FOR JUDGING HOW MUCH MOISTURE HAS BEEN REMOVED FROM THE SOIL

Soil Moisture Deficiency	Coarse Texture	Moderately Coarse Texture	Medium Texture	Fine and Very Fine Texture
0% (Field capacity)	Upon squeezing, no free* water appears on soil but wet outline of ball is left on hand. 0.0	Upon squeezing, no free* water appears on soil but wet outline of ball is left on hand. 0.0	Upon squeezing, no free* water appears on soil but wet outline of ball is left on hand. 0.0	Upon squeezing, no free* water appears on soil but wet outline of ball is left on hand. 0.0
0-25%	Tends to stick together slightly, sometimes forms a very weak ball under pressure. 0.0 to 0.2	Forms weak ball, breaks easily, will not slick. 0.0 to 0.4	Forms a ball, is very pliable, slicks readily if relatively high in clay. 0.0 to 0.5	Easily ribbons out between fingers, has slick feeling. 0.0 to 0.6
25-50%	Appears to be dry, will not form a ball with pressure. 0.2 to 0.5	Tends to ball under pressure but seldom holds together. 0.4 to 0.8	Forms a ball somewhat plastic, will sometimes slick slightly with pressure. 0.5 to 1.0	Forms a ball, ribbons out between thumb and forefinger. 0.6 to 1.2
50-75%	Appears to be dry, will not form a ball with pressure.[1] 0.5 to 0.8	Appears to be dry, will not form a ball.[1] 0.8 to 1.2	Somewhat crumbly but holds together from pressure. 1.0 to 1.5	Somewhat pliable, will ball under pressure.[1] 1.2 to 1.9
75-100% (100% is permanent wilting)	Dry, loose, single-grained, flows through fingers. 0.8 to 1.0	Dry, loose, flows through fingers. 1.2 to 1.5	Powdery, dry, sometimes slightly crusted but easily broken down into powdery condition. 1.5 to 2.0	Hard, baked, cracked, sometimes has loose crumbs on surface. 1.9 to 2.5

1 Ball is formed by squeezing a handful of soil very firmly.
2 Israelsen and Hansen. Irrigation Principles and Practices. Third Edition.

*Feel or appearance of soil and moisture deficiency in inches of water per foot of soil — numbers indicate inches of water deficit per one foot of soil.

ORDER FORM

Prices as of February 1, 1983 (Subject to Change)

Date________________

Bill to: ________________________

Address: ________________________

City: ____________ State: ____________

Zip: ____________ Phone: ____________

Ship to: ________________________

Address: ________________________

City: ____________ State ____________

Zip: ____________ Phone: ____________

Directions for UPS: ________________________

Item No.	Description of item	Qty.	Price	Total
*1.	Backsaver Handle w/Cleaner	/	163.95	
*2.	Backsaver N-3 Handle w/Cleaner		190.35	
*3.	Backsaver N-2 Handle w/Cleaner		62.75	
4.	JMC 26" Rod Extension		21.60	
5.	JMC 13" Rod Extension		21.60	
6.	JMC Sampling Tube. 12" Wet		32.10	
7.	JMC Sampling Tube, 12" Dry		32.10	
8.	JMC Sampling Tube, 15" Wet		33.20	
9.	JMC Sampling Tube, 15" Dry		33.20	
10.	JMC Sampling Tube, 18" Wet		34.25	
11.	JMC Sampling Tube 18" Dry		34.25	
12.	JMC Sampling Tube 1 ¼" x 12"		73.30	
13.	JMC Sampling Tube 1 ¼" x 18"		77.30	
14.	JMC "O" Contamination Tube, 10 Acetate Liners/20 caps	/	97.70	
15.	JMC Moisture Meter Tube		36.95	
16.	JMC 12" T-Handle		23.70	
17.	Dyalon Mallet		17.25	
18.	Special Cleaner		25.85	
19.	Backsaver Handle Kit		467.40	
20.	Backsaver Handle Kit w/o Case		368.40	
21.	Backsaver N-3 Handle Kit		529.90	
22.	Backsaver N-3 Handle Kit w/o Case		405.90	
23.	Backsaver N-2 Handle Kit		219.60	
24.	Backsaver N-2 Handle Kit w/o Case		120.60	
25.	Hand Grip for Mud/Bucket Auger		28.75	
26.	JMC Auger Extension 34"		39.15	
27.	JMC Auger Extension 45"		43.30	
28.	JMC Mud Auger		77.40	
			Total Col. 1	

Item No.	Description of Item	Qty.	Price	Total
29.	JMC 3" General Purpose Bucket Auger		77.40	
30.	JMC 3" Open-Sided Clay Bucket Auger		77.40	
31.	JMC 3" Sand Bucket Auger		77.40	
32.	JMC 2" General Purpose Bucket Auger		77.40	
33.	JMC 2" Open-Sided Clay Bucket Auger		77.40	
34.	JMC 2" Sand Bucket Auger		77.40	
35.	Mud Auger, Hand Grip 34" Extension		138.00	
36.	Mud Auger, Hand Grip 45" Extension		141.95	
**37.	Bucket Auger, Hand Grip, 34" Extension		138.00	
**38.	JMC Bucket Auger, Hand Grip, 45" Extension		141.95	
**39.	JMC Auger Kit with 34" Extensions		522.60	
**40.	JMC Auger Kit with 34" Extensions w/o Case		373.95	
**41.	JMC Auger Kit with 45" Extensions		542.70	
**42.	JMC Auger Kit 45" Extensions w/o Case		403.70	
43.	Foot Pedal for Backsaver & Backsaver N-3 Handles (replacement)		25.25	
44.	Spring for Backsaver Handles (replmt)		5.00	
45.	Push Rod for Backsaver Handle (replmt)		25.50	
46.	Push Rod for Backsaver N-3 Handle (replmt)		30.75	
47.	JMC 20 Acetate Liners/ 40 Caps (For "O" Tubes)	/	23.25	
48.	JMC (O) Rings, 2 Pins (Replace Parts "O" Tubes)		7.10	
49.	Adapter		2.00	
50.	JMC Access Auger 2"		79.40	
51.	JMC Turf Sampler		78.15	
52.	JMC Greens Sampler		40.00	
53.	JMC Turf Specialist System		332.80	
54.	JMC Access Auger 2 3/8"		79.40	
*55.	JMC Conventional T-Handle		34.95	

Total Col. 2 ______

Total Col. 1 ______

Total Columns 1 and 2 ______

*Handles come without tube. Select tube as a separate item.

**Specify Diameter of Bucket Auger when ordering combinations and kits.

Add Shipping Cost for Packing & Guaranteed Delivery:
(HI, AK, and Canada add $4.00 to below)

Values of Order	$ 0.00-20.00	$21.00-50.00	$51.00-100.00	Over $100.00
Shipping Cost	$2.60	$4.30	$4.90	$4.90 plus $1.15 per ea. $50.00 additional

Iowa Sales Tax ____________

Shipping and Packing ____________
(UPS if Possible)
(See Table)

Total Enclosed (U.S. Dollars) ____________

Enclose Check or Money order Payable to:

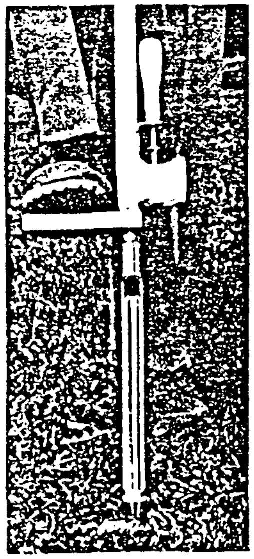
Clements Associates, Inc.
R. R. 1; Box 162 A
Newton, Iowa 50208 U.S.A.
Phone: (515) 792-8285

Printed in U.S.A.

New Product

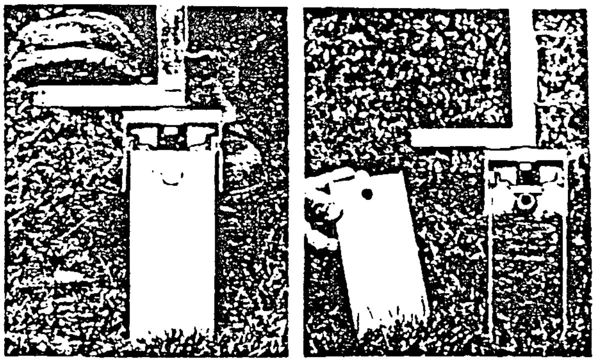
For Setting Access Tubes for Neutron Probes see page 12

Set moisture meters the easy way see pages 7 & 14

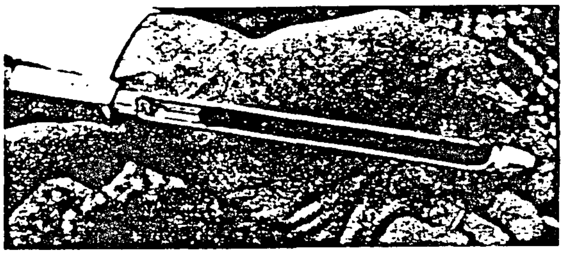


Soil fertility Sampling see pages 5, 6 & 7

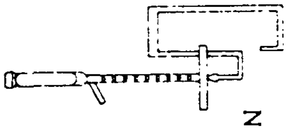
O-contamination tube for Chemical Residue studies see page 7



JMC TURF SAMPLER—see page 9
New Product



JMC GREENS SAMPLER—see page 9
New Product



CLEMENTS ASSOCIATES, INC.
R.R. NO. 1 BOX 162A
NEWTON, IOWA 50208 U.S.A.

Chapter II-2

Truck Bypass Landfarm

270.20 Specific Part B information requirements for land treatment facilities

Except as otherwide provided in 264.1, owners and operators of facilities that use land treatment to dispose of hazardous waste must provide the following additional information:

a. A description of plans to conduct a treatment demonstration as required under 264.272. The description must include the following information;
   1. The waste for which the demonstration will be made and the potential hazardous constituents in the waste;
   2. The data sources to be used to make the demonstration (e.g., literature, laboratory data, field data, or operating data);
   3. Any specific laboratory or field test that will be conducted, including:
      - i. The type of test (e.g., column leaching, degradation);
      - ii. Materials and methods, including analytical procedures;
      - iii. Expected time for completion;
      - iv. Characteristics of the unit that will be simulated in the demonstration, including treatment zone characteristics, climatic conditions, and operating practices.

b. A description of a land treatment program, as required under 264.271. This information must be submitted with the plans for the treatment demonstration, and updated following the treatment demonstration. The land treatment program must address the following items:
   1. The wastes to be land treated;
   2. Design measures and operating practices necessary to maximize treatment in accordance with 264.273(a) including:
      - i. Waste application method and rate;
      - ii. Measures to control soil pH;
      - iii. Enhancement of microbial or chemical reactions;
      - iv. Control of moisture content;
   3. Provisions for unsaturated zone monitoring including:
      - i. Sampling equipment, procedures, and frequency;
      - ii. Procedures for selecting sampling locations;
      - iii. Analytical procedures;
      - iv. Chain of custody control;
      - v. Procedures for establishing background values;
      - vi. Statistical methods for interpreting results;
      - vii. The justification for any hazardous constituents recommended for selection as principal hazardous constituents, in accordance with the criteria for such selection in 264.278(a);
   4. A list of hazardous constituents reasonably expected to be in, or derived from, the wastes to be land treated based on waste analysis performed pursuant to 264.13;
   5. The proposed dimensions of the treatment zone;

c. A description of how the unit is or will be designed, constructed, operated, and maintained in order to meet the requirements of 264.273. This submission must address the following items:
   1. Control of run-on;
   2. Collection and control of run-off;

3. Minimization of run-off of hazardous constituents from the treatment zone;
4. Management of collection and holding facilities associated with run-on and run-off control systems;
5. Periodic inspection of the unit. This information should be included in the inspection plan submitted under 270.14(b)(5);
6. Control of wind dispersal of particulate matter, if applicable;

d. If food-chain crops are to be grown in or on the treatment zone of the land treatment unit, a description of how the demonstration required under 264.276(a) will be conducted including:
1. Characteristics of the food-chain crop for which the demonstration will be made.
2. Characteristics of the waste, treatment zone, and waste application method and rate to be used in the demonstration;
3. Procedures for crop growth, sample collection, sample analysis, and data evaluation;
4. Characteristics of the comparison crop including the location and conditions under which it was or will be grown;
5. If food-chain crops are to be grown, and cadmium is present in the land-treated waste, a description of how the requirements of 264.276(b) will be complied with;
6. A description of the vegetative cover to be applied to closed portions of the facility, and a plan for maintaining such cover during the post-closure care period, as required under 264.280(a)(8) and 264.280(c)(2). This information should be included in the closure plan and, where applicable, the post-closure care plan submitted under 270.14(b)(13);
7. If ignitable or reactive wastes will be placed in or on the treatment zone, an explanation of how the requirements of 264.281 will be complied with;
8. If incompatible wastes, or incompatible wastes and materials, will be placed in or on the same treatment zone, an explanation of how 264.282 will be complied with.

Chapter II-2

Truck Bypass Landfarm

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I. Treatment Demonstration

The 264.272 technical standards require Navajo to demonstrate that hazardous constituents contained in wastes applied to the landfarm area can be completely degraded, transformed or immobilized in the treatment zone. The treatment demonstration for the finite quantity of waste contained in the TEL weathering area will be based on the existing literature detailing the degradation and immobilization of oily and metal bearing wastes during the land treatment process, as supported by the results of a field demonstration.

A. Nonhazardous Refinery Wastes

The Truck Bypass landfarm is an existing land treatment facility for the treatment and disposal of nonhazardous wastes. A summary of landfarmed nonhazardous wastes is contained in Table II-2-1.

Nonhazardous wastes generated at the refinery include kerosene filter clay, tank bottoms, separated wastewater, spilled hydrocarbons and hydrocarbon contaminated materials. In general, these wastes are not considered hazardous because the flash point of liquid and semisolid samples is above 140°F.

Kerosene filter clay is the diatomaceous earth medium through which kerosene is filtered to remove color particles. While the kerosene itself has a flash point below 140°F, there is no prescribed test method to establish the ignitability characteristic of a solid material, so the filter clay may be considered nonhazardous by present definition. Kerosene filter clay is generated when the clay filtration medium no longer effectively removes color particles, estimated to occur every 5 years. No kerosene clay has been generated in the last 2 years.

Tank bottoms is the generic term for all BS&W, oil, slurry and sludges removed from crude oil, intermediate and unleaded product storage tanks. These wastes have widely varying characteristics and may, in some instances, be considered hazardous

Table II-2-1

Truck Bypass Landfarm
Nonhazardous Refinery Wastes

Name of Waste	Waste Source	Waste Generation (tons/year)	Frequency of Generation
Kerosene Filter Clay	Kerosene Treater	5	1/5 year
Tank Bottoms	Storage Tanks	40	1/10 yr
Separated Liquids	Storage Tanks, Sumps	80	4-12/yr
Hydrocarbon Contaminated Materials	Spills	40	0-2/yr

Note: The annual waste generation figures are based on refinery estimates. The quantity of wastes generated could include substantial quantities of water along with sludges, solids and oil. The physical waste characteristics and the sporadic nature of waste generation events make an estimate of the annual tonnage of waste virtually meaningless. The kerosene filter clay, tank bottoms and spill contaminated materials are generally considered nonhazardous, although there may be isolated instances where the wastes or waste mixtures may be considered hazardous due to the characteristic of ignitability (i.e., the liquid or semisolid waste sample may have a flashpoint below 140°F).

due to the characteristic of ignitability. Tanks storing kerosene and lighter materials may accumulate sludges exhibiting the characteristic of ignitability. Tank bottom sludge is generated whenever tankage is cleaned, assumed to occur once every ten years. The majority of the tank bottoms are nonhazardous as the tanks storing heavier petroleum fractions tend to accumulate solids, while lighter petroleum products tend to be free of residual solids.

Separated wastewater is the water phase separated from the crude oils, intermediates or products stored in refinery tankage. The water phase contaminated with hydrocarbon is periodically drawn off and trucked to the Truck Bypass landfarm for land application. The liquid phase is routinely removed from tankage.

Spill contaminated materials include water and debris contaminated with petroleum. These residues are generated in response to refinery housekeeping and spill events. The materials vary widely in waste characteristics. Hydrocarbon contaminated materials are estimated to be generated a maximum of twice per year, although the frequency of generation cannot truly be estimated.

Navajo has determined that the unlisted wastes should not be classified as hazardous by EPA definition, except possibly in isolated instances. Oily refinery wastes which potentially exhibit the characteristic of ignitability are analyzed with Pensky-Martens or Setaflash closed cup methods for flashpoint. If the flashpoint is below 140°F, the waste is considered hazardous due to the characteristic of ignitability. Ignitable wastes are managed as hazardous wastes. Nonhazardous wastes are currently applied to the Truck Bypass landfarm.

B. Waste for the Treatment Demonstration

The TEL weathering area is a nonregulated surface impoundment containing separator sludge contaminated with lead from the Doctor process and leaded tank bottoms, along with nonhazardous wastes such as tank bottoms. Navajo plans to close this facility under interim status standards by excavating waste and contaminated soils and placing these materials in the Truck Bypass landfarm. This landfarm, currently used for nonhazardous wastes, will be used to degrade and immobilize waste constituents present in the TEL weathering area once a RCRA permit is issued for this facility. Because the TEL weathering area contains a finite amount of wastes, the characterization of wastes present at the facility is necessary. This section describes the procedures employed in characterizing the wastes. This information will be used to establish the landfarm application rate for optimum degradation and immobilization of wastes and waste constituents.

Initial waste characterization work was conducted in November of 1982. Three surface samples were collected and analyzed for the concentration of lead and chromium. Results are as follows:

Concentration of Metals in Waste
(mg/kg)

	Range of Values	Average
Lead	29-157	99
Chromium	31-84	50

The wastes present in the impoundment area have been sampled to more accurately quantify the nature of contained wastes. The wastes present in the impoundment are presumed to be randomly heterogeneous in chemical properties. A simple random sampling procedure has been employed by which a grid of all possible sampling locations is identified, and a suitable number of samples is randomly selected from the population. The appropriate number of samples required to generate a sufficiently precise estimate of the true mean waste characteristics is based on the mean and variance for samples already collected.

At each sampling location, an auger was used to obtain a waste sample through the waste depth. The six samples were composited and thoroughly mixed, and are in the process of being analyzed for a full range of analytical parameters: the indicator parameters, including BS&W, bulk density, pH, acidity or alkalinity, TOC and total nitrogen; trace elements, including arsenic, chromium, copper, lead, nickel and vanadium; organics, including volatile organics, organic acids and base neutral extractables; and miscellaneous parameters, including total phenols, cyanides and sulfides. Data will be presented in Table II-2-2.

The hazardous constituents listed in 40 CFR 261, Appendix VIII which might potentially be present in waste in the TEL weathering area includes low concentrations of the metals arsenic, chromium, copper, lead, nickel, and vanadium; selected volatile organic compounds such as benzene, ethylbenzene and toluene; polynuclear aromatic compounds such as anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(ghi) perylene, chrysene, fluoranthene, naphthalene, phenanthrene, and pyrene; low concentrations of chlorinated hydrocarbons such as 1,2-dichloroethylene, hexachloroethane, hexachlorocyclopentadiene, 1,1,2,2-tetrachloroethane, tetrachloroethylene, trichloroethylene; phthalate esters such as bis (2-ethylhexyl) phthalate and diethylphthalate and miscellaneous compounds such as phenolic compounds, cyanide soluble salts and complexes, and sulfides. These and other Appendix VIII compounds may be present in trace or insignificant concentrations.

C. Data Sources

The treatment demonstration consists of a review of the literature, as supplemented by a field demonstration. The transformation, mobility, volatility and toxicity of waste constituents applied to the treatment zone are discussed. The literature cited in the bibliography provides a data base to establish fate mechanisms. Optimum application rates will be established from results of field tests. Based on the literature and estimated waste characteristics, a monitoring program has been established to evaluate the degradation and immobilization of hazardous constituents. Soil and soil pore liquid samples will collected and analyzed for select metals and organics. Further, operational procedures will identify additional monitoring conducted to maximize immobilization, through pH control, and degradation, through

Table II-2-2
Waste Characterization
TEL Weathering Area

Trace Elements
- Arsenic
- Chromium
- Copper
- Lead
- Nickel
- Vanadium

Volatile Organic Compounds
- Benzene
- Ethylbenzene
- Toluene

Polynuclear Aromatic Compounds
- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(ghi)perylene
- Chrysene
- Fluoranthene
- Naphthalene
- Phenanthrene
- Pyrene

Chlorinated Hydrocarbons
- 1,2 Dichloroethylene
- Hexachloroethane
- Hexachlorocyclopentadiene
- 1,1,2,2 Tetrachloroethane
- Tetrachloroethylene
- Trichloroethylene

Phthalate Esters
- Bis(2-ethylhexyl)phthalate
- Diethylphthalate

Miscellaneous Compounds
- Phenols
- Cyanides
- Sulfides

fertilizer application, irrigation and soil aeration. Results of the monitoring program established by Navajo at the North Colony landfarm are also available to supplement the available literature for the treatment demonstration.

1. Literature Review - Organic Constituents

The waste in the TEL weathering area must be demonstrated to degradable in the treatment zone at a sufficiently rapid rate that degradation rather than volatilization, leaching or runoff is the controlling loss mechanism within the landfarm. A review of the literature indicates landfarming of oily wastes is a viable treatment option because the soil provides a natural environment for degradation of waste materials through physical, chemical and biological processes. Soil microorganisms are primarily responsible for inducing the chemical changes in the decomposition process. Bacteria, filamentous fungi, yeasts and actinomycetes can digest and use natural hydrocarbons. Although hydrocarbons provide carbon and energy for microorganisms, rapid degradation of organic compounds also requires an adequate supply of oxygen, moisture and nutrients within the treatment zone. The oil is assimilated in the production of a biomass and aerobic end products, carbon dioxide and water, are produced.

For oily refinery wastes, the aliphatic and aromatic hydrocarbons are the two most prevalent organic compounds. Perry and Cerniglia (1973) ranked aliphatic and aromatic hydrocarbons from most to least biodegradable as straight chain alkanes (C_{12} - C_{18}), gases (C_2 - C_4), straight chain alkanes (C_5 - C_9), branched alkanes (up to C_{12}), straight chain alkenes (C_3 - C_{11}), branched alkenes, aromatics and cycloalkanes. Straight chain aliphatic hydrocarbons are relatively easily assimilated while branched chain paraffins and cycloparaffins decompose slowly. Aromatic hydrocarbons, particularly those of high molecular weight, are decomposed slowly. The bacterial cells and undestroyed cyclic portion of aromatic hydrocarbons are ultimately destroyed, albeit slowly by the combined effect of a mixed population of soil microbes.

Anaerobic digestion of organic matter is more complex than aerobic destruction, and certain hydrocarbons undergo little degradation in an anaerobic environment. Essential mineral nutrients are necessary for rapid biodegradation, particularly nitrogen (as ammonia or nitrate) and phosphorus (as soluble phosphates). Soil pH exerts a marked impact on microbial activity and should be maintained near 7 (neutral). Moisture, temperature and soil waste contact also affect degradation rates.

Land treatability of organic constituents is discussed in general terms by class of organic constituents. Aliphatic hydrocarbons are commonly found in oily refinery wastes. The degradability of these open chain alkanes, alkenes, alkynes and their cyclic analogs is dependent on the molecular weight, vapor pressure, water solubility, number of double bonds, degree of branching and whether the compound has an open chain or cyclic configuration. Straight chain alkanes are more easily degraded than branched chain alkanes of the same molecular weight. The degradation rate decreases with the number and size of alkyl groups as well as the number of double bonds or presence of a benzene group. Straight or branched open chain aliphatics degrade much more rapidly than their cyclic analogs. Cycloalkane and its derivatives are very difficult to degrade.

While aliphatic hydrocarbons are amenable to degradation in a landfarm environment, a long term accumulation of recalcitrant decomposition byproducts may occur. Kincannon (1972) determined one major byproduct of oil decomposition is naphthenic acid, which may degrade slowly in soil (Overcash and Pal, 1979).

Other loss mechanisms for aliphatic hydrocarbons include runoff, leaching and volatilization. Runoff and leaching are generally thought to be minimal due to low water solubility (Raymond et al., 1976). Volatilization can be a significant loss mechanism for low molecular weight aliphatics (Wetherold et al., 1981). The waste volatility is the most important factor affecting emission levels. Emission rates were found to increase with increasing ambient humidity, soil temperature and soil moisture, decrease with increased depth of subsurface injection. Emission rates were found to be greatest within 30 minutes of land application.

Aromatic hydrocarbons are cyclic compounds with multiple double bonds and include monoaromatic compounds such as benzene, nitrobenzene and ethylbenzene and polyaromatic compounds such as naphthalene and anthracene. The decomposition rate of aromatic compounds is very compound specific, although general trends suggest the decomposition rate decreases as the number of fused rings in the compound increases and the decomposition rate increases as the water solubility of the compound increases. In order of increasing degradability, Fedorak and Westlake (1981) ranked the aromatic constituents of crude oil as naphthalene and 2-methylnaphthalene; methylnaphthalene; dimethylnaphthalene, dibenzothiophene and phenanthrene; C_3-naphthalenes; methylphenanthrenes; and C_2-phenanthrenes. A short term accumulation of aromatic hydrocarbons is expected due to the formation of aromatic hydrocarbons from the decomposition of aliphatic hydrocarbons.

Organic acids and halogenated organics may also occur in refinery oily wastes, although they are relatively less prevalent than aliphatic or aromatic hydrocarbons. Organic acids are organic constituents with phenolic or carboxylic acid functional groups. Organic acids are relatively volatile and leachable, although degradation can be relatively rapid under favorable environmental conditions, particularly at lower application rates. Halogenated organics span the range of degradability, leachability and volatility. Chlorinated benzene derivatives are, as a group, less degradable, volatile and leachable than their chlorinated aliphatic counterparts. Halogenated organics are fairly resistant to biodegradation.

2. Literature Review - Metals

The metal content of waste in the TEL weathering area is expected to be relatively greater than common oily refinery wastes. The concentration of metals, and lead in particular, are expected to influence landfarm loading rates and estimated landfarm life. The mobility and toxic effect of metals are largely determined by the chemical form. For land treatment, the soil pH, redox potential and minerology together with metal compound present in the waste stream establishes the fate of metals added to the soil. Metals may be present as insoluble precipitates such as sulfates, carbonates or hydroxides, sorbed or chelated organic complexes, sorbed on exchange sites in either the waste or soil, or in solution in soil pore water. If the metal is insoluble at the normal pH of soil, it will not be present in appreciable amounts in the soil solution and thus not readily absorbed by plants or leached. As long as the metal is strongly sorbed or chelated, it will have low potential for plant uptake and leaching. Immobilization of metals may occur as long as the loading rates are not excessive and proper soil conditions such as soil pH are maintained. Generalized guidelines for maximum metal accumulations in soil and loading rates are presented in Table II-2-3. The type and level of metals present will dictate specific requirements.

Arsenic research has focused on the anions arsenate and arsenite. The cycling of arsenic in the environment is dominated by soil sorption, although leaching and volatilization may also occur. Immobilization of arsenic increases with increased soil pH and increased clay, aluminum and iron content. Arsenic precipitation by iron and aluminum oxides or calcium reduces the potential for leaching. Saturated soils tend to solubilize arsenic from ferric arsentate or arsenite to the more mobile arsines or methyl arsines. Reduction of arsenic under saturated soil conditions can also result in volatilization. However, research by Woolson (1977) has indicated only 1 to 2% of arsenate applied at a rate of 10 ppm was volatilized as dimethyl arsine after 160 days. The toxicity of arsenic results from the interaction with sulhydral groups or SH radicals of some enzymes. Inorganic arsenic is much more toxic than the organic forms which are more easily and rapidly eleminated by animals. Arsenic has been shown to be phytotoxic at soil application rates between 200 and 1000 kg/ha (Overcash and Pal, 1979).

Table II-2-3

Maximum Metal Accumulation and Loading Rates

Element	Metal Content of Native Soils[1] Common Range (mg/kg)	Average (mg/kg)	Suggested Maximum Metal Accumulations[2] (mg/kg)	Suggested Metal Loadings[3] (kg/ha-30 cm)
Ag	0.01-5	0.05		400
Al	10,000-300,000	71,000		
As	1-50	5	300	
Au	n.g.	1		4000
B	2-100	10		
Ba	100-3,000	430		2000
Be	0.1-40	6	50	
Cd	0.01-0.7	0.06	3	
Co	1-40	8	200	
Cr	1-1,000	100	1000	
Cu	2-100	30	250	
Hg	0.01-0.3	0.03		40
La	1-5,000	30		2000
Li	5-200	20	250	
Mg	600-6,000	5,000		
Mn	20-3000	600	1000	
Mo	0.2-5	2	5	
Ni	5-500	40	100	
Pb	2-200	10	1000	
Rb	50-500	10		
Sb	2-10	not given	1000	
Se	0.1-2	0.3	5	
Sn	2-200	10		
Sr	50-1000	200		40
V	20-500	100	500	
Zn	10-300	50	500	
Zr	60-2,000	300		4000

1. Trace element content of soils extracted from Table 6.46 of Hazardous Waste Land Treatment, SW-874.

2. Suggested maximum metal accumulations in soil based on current literature extracted from Table 6.47 of Hazardous Waste Land Treatment, SW-874. Higher levels may be acceptable if it can be demonstrated that the ultimate vegetative cover is metal tolerant.

3. Suggested metal loadings for metals with less well defined information extracted from Table 6.52 of Hazardous Waste Land Treatment, SW-874. Values given should be used as preliminary guide.

In aerobic soils, hexavalent chromium is converted to less toxic trivalent chromium, which is quite immobile (Overcash and Pal, 1979). Trivalent chromium precipitates readily with carbonates, hydoxides and sulfides, which reduces the leaching potential. Such precipitation reactions are favored at a pH greater than 6. Hexavalent chromium, chromate or dichromate is toxic and mobile in soils. Soluble chromium salts (sulfates and nitrates) are much more toxic than insoluble chromium salts (oxides and phosphates). Almost 100% retention of chromiun has been documented by Wentink and Edzel (1972).

Immobilization of copper in soils is dependent on soil pH. The soil should be maintained at 6.5 or more to ensure the predominance of insoluble forms of copper. Copper forms stable complexes with soil organic matter particularly when the iron and manganese oxide concentration is low. However, the loss of organic matter through decomposition reduces the effectiveness of this retention mechanism. A column study (Emmerich et al., 1982) revealed 94% of copper applied was retained in the soil. Overcash and Pal (1979) suggest metal loadings of 125 to 500 kg/ha, depending on soil cation exchange capacity.

Divalent lead is present in soils as lead sulfates, hydroxides and carbonates depending on soil pH. The availability of lead in soils is related to moisture content, soil pH, organic matter content and the concentration of calcium and phosphates. Under saturated soil conditions, naturally occurring lead becomes reduced and mobile. Under the conditions of high pH, cation exchange capacity and available phosphorus, lead is less soluble and thus more strongly adsorbed. Lead toxicity in plants is uncommon, found only in acid soils. Concentrations up to 1000 ppm total lead can safely accumulate without phytotoxicity.

Nickel in soil associates with the oxide and hydroxide ligands and is precipitated as nickel hydroxyoxides at alkaline pH. In an anaerobic system, nickel may be reduced to lower oxidation states and precipitate as nickel carbonate or sulfide. In a column study (Emmerich et al., 1982), 94% of the nickel applied was recovered indicating essentially no nickel leached below the depth of incorporation. Liming of soil can greatly reduce nickel toxicity, not only by increasing soil pH, but by introducing calcium which is apparently antagonistic to nickel uptake. Soil accumulation rates of 100 ppm appear acceptable based on phytotoxicity and microbial toxicity.

Vanadium may be incorporated into clay minerals and is associated with aluminum oxides. Vanadium may be present as a divalent cation or oxidized anion, bound to soil organic matter or organic waste constituents.

3. Field Demonstration

The land treatment demonstration will be conducted by applying waste from the TEL weathering area at two different application rates to two separate 50 ft wide by 100 ft long demonstration plots. The location of the two demonstration plots within the Truck Bypass landfarm was randomly selected. Two lysimeter locations were randomly selected by drawing coordinates from a random number table until two discrete locations within the Truck Bypass landfarm were selected. The location of the field demonstration plots were preferentially selected such that one lysimeter is located within each treatment area. Two soil monitoring locations were then randomly selected within each treatment plot for each month of the expected four month demonstration. The locations of the treatment demonstration plots and unsaturated zone monitoring sites are shown in Figure II-2-1.

The waste from the TEL weathering area will be applied at the rate of 65 tons/acre in treatment plot 1 and 130 tons/acre in treatment plot 2, this loading rate corresponds to 15,000 and 30,000 lb/treatment plot, or 6-12 cy/treatment plot. On a monthly basis for 4 months after waste application, lysimeter samples will be obtained and analyzed for base neutral extractable organics. Soil core samples will be obtained from 2 locations within the treatment plots and analyzed at 6 inch intervals from the land surface to a depth of 36 inches and analyzed for chromium, lead and base neutral

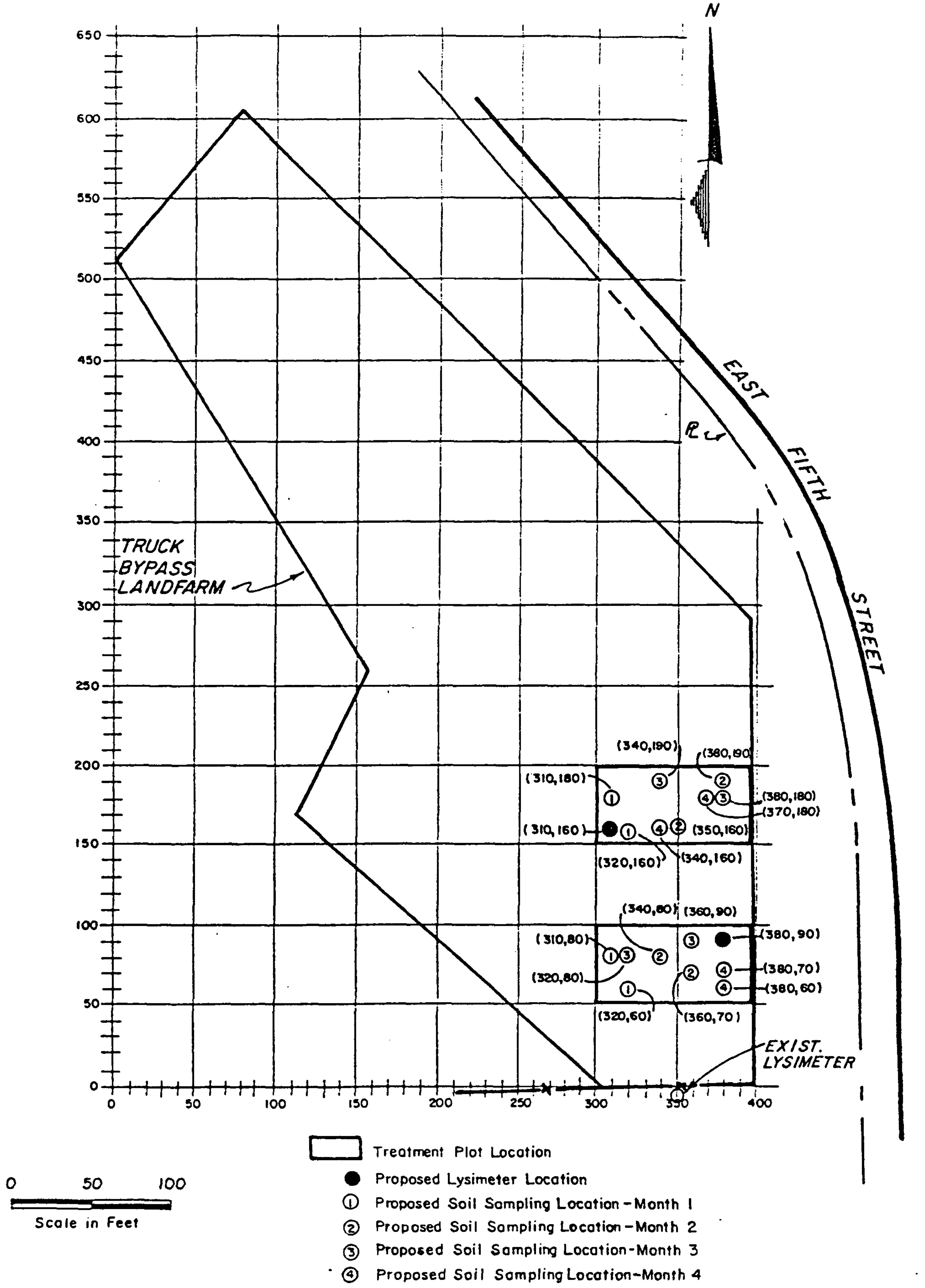


FIGURE II-2-1
FIELD DEMONSTRATION
UNSATURATED ZONE
MONITORING LOCATIONS

extractables. This data will then be reviewed to establish the optimum land application rate for wastes excavated for the TEL weathering area for incorporation into the Truck Bypass landfarm.

II. Land Treatment Program

The land treatment program identifies the operational procedures which will be employed in the treatment and disposal of TEL weathering area wastes. The wastes will be applied and tilled into the landfarm plots at the rates indicated by the treatment demonstration. Surficial soils will be tested annually to identify the soil amendments necessary to adjust pH and nutrient levels to maximize microbial action. Unsaturated zone monitoring will be conducted to demonstrate the effectiveness of the treatment program. Soil and soil pore liquid samples will be collected and analyzed for selected metals and base neutral organics. The data base generated from these investigations should verify degradation and immobilization of waste constituents within the treatment zone.

A. Wastes

The wastes applied to the North Colony landfarm are listed below.

Wastes Applied to Truck Bypass Landfarm
(tons/year)

	Average	Range
Kerosene Filter Clay	0	0-5
Tank Bottoms	0	0-40
Separated Liquids	80	20-120
Hydrocarbon Contaminated Materials	40	20-80
TEL Weathering Area	Dependent on treatment demonstration results	

1. Characteristics

The separated liquids and hydrocarbon contaminated materials are routinely generated rates. The TEL weathering area contains a finite amount of wastes which will be landfarmed at a rate optimum for the degradation and immobilization of waste constituents generated on an intermittent basis. The physical characteristics of the oily waste streams may vary greatly, as indicated below.

Waste Variability

Characteristic	Estimated Range of Waste Variability (%)
Phase	
Water	1-99
Oil	5-40
Solids	1-30
Organics	
Aliphatic or Paraffinic Alkanes	15-30
Cycloparaffinic cycloalkanes, naphthenes	30-50
Aromatic Benzenes and Polynuclear Series	5-20
Asphaltic Asphaltenes, Heterocyclic Compounds	2-15
Metals	1

2. Application Rates

The literature indicates soils have a great capacity for decomposing oily materials and significant quantities of waste can be applied without serious ill effects. Soils do have upper limits as to how much refinery wastes may be applied without producing anaerobic conditions which result in a reducing environment and an accumulation of odors and phytotoxic substances. Based on studies conducted by Cresswell (1977) in Oklahoma, annual degradation rates of 7 to 16 g oil/kg soil with an average 8.5 g/kg are possible. Overcash and Pal (1979) cite a wide range of oil decomposition rates from their literature review and suggest an annual degradation rate of 3.6% (36 g/kg) of soil weight under optimal conditions. Acceptable application rates for the TEL weathering area wastes will be developed from results of the proposed treatment demonstration.

The application, rate and capacity limits for trace elements are shown in Table II-2-4. The theoretical design life of the landfarm based on trace element loading will be calculated upon receipt of waste characterization information.

Table II-2-4

Trace Elements
Application, Rate and Capacity Limits

Waste Constituent	Application Limit (lb/acre)	Rate Limit (lb/acre/yr)	Capacity Limit (lb/acre)	Comments
Arsenic	175-880	--	1300	Toxic to plants at application rates between 200 and 1000 kg/ha; Maximum soil accumulation of 300 mg/kg
Chromium	--	--	4355	Maximum soil accumulation of 1000 mg/kg
Copper	--	--	1090	Maximum soil accumulation of 250 mg/kg
Lead	--	--	4355	Maximum soil accumulation of 1000 mg/kg without phytotoxicity
Nickel	--	--	435	Maximum soil accumulation of 100 mg/kg based on phytotoxicity and microbial toxicity
Vanadium	--	--	2175	Maximum soil accumulation of 500 mg/kg

Source: Hazardous Waste Land Treatment, SW-874

3. Waste Application

TEL weathering area wastes will be excavated from the surface impoundment with a backhoe and/or a bulldozer and tilled into the zone of incorporation. Records will be maintained of the amount and area of application for each waste load removed from the TEL weathering area. The landfarm will be tilled immediately after waste application and thereafter on a monthly basis.

B. Operational Procedures

Operational procedures to encourage degradation and immobilization of hazardous constituents include pH control, nutrient addition and soil aeration. These methods are designed to optimize treatment process occurring in the soil system.

1. pH Control

The existing information suggests the soil in the landfarm area tends to be alkaline, although the addition of oily wastes to the soil should tend to depress soil pH. Soil pH will be monitored annually, and will be maintained in the range of 7 to 9. A soil scientist is in the process of identifying soil pH and making recommendations as to pH control.

2. Nutrient Levels

The action of the microbial population can be enhanced by addition of selected soil nutrients. The level of the nutrients nitrogen, phosphorus and potassium are of concern, and will be analyzed on an annual basis. Fertilizer application rates may be selected on the basis of these results.

Overcash and Pal (1979) state 50 ppm N and 20 ppm P will sustain oil degradation by microbial action. A Soil Scientist is in the process of evaluating landfarm soils and nutrient deficiencies, and will make recommendations to maximize microbial action.

3. Soil Aeration

Monthly tilling of the landfarm plots increases the soil to oil contact, aerates the soil, improves soil moisture and hastens the mineralization of organics. The decomposition of oily wastes has long term beneficial effects on soil physical properties. An increase in water holding capacity and available water and a decrease in wind dispersal losses have been noted.

4. Soil Moisture

Soil moisture should be maintained in the 50 to 70% of available water capacity to maximize biodegradation. The soil scientist evaluating the landfarm will establish the available water capacity in each landfarm plot as well as the existing water content. It may be necessary to irrigate the landfarm in order to maintain sufficiently high water content. As currently envisioned, refinery effluent may be piped to the landfarm and spray nozzles installed to irrigate the land surface or effluent may be trucked to the landfarm by the vacuum truck. The landfarm will be irrigated during periods when soil moisture drops below 50% as evidenced by in situ moisture monitors, tests on soil samples or soil textural analysis.

Navajo plans to have two lysimeters in the landfarm. The location of soil pore liquid samplers have been randomly selected in accordance with the RCRA Guidance Document. A grid was developed for the landfarm, and potential coordinates of the proposed lysimeters drawn for a random number table. The proposed location of lysimeters is shown in Figure II-2-1. The type of lysimeter to be installed is currently being reviewed. Soil moisture lysimeter model numbers 1900 or 1920 are being considered.

C. Unsaturated Zone Monitoring

An unsaturated zone monitoring system will be established in the Truck Bypass landfarm. The unsaturated zone monitoring system will provide subsurface data used to define the treatment zone in the landfarm. A comprehensive monitoring program, in accordance with 264.278, will be established to determine the quality of the soil-pore liquid and the chemical make-up of the soil in and below the treatment zone. The results of the monitoring program will then being used to evaluate the capacity of the soil to attenuate hazardous constituents in the oily wastes applied to the land surface.

1. Lysimeter Installation

Suction lysimeters will be installed in open soil borings. Two 6 in diameter soil core samples will be collected at one foot intervals using a coring device attached to the drilling rig. The core sample will be analyzed to determine both the chemical make-up of the soil below the treatment zone.

Two suction lysimeters (Soilmoisture Equipment Corporation, Model 1900 or Model 1920) will be installed in the open boring excavated by the core sampling work. The lysimeter sampling cup will be placed below the apparent treatment zone, approximately 5 ft, to collect soil pore liquid passing through the treatment zone. A slurry of grade sand and natural material was used to backfill around the lysimeter to ground level.

2. Lysimeter Sampling and Analysis

Soil pore liquid samples will be obtained on a quarterly basis after waste applications or significant rainfall events. The soil water sampling procedures are discussed in Appendix II-5-1. Soil pore liquid samples will be collected, transported and analyzed in house. Chain of custody control procedures will be employed. Each sample will be labelled with the sample number, name of sampler, date and the time of collection and sampling point. Laboratory log books will be maintained which specify the sampler, name, date and time of collection, sampling procedures, analytical procedures, analyst and date and time of analysis.

Soil pore liquid samples will be analyzed for selected hazardous constituents, including the base neutral extractable organics. A qualitative analysis of the base neutral extractable organics will be obtained by gas chromatographic equipment.

3. Soil Sampling and Analysis

A soil auger will be employed to collect soil samples on a semiannual basis. Sampling locations will be randomly selected by the following procedure. A grid has been superimposed over the landfarm as shown in Figure II-2-2. Sampling locations

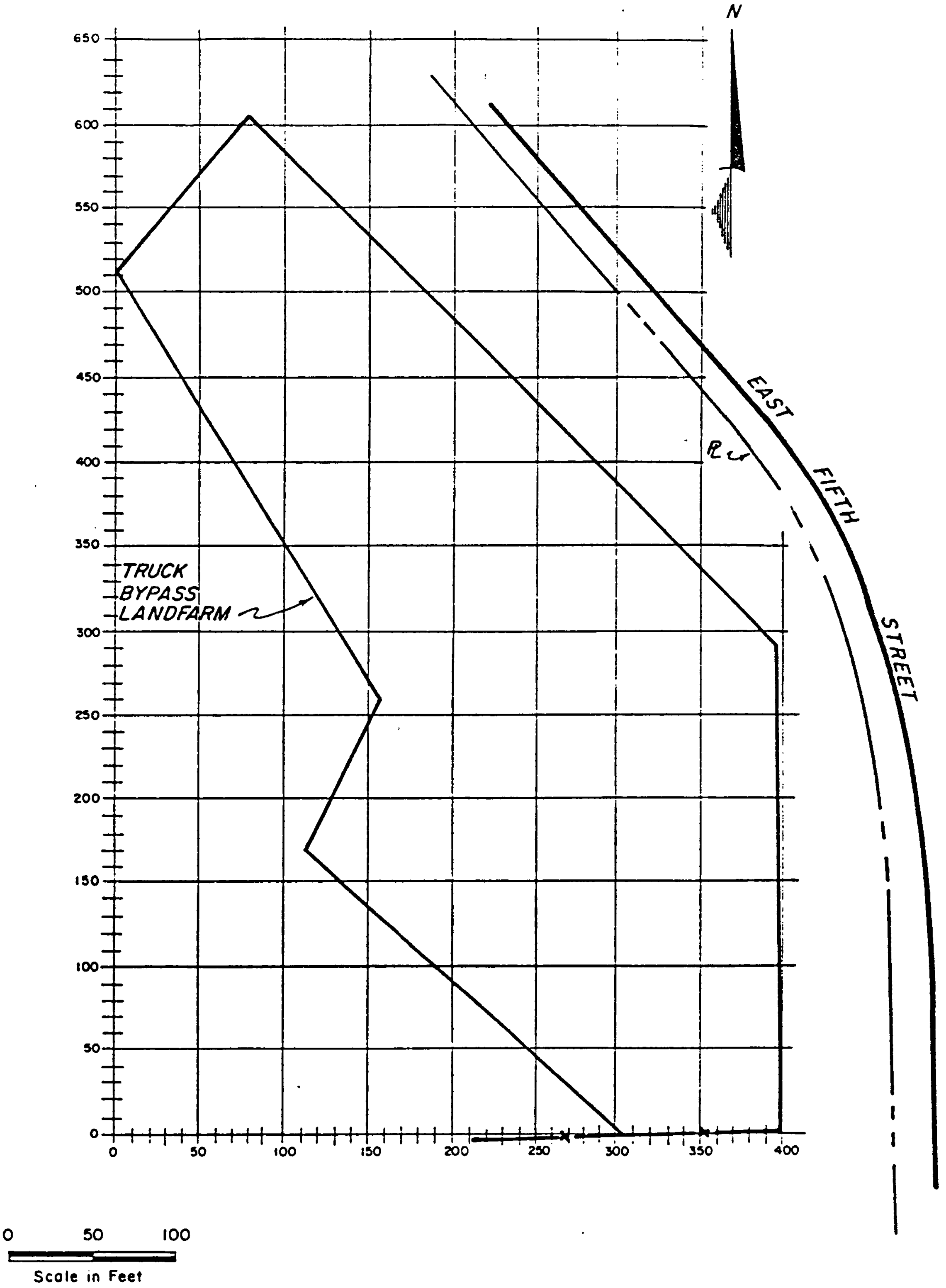


FIGURE II-2-2
SOIL SAMPLING LOCATIONS

will be established by extracting coordinates from a random number table until four sampling locations were identified.

Soil samples will be obtained from the surface and at 6 inch intervals from the soil core. Each subsample will be homogenized and prepared for laboratory analysis. A quantitative analysis will be conducted for the metals chromium and lead. Soil will be prepared by acid digestion procedure followed by analysis by AA. A qualitative analysis will be conducted for the base neutral extractable organic fraction. The soil will be prepared by a soxhlet extraction procedure followed by GC analysis. The metals content and peak area will be plotted as a function of depth to verify the immobilization and degradation processes occurring within the landfarm.

4. Recordkeeping

Soil and soil pore liquid analyses will be conducted on a quarterly and semiannual basis, respectively. Sampling will be conducted after waste applications or significant rainfall events, if possible. Data will be recorded on an example form as shown in Table II-2-5.

D. Treatment Zone

The treatment zone consists of the upper 5 ft of soil in the Truck Bypass landfarm. The base of the treatment zone is 12 ft above the shallow water table which occurs at a depth approximately 17 ft below the land surface.

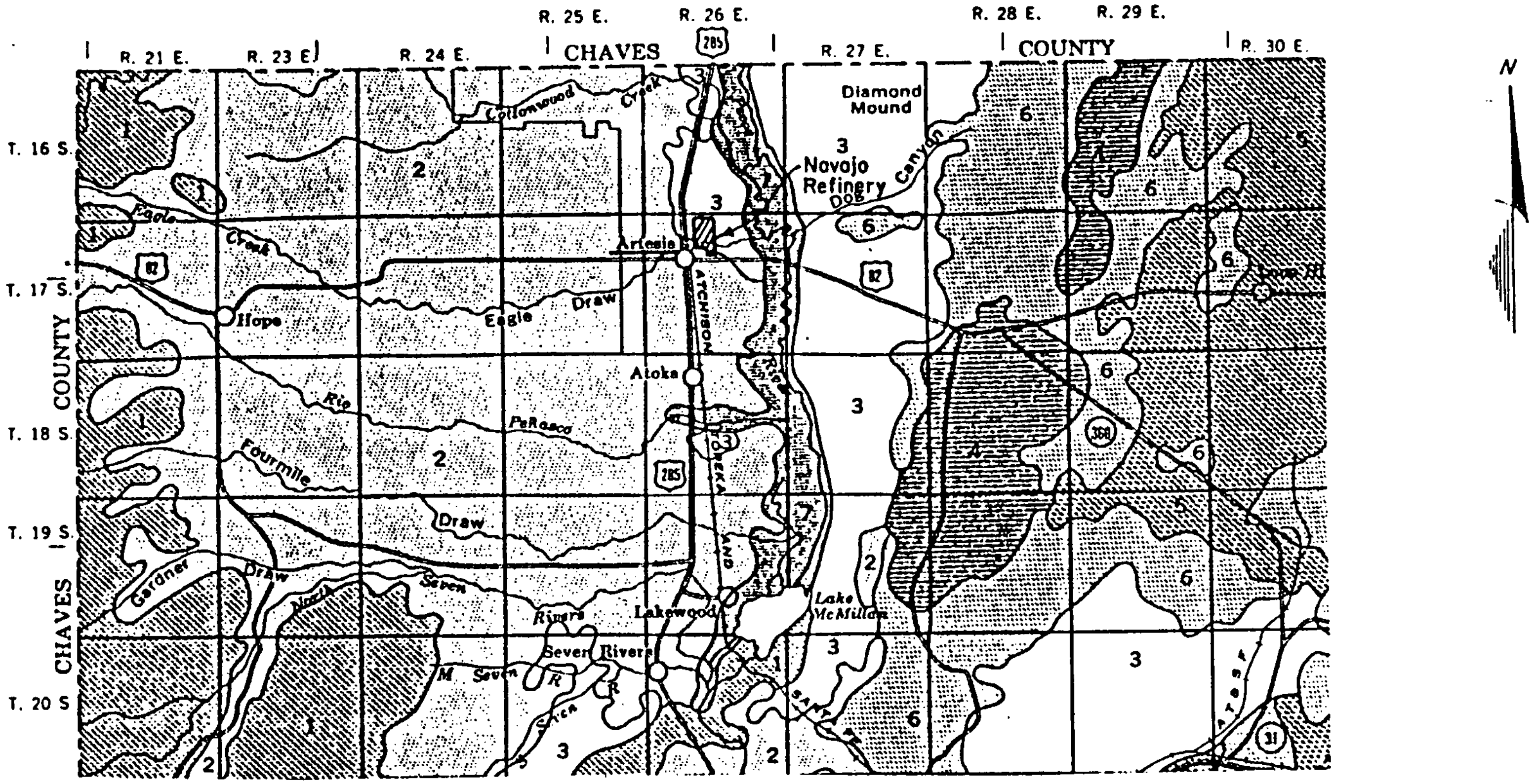
1. Soil Survey

The Navajo refiney is located on the interface of the Reagan-Upton and Reeves-Gypsum Land-Cottonwood associations as shown in Figure II-2-3. The Reagan Upton association are loamy soils which consist of deep to shallow soils on gently undulating plains and in the broader valleys mainly west of the Pecos River. The Pima soils, also in the association, occur on flood plains developed in silty alluvium. The soils are moderately dark colored, calcareous, loamy and are moderately deep over caliche. The Reeves-Gypsum land - Cottonwood association are loamy soils which consist of

Table II-2-5

Unsaturated Zone Monitoring
Example Record Form

		Soil Samples		
		Metal Content (mg/kg)		Base Neutral Extractables
Cell	Sampling Depth (in)	Chromium	Lead	Peak Area
Location A	0			
Sampling Date	6			
______________	12			
Last Waste	18			
Application	24			
______________	30			
Lysimeter Sample	36			
Base Neutral Extractables				
(Peak Area)				
______________				
Location B	0			
Sampling Date	6			
______________	12			
Last Waste	18			
Application	24			
______________	30			
Lysimeter Sample	36			
Base Neutral Extractables				
(Peak Area)				
______________				
Location C	0			
Sampling Date	6			
______________	12			
Last Waste	18			
Application	24			
______________	30			
Lysimeter Sample	36			
Base Neutral Extractables				
(Peak Area)				
______________				
Location D	0			
Sampling Date	6			
______________	12			
Last Waste	18			
Application	24			
______________	30			
Lysimeter Sample	36			
Base Neutral Extractables				
(Peak Area)				
______________				



SOIL ASSOCIATIONS

▨ 1	Limestone rock land-Ector association: Rock land and very shallow, stony and rocky, loamy soils over limestone; on hills and mountains
2	Reagan-Upton association: Loamy, deep soils and soils that are shallow to caliche; from old alluvium
3	Reeves-Gypsum land-Cottonwood association: Loamy soils that are very shallow to moderately deep over gypsum beds, and Gypsum land
4	Kimbrough-Stegall association: Loamy soils that are very shallow to moderately deep to caliche; from old alluvium
▨ 5	Kermit-Berino association: Sandy, deep soils from wind-worked mixed sand deposits
6	Simona-Pajarito association: Sandy, deep soils and soils that are shallow to caliche; from wind-worked deposits
7	Arno-Harkey-Anthony association: Loamy, deep soils from recent mixed alluvium

May 1969

Scale 1:506880

1 0 1 2 3 4 5 6 7 8 Miles

Source: Soil Survey, Eddy Area, New Mexico, USDA, 1971.

FIGURE II-2-3
GENERAL SOIL MAP
NAVAJO REFINERY
URS ENGINEERS

gently undulating soils on plains and low hills, and on gypsum land. Reeves soils are moderately deep, light colored and loamy and occur in swales and drainageways. Karro soils, also in this association, occur on high terraces or flats developed on alluvium. These soils are deep, limy and lightly colored. Soils in the Truck Bypass landfarm consist of the Karro loam (Kr) and Pima silt loam (Pe) as shown in Figure II-2-4. Estimated properties and characteristics are presented in Table II-2-4 and analytical data for selected profiles is shown in Table II-2-7.

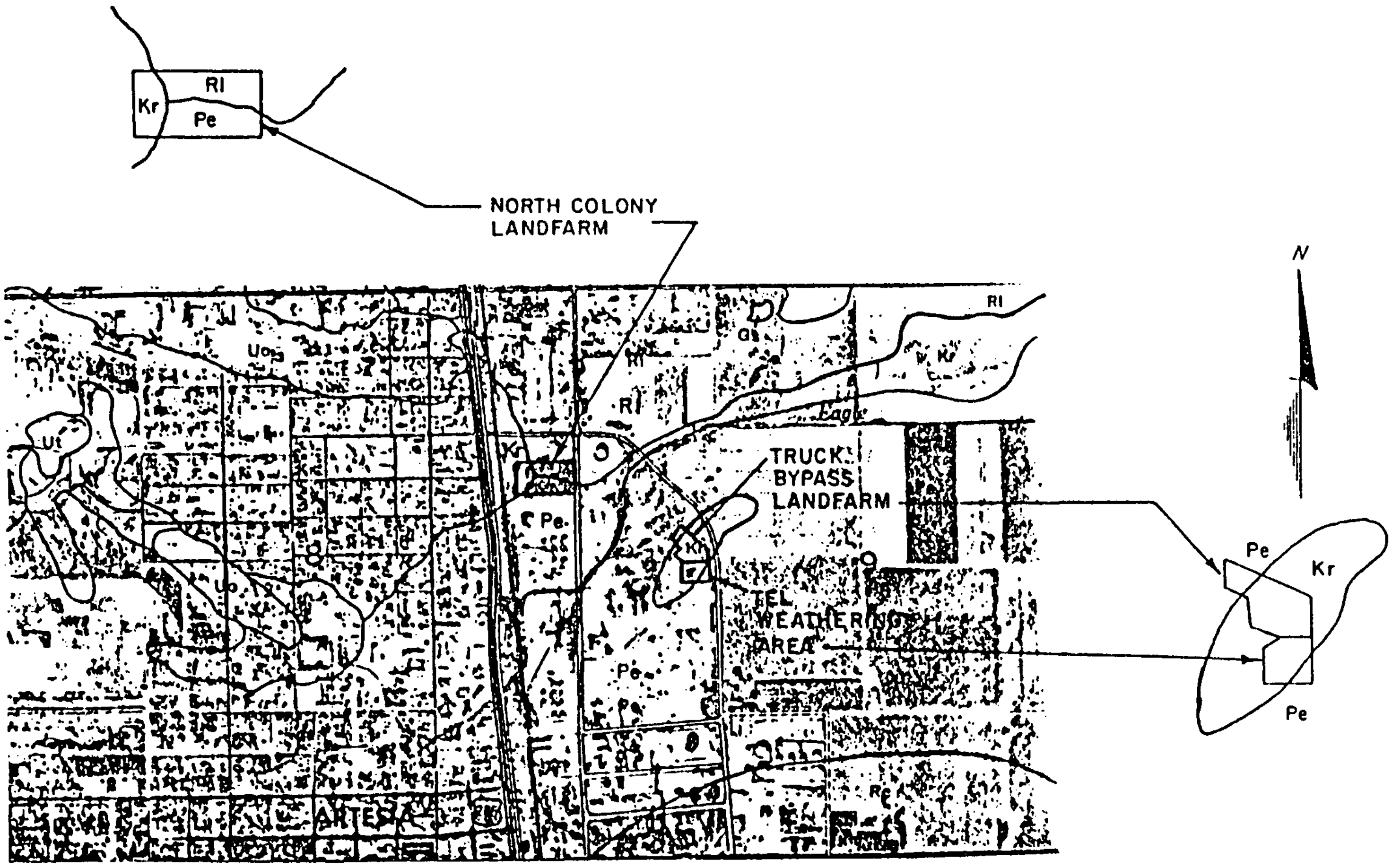
The **Karro** series consists of light-colored, strongly calcareous, loamy soils that developed in deep, old alluvium derived from calcareous, sedimentary rocks. These soils are enriched by lime absorbed from ground water or left by runoff from adjacent limy uplands.

Soils of the Karro series typically have a surface layer of light brownish-gray loam about 10 inches thick. The next layer, about 10 inches thick, consists of very pale brown loam. The substratum is very pale brown and pink clay loam that extends to a depth of more than 60 inches. Calcium carbonate has accumulated at a depth of about 46 inches.

These soils are highly susceptible to wind erosion if the plant cover is seriously depleted or if cultivated areas are left bare. Permeability is moderate. The water-holding capacity is high. The organic-matter content is low.

The **Pima** series consists of deep, well-drained, moderately dark colored, calcareous soils that developed in alluvium derived from limestone. These soils occur on flood plains of narrow drainageways.

Soils of the Pima series typically are light brownish-gray silt loam in the upper 3 inches. Below this brown or light-brown silty clay loam that extends to a depth of 60 inches or more. These soils are subject to periodic flooding, and the floodwaters leave a small amount of deposition. Gullies form if the plant cover is seriously depleted. Runoff is slow. Permeability is moderately slow in the subsoil. The water-holding capacity is high.

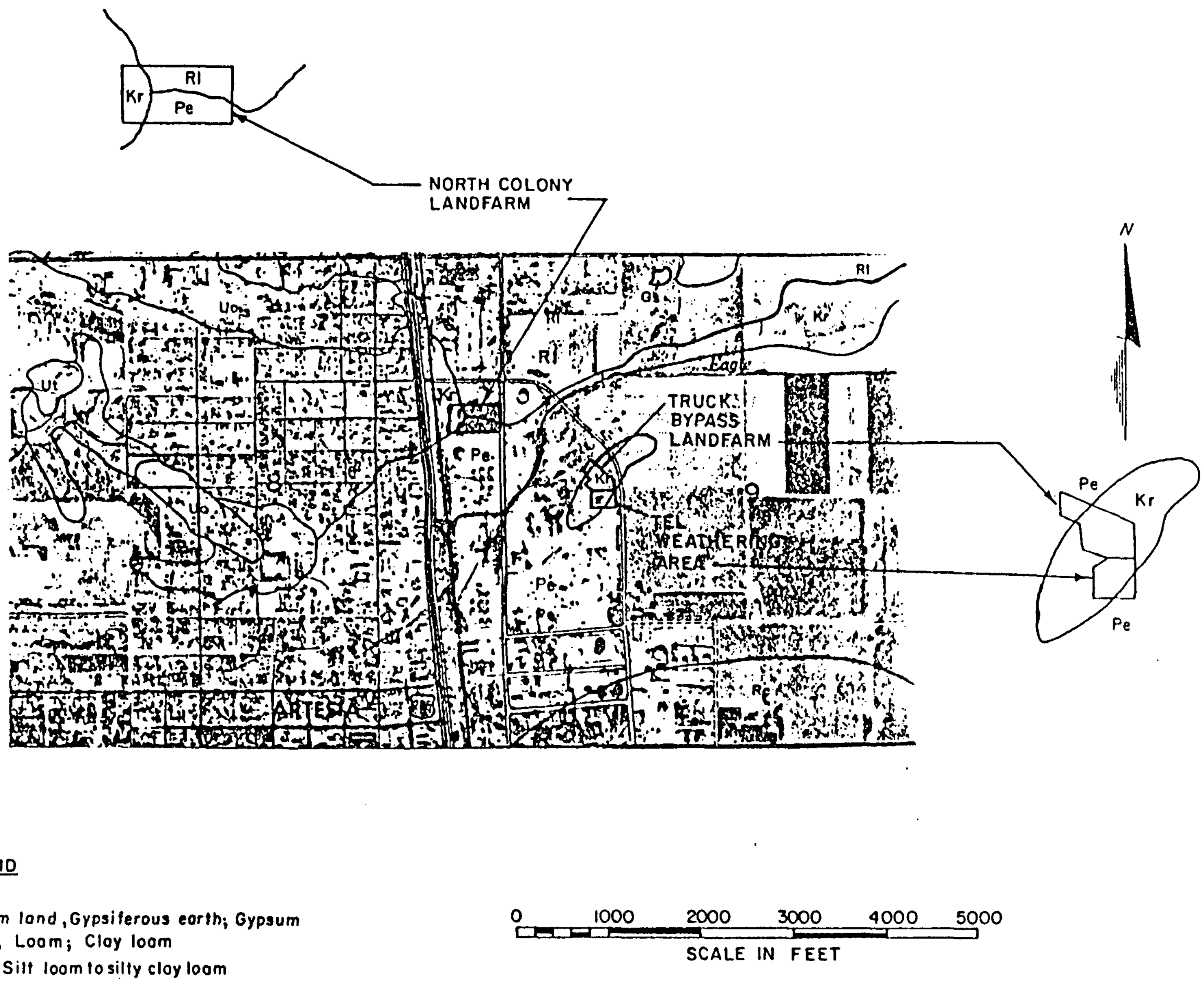


LEGEND

Gs - Gypsum land, Gypsiferous earth; Gypsum
Kr - Karro, Loam; Clay loam
Pe - Pima, Silt loam to silty clay loam
Rc - Reagan, Loam and light clay loam
Rl - Reeves, Heavy loam and light clay loam; Gypsum

Source: Soil Survey, Eddy Area, New Mexico, USDA, 1971.

FIGURE II-2-4
SOIL SURVEY
NAVAJO REFINERY



LEGEND

Gs - Gypsum land, Gypsiferous earth; Gypsum
Kr - Karro, Loam; Clay loam
Pe - Pima, Silt loam to silty clay loam
Rc - Reagan, Loam and light clay loam
Rl - Reeves, Heavy loam and light clay loam; Gypsum

Source: Soil Survey, Eddy Area, New Mexico, USDA, 1971.

FIGURE II-2-4
SOIL SURVEY
NAVAJO REFINERY

TABLE II-2-6

ESTIMATED PROPERTIES AND CHARACTERISTICS

Soil series and map symbols	Depth to bedrock, hard caliche, or gypsum	Depth from surface	Classification		Permeability	Available water capacity	Reaction	Electrical conductivity (Ec × 10^3)
			USDA texture	Unified				
	Inches	Inches			Inches per hour	Inches per inch of soil	pH	Mmho./cm. at 25° C.
Karro: KA, KL, Kr, Ku, Kv	More than 60.	0-20	Loam	ML-CL	0.8-2.5	0.16-0.18	7.9-8.4	4.0-10.0
		24-60	Clay loam	CL	0.8-2.5	0.18-0.20	7.9-8.4	8.0-15.0
Pima: PM, Pe, Pn, Pv	More than 60.	0-60	Silt loam to silty clay loam	CL	0.2-0.8	0.18-0.20	7.4-7.8	0-4.0
Reeves: RG, RM, Rl, Rn, Rt (For Reagan part of RM, see Reagan series; for Gypsum land part of RG, see Gypsum land.)	Soft or hard gypsum at a depth of 10 to 36 inches.	0-32	Heavy loam and light clay loam.	CL	0.8-2.5	0.17-0.19	7.4-7.8	4.0-8.0
		32	Gypsum.					

Source: Soil Survey, Eddy Area, New Mexico, USDA, 1971

TABLE II-2-7

ANALYTICAL DATA FOR SELECTED PROFILES

Soil type, location of sample, and sample number	Horizon	Depth	Texture	Organic carbon	Nitrogen	Electrical conductivity	$CaCO_3$ equivalent	Gypsum	Cation exchange capacity	Extractable cations		Saturation extract soluble cations				Moisture at saturation	Saturation extract soluble sodium	Exchangeable sodium
										Na	K	Na	K	Ca	Mg			
				Pct.	*Pct.*	*Ec × 10³ Mmhos./cm. at 25° C.*	*Pct.*	*Pct.*	*Meq./100 gm.*	*Meq./100 gm.*	*Meq./100 gm.*	*Meq./liter*	*Meq./liter*	*Meq./liter*	*Meq./liter*	*Pct.*	*Meq./100 gm.*	*Meq./100 gm.*
Karro loam: Location: At the center of the E½NW¼SE¼ sec. 7, T. 21 S., R. 28 E. (Sample No. S56NMex-8-21-(1-6); laboratory No. 309-314)	Ap	0-10	Loam.....	.74	.100	9.5	23.4	2.2	12.3	2.8	.8	49.6	1.5	31.0	13.9	32	1.6	1.
	AC	10-20	Loam.....	.52	.091	10.0+	28.7	2.1	12.2	3.8	.8	71.3	1.5	29.4	15.2	38	2.7	1.
	C1	20-46	Clay loam.	.36	.083	10.0+	29.4	1.2	11.3	4.3	.9	84.6	2.0	35.9	24.8	37	3.1	1.
	C2ca	46-60	Clay loam.	.34	.062	10.0+	38.6	.7	10.2	3.2	.9	67.4	2.2	40.4	25.3	36	2.4	.
	C3ca	60-90	Clay loam.	.20	.037	9.0	46.6	.4	8.6	2.0	.4	29.7	1.2	27.9	21.0	37	1.1	.9
Reeves loam: Location: 800 feet E. and 100 feet S. of the NW. corner of sec. 24, T. 23 S., R. 27 E. (Sample No. S57NMex-8-7-(1-4); laboratory No. 355-359)	Ap	0-8	Heavy loam.....	.60	.102	5.0	22.5	1.2	19.9	1.3	.7	9.0	.1	32.4	9.4	40	.4	.9
	AC	8-15	Clay loam......	.51	.096	5.0	30.1	2.0	20.5	1.1	.7	9.9	.1	31.7	9.6	42	.4	.7
	C1ca	15-23	Clay loam......	.31	.064	6.0	43.8	2.6	17.6	3.5	.5	24.9	.1	29.1	13.4	43	1.1	2.4
	C2cs	23-32	Light clay loam; many crystals of gypsum.	.12	.033	6.1	22.3	31.3	13.0	1.4	.2	20.8	.9	29.4	17.4	62	1.1	.1
	Rcs	32	Gypsum															

Source: Soil Survey, Eddy Area, New Mexico, USDA, 1971.

2. Soil Sampling

A soil scientist has been contacted to conduct a soil sampling and analysis program at the North Colony landfarm. In addition to standard investigative procedures, the Soil Scientist has been requested to ascertain the soil pH, cation exchange capacity and nutrient (nitrogen, phosphorus and potassium) levels in the zone of incorporation. He is expected to provide Navajo with recommendations to enhance microbial activity. His soil description report is due by the end of January, 1984.

III. Design, Construction, Operation and Maintenance

A. Surface Water Control

The Truck Bypass landfarm will be surrounded by a dike constructed up to 1.5 ft above grade. The dike will be designed to contain rainwater impacting the landfarm area, preventing surface water runon and runoff. The statistical intensity of a storm with a 24 hour duration and 25 year recurrence frequency is 4 inches. The perimeter dike will be capable of containing precipitation impacted in the landfarm. The rainwater will be impounded and allowed to either infiltrate into the soil or evaporate. There is no need to construct separate stormwater control and storage facilities given the climate and operational procedures.

The arid climate of Artesia controls soil moisture in the North Colony landfarm. Climatic data is tabulated in Table II-2-8. As can be seen, the average annual precipitation is 12.4 inches and the average annual pan evaporation is 112.75 inches. It is estimated that one year in ten will have less than 6.4 inches of rainfall and one year in ten will have more than 18.1 inches of rainfall. The 10 year minimum and maximum monthly rainfall amounts reflect the amount recorded in any one month of a dry or wet year. These monthly minimum and maximum rainfall amounts are not additive in establishing the 10 year minimum and maximum precipitation on an annual basis (i.e., 12 consecutive months of extremes in precipitation is not statistically representative of a 10 year period). The sum of the 10 year minimum and maximum monthly

Table II-2-8

Climatic Data

	Precipitation Data					
		One Year in 10 Will Have		Average Number of Days With		
	Average Total (in)	Less Than (in)	More Than (in)	0.1 in. or more (days)	0.25 in. or more (days)	Evaporation (in)
January	0.44	0.005	0.9	1	1	4.44
February	0.37	0.005	1.0	1	1	5.75
March	0.46	0.005	1.1	1	1	9.51
April	0.54	0.005	1.3	1	1	12.04
May	1.76	0.4	3.4	3	2	14.14
June	1.33	0.1	3.1	2	1	14.79
July	1.56	0.6	2.5	3	2	13.65
August	1.60	0.2	3.1	3	2	12.68
September	1.94	0.2	5.8	3	2	10.13
October	1.61	0.2	3.3	3	1	7.17
November	0.35	0.005	0.7	1	1	4.54
December	0.47	0.005	1.9	1	1	3.91
TOTAL	12.43	6.4	18.1	23	15	112.75

Source: Soil Survey, Eddy Area, New Mexico; Soil Conservation Service, March 1971 precipitation amounts is 1.7 and 28.2 inches, as opposed to the 10 year minimum and maximum precipitation amounts of 6.4 and 18.1 inches, respectively. An average of 23 days in one year will have 0.1 inches or more rainfall, and 15 days in one year will have 0.5 inches or more rainfall.

Several water balances for the landfarm have been developed as shown in Tables II-2-9 and II-2-10. Several assumptions were employed in generating these water balances. The waste is considered to have an average 50% water content. Evaporation is estimated to be 70% of the Class A pan evaporation rate. For evenly distributed waste application, there is a negative amount of storage required in both average and wet years.

The average net precipitation minus evaporation is shown in Table II-2-11 for average, wet and dry years. As can be seen, evaporation exceeds precipitation in each month for each scenario. Single waste applications would be possible in any month without active runoff control because ponding is not expected.

B. Wind Dispersal

The incorporation of wastes into the soil is expected to result in a long term improvement in soil characteristics. The increase in organic matter and water holding capacity should result in a decreased potential for wind dispersal as compared to native soils.

C. Inspection Plan

The landfarm will be inspected weekly and after storms. The active portions of the landfarm are visually inspected for proper spreading and incorporation procedures, the dikes are inspected for any evidence of seepage or structural damage and the security devices are inspected for any signs of corrosion or damage. More details of the inspection plan are contained in Chapter I-5.

IV. Food Chain Crops

Navajo has no plans to grow food chain crops on the landfarm during either the active life or the post closure care period.

Table II-2-9

Water Balance
Average Year - Evenly Distributed Waste Application
(all values in inches)

	Precipitation	Water* In Waste	Evaporation	Percolation	Change in Storage	Cumulative Storage
September	1.94	0.02	10.13	0	-8.17	-8.17
October	1.61	0.02	1.17	0	-5.54	-13.71
November	0.35	0.02	4.54	0	-4.17	-17.88
December	0.47	0.02	3.91	0	-3.42	-21.30
January	0.44	0.02	4.44	0	-3.98	-25.28
February	0.37	0.02	5.75	0	-5.36	-30.64
March	0.46	0.02	9.51	0	-9.03	-39.67
April	0.54	0.02	12.04	0	-11.48	-51.15
May	1.76	0.02	14.14	0	-12.36	-63.51
June	1.33	0.02	14.79	0	-13.44	-76.95
July	1.56	0.02	13.65	0	-12.07	-89.02
August	1.60	0.02	12.68	0	-11.06	-100.08
TOTAL	12.43	0.25	112.75	0	-100.08	

*Note: Includes water in nonhazardous waste only. Contribution of water from TEL weathering area waste can be included once treatment demonstration identifies optimum application rate.

Table II-2-10

Water Balance
Wet Year - Evenly Distributed Waste Application
(all values in inches)

	Precipitation	Water* In Waste	Evaporation	Percolation	Change in Storage	Cumulative Storage
September	3.1	0.02	10.13	0	-7.01	-7.01
October	5.8	0.02	7.7	0	-1.35	-8.36
November	3.3	0.02	4.54	0	-1.22	-9.58
December	0.7	0.02	3.91	0	-3.19	-12.77
January	1.9	0.02	4.44	0	-2.52	-15.29
February	0.9	0.02	5.75	0	-4.83	-20.12
March	1.0	0.02	9.51	0	-8.49	-28.61
April	1.1	0.02	12.04	0	-10.92	-39.53
May	1.3	0.02	14.14	0	-12.82	-52.35
June	3.4	0.02	14.79	0	-11.37	-63.72
July	3.1	0.02	13.65	0	-10.53	-74.25
August	2.5	0.02	12.68	0	-10.16	-84.41
TOTAL	18.1	0.25	112.75	0	-84.41	

Note: Includes water in nonhazardous wastes only. Contribution of water from TEL weathering area waste can be included once treatment demonstration identifies optimum application rate.

Table II-2-11

Average Net Precipitation Minus Evaporation
(all values in inches)

	Average Year	Wet Year	Dry Year
September	-8.19	-4.33	-9.93
October	-5.56	-3.87	-6.97
November	-4.10	-3.75	-4.45
December	-3.44	-2.01	-3.91
January	-4.00	-3.54	-4.44
February	-5.38	-4.75	-5.20
March	-9.05	-8.41	-9.51
April	-11.50	-10.74	-12.04
May	-12.38	-10.74	-13.74
June	-13.46	-11.69	-14.69
July	-12.09	-11.15	-13.05
August	-11.08	-9.58	-12.48
TOTAL	-100.32	-94.65	-106.35

V. Closure

The 3 ac Truck Bypass landfarm will be used to treat wastes excavated from the TEL weathering area and to treat oily refinery wastes generated by Navajo. The landfarm is anticipated to be a viable treatment and disposal facility as long as the refinery is operating. Navajo intends to close the facility when refinery operations cease waste generation in accordance with 264.280.

On an annual basis during the normal operating life of the landfarm, Navajo will analyze samples of surficial soils for pH and nutrients. Soil amendments in the form of lime and fertilizer are then incorporated into the soil to maintain pH and nutrient levels within the desired ranges. Prior to the final waste application, soils will be analyzed to establish whether soil amendments are necessary. If necessary, soil additives will be incorporated into the treatment zone to prepare the landfarm to receive wastes. Once the refinery has ceased operation, all accumulated waste will be removed from the points of generation using standard Navajo waste removal procedures. Navajo will till the treatment zone as soon as possible after the final application of wastes to the treatment zone. Navajo will continue normal operating practices, i.e., till the treatment zone, add fertilizer, maintain pH and control soil moisture, during the 90 days following the last waste application. The inspection schedule, preparedness and prevention precautions and contingency and security considerations pertaining to the land treatment facilities will remain in effect as a part of standard landfarm operations at closure.

Unsaturated zone monitoring will be conducted at the land treatment facility during closure activities. The results of unsaturated zone monitoring will be used in conjunction with inspection results to determine when sufficient treatment has occurred to discontinue tilling and to establish a vegetative cover. Three months after the final waste application, soil and soil pore liquid samples will be obtained in accordance with the unsaturated zone monitoring plan established for each facility. If the soil pore liquid monitoring results do not indicate the presence of hazardous constituents, soil pore monitoring will be discontinued. Navajo does not anticipate conducting soil-pore liquid monitoring for more than 90 days following the last application of wastes. If soil core monitoring does not indicate the presence of metals at levels in excess of phytotoxic concentrations, the tilling of landfarm plots will be discontinued. Soil core monitoring however will continue through closure and the post-closure care period. Once it has been determined that no further tilling or other soil disturbance is necessary for sufficient treatment of wastes, Navajo will establish a vegetative cover over the landfarm plots. Potential candidates for vegetative cover include Russian Thistle and Johnson Grass as these native species require little or no maintenance to thrive. Once this cover has been established, the land treatment facilities will be considered to be closed.

VI. Special Considerations

A. Ignitable and Reactive Wastes

The oily refinery wastes applied to the landfarm are generally not considered ignitable or reactive. However, even if an isolated waste shipment exhibited the characteristics of ignitability or reactivity, once applied to the land surface and incorporated into the surficial soils, the wastes should not be considered ignitable or reactive.

B. Incompatible Wastes

The various oily refinery wastes applied to the North Colony landfarm are not incompatible, so no special handling procedures are necessary.

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Chapter III-I

Additional Information Requirements

40 CFR Part 270.14(c)

The following additional information regarding protection of ground water is required for owners or operators of hazardous waste surface impoundments, piles, land treatment units, and landfills, except as otherwise provided in 264.90(b):

1. A summary of the ground-water monitoring data obtained during the interim status period under 265.90-265.94, where applicable.

2. Identification of the uppermost aquifer and aquifers hydraulically interconnected beneath the facility property, including ground-water flow direction and rate, and the basis for such identification (i.e., the information obtained from hydrogeologic investigations of the facility area).

3. On the topographic map required under paragraph (a)(19) of this section, a delineation of the waste management area, the property boundary, the proposed "point of compliance" as defined under 264.95, the proposed location of ground-water monitoring wells as required under 264.97 and, to the extent possible, the information required in paragraph (c)(2) of this section

4. A description of any plume of contamination that has entered the ground water from a regulated unit at the time that the application is submitted that:
    - i. Delineates the extent of the plume on the topographic map required under paragraph (a)(19) of this section;
    - ii. Identifies the concentration of each Appendix VIII of Part 261 of this chapter constituent throughout the plume or identifies the maximum concentrations of each Appendix VIII constituent in the plume.

5. Detailed plans and an engineering report describing the proposed ground-water monitoring program to be implemented to meet the requirements of 264.97;

6. If the presence of hazardous constituents has not been detected in the ground water at the time of permit application, the owner or operator must submit sufficient information, supporting data, and analyses to establish a detection monitoring program which meets the requirements of 264.98. This submission must address the following items as specific under 264.98:
    - i. A proposed list of indicator parameters, waste constituents, or reaction products that can provide a reliable indication of the presence of hazardous constituents in the groundwater;
    - ii. A proposed groundwater monitoring system;
    - iii. Background values for each proposed monitoring parameter or constituent, or procedures to calculate such values; and
    - iv. A description of proposed sampling, analysis and statistical comparison procedures to be utilized in evaluating ground-water monitoring data.

7. If the presence of hazardous constituents has been detected in the ground water at the point of compliance at the time of permit application, the owner or operator must submit sufficient information, supporting data, and analyses to

establish a compliance monitoring program which meets the requirements of 264.99. The owner or operator must also submit an engineering feasibility plan for a corrective action program necessary to meet the requirements of 264.100, except as provided in 264.98(h)(5). To demonstrate compliance with 264.99, the owner or operator must address the following items:

i. A description of the wastes previously handled at the facility;
ii. A characterization of the contaminated ground water, including concentrations of hazardous constituents;
iii. A list of hazardous constituents for which compliance monitoring will be undertaken in accordance with 264.97 and 264.99;
iv. Proposed concentration limits for each hazardous constituent, based on the criteria set forth in 264.94(a), including a justification for establishing any alternate concentration limits;
v. Detailed plans and an engineering report describing the proposed ground-water monitoring system, in accordance with the requirements of 264.97; and
vi. A description of proposed sampling, analysis and statistical comparison procedures to be utilized in evaluating ground-water monitoring data.

8. If hazardous constituents have been measured in the ground water which exceed the concentration limits established under 264.94 Table 1, or if ground-water monitoring conducted at the time of permit application under 265.90-265.94 at the waste boundary indicates the presence of hazardous constituents from the facility in ground water over background concentrations, the owner or operator must submit sufficent information, supporting data, and analyses to establish a corrective action program which meets the requirements of 264.100. However, an owner or operator is not required to submit information to establish a corrective action program if he demonstrates to the Regional Administrator that alternate concentration limits will protect human health and the environment after considering the criteria listed in 264.94(b). An owner or operator who is not required to establish a corrective action program for this reason must instead submit sufficient information to establish a compliance monitoring program which meets the requirements of 264.99 and paragraph (c)(6) of this section. To demonstrate compliance with 264.100, the owner or operator must address, at a minimum, the following items:

i. A characterization of the contaminated groundwater, including concentrations of hazardous constituents;
ii. The concentration limit for each hazardous constituent found in the groundwater as set forth in 264.94;
iii. Detailed plans and an engineering report describing the corrective action to be taken; and
iv. A description of how the ground-water monitoring program will assess the adequacy of the corrective action.

Chapter III

Groundwater Monitoring

List of Tables

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Groundwater Monitoring

I. Introduction

Navajo has instituted a groundwater monitoring program to satisfy the interim status groundwater monitoring requirements outlined in Part 265, Subpart F. The wells were located such that one upgradient and three downgradient wells would allow immediate detection of subsurface contaminant movement due to the simple proximity of well locations. The groundwater protection standards of Part 264, Subpart F contain additional monitoring requirements to which regulated hazardous waste management units are subject. The proposed monitoring program, as outlined in the following pages, is responsive to these standards and the additional information requirements of 270.14(c).

II. Hydrogeologic Framework

The refinery is located in south central Eddy County, just east of Artesia, New Mexico. The site has approximate map coordinates of latitude 32° 50' 40" N and longitude 104° 23' 22" W. The site is bounded by State Highway 82 on the south, ATSF Railroad on the west and East Fifth Avenue on the east and north. The climate is semi-arid with an average annual temperature of 60.9°F and an average annual precipitation rate of 12.4 inches.

The site is basically flat with altitudes ranging from 3360 to 3370 ft National Geodetic Vertical Datum (NGVD). Natural site drainage is to Eagle Draw, which transects the site from the west to the northeast.

A. Regional Setting

The Navajo refinery is located in the Roswell Artesian Basin, as declared by the New Mexico State Engineer, where both artesian and shallow waters are fully appropriated and applications for new development are not approved. The geology and groundwater in the Roswell basin have been studied more thoroughly than those of any other area in New Mexico. The geologic units important to the groundwater supply in the Roswell basin are the San Andres formation, the Chalk Bluff formation and the Quaternary alluvium.

1. San Andres and Chalk Bluff formations

The San Andres formation, about 1,000 feet thick in this area, is composed of limestone and dolomite, and it contains solution cavities ranging from a fraction of an inch to several feet in diameter. The cavernous zones are not confined to certain beds but are extremely irregular and erratic. The San Andres formation crops out in the western highlands and dips eastward under younger sedimentary rocks in the irrigated area. This formation is the chief artesian aquifer in the Roswell basin.

The Chalk Bluff formation consists of redbeds, gypsum, and limestone and overlies the San Andres formation. It crops out in a broad area east of the outcrop of the San Andres. The limestone of the basal part of the Chalk Bluff formation is an important artesian aquifer in the southern part of the Roswell basin.

The Chalk Bluff has a total thickness of more than 1,000 feet; however, erosion has removed much of the formation in the lowland part of the basin. The thickness of the Chalk Bluff increases rapidly from west to each across the basin, for the dip of the beds is greater than the surface slope. The maximum thickness of the Chalk Bluff, in the irrigated area, about 800 to 900 feet, is between Hagerman and Lake Arthur north of Artesia. The thickness near Lakewood, west of Lake McMillan, is about 400 to 600 feet.

The water in the San Andres formation and overlying Chalk Bluff formation moves eastward to discharge indirectly into the Pecos River. Except for a few wells drawing water from perched zones, the altitudes of water levels decline fairly uniformly eastward. The slope is about 3 feet per mile near the north boundary of the county and about 10 feet per mile near Seven Rivers, at the south boundary of the artesian basin.

Discharge from the artesian aquifer is by wells, by upward percolation through the shaly beds of the Chalk Bluff into the alluvium and to springs, and by leakage through poorly cased wells. The lowering of artesian pressures due to discharge of wells probably has decreased the discharge by the other methods and discharge by wells is now greater than that by all other methods. The discharge of artesian wells in Eddy and Chaves Counties has almost stopped the flow of the large artesian springs near Roswell, which formerly discharged most of the water from the artesian aquifer. As a result of the lowering of artesian pressures, few artesian wells flow in the summer.

The amount of water that can be obtained from storage per unit of area in an artesian aquifer depends in part on the compressibility of the aquifer. The compressibility of limestone is generally very small, and the amount of water available from storage represented by a reduction in pressure is correspondingly small. Because of the small amount of water available from storage, pumping from a well affects the water levels in other wells over a large area. Water discharged by artesian wells in this area must eventually be balanced by a decrease in the natural discharge and/or a reduction in storage in the outcrop area of the aquifer where the water is unconfined.

As the water in the San Andres formation moves chiefly through cavities in the limestone, which are irregularly distributed, the yield of wells differs greatly within short distances. However, yields large enough for irrigation can generally be obtained from wells penetrating the artesian aquifers in most of the Roswell basin.

2. Alluvium

The Quaternary alluvium, consisting of clay, silt, sand, gravel, and conglomerate, is at the surface over the entire irrigated area and is the source of shallow water used for irrigation in the area. The alluvium unconformably overlies both the San Andres and the Chalk Bluff formations and locally is slumped and distorted owing to solution and collapse of underlying rocks. The material varies widely in composition both vertically and horizontally. The thickness of the alluvium ranges from a feather edge in the west to more than 300 feet in places a short distance west of the Pecos River.

The water in the alluvium is from five sources: local precipitation, surface water, losses from leaky artesian wells, natural leakage of artesian water from the underlying artesian aquifers, and irrigation return. The amount of water from each source is variable and indeterminate; however, the importance of the various sources of shallow groundwater can be inferred from the conditions governing each. The greater part of the shallow groundwater supply is derived directly or indirectly from the artesian supply. Contributions from direct precipitation and from surface drainage on the whole contribute only a small part of the total recharge. Of the recharge from the artesian supply, natural leakage is believed to be the more important.

The movement of the shallow groundwater is in general to the east toward the Pecos River where it discharges. Shallow groundwater also discharges into most of the lower courses of tributary streams where their channels are cut below the water table; hence, groundwater locally moves toward those streams.

There are a great number of shallow irrigation wells in the irrigated area which discharge large quantities of water in addition to the artesian irrigation wells. Introduction of this artificial discharge has altered locally the movement of shallow groundwater, inducing it to flow to the wells.

The capacities of the wells taking water from the alluvium vary widely because of the erratic occurrence of the sand and gravel beds that supply the water. However, sufficient water for irrigation is available from wells in the valley fill in most of the area. Measured specific capacities of 13 wells distributed throughout the valley in Chaves and Eddy Counties ranged from 12 to 78 gallons per minute per foot of drawdown (Theis, Sayre, and others, 1942, p. 49). The average transmissibility of the alluvium has been estimated at 100,000 to 150,000 and the average coefficient of storage at about 10 percent. (Theis, Sayre, and others, 1942, p. 49). The coefficient of storage in the alluvium is much greater than that in the artesian aquifer.

B. Local Setting

1. Overview

The refinery is located above the Orchard Park terrace on the Roswell Basin as shown in Figure III-1. The Orchard Park terrace is about 40 to 60 ft above the Pecos River and flanks the Lakewood terrace which is about 20 to 30 ft above the Pecos River. The Orchard Park terrace, which slopes gently toward the Pecos, is very little dissected. More than 90 percent of the irrigated farms in the county are located on this terrace.

The younger alluvium deposited by the Pecos River and its tributaries forms a veneer, 5 to 20 ft thick, over the Orchard Park terrace. The alluvium underlies the Lakewood terrace adjacent to the Pecos River to a maximum depth of approximately 40 ft. The deposits which overlay the Orchard Park terrace are of Pleistocene age, whereas those associated with the Lakewood terrace were deposited in recent time.

The younger alluvium consists of undisturbed silt, sand, gravel and cobbles. The deposits associated with the Orchard Park and Lakewood terraces are generally finer grained than the same alluvium at higher elevations. In general, the younger alluvium is above the water table over most of the Orchard Park terrace. Some wells in the Lakewood terrace yield water, but the highest yielding wells on the terrace probably tap the underlying quartzose conglomerate.

The quartzose conglomerate ranges in thickness from a feather edge to more than 300 feet and consists of clay, silt, sand, gravel, and conglomerate (mainly caliche). The quartzose conglomerate is thought to be basal Ogallala (late Tertiary).

The confined water table identified at Navajo Refinery by existing monitoring well installations appears to be a thin cobble seam in the younger alluvium deposits. It

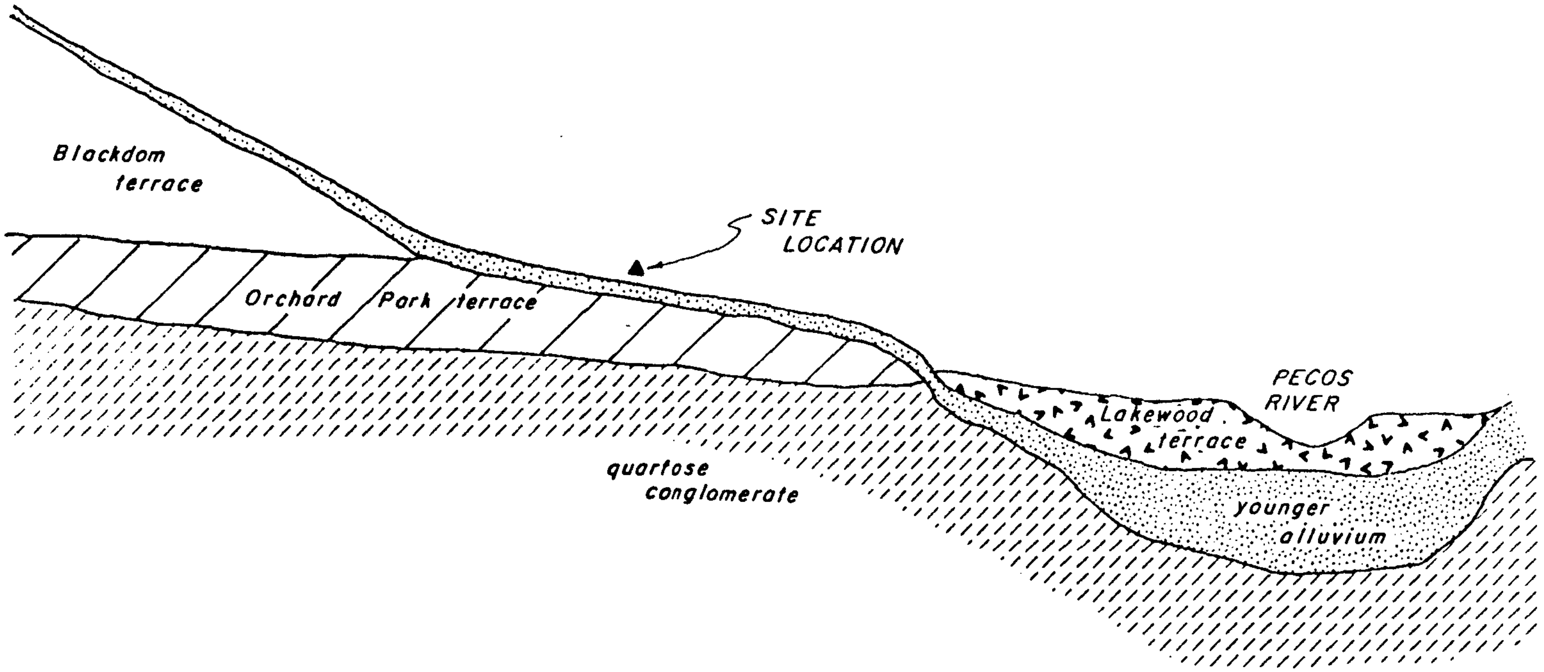

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FIGURE III-1
REGIONAL GEOLOGIC
CROSS SECTION
NAVAJO REFINERY

is also possible that the water bearing zone is the seam between the Orchard Park terrace and the younger alluvium. The potentiometric surface of this water bearing zone slopes with the land surface to the northeast toward Eagle Draw and the Pecos River.

2. Subsurface Characteristics

A subsurface soil profile of the North Colony Landfarm Area is represented in Figure III-2. The soil boring logs from which this profile was constructed is presented in Appendix III-1. The water bearing zone typically is a confined pebble seam under pressure. A silty clay comprises the upper confining layer, and a clay comprises the lower confining layer.

Soil samples were retained in Shelby tubes during the drilling of the monitoring well borings to characterize the lithography above, below and in the water bearing zone. Geotechnical analyses were conducted on selected samples to determine grain size distribution (with hydrometer analysis, where necessary), vertical permeability, specific gravity, and dry unit density. This information was used to calculate porosity and hydraulic conductivity for the various sub-surface zones and is presented in Table III-1. Most of the porosities are high and reflect the presence of very fine soil materials. These fines are responsible for the low permeabilities measured in the lab.

A value for hydraulic conductivity was calculated based on the uniformity coefficient and median grain size extracted from the grain size distribution curves. The measured and calculated values for hydraulic conductivity for boring 34 are quite different. It is suspected that the boring 34 sample pulled away from the laboratory permeametet and some channeling occurred, increasing the apparent permeability value. The high porosity (indicative of clayey soil) is another indicator that the vertical permeability associated with boring 34 is too high.

The vertical permeabilities of the upper and lower confining zones were measured in the laboratory, and found to be between 10^{-6} and 10^{-8} cm/sec. The

Table III-1

Porosity and Hydraulic Conductivity

Boring	Depth (feet)	Laboratory Permeability (cm/sec)	Calculated Permeability (cm/sec)	Porosity
31	20'	4.80×10^{-7}	10^{-6}	.49
33	10'	2.27×10^{-6}	10^{-6}	.33
34	16'	2.20×10^{-4}	10^{-6}	.47
36	15'	-	10^{-6}	-
37	15'	8.17×10^{-8}	10^{-6}	.46
38	10'	-	10^{-3}	-

hydraulic conductivity calculated for boring 38 is representative of the water bearing zone permeability.

3. Groundwater Flow Information

Water level elevations were obtained to define the potentiometric surface and the direction of groundwater flow. Table III-2 presents the water level measurements made during the collection of groundwater samples during first, third and fourth quarters. Groundwater elevations at the time of collection of second quarter monitoring samples are unavailable. The configuration of the potentiometric surface from the water level data is illustrated in Figures III-3, III-4 and III-5. Contours determined from the shallow wells indicate the principal direction of groundwater flow is in a northerly to northeasterly direction. The maximum northeasterly hydraulic gradient ranged from 0.36 to 0.90%.

Annual determinations of the uppermost aquifer flow rate and direction are made by first measuring the water levels in the monitor wells. Water level elevations are calculated by subtracting the water level depth measurement from the elevation of the top of the monitor-well casing. The water-table elevations are plotted on a well location map and contoured. The direction of movement is perpendicular to the contours. It is anticipated that the potential direction of flow will remain northeasterly.

The potential rate of flow is calculated by first estimating the hydraulic gradient. It is determined by dividing the difference between the highest and lowest water table elevation contours, shown on the water table contour map, by the average horizontal distance between the contour lines. Darcy's law is used to calculate the flow velocity according to the following equation, $v = Ki/N_e$, where: v = the interstitial pore water velocity; K = hydraulic conductivity; i = hydraulic gradient; N_e = effective porosity. The hydraulic conductivity of the uppermost aquifer is assumed to be 10^{-3} cm/sec and the effective porosity is estimated at 0.3. Using an average hydraulic gradient of 0.0060, the flow velocity is 20.7 ft/year.

Table III-2

Water Level Measurements

	Elevation at Top of Casing (ft above msl)	Water Level Evaluation (ft above msl)		
		First Quarter (10-22-82)	Third Quarter (7-83)	Fourth Quarter (10-3-83)
Upgradient				
Well 31	3366.30	3356.14	3354.22	3356.30
Downgradient				
Well 32	3363.72	3354.02	3352.80	3352.72
Well 33	3363.28	3353.47	3352.20	3351.45
Well 34	3364.74	3354.14	3352.64	3353.53

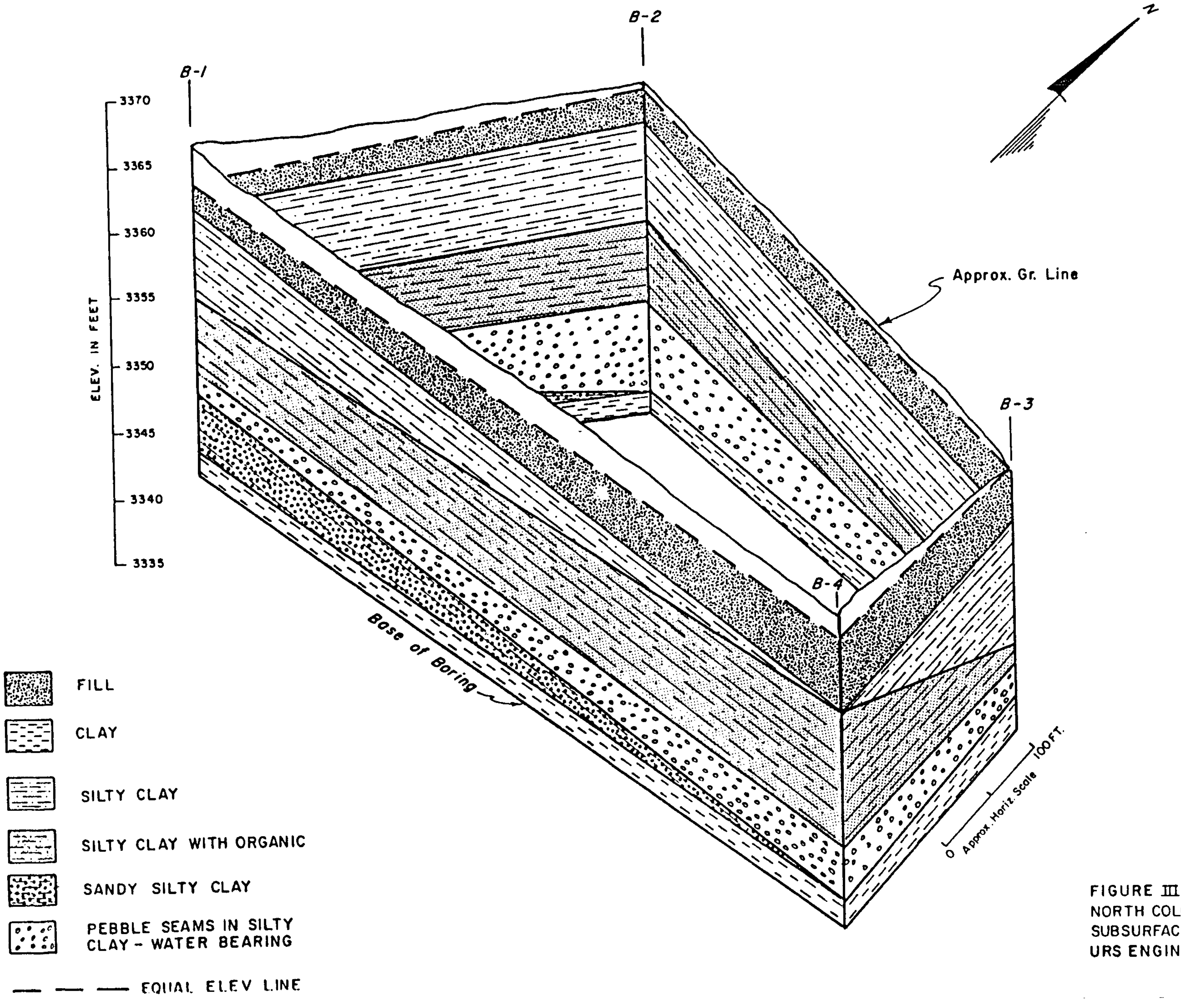

FIGURE III-2
NORTH COLONY LANDFARM
SUBSURFACE SOIL PROFILE
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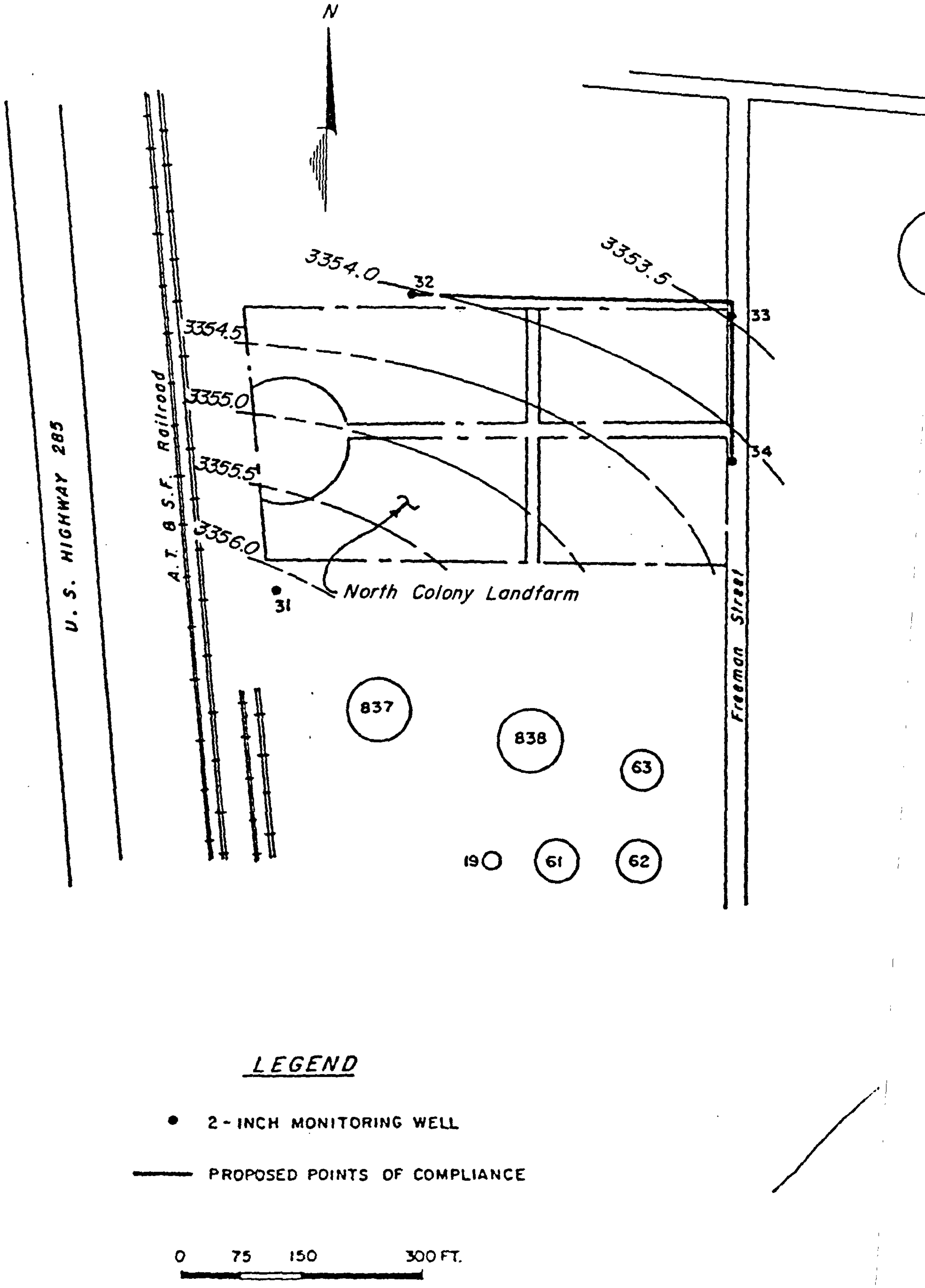

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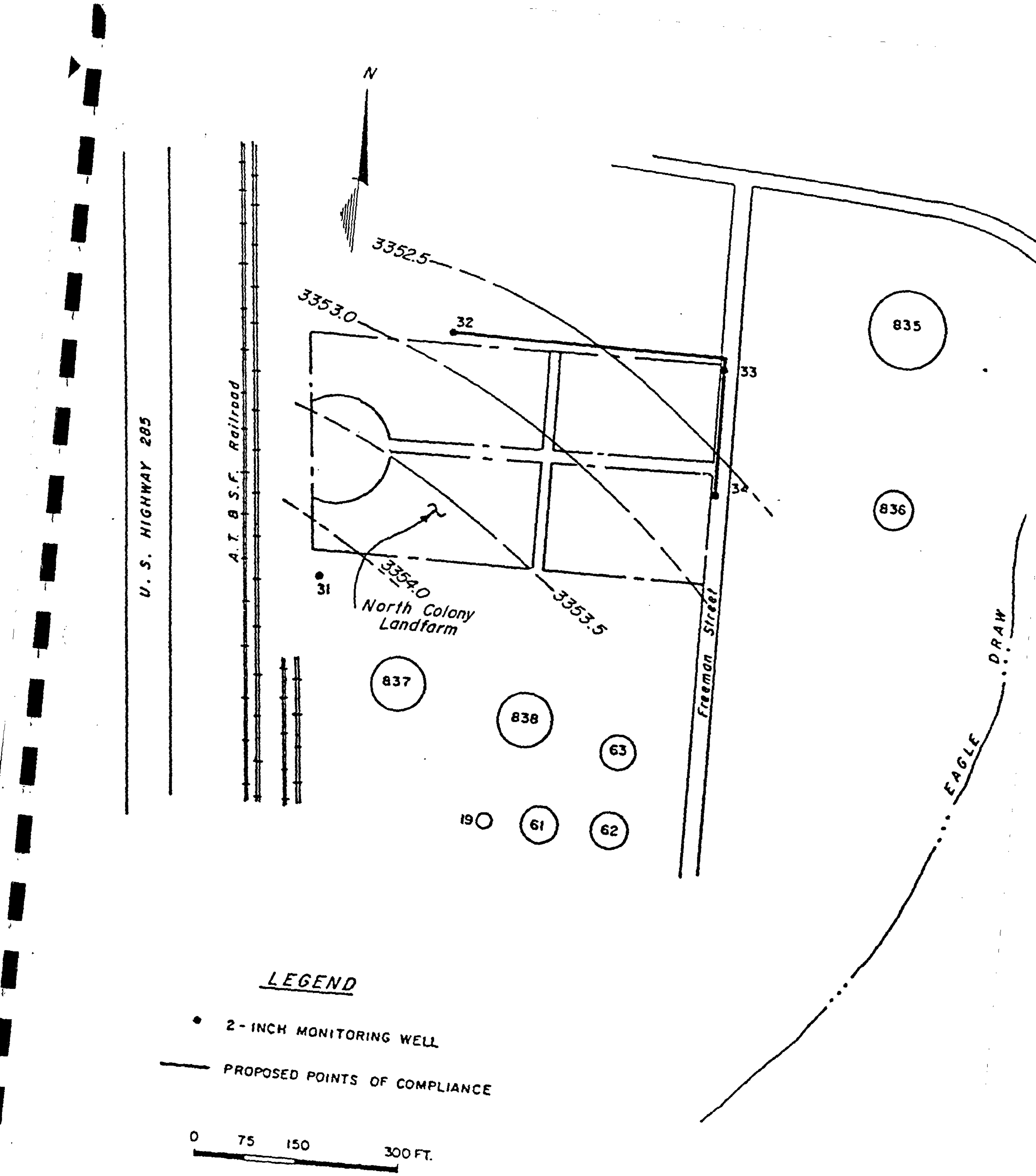

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FIGURE II-1-4
POTENTIOMETRIC SURFACE
JULY 1983

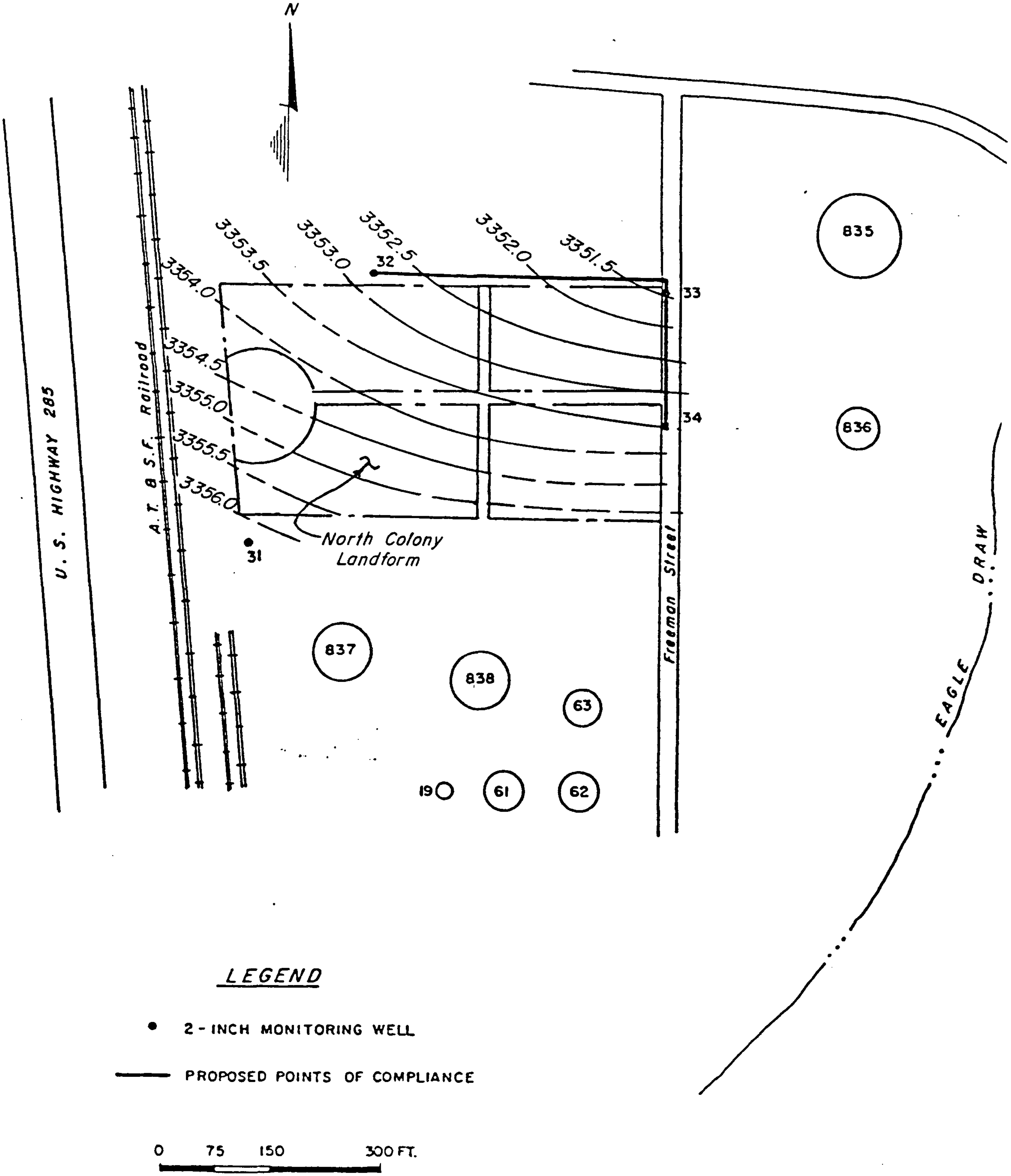

FIGURE II-1-5
POTENTIOMETRIC SURFACE
OCTOBER 1983

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The Pecos River is the hydraulically connected surface water body that would be "potentially influenced" by groundwater underlying the North Colony landfarm. It is located 3 miles to the northeast of the landfarm. The quantity of groundwater flow away from the landfarm in the uppermost aquifer is conservatively estimated to be about 26,910 cubic feet per year as calculated by the equation $Q = AV$, where Q is the flow in cubic feet per year, A is the cross sectional area in square feet and V is the velocity in ft/year. The cross sectional area is estimated to be 1300 square feet, assuming an aggregate thickness of 2 ft of 2 inch thick cobble seams in the silty clay and a maximum horizontal landfarm dimension of 600 ft.

III. Existing Groundwater Monitoring System

A groundwater monitoring system has been installed and maintained at the Navajo facility to up and down gradient of the North Colony landfarm to detect the migration of contaminants and to characterize geohydrology conditions. One well is placed upgradient and three wells are located downgradient of the waste management area as required by interim status standards.

A. Installation Procedures

The wells were installed in borings created with a hollow stem auger. The borings average 20 ft in depth. Split spoon samples were taken at 5 ft intervals to help characterize the soil lithography. Shelby tube samples were taken to retain soil cores for geotechnical testing to further characterize subsurface characteristics. Cores were retained from above, below and in the water bearing zone. The cores were tested for permeability, natural moisture content, grain size distribution and dry unit density.

The wells were completed with 2 in schedule 40 screw together PVC casing. All the wells have a gravel pack around the entire 5 feet of the 0.02 slotted screen at the water bearing zone. A bentonite plug was put in place above the gravel pack, followed by a bentonite-cement grout seal from the plug to the ground surface. Also, protective steel casing was placed around the top of each monitoring well. Well completion specifics are presented in Appendix III-2.

An air-lift method was employed to develop the monitoring wells. The wells were blown out to develop the gravel pack filter around the screen. This procedure helps to insure that the samples obtained are representative of the in situ groundwater and not the well drilling operation.

2. Monitoring Data

Groundwater samples are collected at the compliance point, defined by 264.95(a) as the vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated unit. The waste management area is defined under 264.95(b) as the outer limit of the area on which waste will be placed during the active life of a regulated unit.

The existing groundwater monitoring system has provided Navajo with four quarters of monitoring results. Interim status standards require sampling and analysis for parameters used as indicators of groundwater contamination (265.92(b)(3)), parameters establishing groundwater quality (265.92(b)(2)), and parameters characterizing the suitability of groundwater as a drinking water supply (265.92(b)(1)). The results of the chemical analyses from samples obtained from the monitoring network is presented in Tables III-3 through III-6.

3. Data Evaluation

Interim status standards require Navajo to establish initial mean concentrations for parameters indicative of groundwater contamination, groundwater quality and drinking water quality. The mean concentrations for all parameters analyzed during the first four quarters of groundwater monitoring are presented in Table III-7.

The statistical procedure outlined in Part 264, Appendix IV, Cochran's approximation to the Behrens-Fisher Students' t-test (as outlined in Section IV.C.2 of

Table III-3

North Colony Landfarm
First Quarter Groundwater Monitoring Results
(Sampled 11-1-82 and 12-1-82)

Parameter	Unit	Well Number 31 upgradient	32 downgradient	33 downgradient	34 downgradient
Indicator					
pH	Std. Units	7.31*	7.41	7.41	7.30
Specific Conductance	umho/cm	2545*	2693	3590	2563*
Totol Organic Carbon	mg/l	63*(49)	240(8)	625(14)	25(64)
Total Organic Halogen	mg/l	0.042*	0.102	0.065	0.026
Total Dissolved Solids	mg/l	1434	2014	2812	1684
Groundwater Quality					
Chloride	mg/l	89(105)	116(125)	163(170)	173(180)
Iron	mg/l	0.06	<0.01	<0.01	1.81
Manganese	mg/l	1.08	0.311	0.521	0.567
Phenols	mg/l	<0.001	<0.001	<0.001	<0.001
Sodium	mg/l	100(86)	35.4(36)	44.4(39)	88.5(92)
Sulfate	mg/l	423(540)	1049(1120)	1428(1310)	613(430)
Primary Drinking Water					
Arsenic	mg/l	<0.01	<0.01	<0.01	<0.01
Barium	mg/l	0.1	<0.1	<0.1	0.1
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001
Chromium	mg/l	<0.001	<0.001	<0.001	0.004
Fluoride	mg/l	1.15	1.28	2.70	1.28
Lead	mg/l	0.002	0.001	0.001	0.005
Mercury	mg/l	<0.0004	<0.0004	<0.0004	<0.0004
Nitrate (as N)	mg/l	0.1	0.1	<0.1	<0.1
Selenium	mg/l	<0.01	<0.01	<0.01	<0.01
Silver	mg/l	<0.01	<0.01	<0.01	<0.01
Pesticides & Herbicides	--	ND	ND	ND	ND
Radioactivity		samples not analyzed due to high TDS			
Turbidity	Jackson Units	75	40	30	190
Coliform	col/100 ml	1	200	1	200,000

* average of four replicates

values in parentheses are the results of resampling (12-1-82) and reanalysis.

Table III-4
North Colony Landfarm
Second Quarter Groundwater Monitoring Results
(Sampled 2-24-83)

Parameter	Unit	Well Number			
		31 upgradient	32 downgradient	33 downgradient	34 downgradient
Indicator					
pH	Std Units	7.0	6.7	6.8	7.1
Specific Conductance	umho/cm	2135*	2300	3030	1900
Total Organic Carbon	mg/l	88*	10	20	20
Total Organic Halogen	mg/l	0.038*	0.037	0.017	0.043
Total Dissolved Solids	mg/l	1810	3290	2790	1510
Groundwater Quality					
Chloride	mg/l	120	150	150	140
Iron	mg/l	0.88	0.09	0.30	0.03
Manganese	mg/l	1.5	0.439	0.234	0.260
Phenols	mg/l	0.006	<0.001	0.001	0.005
Sodium	mg/l	81	33	40	43
Sulfate	mg/l	690	990	1450	440
Primary Drinking Water					
Arsenic	mg/l	<0.01	<0.01	<0.01	<0.01
Barium	mg/l	0.2	<0.1	<0.1	0.1
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001
Chromium	mg/l	0.002	0.004	0.002	0.001
Fluoride	mg/l	1.3	1.7	3.5	1.4
Lead	mg/l	<0.001	<0.001	<0.001	<0.001
Mercury	mg/l	<0.0004	<0.0004	<0.0004	<0.0004
Nitrate (as N)	mg/l	<0.1	<0.1	<0.1	<0.1
Selenium	mg/l	<0.01	<0.01	<0.01	<0.01
Silver	mg/l	<0.01	<0.01	<0.01	<0.01
Pesticides & Herbicides	--	ND	ND	ND	ND
Radioactivity		samples not analyzed due to high TDS			
Turbidity	Jackson Units	175	40	110	75
Coliform	col/100 ml	<1	<1	<1	<1

* average of four replicates

Table III-5
North Colony Landfarm
Third Quarter Groundwater Monitoring Results
(Sampled 7-14-83)

Parameter	Unit	Well Number			
		31 upgradient	32 downgradient	33 downgradient	34 downgradient
Indicator					
pH	Std Units	7.56*	7.59	7.46	7.47
Specific Conductance	umho/cm	3040*	3900	5100	2400
Total Organic Carbon	mg/l	37*	14	21	25
Total Organic Halogen	mg/l	<0.05*	0.184	0.748	0.336
Total Dissolved Solids	mg/l	2130	2730	3570	1680
Groundwater Quality					
Chloride	mg/l	130	200	200	140
Iron	mg/l	<0.01	0.32	0.74	0.09
Manganese	mg/l	0.814	0.335	0.165	0.085
Phenols	mg/l	<0.001	<0.001	<0.001	<0.001
Sodium	mg/l	86	37	40	61
Sulfate	mg/l	520	1000	1480	330
Primary Drinking Water					
Arsenic	mg/l	<0.01	<0.01	<0.01	<0.01
Barium	mg/l	0.1	<0.1	<0.1	0.1
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001
Chromium	mg/l	<0.001	<0.001	<0.001	<0.001
Fluoride	mg/l	0.82	1.1	2.5	1.0
Lead	mg/l	0.003	0.003	0.005	0.003
Mercury	mg/l	<0.0004	<0.0004	<0.0004	<0.0004
Nitrate (as N)	mg/l	<0.1	<0.1	0.1	0.3
Selenium	mg/l	<0.01	<0.01	<0.01	<0.01
Silver	mg/l	<0.01	<0.01	<0.01	<0.01
Pesticides & Herbicides	--	ND	ND	ND	ND
Radioactivity		samples not analyzed due to high TDS			
Turbidity	Jackson Units	75	40	220	40
Coliform	col/100 ml	1	1	1	1

* average of four replicates

Table III-6
North Colony Landfarm
Fourth Quarter Groundwater Monitoring Results
(Sampled 10-3-83)

Parameter	Unit	Well Number 31 upgradient	 32 downgradient	 33 downgradient	 34 downgradient
Indicator					
pH	Std Units	7.40	7.44	7.82	7.36
Specific Conductance	umho/cm	2076	2120	2680	1710
Total Organic Carbon	mg/l	26*	12	20	75
Total Organic Halogen	mg/l	0.063*	0.077	0.321	0.044
Total Dissolved Solids	mg/l	1730	2050	1670	1580
Groundwater Quality					
Chloride	mg/l	150	210	210	150
Iron	mg/l	0.77	0.30	1.2	0.28
Manganese	mg/l	1.99	0.502	0.272	0.115
Phenols	mg/l	<0.001	<0.001	<0.001	<0.001
Sodium	mg/l	85	43	44	62
Sulfate	mg/l	520	1010	1400	260
Primary Drinking Water					
Arsenic	mg/l	<0.01	<0.01	<0.01	0.02
Barium	mg/l	<0.1	<0.1	<0.1	<0.1
Cadmium	mg/l	<0.001	<0.001	<0.001	<0.001
Chromium	mg/l	<0.001	<0.001	<0.001	<0.001
Fluoride	mg/l	0.9	1.1	2.4	1.0
Lead	mg/l	0.006	0.006	0.007	0.006
Mercury	mg/l	<0.0004	<0.0004	<0.0004	<0.0004
Nitrate (as N)	mg/l	<0.1	<0.1	<0.1	<0.1
Selenium	mg/l	<0.01	0.01	0.01	<0.01
Silver	mg/l	<0.01	<0.01	<0.01	<0.01
Pesticides & Herbicides	--	ND	ND	ND	ND
Radioactivity		samples not analyzed due to high TDS			
Turbidity	Jackson Units	123	26	19	88
Coliform	col/100 ml	1	1	1	1

* average of four replicates

Table III-7
Sample Means for All Monitoring Parameters
Through Fourth Quarter

Parameter	Unit	Well Number			
		31 upgradient	32 downgradient	33 downgradient	34 downgradient
Indicator					
pH	Std Units	7.39	7.29	7.37	7.31
Specific Conductance	umho/cm	2535	2753	3600	2143
Total Organic Carbon	mg/l	53	57	140	42
Total Organic Halogen	mg/l	0.048	0.100	0.288	0.112
Total Dissolved Solids	mg/l	1776	2529	2711	1614
Groundwater Quality					
Chloride	mg/l	119	160	179	157
Iron	mg/l	0.43	0.18	0.56	0.55
Manganese	mg/l	1.35	0.40	0.30	0.26
Phenols	mg/l	0.002	0.005	0.001	0.002
Sodium	mg/l	88	37	41	101
Sulfate	mg/l	539	1034	1414	415
Primary Drinking Water					
Arsenic	mg/l	0.005	0.005	0.005	0.009
Barium	mg/l	0.10	0.05	0.05	0.10
Cadmium	mg/l	0.0005	0.0005	0.0005	0.0005
Chromium	mg/l	0.0009	0.0014	0.0009	0.0015
Fluoride	mg/l	1.04	1.30	2.78	1.17
Lead	mg/l	0.0029	0.0030	0.0030	0.0036
Mercury	mg/l	0.06	0.06	0.06	0.11
Nitrate (as N)	mg/l	0.005	0.006	0.006	0.005
Selenium	mg/l	0.005	0.006	0.006	0.005
Silver	mg/l	0.005	0.005	0.005	0.005
Endrin	mg/l	0.0001	0.0001	0.0001	0.0001
Lindane	mg/l	0.002	0.002	0.002	0.002
Methyoxychlor	mg/l	0.05	0.05	0.05	0.05
Toxaphene	mg/l	0.0025	0.0025	0.0025	0.0025
2,4-D	mg/l	0.05	0.05	0.05	0.05
2,4,5-TP Silvex	mg/l	0.005	0.005	0.005	0.005
Turbidity	Jackson Units	112	31	95	98
Coliform	col/100 ml	0.5	50	0.5	50,000

*Note: When analytical result reported as less then detection limit, value assumed to be one half of detection limit.

this Chapter) was applied to the indicator parameters. There was no statistically significant increase in indicator parameter concentration over background levels at the 0.05 significant level. Likewise, there was no statistically significant increase in the concentration of hazardous constituents over background levels at the 0.05 significant level. There were statistical increases in the chloride, sulfate and fluoride levels, although these parameters are not subject to the statistical evaluation procedures outlined in Part 264 or Part 265. Elevated levels of these parameters may be a function of previous development in the area. The landfarm area was previously the site of a residential development. The homes were demolished and sewer pipes removed, although a main sewer line runs parallel to the southern landfarm boundary. This sewer line receives, at a minimum, septage from control room septic tanks. Leakage from the sewer line or previous residential development may be responsible for the statistically significant increases in chloride, sulfate and fluoride. Fecal coliforms (in excess of 200,000 organisms/100 ml in one well sample) were found in several samples.

The detection monitoring program developed in response to Part 265. Supart F includes a selection of monitoring parameters specific to landfarm operations. While analysis of the indicator and selected metals will continue, hazardous constituents likely to be present in the waste or formed as a degradation byproduct will be added and the remaining interim status parameters dropped from the detection monitoring program.

IV. Detection Monitoring Program

Navajo proposes to utilize the existing groundwater monitoring system to the extent possible in order to satisfy the groundwater monitoring requirements specified in Part 264, Subpart F. Navajo will conduct detection monitoring in accordance with 264.98. Sampling procedures, sampling frequency and analytical procedures are outlined. Monitoring data will be subjected to a statistical procedure to establish whether a statistically significant increase in the concentration of indicator parameters and hazardous constituents over background levels has occurred at the 0.05 significant level. Procedures are outlined to respond to statistically significant increases.

A. Monitoring Well Locations

1. North Colony Landfarm

The North Colony landfarm is an existing waste management area. This landfarm, which began operations in 1980, receives listed hazardous wastes. A monitoring network of one upgradient and three downgradient wells has been established as shown in Figure III-6. Monitoring wells were located from the known hydraulic gradient developed from water level readings in proximate monitoring wells. The hydraulic gradient, as shown in Figure III-3, III-4 and III-5, is from southwest to northeast. The upgradient well is located at the most southwesterly point of the landfarm. The downgradient wells are located to the northeast. Well 32 is located 400 ft to the northeast of well 31. The steepest hydraulic gradient reported is from well 31 to well 32, so this well is directly downgradient from well 31. Well 33 is 650 ft to the northeast of well 31. As such, groundwater passes the greatest distance under the landfarm between the upgradient well and well 34. Well 34 is 575 ft northeast of well 31. Downgradient wells are located from 185 to 385 ft apart. The lateral spacing of wells should allow early detection of any plume of contamination.

The wells are screened in the first water bearing zone. The uppermost aquifer is considered to be the thin water bearing an hydritic sand with cobble seams interbedded with clay, silty clay, sandy clay and gypsum found at depths ranging from 14 to 22 ft. This water bearing seam is confined by overlying gray silty clay with gypsum and unweathered anhydrite and underlying red to gray clay. Underlying and overlying clay layers confine the groundwater such that water levels in the monitoring wells rise above the water bearing zone.

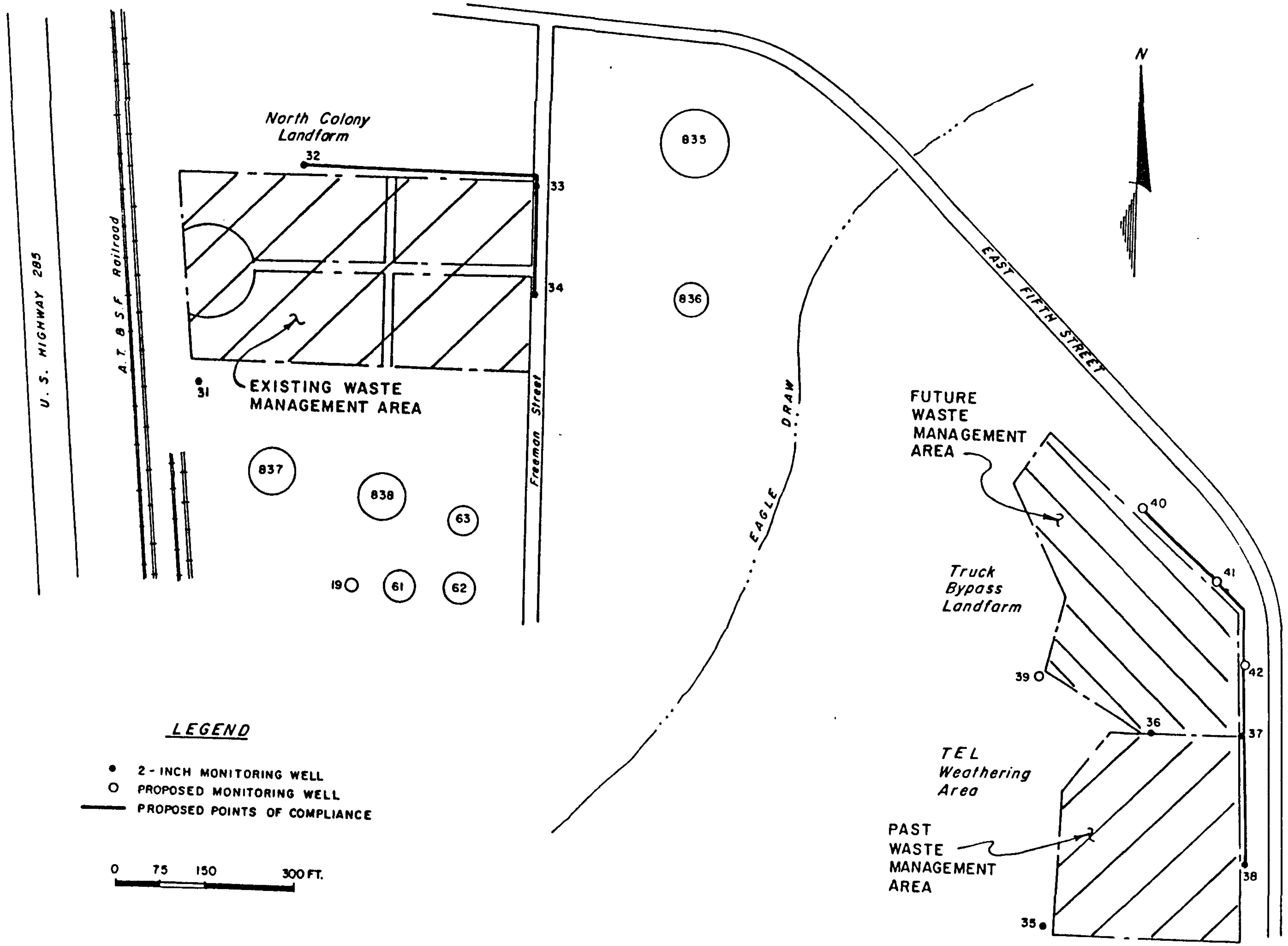


FIGURE III - 6
MONITORING WELL LOCATIONS

NAVAJO REFINERY

URS ENGINEERS

2. Truck Bypass Landfarm

The truck bypass landfarm is an existing waste management area for oily refinery wastes. This landfarm will be used for the disposal of hazardous wastes once a RCRA permit is issued. Initially, wastes contained in the TEL weathering area will be excavated and applied to the truck bypass landfarm for degradation of the oily phase and immobilization of metals. Thereafter, other refinery hazardous wastes will be applied to the landfarm. Proposed monitoring well locations are shown in Figure III-6. The monitoring well network is to consist of two upgradient wells, wells 36 and 39, and three downgradient wells, wells 40, 41 and 42.

Monitoring wells are located from the known hydraulic gradient in the area developed from water level readings in the monitoring wells surrounding the TEL weathering area. Upgradient well 36 will be downgradient of the TEL weathering area and should reflect the impact of previous disposal activities. Upgradient well 39 should provide an indication of groundwater quality unimpacted by local waste disposal activities. Downgradient wells 40, 41 and 42 will be located to the northeast of upgradient wells.. The three downgradient wells will have a lateral spacing of 150 to 200 ft and be 300 to 350 from upgradient well 39. Wells will be screened in the uppermost aquifer as defined during well drilling and installation.

B. Sampling Procedures

The initial component of the groundwater monitoring program is the establishment of procedures by which a representative sample of groundwater is obtained. To ensure groundwater sampling at Navajo is consistent, timely and representative, sampling protocols have been established.

1. Sampling Equipment

Equipment items necessary for collecting representative groundwater samples include 50 ft fiberglass, plastic or steel measuring tape with weighted bottom or a water level indicator (M-scope) consisting of an ammeter, electrode and 50 ft cable, distilled water, wash bottle, paper towels or clean rags, plastic sheeting or large plastic garbage bags, bottom filling PVC bailer for each well and 50 ft of rope or a peristaltic pump, graduated bucket, 8 properly preserved sample containers per sampling point, sample bottle labels, water proof working pen, pH meter, thermometer, specific conductivity meter, field sample log book and pen, and ice chest and ice.

2. Sampling Techniques

a. Water Level Measurement

Prior to collecting any groundwater samples, the level of water in the well bore is measured and recorded in the field log book. The procedures to be used in measuring water levels are as follows. First, plastic sheeting is placed around the well to protect sampling equipment from possible contamination. Second, the casing cap is unscrewed in order to measure the depth to the water in the well. All measurements are made from the top of the casing. Third, the M-scope or tape is cleaned with distilled water and dried with a clean towel.

To measure water levels using the 50 ft tape, the weighted tape is dropped down the center of the casing. Upon encountering water in the well, the tape measurement at the top of the casing is recorded. Then, the tape is wound up and the measurement where the tape becomes wet is recorded. The depth to the water is found by subtracting the "wet" measurement from the "held" measurement.

To measure water levels using the M-scope, the probe is dropped down the center of the casing carefully avoiding tangles. When the ammeter indicates a closed electrical circuit, the depth to the water from the top of the casing is recorded. The water level elevation is found by subtracting the depth to the water from the elevation at the top of the casing.

b. Removal of Standing Water

Standing water is always removed from the well bore prior to collecting groundwater samples. Generally three well volumes are recommended to be removed to ensure that an accurate sample of groundwater quality is obtained. If the wells are low yielding and it is not practical to purge three well volumes, the well should be pumped or bailed to dryness before sampling. The following formula is used to calculate the well volume:

$V = \pi r^2 h$

$\pi = 3.14$

r = radius of well casing (ft)

h = height of standing water (ft)

V = Volume of standing water (ft^3)

The monitoring wells are 2 inch diameter, so the volume, V, is equal to 0.087 times the height, h, of standing water. The height of standing water in the well is determined by subtracting the measured depth to the water from the total depth of the well. A graduated bucket is used to measure the volume of water removed from the well.

c. Sample Collection and Field Analyses

The following procedures are used when collecting groundwater samples and conducting field analyses. The well is allowed to recharge sufficiently to obtain samples. In some wells, this may require waiting a few minutes to a few hours; in other wells, recovery time may be extremely slow and sampling may not be possilbe until after 24 hours. If the well is incapable of producing sufficient water required for analyses, composite sampling may be necessary where small quantities of samples are taken several days in a row.

Analyses of select parameters, pH, temperature, and specific conductance, should be made in the field at the time of sampling because these parameters change rapidly and a laboratory analysis might not be representative of the true groundwater quality. Enough water from the well is removed to determine the temperature, specific conductivity, and pH. These values are recorded in the field log and the water then discarded in a manner so as to avoid potential contamination.

All sample containers are rinsed with sampled groundwater except those which contain chemical preservatives. The rinsate is discarded in a manner so as to avoid potential contamination.

The water from the well sampling device is then transferred to the sample bottles provided by the laboratory. Care is taken to not agitate the sample in order to limit the amount of oxygen added to the sample. The number of containers used is minimized as much as possible in order to limit the addition of outside contaminants.

If there is insufficient water in the well to supply the necessary volume for analyses, the sample collector fills up as many bottles as possible, labeling them as specified and continues sampling daily until the remaining bottles are filled.

3. Chain of Custody Documentation

Navajo satisfies chain of custody requirements in the documentation of the handling history of groundwater samples. These procedures ensure the integrity of the sample from time of collection to data reporting.

a. Sample Labels

All samples collected for analyses at Navajo are labeled at the time of sampling. The labels include the following information:

- i. Name of collector
- ii. Date and time of collection
- iii. Point of collection
- iv. Sample identification number

b. Sampling Log Books

All samples collected for analyses at Navajo are recorded in the Field Sampling Log Book. The Field Sampling Log Book is maintained by the Environmental Tester and each sample is recorded in the log at the time of sample collection. Entries in the log book include the following information:

- i. Date and time of sample collection

ii. Sample identification number

iii. Monitoring well number

iv. Water level measurement results

v. Results of field analyses

vi. Number and volume of samples

vii. Physical appearance of samples

viii. Purpose of sampling

ix. Field observations

x. Sampler signature

c. Chain of Custody Record

Navajo completes and maintains chain of custody forms to trace sample possession from the time of collection to analysis. A copy of this form accompanies the samples to the testing laboratory to ensure that proper analyses are performed and to inform the analyst of pertinent sampling data. The information provided on the form includes:

i. Monitoring well number

ii. Sample type

iii. Date and time of sample collection

iv. Sample volume

iv. Sample identification number

vi. Field information and special instructions

vii. Signatures of persons involved in the chain of custody and the dates of possession

viii. Signature of person shipping the sample and the method of shipment

ix. Signature of person receiving the sample and the date of receipt

C. Detection Monitoring Parameters

1. Selection of Parameters

The detection monitoring program requires Navajo to monitor for indicator parameters, waste constituents and waste reaction byproducts which will provide a reliable indication of the presence of hazardous constituents in the groundwater. These parameters are to be selected based on waste constituents present in the waste materials, the fate of waste constituents in the unsaturated zone, the detectability of selected parameters, and preliminary statistical evaluation of monitoring results. The selected monitoring parameters are listed in Table III-8. Total organic halogen has been dropped from the list of indicator parameters. The contract laboratory has reported that the inorganic chlorides present in previous samples caused interference in EPA approved analytical methodology for total organic halogen. The hazardous constituents selected include the metals chromium and lead, and the base neutral extractable organic fraction which might potentially be present in the waste or reaction byproducts.

2. Establishment of Background Values

Background values of the selected monitoring parameters will be developed by subjecting data to the statistical procedures outlined in Cochrans' approximation to the Behrens-Fisher Students' t-test (40 CFR 264, Appendix IV), reproduced below.

Using all the available background data (n, readings), calculate the background mean (X_s) and background variance (s_B^2). For the single monitoring well under investigation (n_m reading), calculate the monitoring mean (X_m) and monitoring variance (s_m^2).

For any set of data ($X_1, X_2 \ldots X_n$) the mean is calculated by:

$$X = \frac{X_1 + X_2 \ldots + X_n}{n}$$

and the variance is calculated by:

Table III-8
Detection Monitoring Parameters

INDICATOR PARAMETERS

- pH
- Specific Conductance
- Total Organic Carbon

HAZARDOUS CONSTITUENTS

<u>Metals</u>

- Chromium
- Lead

<u>Base Neutral Extractables</u>

- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(ghi)perylene
- Bis(2-ethylhexyl)phthalate
- Chrysene
- Diethylphthalate
- Fluoranthene
- Hexachlorocyclopentadiene
- Hexachloroethane
- Naphthalene
- Phenanthrene
- Pyrene
- 1,1,2,2-tetrachloroethane
- Tetrachloroethylene
- Trichloroethylene

$$s^2 = \frac{(X_1 - X)^2 + (X_2 - X)^2 \ldots + (X_n - X)^2}{n - 1}$$

where "n" denotes the number of observations in the set of data.

The t-test uses these data summary measurements to calculate a t-statistic (t*) and a comparison t-statistic (t_c). The t* value is compared to the t_c value and a conclusion reached as to whether there has been a statistically significant change in any indicator parameter.

The t-statistic for all parameters except pH and similar monitoring parameters is:

$$t^* = \frac{X_m - X_B}{\frac{s_m^2}{n_m} + \frac{s_B^2}{n_B}} = \frac{X_m - X_B}{W_m + W_B}$$

If the value of this t-statistic is negative then there is no significant difference between the monitoring data and background data. It should be noted that significantly small negative values may be indicative of a failure of the assumption made for test validity or errors have been made in collecting the background data.

The t-statistic (t_c), against which t* will be compared, necessitates finding t_B and t_m from standard (one-tailed) tables where,

t_B = t-tables with (n_B - 1) degrees of freedom, at the 0.05 level of significance (from Table III-9).

t_m = t-tables with (n_m - 1) degrees of freedom, at the 0.05 level of significance (from Table III-9).

Finally, the special weightings W_B and W_m are defined as:

$$W_B = \frac{s_B^2}{n_B} \quad \text{and} \quad W_m = \frac{s_m^2}{n_m}$$

and so the comparison t-statistic is:

$$t_c = \frac{W_B t_B + W_m t_m}{W_B + W_m}$$

The t-statistic (t*) is now compared with the comparison t-statistic (t_c) using the following decision-rule:

Table III-9

Standard T-Tables 0.05 Level of Significance

Degrees of freedom	t-values (one-tail)	t-values (two-tail)
1	6.314	12.706
2	2.920	4.303
3	2.353	3.182
4	2.132	2.776
5	2.015	2.571
6	1.943	2.447
7	1.895	2.365
8	1.860	2.306
9	1.833	2.262
10	1.812	2.228
11	1.796	2.201
12	1.782	2.179
13	1.771	2.160
14	1.761	2.145
15	1.753	2.131
16	1.746	2.120
17	1.740	2.110
18	1.734	2.101
19	1.729	2.093
20	1.725	2.086
21	1.721	2.080
22	1.717	2.074
23	1.714	2.069
24	1.711	2.064
25	1.708	2.060
30	1.697	2.042
40	1.684	2.021

Source: Adopted from Table III of "Statistical Tables for Biological, Agricultural, and Medical Research" (1947, R. A. Fisher and F. Yates).

1. If t^* is equal to or larger than t_c, then conclude that there most likely has been a significant increase in this specific parameter.
2. If t^* is less than t_c, then conclude that most likely there has not been a change in this specific parameter.

The t-statistic for testing pH and similar monitoring parameters is constructed in the same manner as previously described except the negative sign (if any) is discarded and the caveat concerning the negative value is ignored. The standard (two-tailed) tables are used in the construction t_c for pH and similar monitoring parameters. If t^* is equal to or larger than t_c, then conclude that there most likely has been a significant increase (if the initial t^* has been negative, this would imply a significant decrease). If t^* is less than t_c, then conclude that there most likely has been no change.

Background values are to be based on quarterly sampling with at least four replicate measurements. For the North Colony landfarm, the sample from the upgradient well 31 will be split into four aliquots and separate analyses will be conducted on each aliquot. For the truck bypass landfarm, samples from upgradient wells 35 and 39 will be split into two aliquots and separate analyses will be conducted on each aliquot. Data from upgradient monitoring wells is used to establish the number of replicate samples required for each of the downgradient wells. If the background value has a sample coefficient of variation (defined as the square root of background variance divided by the mean) less than 1.00, 4 replicates from each well sample will be analyzed. Otherwise, a single sample for each well will be analyzed for the indicated parameters.

3. Detection Monitoring

During the first year of the detection monitoring program, quarterly analyses will be conducted in accordance with Table III-10. Thereafter, samples will be obtained semiannually during the active life of the facility and period of post closure

Table III-10
Detection Monitoring Program
First Year Quarterly Analyses

	North Colony Landfarm		Truck Bypass Landfarm	
	Upgradient Well 31	Downgradient Wells 32,33&34	Upgradient Wells 36 & 39	Downgradient Wells 40,41&42
INDICATOR PARAMETERS				
pH	4 replicates	4 replicates	2 replicates	4 replicates
Specific Conductance	4 replicates	4 replicates	2 replicates	4 replicates
Total Organic Carbon	4 replicates	4 replicates	2 replicates	4 replicates
HAZARDOUS CONSTITUENTS				
Metals				
Chromium	4 replicates	4 replicates	2 replicates	4 replicates
Lead	4 replicates	4 replicates	2 replicates	4 replicates
Base Neutral Extractable Organics				
Anthracene	4 replicates	Single sample	2 replicates	Single sample
Benzo(a)anthracene	4 replicates	Single sample	2 replicates	Single sample
Benzo(a)pyrene	4 replicates	Single sample	2 replicates	Single sample
Benzo(a)perylene	4 replicates	Single sample	2 replicates	Single sample
Bis(2-ethylhexyl)phthalate	4 replicates	Single sample	2 replicates	Single sample
Chrysene	4 replicates	Single sample	2 replicates	Single sample
Diethylphthalate	4 replicates	Single sample	2 replicates	Single sample
Fluoranthene	4 replicates	Single sample	2 replicates	Single sample
Hexachlorocyclopentadiene	4 replicates	Single sample	2 replicates	Single sample
Hexachloroethane	4 replicates	Single sample	2 replicates	Single sample
Naphthalene	4 replicates	Single sample	2 replicates	Single sample
Phenanthrene	4 replicates	Single sample	2 replicates	Single sample
Pyrene	4 replicates	Single sample	2 replicates	Single sample
1,1,2,2-tetrachloroethane	4 replicates	Single sample	2 replicates	Single sample
Tetrachloroethylene	4 replicates	Single sample	2 replicates	Single sample
Trichloroethylene	4 replicates	Single sample	2 replicates	Single sample

Note: For all downgradient wells, a single sample for each well should be analyzed for the selected parameters unless the background value has a coefficient of variation less than 1.00. If the background value has a coefficient of variation less than 1.00, a sample from each well should be split into four aliquots and analyzed for indicated parameters. Based on interim status monitoring results, 4 replicates will be required for the analysis of pH, specific conductance, total organic carbon, chromium and lead.

care. After receipt of each quarter of monitoring data, the results will be subjected to a statistical analysis. First, the sample mean, sample variance and coefficient of variation will be calculated for the upgradient wells. If the background coefficient of variation is less than 1.00, four portions from a sample at each downgradient well will be analyzed for the indicated parameters to determine the difference between the mean of the constituent at each well and the background value at the 0.05 level using the described statistical procedure. If the test indicates the difference is significant, the procedure will be duplicated using a fresh sample from the downgradient well. If the second round of analyses indicates that the difference is significant, the conclusion that a statistically significant change has occurred may be drawn.

4. Response to Statistically Significant Increases

If it is determined that a statistically significant increase in any monitoring parameter has occurred, Navajo will notify the EPA of this finding in writing within seven days indicating the parameters which have shown statistically significant increases. At this time, Navajo may indicate their intention to demonstrate that a source other than Navajo facility caused the increase or that the increase resulted in an error in sampling, analysis or evaluation.

If Navajo determines that the source of the statistically significant increase is the Navajo facility, it will immediately sample the groundwater in all monitoring wells in the system to determine the concentration of Part 261, Appendix VIII constituents which may be present in the groundwater. Background values for these constituents may be established from existing data acquired during the active life of the facility.

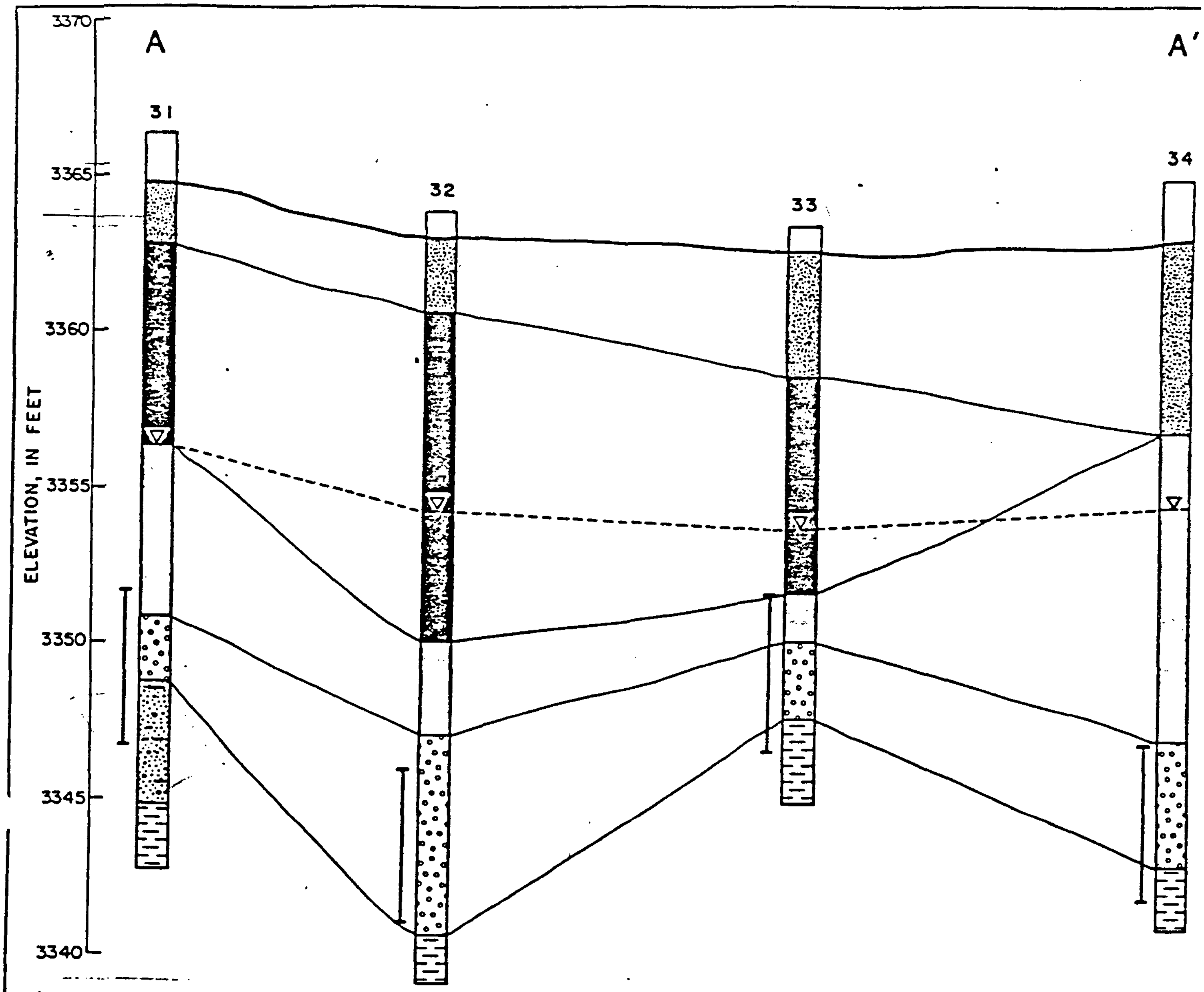
A compliance monitoring program will be submitted within 90 days. The concentration of any Appendix VIII constituents found in the groundwater monitoring system will be identified. Any changes to the monitoring frquency, sampling and analysis methods or statistical procedures will be identified. For each hazardous constituent, a proposed concentration limit or a notice of intent to seek a variance will be included. Within 180 days, Navajo will submit to the EPA data to justify a variance to maximum concentration limits under 264.94(b), if necessary. Also, Navajo will submit an engineering feasibility plan for a corrective action program satisfying the requirements of 264.100. The feasibility plan will not be submitted if Navajo seeks a variance in the concentration limits under 264.94(b) for all Appendix VIII constituents identified in the groundwater or if all of the hazardous constituents identified in the groundwater are listed in Table I of 264.94 and their concentrations do not exceed the respective values given in the table.

If Navajo intends to make a demonstration that another source caused the statistically significant increase or that the increase is a result of an error in sampling, analysis or evaluation, Navajo will submit to the EPA a report demonstrating that fact within 90 days. Navajo will submit to the EPA an application for a permit modification within 90 days to make any appropriate changes in the detection monitoring program. Navajo will also continue to monitor in accordance with its approved detection monitoring program.

Finally, Navajo will take all measures necessary throughout the post closure care period to achieve compliance with the groundwater protection standard under 264.92 and if the detection monitoring program no longer satisfies the requirements specified in 264.98, Navajo will submit an application for a permit modification to make any appropriate changes in the program.

APPENDIX III-I

Soil Boring Logs



HORIZONTAL SCALE: NONE

EXPLANATION

- ▨ Fill
- ☰ Clay
- ▩ Silty Clay
- ☐ Silty Clay With Organic
- ▦ Sandy Silty Clay
- ⁘ Pebble Seams In Silty Clay - Water Bearing
- ⌶ Screened Interval

SUBJECT

COLONY LANDFARM
GEOLOGIC CROSS SECTION

PREPARED FOR

NAVAJO REFINING COMPANY
ARTESIA, NEW MEXICO

Geraghty & Miller, Inc.	COMPILED BY Bouvette/Dauchy PREPARED BY C. Robertson PROJECT MGR J. Dauchy	SCALE Shown DATE Dec. 82	FIGURE 3

Well #1

Sample Log

Page 1 of

Project Navajo Refinery

Location SW corner of Colony Landfarm

Drilling Contractor D. Anderson

Driller Richard

Helper Eddie

Rig Type Hollow stem

Hole Diameter 8 inches

Drilling Fluid N/A

Type of Sample split spoon & Shelby

Date and Time Drilling Began 10/19/82 1:30pm

Date and Time Drilling End 3:00

Geraghty and Miller Representative J. Dauchy and T. Bouvette

Blows per 6 inches	% Recovery	Sample Description	Depth Feet to Feet
		Fill - brown topsoil with gravel and concrete	0 - 2
		brittle brown silty clay, poorly sorted with white pebbles	2 - 3
		brittle brown silty clay, dense no pebbles	3 - 7
		tan silty clay, plastic, moist	7 - 8½
9 - 11-16	split spoon 8½ - 10	gray silty clay w/gyp. & unweather anhydrite poorly sorted, organic smell	8½ - 14
6 - 6 - 8	split spoon 14 - 15½	dolmite gravel water bearing seams (2") interbed w/gray brown silty clay,saturated	14 - 16
4 - - - 5	split spoon 17½ - 19	brown brittle sandy silty clay w/red & white coarse grains	16 - 20
	Shelby tube 20 - 22	red clay, well sorted, unsaturated	20 - 22

Well #2

Sample Log

Page 2 of

Project Navajo Refinery

Location SE corner of Telephone Storage

Drilling Contractor D. Anderson

Driller Richard

Helper Eddie

Rig Type Hollow stem

Hole Diameter 8" inches

Drilling Fluid N/A

Type of Sample split spoon & shelby

Date and Time Drilling Began 10/20/82 7:20 am

Date and Time Drilling End 9:00am

Geraghty and Miller Representative J. Dauchy T. Bouvette

Blows per 6 inches	% Recovery	Sample Description	Depth Feet to Feet
		dark brown topsoil	0 - 2½
		light brown silty clay w/unweather anhydrite, poorly sorted	2½ - 4
3 - 4 - 5	split spoon 5 - 6½	tan silty clay, brittle, poorly sorted	4 - 6
		red silty clay	6 - 6½
5 - 6-10	split spoon 1- - 11½	light brown silty clay, mottled, poorly sorted	6½ - 10½
	organic smell	pebble seam wet, dolmite gravel, 2"	10½
		tan silty clay, same as above	10½ - 13
5 - 8 -12	split spoon 15 - 16½	gray silty clay, well sorted less dense organic smell	13 - 16
9 -16-17	split spoon 17½ - 19	anhydritic sand & pebble seams interbed with brownish red sandy silty clay	16 - 22
6 - 7- 9	split spoon 20 - 21½		
7 - 8-9	split spoon 22½ - 24	red clay, well sorted, dry & hard	22½ - 24

Well #3

Sample Log

Page 3 of

Project Navajo Refinery

Location NE of Colony @ Entrace Gate

Drilling Contractor D. Anderson

Driller Richard

Helper Eddie

Rig Type Hollow stem

Hole Diameter 8" inches

Drilling Fluid N/A

Type of Sample split spoon & Shelby

Date and Time Drilling Began 10/20/82 10:00 am

Date and Time Drilling End 11.30

Geraghty and Miller Representative J. Dauchy T. Bouvette

Blows per 6 inches	% Recovery	Sample Description	Depth Feet to Feet
		Brown topsoil	0 - 4
	Shelby tube 10 - 11	poorly sorted light brown silty clay w/unweathered anhydrite	4 - 13
	organic smell	gray brittle silty clay with white & red coarse grains	13 - 14½
3 - 7 - 8	split spoon 15 - 16½	anhydrite sand interbedded in white clay silty clay and red & tan silty clay	14½ - 17
5 - 5 - 7	split spoon 17 - 18½	red clay	17 - 19½

Well #4 **Sample Log** Page 4 of

Project Navajo Refinery Location East fence of Colony

Drilling Contractor D. Anderson Driller Richard Helper Eddie

Rig Type Hollow stem Hole Diameter 8" inches Drilling Fluid N/A

Type of Sample split spoon & shelby Date and Time Drilling Began 10/20/82 2:10 pm Date and Time Drilling End 3:30 p

Geraghty and Miller Representative J. Dauchy T. Bouvette

Blows per 6 inches	% Recovery	Sample Description	Depth Feet to Feet
		brown topsoil & fill	0 - 6
	organic smell	gray brown mottled silty clay w/unweather anhydrite, poorly sorted	6 - 10
7 - 12 -16	split spoon 10 - 11½	very brittle gyp in silty clay w/unweathered anhydrite	10 - 16
	shelby tube 15 - 17	water bearing anhydritic sand inter lain in gray silty clay & gyp	16 - 20
		gray clay, well sorted	20 - 22

APPENDIX III-2

Details of Well Construction

DETAILS OF WELL CONSTRUCTION

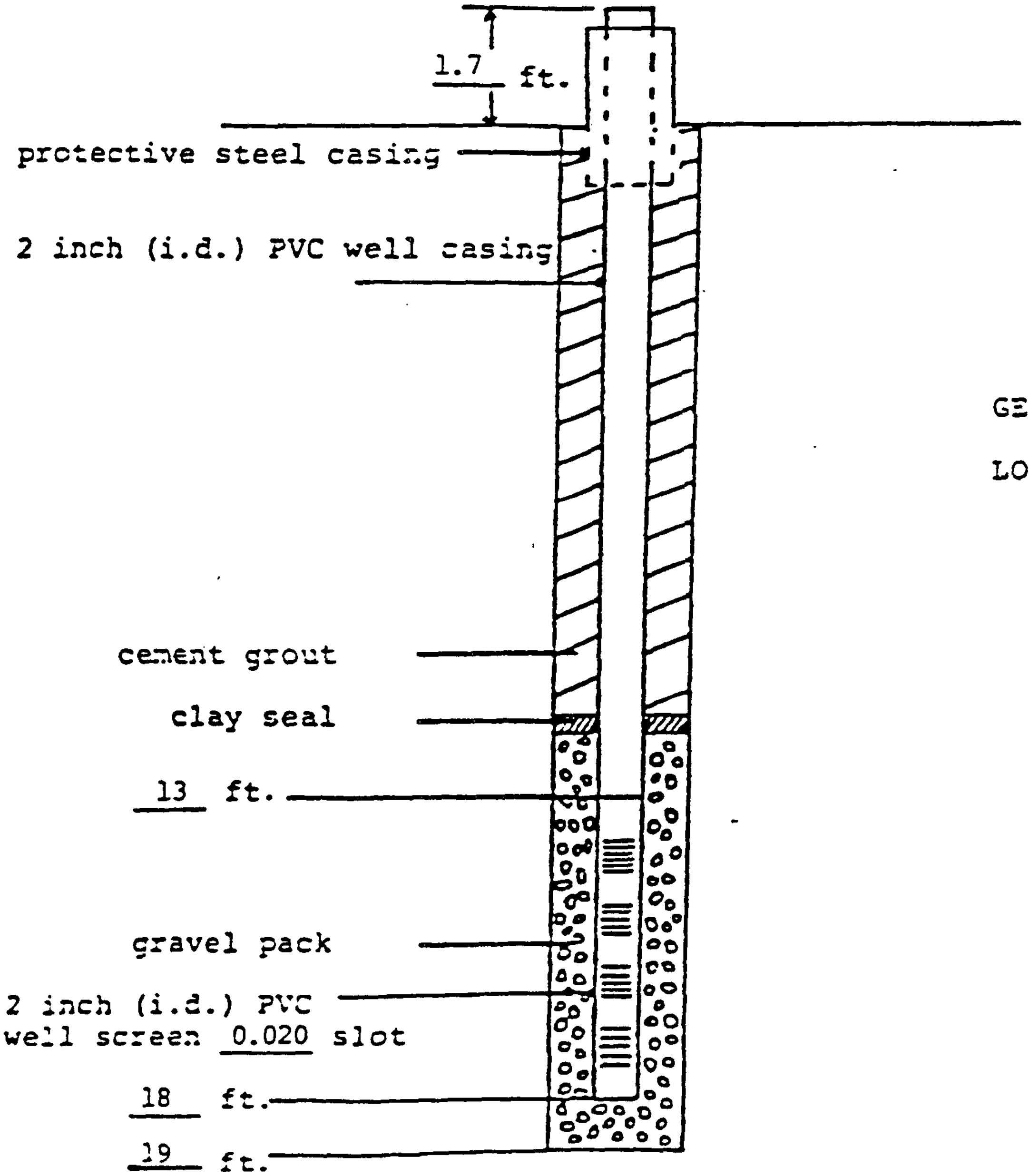
DATE 10/22/82

WELL #1

PROJECT Navajo Refinery

LOCATION

WATER LEVEL MEASUREMENT Held 10.5 Wet 0.34 DTW 10.16



GEOLOGIC

LOG

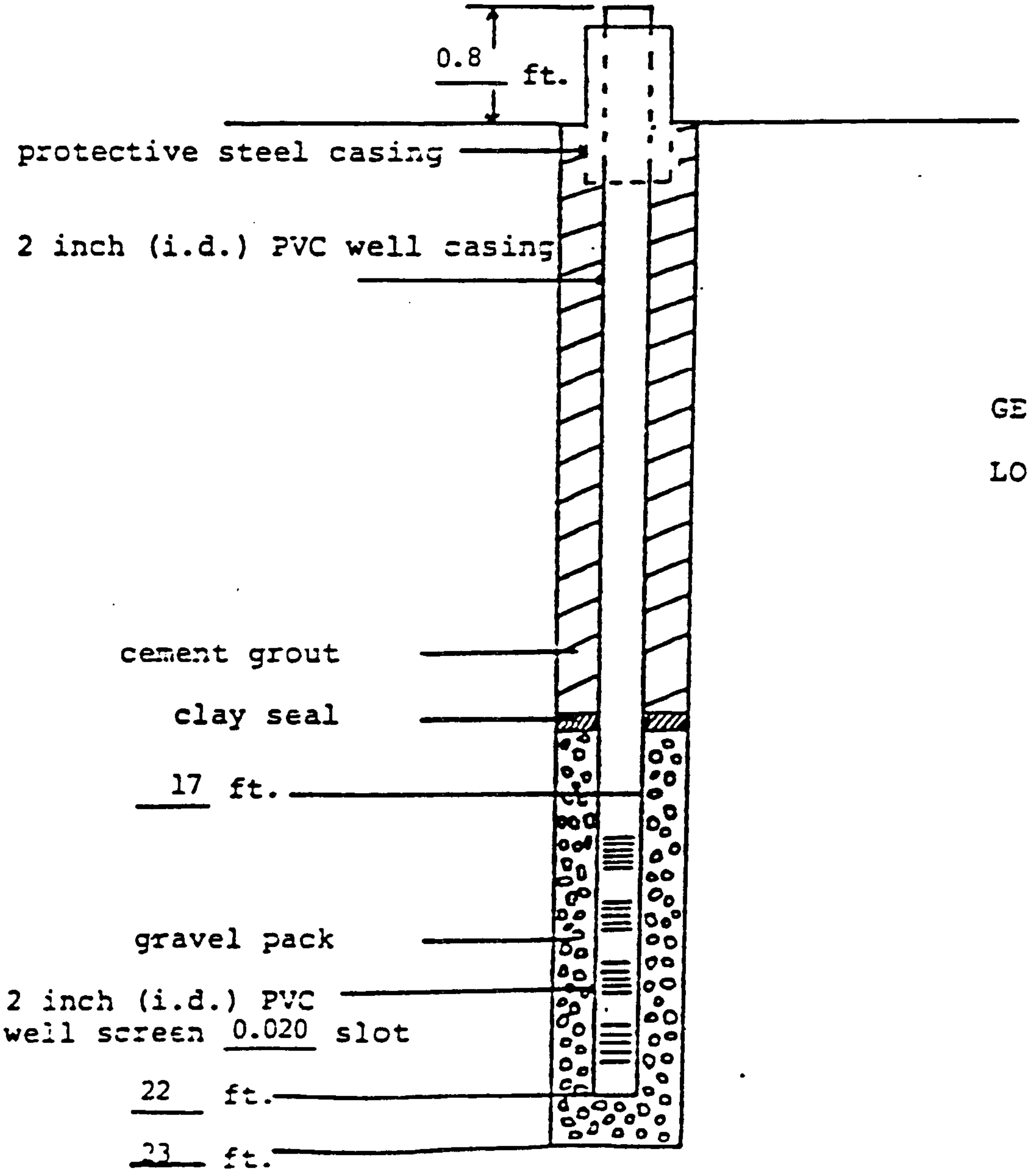
All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

DATE 11/22/82 WELL #2

PROJECT Navajo Refinery LOCATION

WATER LEVEL MEASUREMENT Held 10.0 Wet 0.30 DTW 9.7



GEOLOGIC

LOG

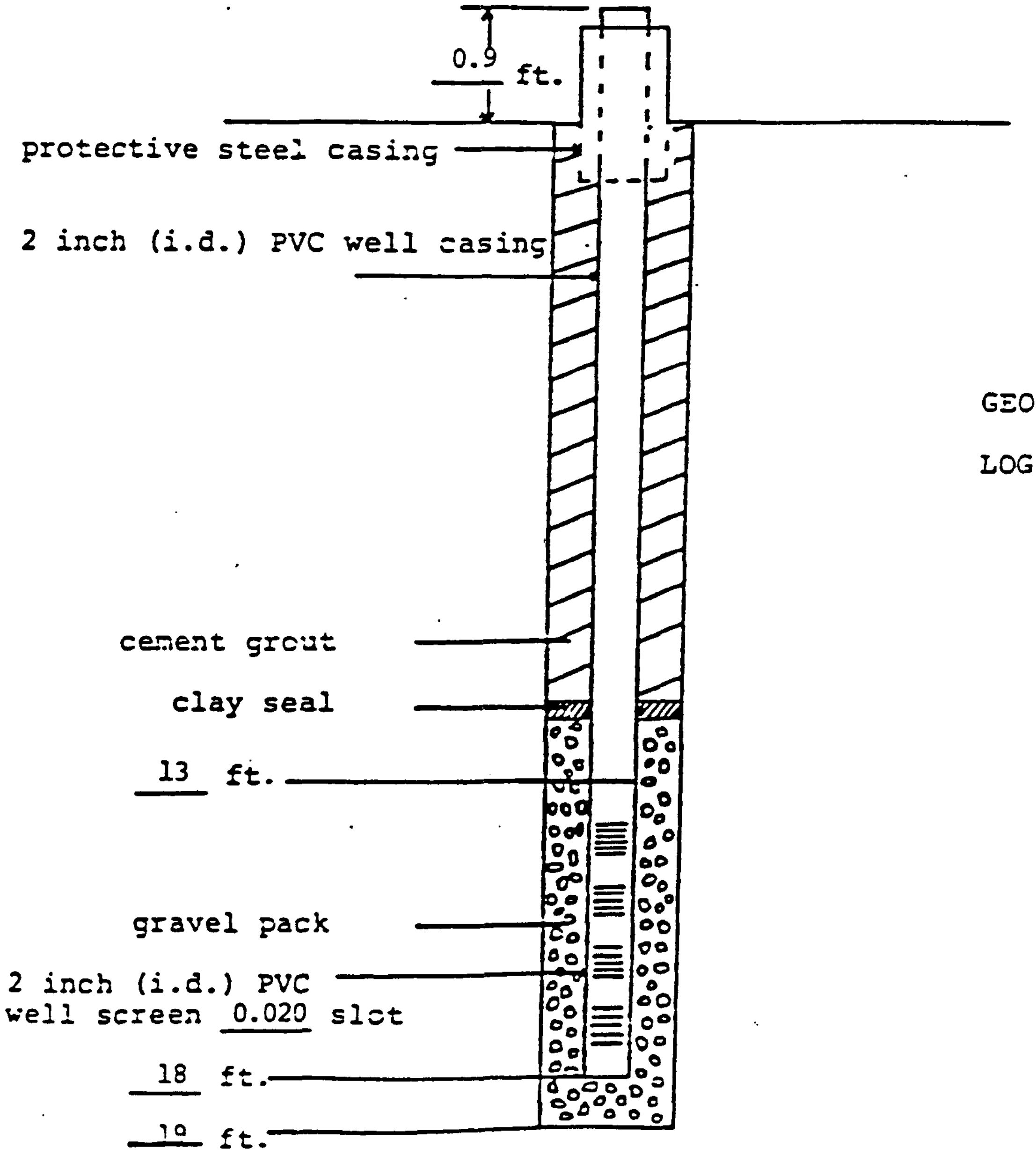
All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

DATE 10/22/82 WELL #3

PROJECT Navajo Refinery LOCATION

WATER LEVEL MEASUREMENT Held 10.0 Wet 0.19 DTW 9.81



GEOLOGIC

LOG

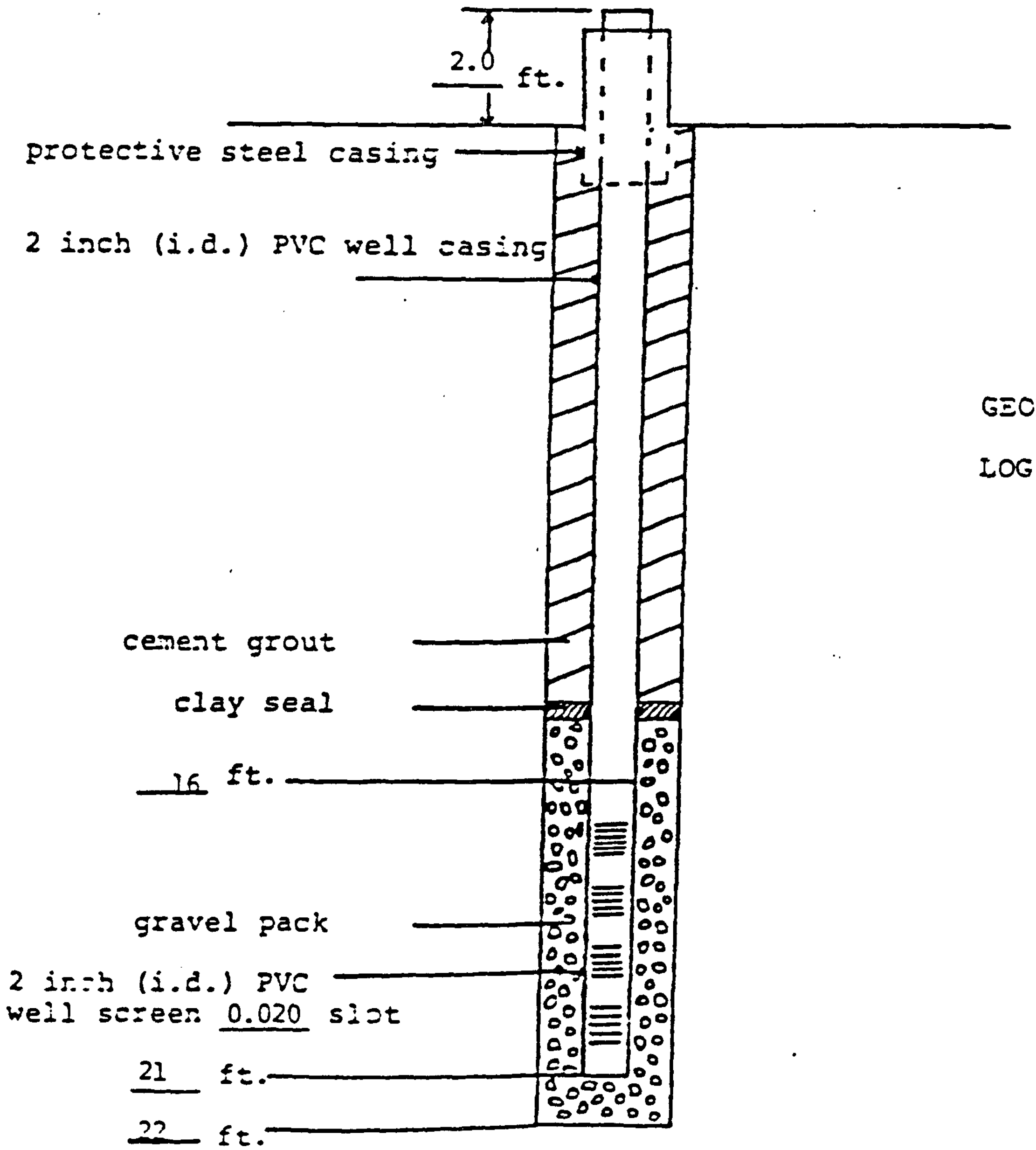
All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

DATE 10/22/82 WELL #4

PROJECT Navajo Refinery LOCATION

WATER LEVEL MEASUREMENT Held 11.3 Wet 0.70 DTW 10.60



GEOLOGIC

LOG

All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

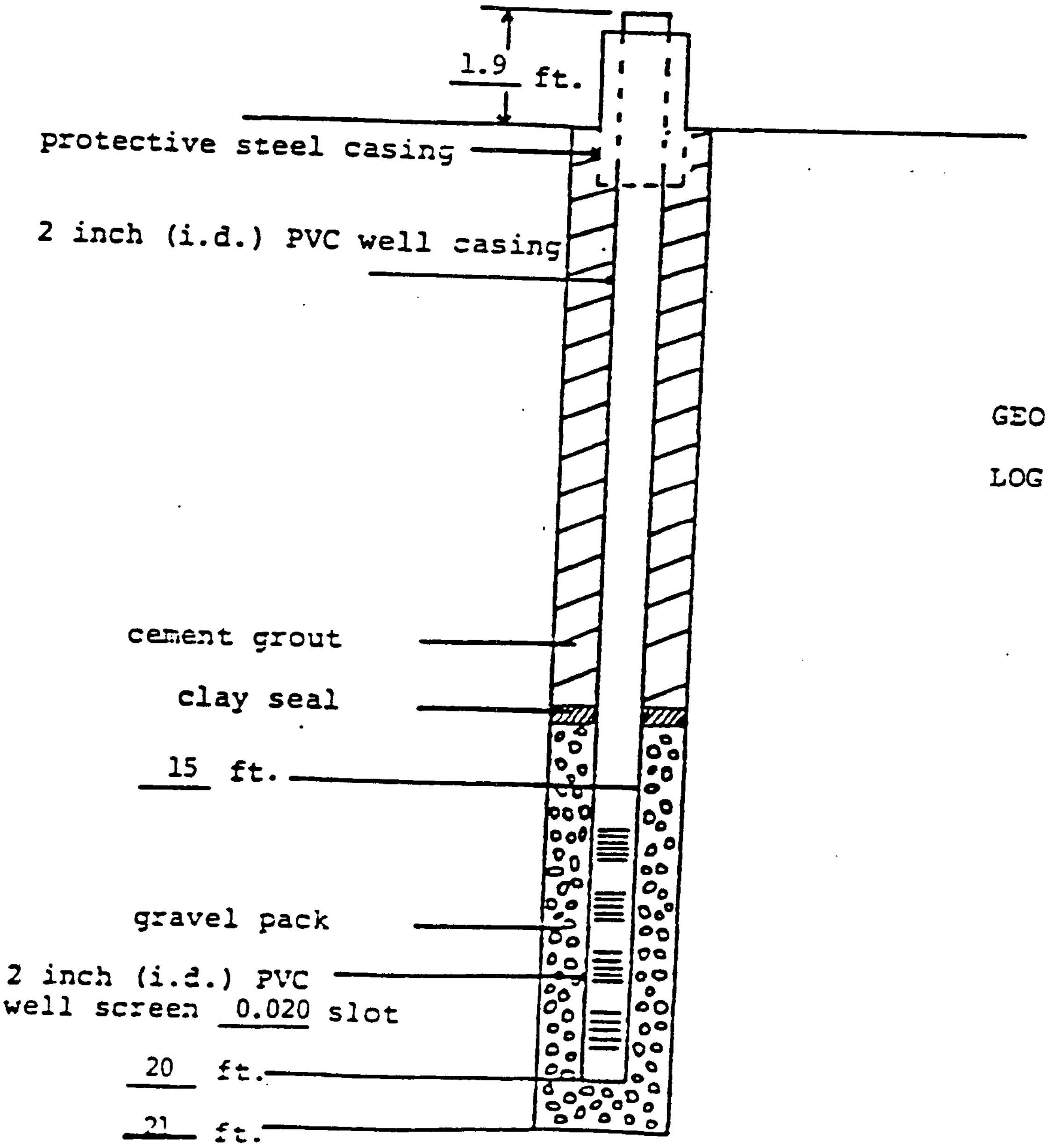
DATE 10/22/82

WELL #5

PROJECT Navajo Refinery

LOCATION

WATER LEVEL MEASUREMENT Held 9.1 Wet 0.73 DTW 8.37



GEOLOGIC

LOG

All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

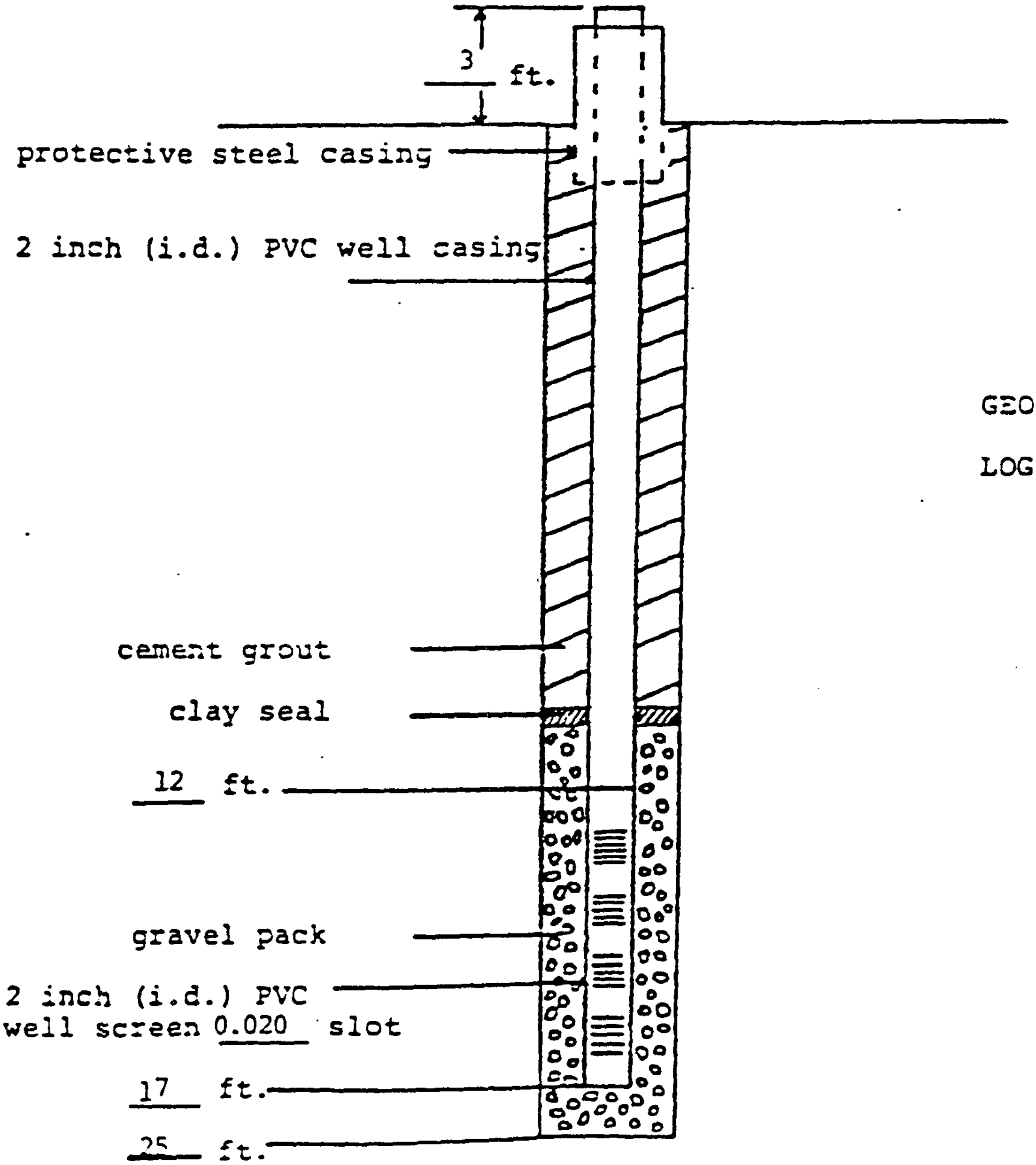
DATE 10/22/82

WELL #6

PROJECT Navajo Refinery

LOCATION ______

WATER LEVEL MEASUREMENT Held 9.7 Wet .81 DTW 8.89



GEOLOGIC LOG

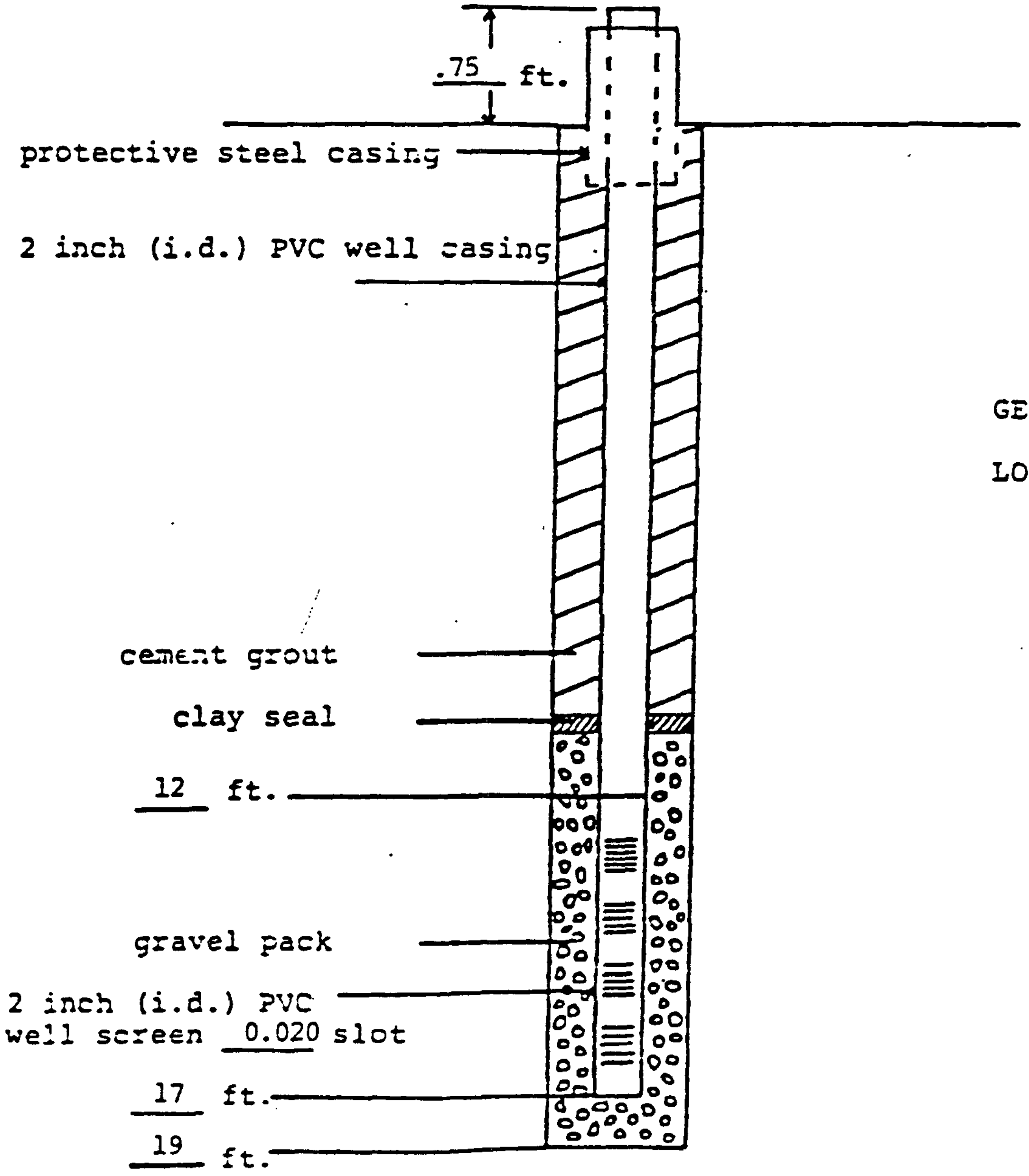
All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

DATE 10/22/82 WELL #7

PROJECT Navajo Refinery LOCATION

WATER LEVEL MEASUREMENT Held 9.5 Wet 0.94 DTW 8.56



GEOLOGIC

LOG

All measurements are referred to land surface except depth to water which is measured from top of casing

DETAILS OF WELL CONSTRUCTION

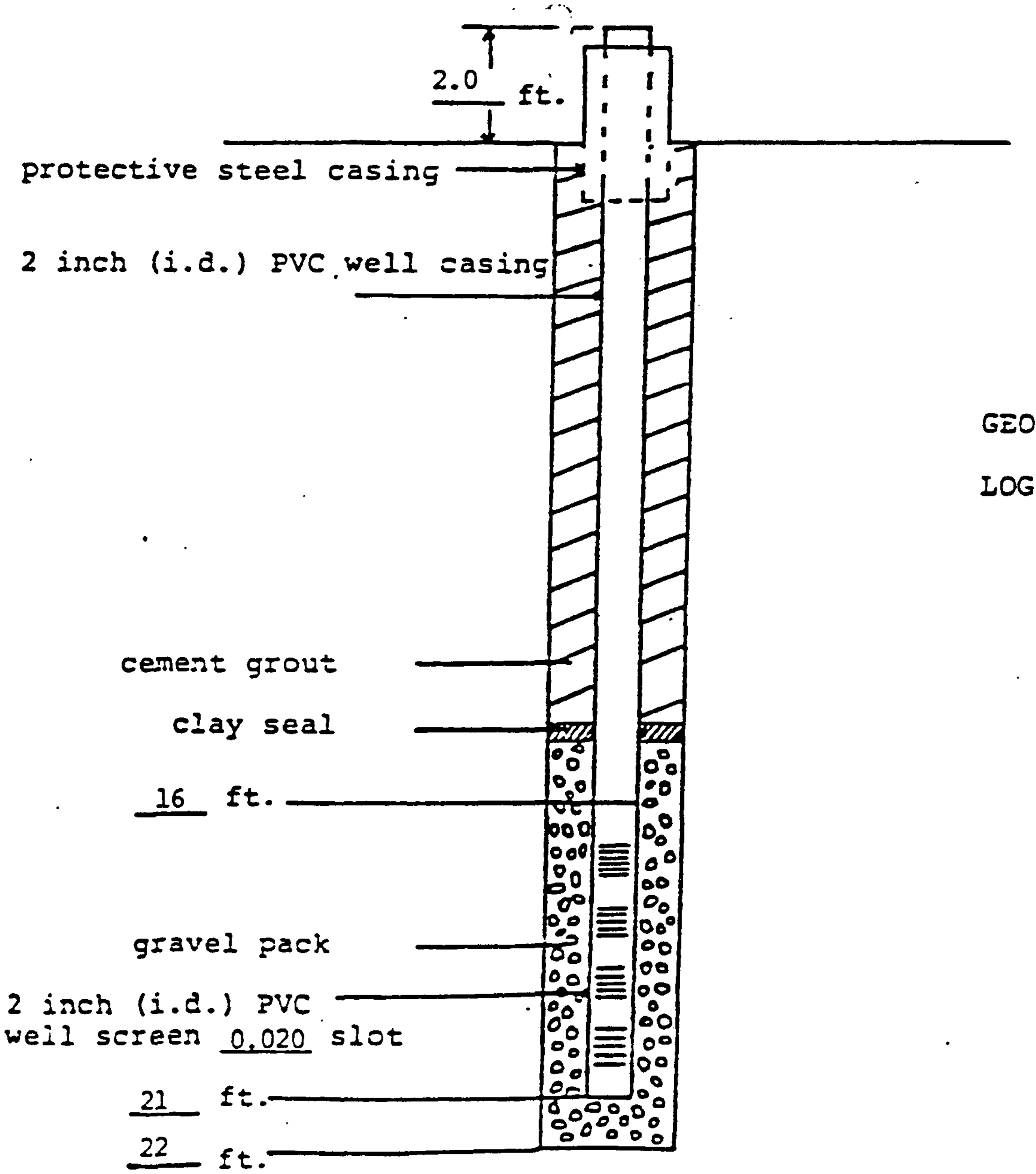
DATE 10/22/82

WELL #8

PROJECT Navajo Refinery

LOCATION ____________

WATER LEVEL MEASUREMENT Held 9.2 Wet 0.69 DTW 8.51



GEOLOGIC

LOG

All measurements are referred to land surface except depth to water which is measured from top of casing