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EVALUATION OF POLLUTION ABATEMENT ALTERNATIVES: PICILLO PROPERTY, COVENTRY, RHODE ISLAND

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16. ABSTRACT

This report describes the second phase of a two-phase investigation undertaken by the MITRE Corp. to determine the nature and severity of ground and surface water contamination at the Picillo property in Coventry, Rhode Island and to make recommendations for permanent abatement of the situation.

The following Phase II activities were subsequently carried out to obtain the necessary additional information and to provide further elaboration on the problem:

-- Bedrock sampling, installation of bedrock wells, and field permeability testing

-- Exploratory excavation of drums

-- Groung-penetrating radar survey

-- Seismic refraction survey

-- Collection and chemical analysis of additional soil, ground water, and surface water samples.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, reassuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report describes the second phase of a two phase investigation undertaken in order to determine the nature and severity of ground and surface water pollution at the Picillo property in Coventry, Rhode Island and to make recommendations for permanent abatement of the situation.

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ABSTRACT

This report describes the second phase of a two-phase investigation undertaken by The MITRE Corporation to determine the nature and severity of ground and surface water pollution at the Picillo property in Coventry, Rhode Island and to make recommendations for permanent abatement of the situation. This study was funded by the U.S. Environmental Protection Agency, Solid and Hazardous Waste Research Division, in order to assist the Rhode Island Department of Environmental Management.

Recommendations for interim actions, conclusions, results, and field procedures of the first phase of the study are contained in the project report: "Hazardous Waste Investigation: Picillo Property, Coventry, Rhode Island," MITRE Technical Report 80W00032, April 1980.

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CONTENTS

FIGURES

TABLES

SECTION 1

INTRODUCTION

Section 1 covers the purpose and scope of the work documented in this report and presents a summary of the results of a preliminary study of the site under investigation.

PURPOSE AND SCOPE

This report describes the second phase of a two-phase investigation undertaken by The MITRE Corporation to determine the nature and severity of ground and surface water pollution at the Picillo property in Coventry, Rhode Island and to make recommendations for permanent abatement of the situation. This study was funded by the U.S. Environmental Protection Agency, Solid and Hazardous Waste Research Division, Municipal Environmental Research Laboratory (EPA/SHWRD) in order to assist the Rhode Island Department of Environmental Management (DEM) and to evaluate the use of several remote sensing techniques in an actual hazardous waste investigation.*

The first phase of the study was conducted by MITRE under contract with the DEM** and the field procedures, results, conclusions, and recommendations are contained in the project report: "Hazardous Waste Investigation: Picillo Property, Coventry, Rhode Island," MITRE Technical Report 80W00032, April 1980. The Table of Contents, List of Illustrations, and List of Tables of the above report are reproduced in Appendix A and the results and conclusions are summarized in the following subsection.

An uncontrolled hazardous waste situation was created on the Picillo property by the deliberate discharge of bulk chemicals into the ground and by the burial of drums containing chemicals. When MITRE first became involved, the number and locations of the buried drums were unknown. Leachate from the dump site had migrated approximately 1200 ft through the soil and into the surface waters of a swamp. Although the Picillo site is in a rural area, the contamination of the swamp is of concern because the swamp discharges to a body of water, Whitford Pond, that is used as a source of irrigation water for a cranberry bog.

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*Detailed analysis and evaluation of the remote sensing techniques are presented in a separate publication: "Use of Remote Sensing Techniques in a Systematic Investigation of an Uncontrolled Hazardous Waste Site," MITRE Technical Report 80W00244, January 1981.

**The following portions of the Phase I study were funded by EPA/SHWRD: chemical analysis of soil and water samples, and preliminary engineering of abatement options.

The following tasks were performed under the first phase of the investigation:

- review of DEM data pertinent to the dump site in question
- metal detection and electrical resistivity surveys of the dump site
- installation of ground water monitoring wells
- collection and chemical analysis of soil, ground water, and surface water samples
- preliminary determination of site hydrology
- preliminary engineering analysis of abatement options.

Cost estimates and conceptual designs were produced for four abatement methods but a preferred one could not be recommended because additional field data were needed, specifically the existence of fractures and contaminants within the bedrock and the condition of the buried drums.

The following Phase II activities were subsequently carried out to obtain the necessary additional information and to provide further elaboration on the problem:

- bedrock sampling, installation of bedrock wells, and field permeability testing
- exploratory excavation of drums*
- ground-penetrating radar survey
- seismic refraction survey
- collection and chemical analysis of additional soil, ground water and surface water samples.

The field procedures and results of the above study are presented in Sections 2 and 3, respectively.

SUMMARY OF PHASE I STUDY

The salient conclusions and recommendations of the preliminary (Phase I) study are shown in Tables 1 and 2. Conclusions concerning the estimated number of drums, the bedrock mound, and the total quantity of contaminated ground water flowing away from the site have been amended on the basis of the Phase II results. These changes are presented and discussed in Section 3.

*Conducted and funded by the Rhode Island Department of Environmental Management.

TABLE 1. SUMMARY OF PHASE I CONCLUSIONS

Chemical Contamination

- Ground water and surface water are contaminated predominantly with chlorinated and non-chlorinated volatile organic chemicals (total concentration less than 100 ppm).
- Air quality near the swamp is degraded due to release of chlorinated and non-chlorinated volatile organic chemicals.
- Soil around the site is contaminated with phthalate esters (total concentration less than 20 ppm).

Health Effects

- Although the chemicals detected are potentially hazardous, the potential route of exposure to the public appears to be limited to airborne transport in certain sections of the swamp.
- The low population density of the affected area minimizes the threat to public health, unless Whitford Pond is contaminated.

Hydrology and Buried Drums

- A bedrock mound located off the northwest corner of the site diverts leachate into two primary plumes;* however, both plumes discharge to the swamp.
- The quantity of contaminated ground water flowing away from the site is less than 260,000 gal/day.*
- Drums are buried in two major trenches, along the western and northern boundaries of the site.*
- The estimated range of the total number of drums buried is 3,500 to 9,000.*

Abatement Options

- Information available at the present time (April 1980) concerning condition and number of drums and impermeability and topography of bedrock is not sufficient for recommendation of permanent abatement methods.

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*Original conclusion which was subsequently modified on the basis of additional information obtained from Phase II study (see Section 3).

Table 2. Recommended Actions: Phase I

	Activity	Purpose	Time Frame (1980)
1.	Post contaminated areas of dump and swamp	Alert trespassers to threat to public health	April
2.	Analyze quantity and quality of influent to Whitford Pond	Determine potential threat to public health	April
3.	Analyze residential wells (within 1 mile radius of site) for volatile organics	Determine potential threat to public health	April
4.	Sample air quality around swamp	Determine nature of hazard	Periodically
5.	Evaluate need to restrict access to contaminated area of swamp	Determine if nature of potential hazard justifies cost of fencing contaminated regions of swamp	Periodically
6.	Excavate and dispose of drums in northeast trench (backfilling with aerated soil)	Confirm continued existence of source of chemicals	April - August (including procurement)
7.	Install absorbent booms and sheets at several locations and evaluate their effectiveness	Limit potential of surface pollutant flow to Whitford Pond	April - May (installation only)
8.	Examine bedrock for presence of fractures and contamination	Assist in the design of long-term abatement measures	April - June
9.	Install additional wells	Define plume boundaries and investigate swamp underflow of contaminants	April - June
10.	Sample existing wells	Monitor changes in water quality	Periodically
11.	Analyze condition of Whitford Pond (aquatic life, surface water, and sediment)	Determine potential threat to public health	April - June
12.	Determine all uses of Whitford Pond water in addition to cranberry irrigation	Determine potential threat to public health	April - May
13.	Conduct detailed evaluation of long-term abatement approach and implementation plan for preferred approach	Abate pollutants in a cost-effective manner	July - September

The Phase I investigation and evaluation identified the following additional information necessary to define the public health threat presented by the site and to evaluate methods for abatement of the problem:

- condition and number of buried drums
- topography and imperviousness of bedrock
- effectiveness of the swamp to act as a treatment mechanism for volatile organic chemical contamination.

Condition and Number of Buried Drums

Although metal detection had been used to find the locations of the buried drums, it was unknown whether the drums were intact and whether they contained liquid or solids. Drums containing liquids would act as a future and continuous source of contamination due to rupture and release. This made it impossible to estimate the future concentration of pollutants in the ground water or the length of time that the ground water would remain contaminated. On the other hand, there was speculation by DEM officials that the drums were crushed at the time of burial and that no future releases would occur. Thus, it was necessary to determine, by limited excavation, the actual condition of the drums and whether they contained chemicals, in order to determine an appropriate abatement method.

A second area of uncertainty was the depth of the buried drums and therefore their number. The estimate of the number of drums buried on the site was based upon certain unverified assumptions concerning the side slopes of the trenches, the depth of the trenches, and the packing density of the drums. Since metal detection does not supply any of the preceding information, considerable guess work had to be employed for the initial drum number estimates. Limited excavation of drums would therefore afford the opportunity to directly observe the condition and number of some of the drums and reduce some of the uncertainties inherent in the drum number estimates.

Topography and Condition of Bedrock

The effectivess of two of the abatement options being evaluated, encapsulation and interceptor trenches for leachate collection, depended upon an unfractured, impermeable bedrock. If the bedrock were found to be fractured, it could not be relied upon as a barrier to leachate movement, and therefore the above two abatement options would be rejected. Additionally, it was necessary to determine the topographic profile of the bedrock in order to provide more accurate cost estimates for each option, in particular for the interceptor trenches. If the bedrock profile were highly irregular, the cost of installing interceptor trenches might become prohibitive because gravity flow would be impossible and pumping stations would be needed. Rock excavation was not considered feasible because of the possibility of inducing fractures.

An additional factor to be explored concerned the possibility of vertical migration of contaminants through the bedrock fractures. Sampling and analysis of ground water from wells in the bedrock was needed to determine the presence of contaminants in order to better define the potential threat to public health.

Effectiveness of the Swamp as a Treatment Mechanism

The Phase I study showed that the swamp was the receptor and surface discharge area for contaminated ground water. Because the swamp discharges to a pond which is used for irrigation, a potential public health problem might exist if chemicals were released from the swamp. On the basis of a single downstream surface water sample, it appeared that air-borne dispersion of volatile organic chemicals (the predominant species present in the ground water) in the swamp was the principal mechanism for dilution to relatively safe levels and contaminants were not being discharged to Whitford Pond. However, the above statement was posed only as a hypothesis requiring validation.

Analysis of Abatement Alternatives

The alternative actions selected for investigation were the following:

- no action
- removal and disposal of the source of contaminants
- encapsulation of the source of contaminants
- collection and treatment of the contaminated ground water

These activities encompass the principal methods available for response to the specific problems created by the Picillo site. Conceptual designs and estimated costs were developed for each, and a comparison of their advantages and disadvantages is shown in Table 3. In addition, Table 3 presents the information determined necessary to complete the evaluation and the techniques used during Phase II to obtain the appropriate data.

In addition to the above four activities, surface preparation (grading and capping with an impermeable barrier) was evaluated as both a short-term and a long-term option and was removed from further consideration (except in conjunction with encapsulation) because of the relatively insignificant effect of precipitation directly on the dump site (when compared with the large upgradient recharge area).

TABLE 3. COMPARISON OF ABATEMENT METHODS AT THE CONCLUSION OF PHASE I

Alternative	Key Advantages	Key Disadvantages	Additional Information Required to Implement Alternative	Technique to Obtain Information
1. No Action	• effective if source of contamination is exhausted • effective if total mass of contaminants volatilizes in swamp, the swamp remains isolated, and Whitford Pond is unaffected	• does not remove source of pollutants • potential for future release of pollutants still exists • uncontrolled release of pollutants may cause public health problems	• condition of source (drums) • state of nearby pond • contaminant underflow at swamp • ultimate disposition of all pollutants	• radar, exploratory excavation • additional wells, chemical analysis of soils and water samples
2. Drum Removal and Disposal (excavation, testing, and proper disposal of drums and contents, and contaminated soils)	• remove source of pollutants	• ineffective if drums are ruptured and chemicals dispersed • potential for injury to workers exists	• condition of source (drums) • condition of soil	• radar, exploratory excavation • exploratory excavation, chemical analysis of soil samples
3. Site Encapsulation (construction of impermeable barriers around source of pollutants)	• stops/controls pollution at source • working conditions safer than for drum removal	• does not remove source of pollutants • potential for future release of pollutants still exists • success of containment requires absence of fractures in bedrock surface • requires periodic and perpetual monitoring and maintenance	• condition of source (drums) • condition of bedrock	• radar, exploratory excavation • seismic refraction, core drilling, deep wells
4. Leachate Collection and Treatment				
a. Limited Option (interceptor trenches constructed adjacent to site walls)	• controls pollution at source • working conditions safer than for drum removal	• does not remove source of pollutants • success of collection depends on condition of bedrock • treatment system does not remove all contaminants from leachate • unknown and potentially large life-cycle cost	• condition of source (drums) • condition of bedrock	• radar, exploratory excavation • seismic refraction, core drilling, deep wells
b. More Complete Option (interceptor trenches constructed 600 ft downgradient of site walls)	• controls pollution at source including additional downgradient contaminated soil • working conditions safer than for drum removal	• same as above	• same as above	• same as above

SECTION 2

FIELD PROCEDURES

Section 2 describes the field procedures employed during Phase I and the following activities under Phase II: ground-piercing radar; seismic refraction; bedrock coring and well installation, and field permeability testing; water and soil sampling and chemical analysis; and limited drum excavation.

FIELD PROCEDURES: PHASE I

This section briefly summarizes the field procedures used during the Phase I investigation.

Metal Detection Survey

The entire cleared area of the dump site was surveyed with a hand-held Fisher M-Scope (Model TW-5) metal detector. The average depth of detection was approximately 4 to 6 feet.

Electrical Resistivity Survey

Electrical resistivity surveys were conducted to locate the presence and lateral extent of ground water contamination prior to the installation of monitoring wells. A Bison Instruments, Earth Resistivity Meter (Model 2350B) was used for all surveys. Approximately 170 measurements were made using electrode (or A-) spacings of 20 and 50 feet. Information concerning soil characteristics was obtained by digging test pits with a backhoe in selected locations.

Monitoring Well Installation

Drilling operations were performed using a wash boring rig, and drillers were instructed to proceed to bedrock. The wells were constructed of 1-1/2 in O.D. schedule 40 pressure-fitted PVC pipe. The entire saturated thickness of the aquifer was screened with factory-slotted pipe. Fifteen wells were installed, and nine of them were developed by injection and pumping to remove fine sand.

Soil and Water Sampling

Soil samples were collected with a split-spoon sampler every 5 feet during drilling operations. Stainless steel bailers were used to collect

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ground water samples from each well. Representative samples were obtained by withdrawing several casing volumes of water until the temperature had stabilized.

Chemical Analysis

Analysis for priority pollutants by gas chromatography/mass spectrometry (GC/MS) was performed on composites of both soil and water samples. Wells closest to the dump area were chosen for the soil and water priority pollutant analysis in order to obtain samples which were least affected by attenuation, dispersion, or dilution. The remaining samples were quantitatively analyzed for total volatile organics (TVO) using a GC with a flame ionization detector and reporting the total output peak area in terms of selected standards.

FIELD PROCEDURES: PHASE II

This section details the field procedures used during the Phase II investigation.

Ground-Penetrating Radar

A ground-penetrating radar survey over the trench areas was performed by Geophysical Survey Systems, Inc. (GSSI) of Hudson, New Hampshire under contract to MITRE; areas of buried drums had been previously located by the metal detection survey. The general areas of buried drums are identified on the site map (Figure 1). The radar survey, which was completed in two days, was conducted to determine the feasibility of using this technique to provide information on the packing density of buried drums, the depth and geometric construction of trenches, and the location (trench boundaries near the surface) of the buried drums. This was a relatively new application of ground-penetrating radar, which had been previously used in a variety of underground investigations, such as assessing the extent of peat deposits, locating artifacts at archaeological sites, and locating soil interfaces at construction sites.

In a ground-penetrating radar survey, an electromagnetic impulse is repetitively propagated downward into the ground from a broad band width antenna on the surface. Reflections from subsurface interfaces are received by the antenna, processed electronically, and printed to yield a continuous profile of subsurface conditions as the antenna is moved across the ground surface. The depth to an interface, or the surface of a "target" such as a metal drum, is determined by measuring the time for a radar pulse to travel to the interface and reflect back to the surface.

The radar equipment used at the site in Coventry was the SIR System 7 ground radar system manufactured by GSSI. Following experimentation with two alternative antennas and center frequencies, GSSI Model 3105AP operating at a center frequency of 300 MHz and GSSI Model 3102 operating at 600 MHz, the latter was chosen for most of the survey due to its improved spatial resolution at shallower depths.

The West Trench was surveyed with the 300 MHz antenna set at a nominal depth of 25 ft, later calibrated at 24.4 ft, based on average soil conditions. The Northwest, Northeast, and South Trenches were subsequently surveyed using the 600 MHz antenna set at a nominal depth of 12.5 ft. The survey was conducted according to a rectangular grid. All trenches were surveyed longitudinally by using parallel radar transects at spacings of 10 ft. Transverse transects, or cross-cuts, were made at intervals of 20 ft for the Northeast Trench and 40 ft for the West and Northwest Trenches. The antenna was pulled along the transect manually, and the data recorded by wire connection with equipment located in a stationary van on the site, which also served as the power source.

Seismic Refraction

Seismic refraction profiling of approximately 2850 linear feet was performed at the Coventry site in two days of field work. This technique was primarily employed to determine the depth to bedrock between deep wells. A profile was also conducted over the West Trench to determine if seismic refraction could be used to determine the depth of the buried drums.

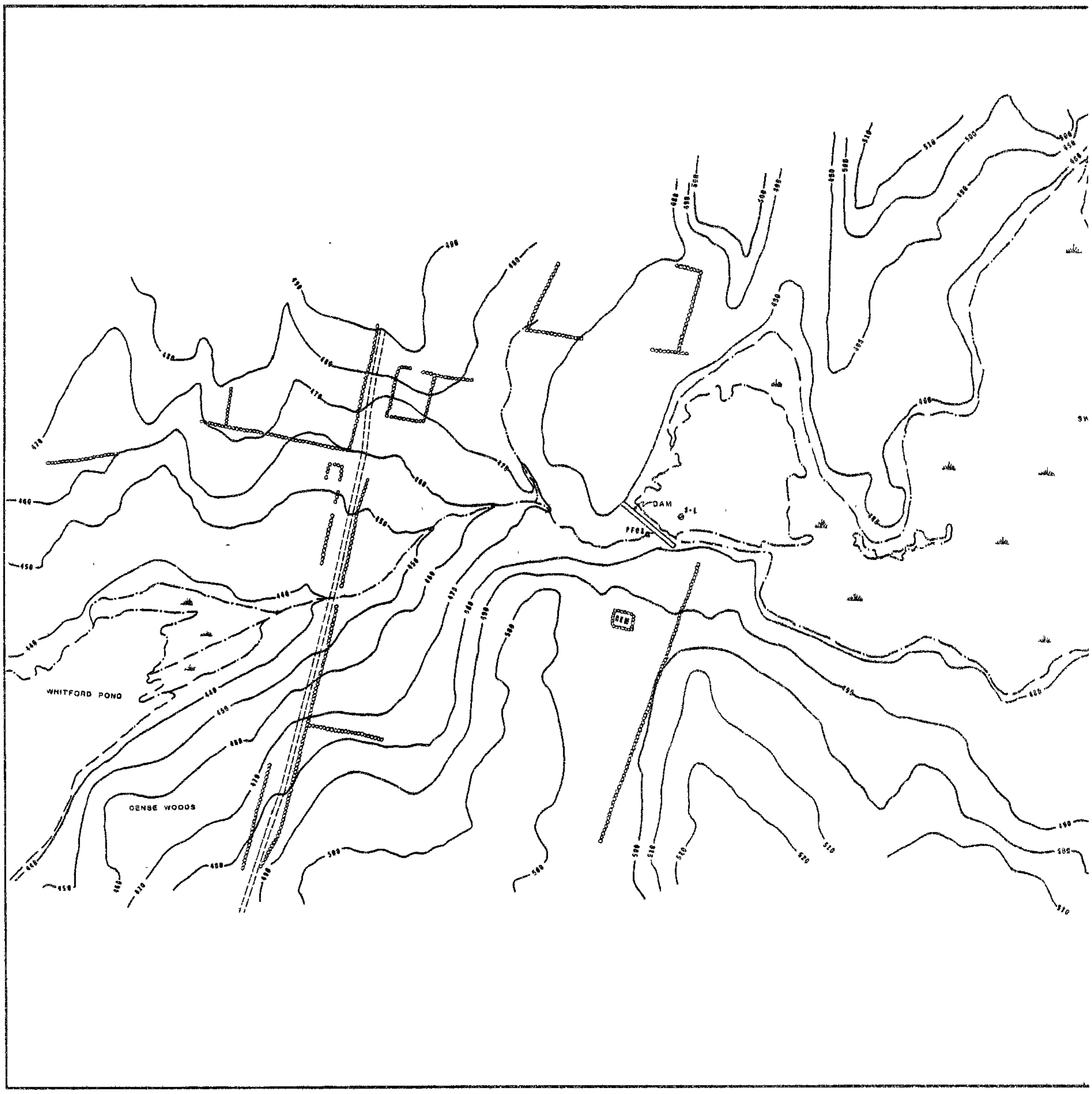
The seismic refraction method is based on the principle that elastic waves (mechanical rather than electromagnetic) travel through different subsurface strata at different velocities. Elastic waves are introduced to the ground surface by an energy source and the refracted waves are detected by small seismometers (geophones) located on the surface at various distances from the energy source. A seismograph records the travel time between the vibration and the arrival of the elastic wave at the geophones. Plotting arrival time versus distance from the energy source to geophone from a series of readings enables the determination of strata depths and their seismic velocities through the use of simple refraction theory.

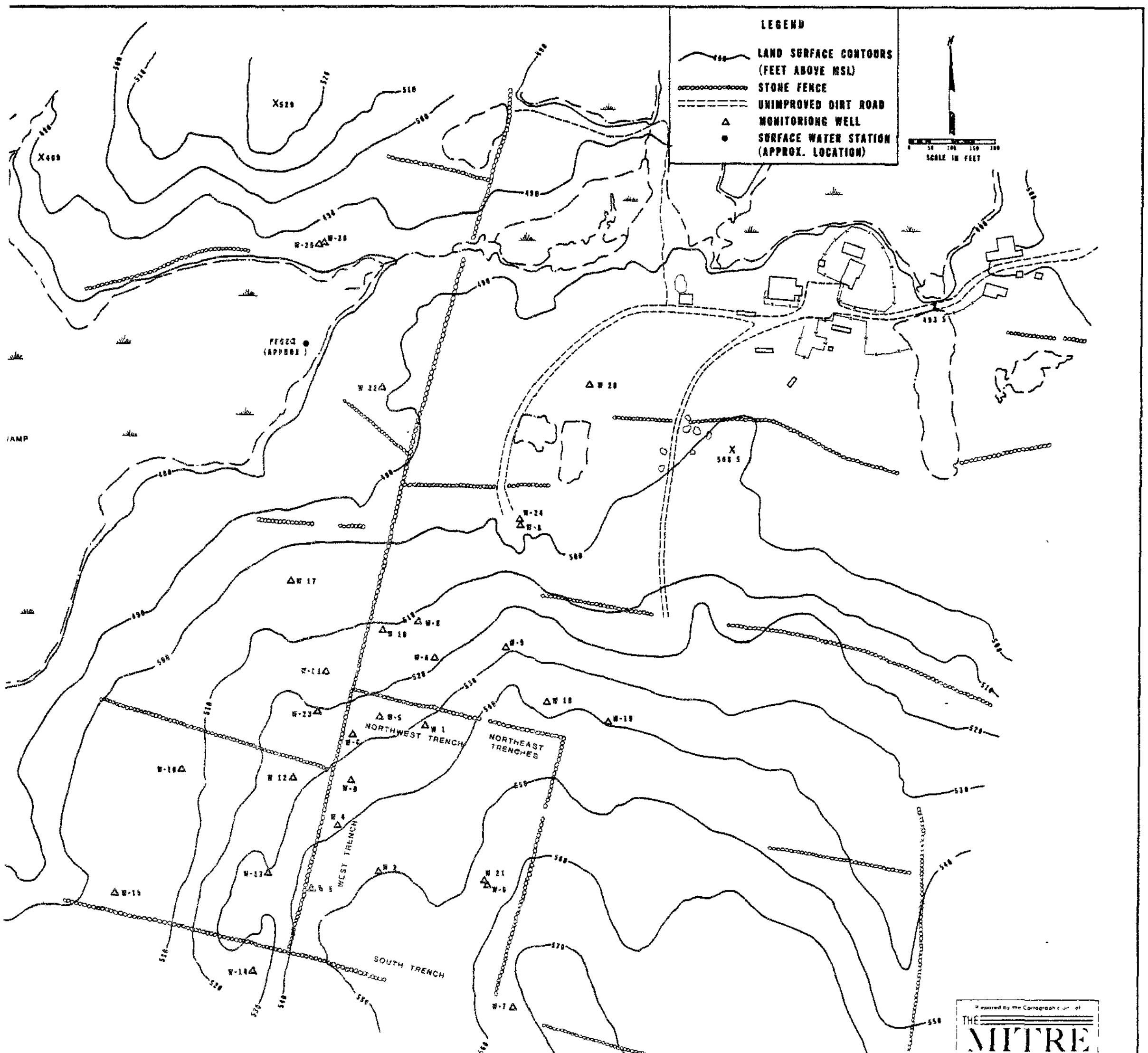
Stephen A. Alsup and Associates, Inc. of Newton, Massachusetts performed the survey using a Geometrics/Nimbus Model ES1210F Multichannel Seismograph. Voltage outputs from 12 Mark Products L-15 vertical geophones spaced at 20-ft intervals were recorded and collected for each refraction spread. The energy source used to initiate each record and shock wave was a 30-lb dropped weight or 10-lb sledge hammer blow on a steel plate with an attached impact start switch. Impact points for this survey were at the end of, and quarterly along the refraction spread, providing a locus for depth calculations at 80-foot intervals along each spread. Data continuity and repetition were achieved by repeating end shots where refraction lines were longer than one spread length.

Rock Drilling, Well Installation, and Field Permeability Testing

Installation of six additional ground water monitoring wells began on June 5, 1980. Drilling was performed by Guild Drilling Co., Inc., of East Providence, Rhode Island. Geotechnical Engineers Inc. (GEI) of Winchester, Massachusetts, also under contract to MITRE, acted as geotechnical consultant.

Drilling was performed using a hydraulic rotary rig, which has the capability to core rock. Initially, hollow-stem augers were to be used to refusal, and then steel casing was to be set prior to rock coring. However,


WHITFORD POND
DENSE WOODS
DAM



NOTE 1. BASE MAP ORIGINALLY PREPARED BY CAPHEO & WICK INC., RUMFORD, R.I.
2. LAND SURFACE CONTOURS BASED ON 1974 AERIAL PHOTOGRAPHY

FIGURE 1: MAP OF SITE WITH LOCATION OF WELLS AND SURFACE WATER SAMPLING POINTS

these plans had to be changed due to problems in setting casing following removal of the hollow-stem auger. As a result, borings were generally advanced by alternately driving steel casing downward in five foot increments and then washing out the sediment within. Finally, 2-1/8 in diameter ("N" size) cores were recovered using a hollow core barrel with a diamond bit.

Each well was constructed of 1-1/2 in O.D. schedule 80 pressure-fitted PVC pipe. Ten-foot sections of pipe were sealed with water repellent duct tape. In the five borings from which at least 15 ft of rock were cored, a 10-ft or less section of factory-slotted pipe was capped and set at the bottom. A sixth well, which was installed within the unconsolidated deposits on the north side of the swamp, was slotted between three and 13 ft below the surface. The slotted section of each well was backfilled with Ottawa sand and sealed with alternate layers of bentonite pellets and Ottawa sand totaling approximately one foot in length. The boring was then grouted to the surface with a mixture of cement and bentonite. A five-foot steel riser with locking cap was placed over each PVC well and sealed in place with the grout. Each well was pumped or bailed following installation. Water levels were measured periodically to insure that they had stabilized prior to sampling.

Drilling was completed on July 10. Figure 1 shows the locations of the new wells (numbers W21 through W26) in addition to the wells previously installed. Well locations and elevations were surveyed by Caputo and Wick, Inc. of Rumford, Rhode Island.

Field permeability measurements were taken at two well locations, W24 and W21, using either the borehole permeability or rising head methods. Three tests were conducted at different depths in Well 24.

Soil and Water Sampling and Chemical Analysis

Soil samples, collected every five feet using a split-spoon, were used by MITRE and GEI personnel to determine the geology.

Sixteen soil samples were put in 40 ml sampling vials for total volatile organic (TVO) analysis by Energy Resources Co. (ERCO) of Cambridge, Massachusetts. The sample depths were selected to be representative of each entire well. The vials had teflon and rubber seals with Bakelite tops and were specially designed for GC/MS analytical work with volatile organic compounds. The samples were taken from the following borings at the indicated depth (approximate) in feet below ground surface:

W21 - 10, 20, 30, 40
W22 - 10, 15, 20
W23 - 10, 15, 20, 23
W24 - 10, 15, 20
W25 - 8, 13

Samples were delivered to ERCO on the same day they were collected.

Due to seasonal low-flow conditions in July, it was possible to sample the surface water at only one location. The swamp waters had receded to a relatively narrow channel in its center with no surface discharge to Whitford Pond occurring. The western-most extent of the swamp water was within 40 ft of its normal outflow channel and it was at this point that the sample was taken. The surface water sample was placed into four 40 ml septum vials for TVO and volatile priority pollutant analysis and into a quart container for inorganic constituent analysis. Ground water samples were collected from wells 14, 21, 23, and 26 using a stainless steel bailer. To insure that a representative sample of the aquifer being taken, each well was pumped and/or bailed until two similar measurements of temperature and specific conductivity had been recorded. These measurements were taken using a Yellow Springs Inc. Model 33 Salinity-Conductivity-Temperature Meter.

The seven samples were delivered to ERCO on the morning of July 29, where they were to be analyzed for TVO, volatile priority pollutants, and five general water quality parameters (pH, COD, TDS, Fe, and Cl). Results of the analysis were given to MITRE on September 12.

Limited Excavation

Exploratory excavation of the Northeast Trench commenced on June 10, 1980 and was completed on August 27, 1980. The excavation was carried out by Jet Line Services, Inc. under supervision of the DEM. By the time of the start of work, the ground-penetrating radar survey had been completed and these results were given to the contractor. The radar survey was quite timely because the data it supplied showed that the Northeast Trench was in fact two discrete and separate trenches whose surface areas were larger than measured previously with the metal detector. Earth was removed by front end loader (Caterpillar 966) and the predominant method of drum location and exposure was scraping of the excavated earth face with the bottom of a backhoe bucket. The backhoe was used to allow the exposed drums to be lifted by chains attached to the bucket or in the bucket itself.

Bobcats (small front-end loaders) were used as well to expose drums, to extract drums with chains, and to carry them out to the sampling areas. Mechanical equipment was initially used for finding, exposing, and removing drums, and later on hand probing and shoveling were employed to a greater extent. An undetermined number of drums ruptured during the course of the project, and liquid chemicals were released to the ground. The contractor added earth and absorbent to the collected pools of liquid and placed this material on plastic-lined staging areas which were bermed on all sides. Crushed, empty drums were separated from whole drums. Drums containing materials were subsequently analyzed by general chemical classifications (solid, liquid, acid, base, incinerable) for disposal.

The information obtained from the excavation and revised estimates of drum numbers are presented in Section 3.

SECTION 3

RESULTS OF FIELD TESTS

Section 3 discusses the location, number, and condition of buried drums; local hydrogeology and bedrock topography; and the extent of chemical contamination based on the additional information obtained during the Phase II investigation.

LOCATION, NUMBER, AND CONDITION OF BURIED DRUMS

This section describes the results of the exploratory excavation of the Northeast Trenches, the results of the radar and seismic surveys, and estimates for the number of drums remaining buried.

Results of Excavation of Northeast Trenches

Table 4 presents information received from the DEM Site-Representative, Larry D. Riggs, concerning the results of the excavation of the Northeast Trenches. It is clear that the number of drums found in the trenches exceeded, by a considerable amount, the preliminary estimates produced at the conclusion of Phase I.

Approximately 70 percent of the chemical-containing drums were leaking or corroded and many burst open as a result of the activities of excavation, generating approximately 10,000 cu yd of contaminated earth.* It was the opinion of the Site-Representative that the deteriorated condition of the drums was caused by bulk discharge of acid into the trenches and the resulting release of additional acid from deteriorated drums. The drums appeared to have been pushed into the trenches and covered periodically with earth, thereby producing clusters similar to cells in a landfill. Some sections had been run over by bulldozers to crush and compact the drums, and many drums were buried with their bungs removed in order to allow their contents to drain out. Pockets of nested liquids were found in the areas identified as "plumes" by the radar survey (see Appendix B). These subsurface pockets of liquid were due to isolated blockage of void spaces by sludge and semi-solid materials. The depths of the two trenches varied from 8 ft to 35 ft and 8 ft to 25 ft respectively, with the greater distance found at the longitudinal middle.

Results of Radar and Seismic Surveys

The locations of the buried drums, as determined by both metal detection and ground-penetrating radar, are shown in Figures 2 and 3. Trench locations are

*All earth contaminated by the excavation activities had been stockpiled over an impermeable liner awaiting final disposition.

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TABLE 4. RESULTS OF EXCAVATION OF DRUMS FROM THE NORTHEAST TRENCHES

Item	Number
Drums Removed	2314[a]
Drums Which Were Found Crushed	750[b]
Drums Which Contained Chemicals (liquid or solid)	1800
Percent Solid and Sludge	60
Percent Liquid	40
Percent Incinerable	30
Percent Aqueous Liquids (predominantly acids or caustics)	70
Percent Leaking	70
Depth of Trenches	8 to 35 ft and 8 to 25 ft

a. Total number, including crushed drums.

b. This refers to the drums that were crushed during the dumping operation and not to the crushing of empty drums conducted by the DEM during the excavation activities.

Source: Rhode Island DEM.

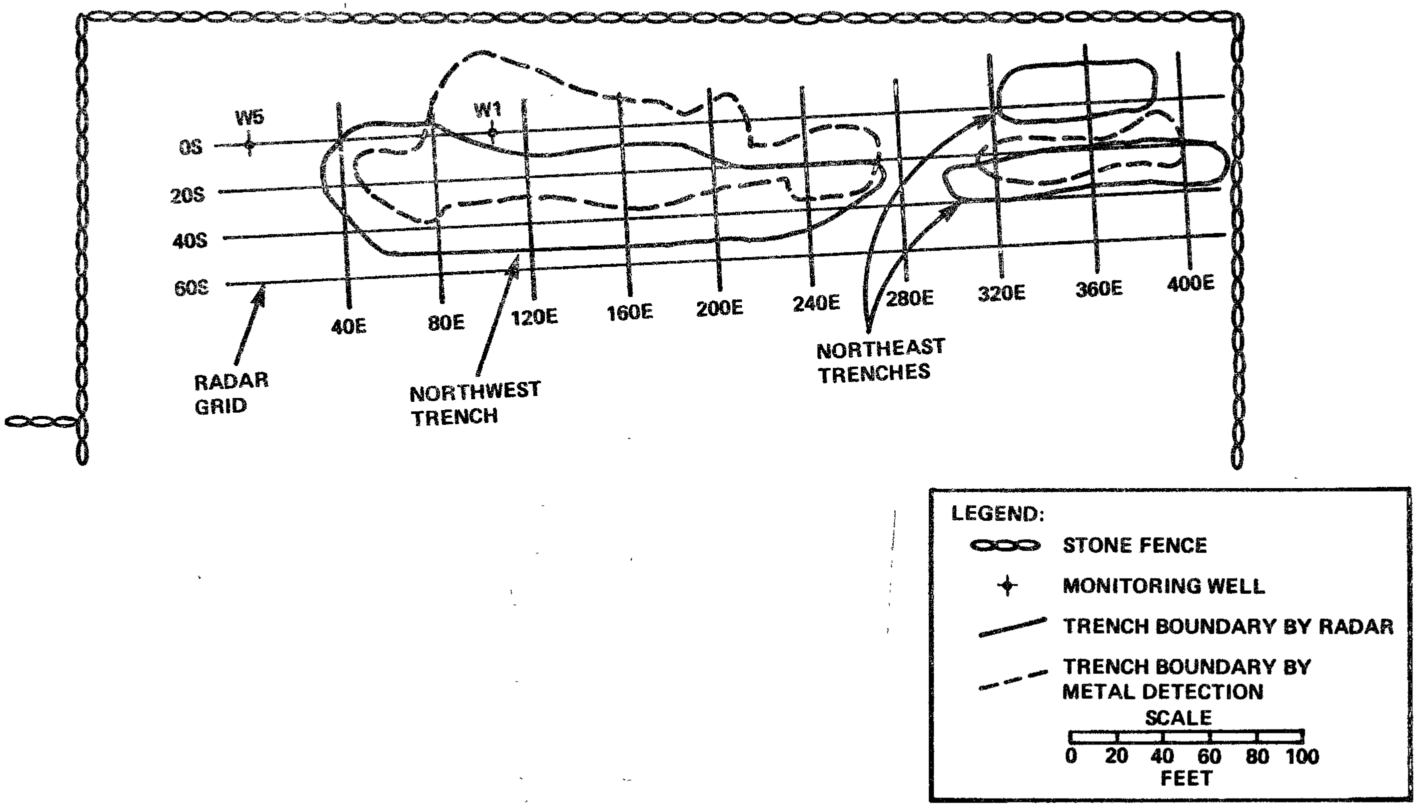


Figure 2. Comparison of Northeast and Northwest Trench Locations as Detected by Ground-Penetrating Radar and Metal Detection
(Grid based on locations of W5 and W1)

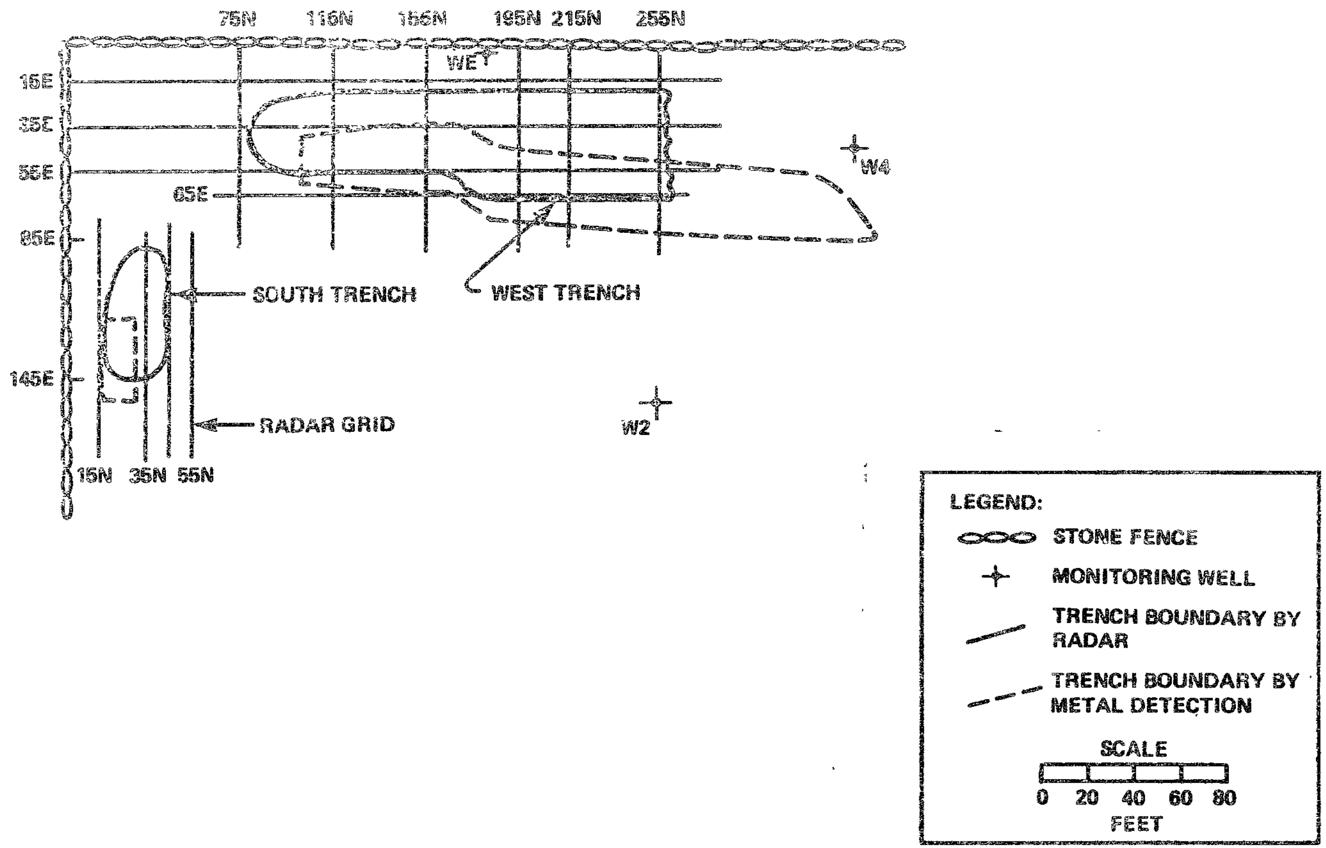


Figure 3. Location of South and West Trenches as Determined by Ground-Penetrating Radar and Metal Detection (Grid based on locations of south and west stone fences)

presented as reported by the subcontractors who conducted the field surveys. Although there is not complete overlap between the outlines determined by the two methods, it is suspected that the deviation is due mainly to inaccuracies in the reporting of the metal detection results. However, it is recommended that the trench boundaries as determined by metal detection be accepted until their validity is either proven or disproven by actual excavation. Since the radar probed to a depth of 12 ft in contrast to the four to six feet for metal detection, the radar would be expected to present a somewhat more accurate indication of trench boundaries. Trench boundaries from the two techniques were compared for all trenches. The radar found two trenches in the "Northeast Trench", versus the single trench identified earlier with metal detection. On the other hand, the radar data for the West Trench proved to give incomplete areal coverage and therefore were supplemented by data from the metal detection.

The radar provided, in addition, some useful qualitative information on the way drums were placed and on the trench construction. For example, although there were isolated instances where several drums appeared to be neatly stacked, this was the exception rather than the rule; the drums for the most part were randomly stacked, and, at least in the top eight feet below the surface (where individual drums most clearly could be identified), the drums appeared to be present in clusters as opposed to being uniformly dense throughout a trench. The radar also indicated that the top surface of the drums displayed an "angle of repose" from the center of the trench cross-section to the sides.

The radar was not able to detect the bottom of the trenches, principally because the upper drums masked what was beneath. Even in the West Trench, where a 25-ft nominal depth was probed, the trench bottom could not be located from the data.

The radar was able to detect five areas of liquid plumes within trenches. This was possible because of the higher dielectric constant of the fluid relative to the ground water. As described in the preceding subsection, the plumes were actually nested pockets of chemicals. The location of the trenches as determined by ground-penetrating radar are shown in Appendix B.

The seismic refraction survey conducted over the West Trench indicated that drums were buried to a maximum depth of 14 feet, but since this was an experimental application of the process, the results may not be used without qualification until the method has been field verified. Figure 4 presents the subsurface profile of the West Trench based upon the results of the seismic work. The tentative drum burial area appears on the figure as a region with seismic velocities between 600 and 1100 feet per second (fps); such velocities are typical of loose or unconsolidated soil or fill. There is a sharp distinction between this zone and the one directly underneath having velocities between 3200 and 3600 fps. The velocities of the second zone are typical of non-saturated sands and gravels or compacted fills. Because this zone extends below the water table, it is interpreted that the buried drums end at 14 ft, the interface between the two zones. The lowest zone with a velocity of 15,400 fps represents the underlying bedrock.

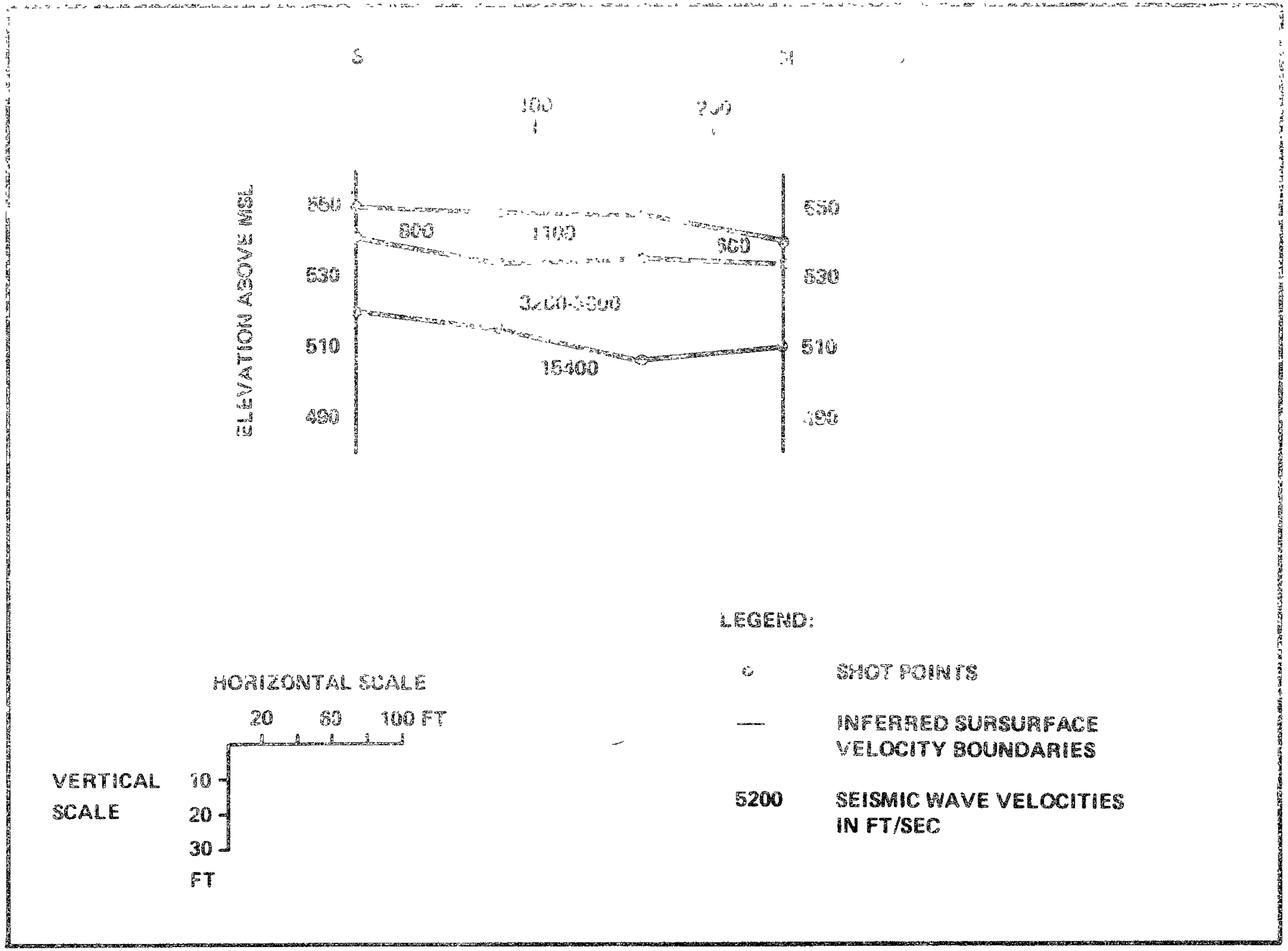


Figure 4. Subsurface Profile of the West Trench as Determined by Seismic Refraction (Ground surface represented by top line of figure)

Estimate of Number of Buried Drums

In order to produce estimates for the number of drums remaining buried, a theoretical trench geometry shown by Figure 5 was employed. The angle of the vertical side walls was assumed to be 60°, the angle of the declining surface of drums 45°, and the angle of descent at the trench ends 45°. The angle of repose for disturbed site soil is approximately 45°, but the excavated side walls can maintain a much steeper slope. Table 5 compares the geometrical assumptions used for the drum number estimates produced from the Phase I and Phase II investigations.

It is also assumed for the purpose of the drum estimates that a two-foot layer of soil covered the top of the burial area and two nominal trench depths of 14 and 22 ft were used in order to bracket the range determined from remote sensing and direct excavation.* The bottom of the trenches are assumed to be level with no irregularities. Straight sides for the horizontal widths and lengths have also been assumed; the dimensions used for determining the volumes of each trench are shown in Table 6.

Two densities of drums (percent of volume of drums within trench volume below the cover layer of soil) were used for the drum number estimates: 90 percent and 50 percent. A drum density of 90 percent represents the closest packing arrangement possible for cylinders without regard to interferences imposed by the actual geometry of the trench boundaries. An actual drum density of 54 percent was calculated for the Northeast Trenches using the results** obtained from the DEM Site-Representative combined with the theoretical geometry shown by Figure 5. The calculated 54 percent density was rounded off to 50 percent for the lower limit calculations of the drum number estimates.

The estimated range of the number of drums remaining buried at the Picillo site is found in Table 7. The drum estimate was performed by calculating the volume of each trench and multiplying the volume by the assumed drum density to yield the total volume of drums. The estimate for the number of whole drums is provided by dividing the total volume by the volume of a single drum (7.35 cu ft). As Table 7 shows, the overall range varies by a factor of 2-1/2, from 16,700 to 44,700, while the more likely range based upon the observed depth of the Northeast Trenches is less than a factor of 2, from 25,000 to 44,700.

The above estimates are for whole, uncrushed 55-gallon drums. The numbers will necessarily increase if some are crushed, enabling closer packing. The drum number estimates can be corrected for the presence of crushed drums by multiplying by $g/(f + g - gf)$, in which f represents the fraction of crushed drums and g is equal to the ratio of the volume of a whole drum to the volume of a crushed drum. If $g = 2$ and $f = 0.3$, for example, as indicated by

*14 ft - seismic survey of West Trench
22 ft - average depth of deeper Northeast Trench.
**2300 drums removed from two trenches with the following dimensions:
Trench A: 120 ft long, 20 ft wide, and 22 ft deep (average)
Trench B: 60 ft long, 15 ft wide, and 17 ft deep (average)

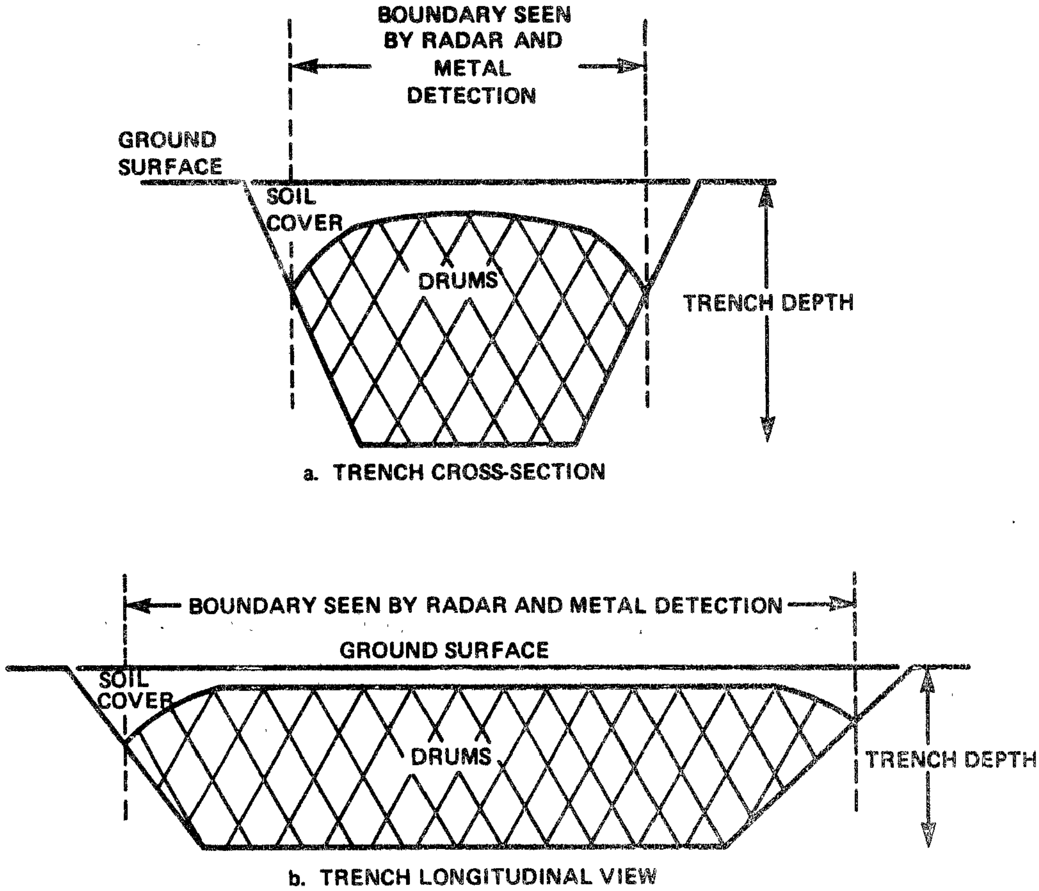


Figure 5. Illustrative Trench Geometry

TABLE 5. COMPARISON OF ASSUMPTIONS USED FOR ESTIMATING TOTAL NUMBER OF DRUMS IN PHASES I AND II

Item	Phase I	Phase II	Reason for Change
Total surface area of buried drums	19,600 sq ft	23,800 sq ft	Radar combined with metal detection more accurate than metal detection alone.
Slope of side walls	45°	60°	Results of excavation.
Maximum depth	7 to 25 ft[a]	22 ft	Phase I assumption based on observed trench geometry of unfilled trench on site; Phase II assumption based on results of excavation.
Cross-sectional geometry	Triangular	Trapezoidal	Results of excavation; deeper penetration of radar.

a. Depth depended upon convergence of side walls with 45° slope.

TABLE 6. ESTIMATED RECTANGULARIZED DIMENSIONS OF SURFACE OF TRENCHES

Trench Location	Width (feet)	Length (feet)
Northwest	50	235
West	45	240
South	30	60

Source: Ground-penetrating radar and metal detection survey.

TABLE 7. ESTIMATED NUMBER OF BURIED DRUMS
BASED ON EXTRAPOLATION OF BEST AVAILABLE DATA

Trench Location	Maximum Drum Density		Drums Randomly Stacked	
	d = 14 ft	d = 22 ft	d = 14 ft	d = 22 ft
Northwest	14,800	22,400	8,200	12,400
West	13,500	20,200	7,500	11,200
South	1,700	2,100	1,000	1,200
Total	30,000	44,700	16,700	25,000

Notes: d = nominal trench depth

Random stacking indicated by results of excavation of Northeast Trenches, approximated by 50 percent drums, 50 percent earth by volume in trench below 2-foot cover and assumed trench geometry, as shown by Figure 5.

Drums are assumed to be uncrushed, 55-gallon drums.

the exploratory excavation of the Northeast Trenches, there would be 18 percent more drums (whole plus crushed); however, there would be 17 percent fewer whole drums.

As mentioned above, prior to the radar survey an estimated range of drums was made which was substantially lower than the estimates presented here. The earlier analysis plausibly assumed that the trenches with buried drums were of similar construction to that of an unfilled trench on the site: nine feet in depth and with sides of slope 45°. As a lesson for other similar sites, it is wise to keep in mind that without the benefit of more accurate information, the "worst case" corresponds to a steep-sided trench (depending on local soils) with depth approximately equal to the water table, to bedrock, or to the maximum feasible excavation depth.

The finding with the most significance toward the evaluation of abatement methods is that there is a large number of whole drums containing liquid and semi-solid chemicals, rather than piles of ruptured or crushed drums. Although many of the drums in the Northeast Trenches were found to be deteriorated by the results of chemical corrosion, it was possible to minimize the release of their contents to the environment by careful handling, pumping of spilled liquids, use of absorbents, and removal of contaminated soil. It is important to emphasize that there is no guarantee that the remaining trenches are similar in construction, depth, or contents to the Northeast Trenches. Thus, due caution is still advised in interpreting and using even the revised drum estimates, despite their being based on the best available data.

HYDROGEOLOGY

The objective of the Phase I hydrogeologic study was to obtain a preliminary interpretation of subsurface conditions. In order to achieve this, the following tentative assumptions were used for calculations regarding aquifer thickness, ground water flow rates, and abatement method evaluation:

- Refusal depths in borings W6-W20 are due to bedrock.
- The bedrock surface is tight and impermeable.
- Literature values for hydraulic conductivity of till in Rhode Island vary from approximately 10^{-5} to 10^{-2} cm/sec; therefore, site conditions exhibit these extremes.

A key purpose of the Phase II investigation was to determine the depth, topography, and relative fracturing of the bedrock and the hydraulic conductivity of the unconsolidated deposits by field measurements. The techniques used to obtain the above information were: bedrock sampling, seismic refraction surveys, and field permeability tests. In summary, the following points were learned as a result of these activities at the Picillo site:

- Refusal depths of the previous borings were due to either boulders or very hard till. The bedrock is generally 10 to 30 ft deeper than anticipated; the actual depth varies from less than 10 ft near the swamp (according to wave velocities from the seismic survey) to near 70 ft on top of the site (boring W21).

- The bedrock is highly fractured throughout the upper 10 to 15 ft and in hydraulic connection with the overlying glacial deposits. A permeability test within the fractured granite gneiss indicates a hydraulic conductivity of 10^{-6} cm/sec.

- Additional field permeability tests performed during and following drilling activities indicate that the hydraulic conductivity of the unconsolidated deposits at the Picillo site range from 10^{-4} to 10^{-5} cm/sec.

- Ground water flows from the dump site to the swamp in a general southeast to northwest direction with no discontinuity at the northwest corner, as was concluded in Phase I. The unconsolidated zone in the region of the northwest corner is relatively thin and most of the saturated zone is within the bedrock.

Measurements of the water level in all the wells were taken on August 12, 1980 and used to prepare Figure 6. (Appendix C contains a monthly plot of the water level below ground surface since January for several wells at the site.) Horizontal ground water flow is perpendicular to the equipotentials (lines of equal water level elevation) shown on the figure. Missing from the map is the area of no ground water flow, which had been part of the January 14, 1980 water level map presented in the Phase I report.

It was determined by the installation of well W23 during the Phase II investigation that ground water does exist in this region, but it is deeper than the refusal depths of borings drilled previously (C, 10, 11, and 12). The Phase I borings were driven by the wash boring method and the Phase II borings were driven by power augering and coring of boulders and rocks. Phase II boring logs are presented in Appendix D.

The Phase I resistivity values obtained for the northwest corner were higher than other regions of the site, indicating little conductive ground water contamination. It was thought that a mound in the bedrock caused a diversion of contaminated ground water away from this area. The high resistivity values now seem to have been the result of the depth of the saturated zone, since the ground water sample from W23 showed a relatively high concentration of contaminants (see following subsection for results of chemical analysis). The depth to the water table off the northwest corner is approximately 24 ft, while it varies from less than 5 ft to almost 17 ft in other regions surrounding the site.

Figure 6 additionally shows that the direction of ground water flow on the north side of the swamp is toward the swamp. Consequently, the existence of swamp underflow of contaminants is unlikely.

The locations of the seismic profiles in relation to the site are shown on Figure 7. It should be noted that these profiles were not surveyed and their locations are only approximated in Figure 7. Figures 8 to 11 present the results of the seismic refraction survey, and Table 8 provides correlations between seismic velocities and various geologic strata. Although the seismic profiles crossing the northwest region (lines 1 and 2) do not show the presence of a mound in the bedrock, the depression that exists at the 400 ft location of line 1 (in the region of well WD) and subsequent rise toward the northwest corner may account for the thin saturated zone and contamination of the bedrock (as described in the following subsection).

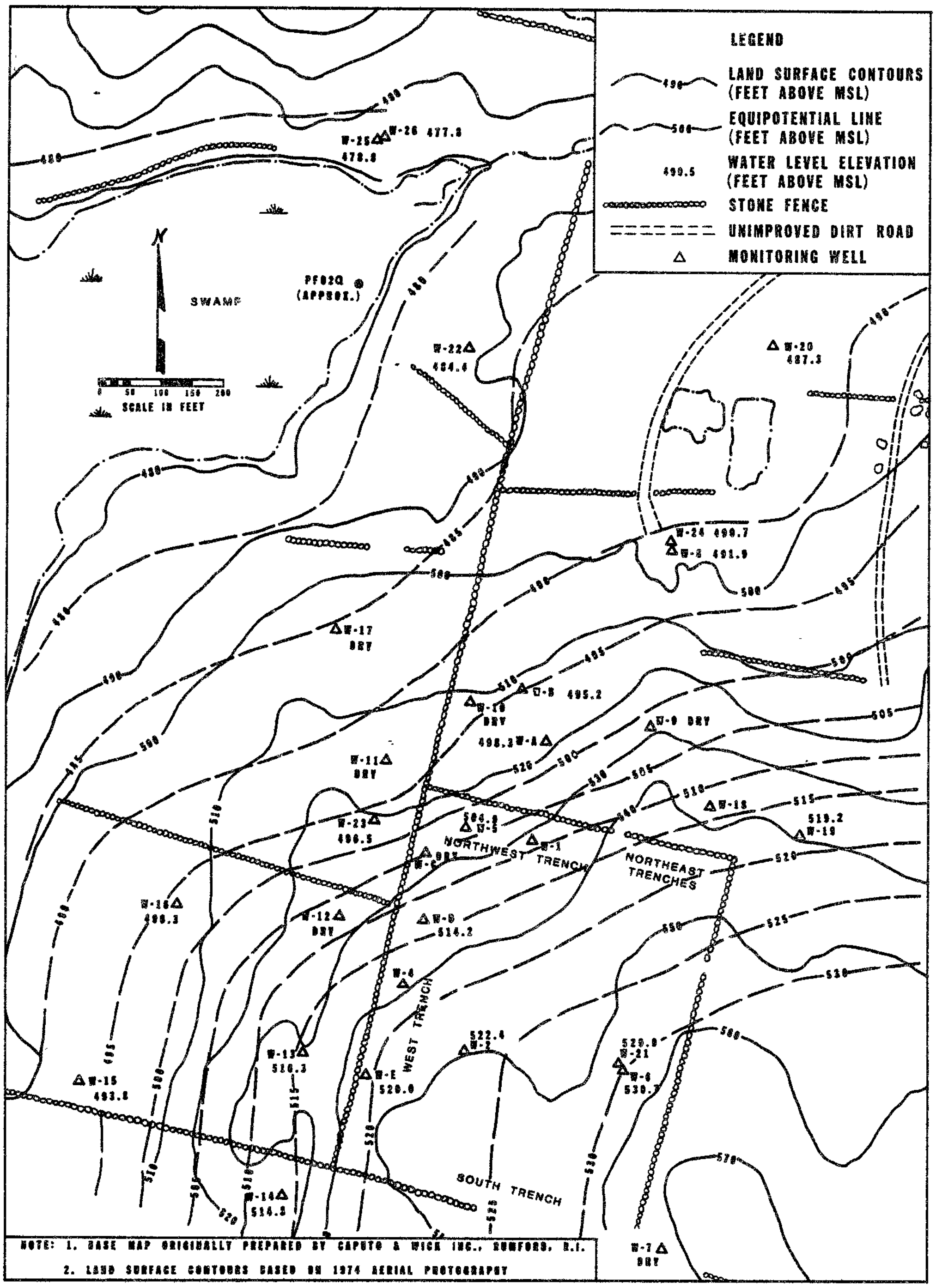


Figure 6. Water Table Map for August 12, 1980

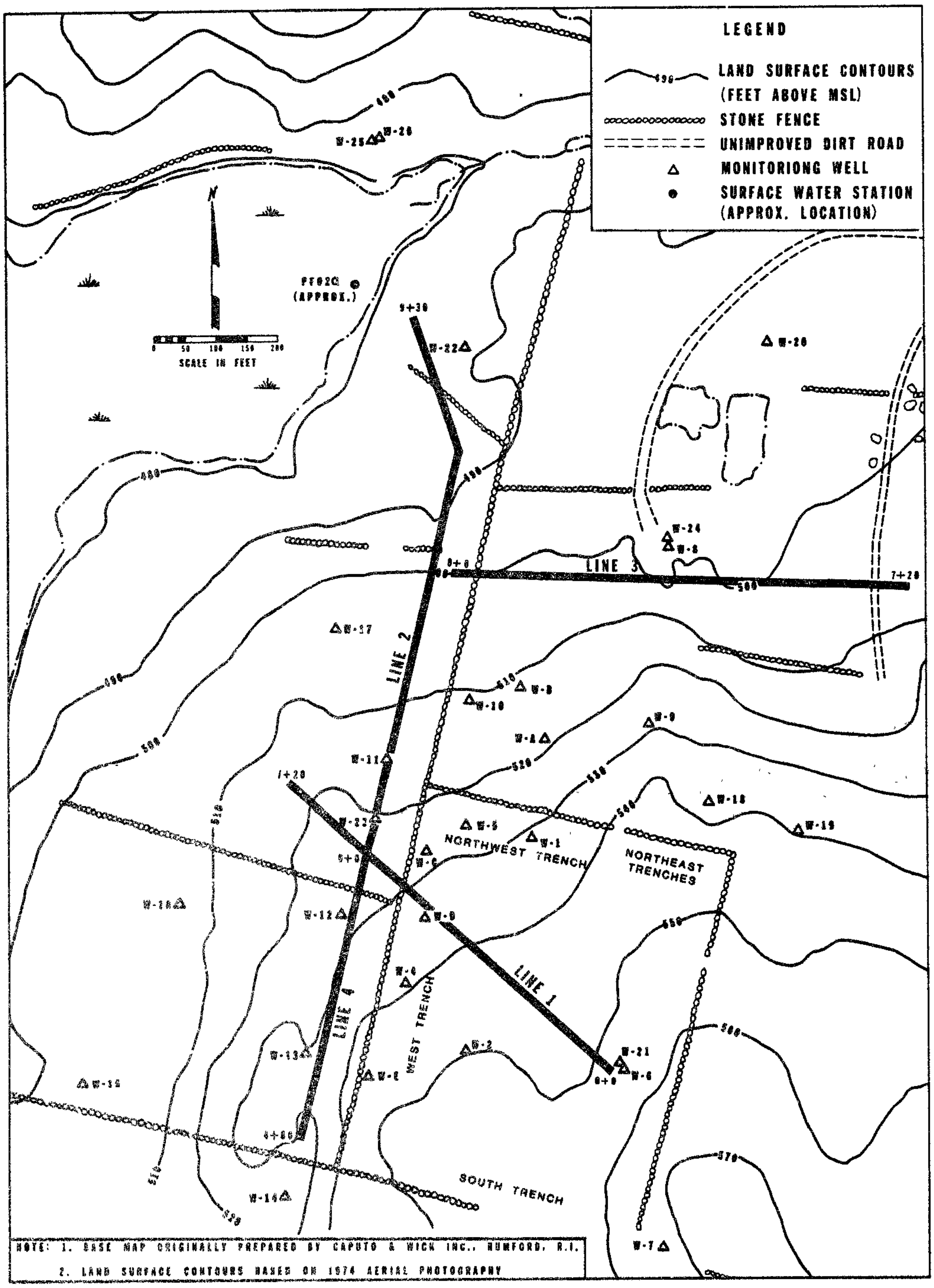
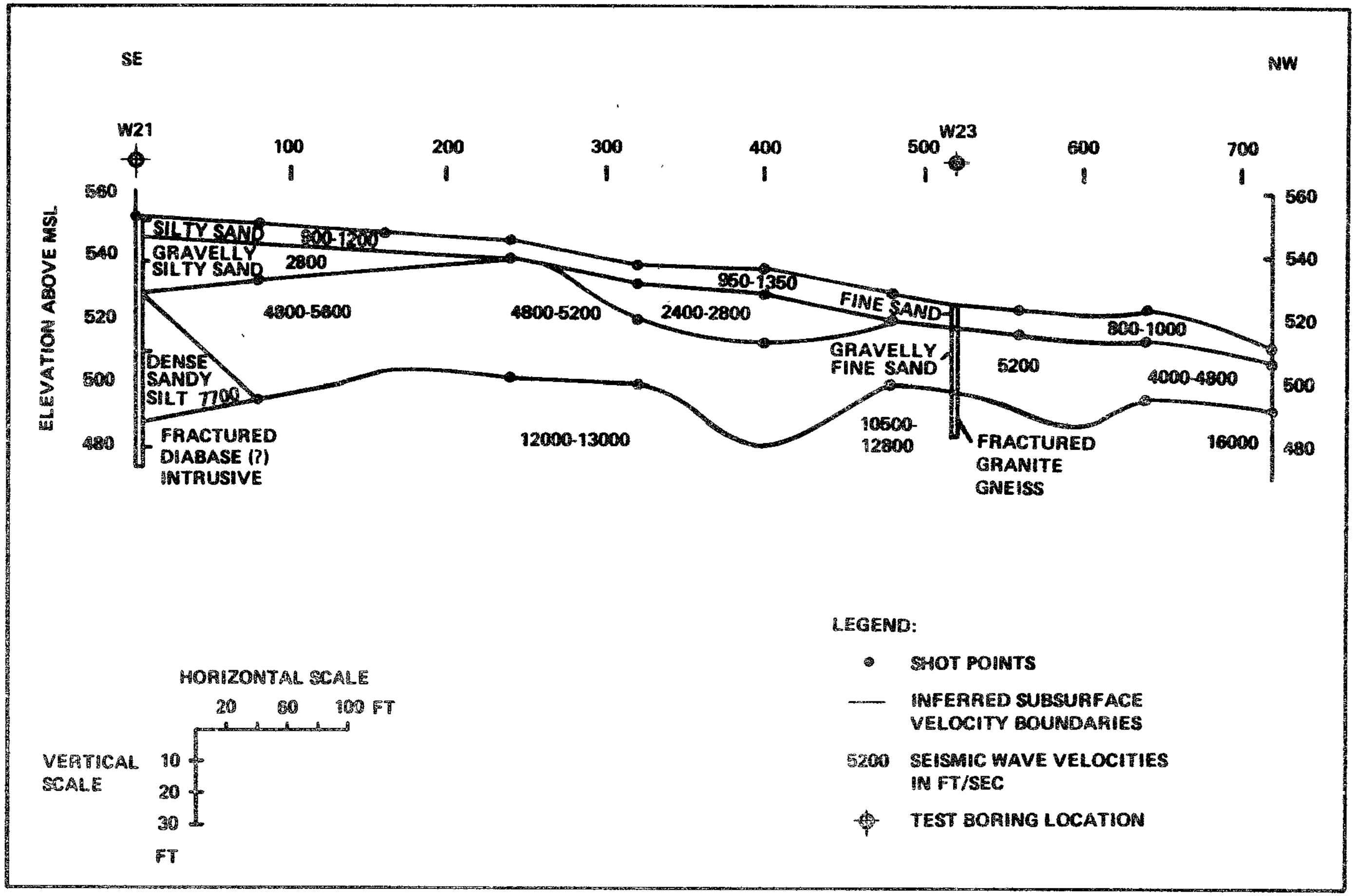
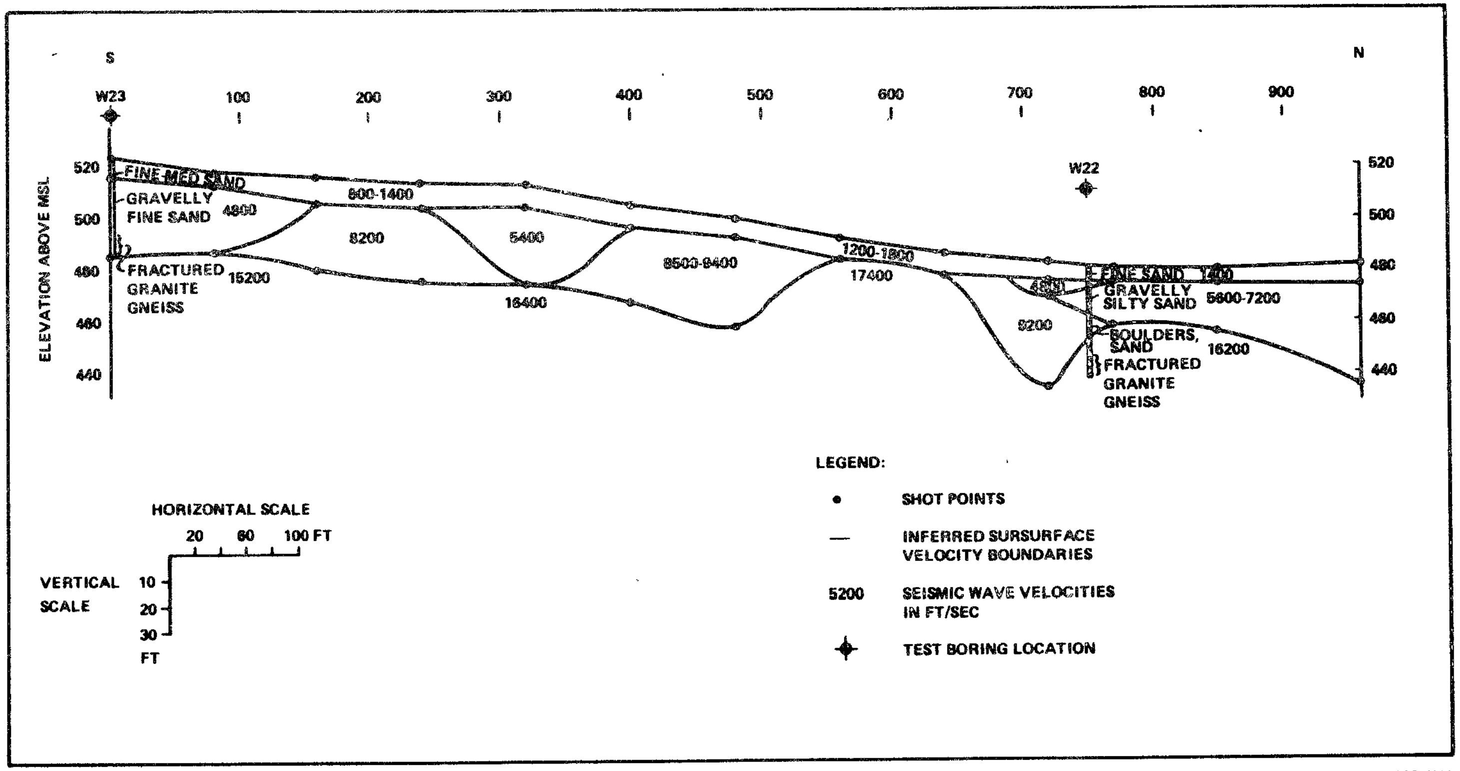


Figure 7. Location of Seismic Refraction Profiles
(Note: Profile locations are approximate only
and are not based on survey results.)



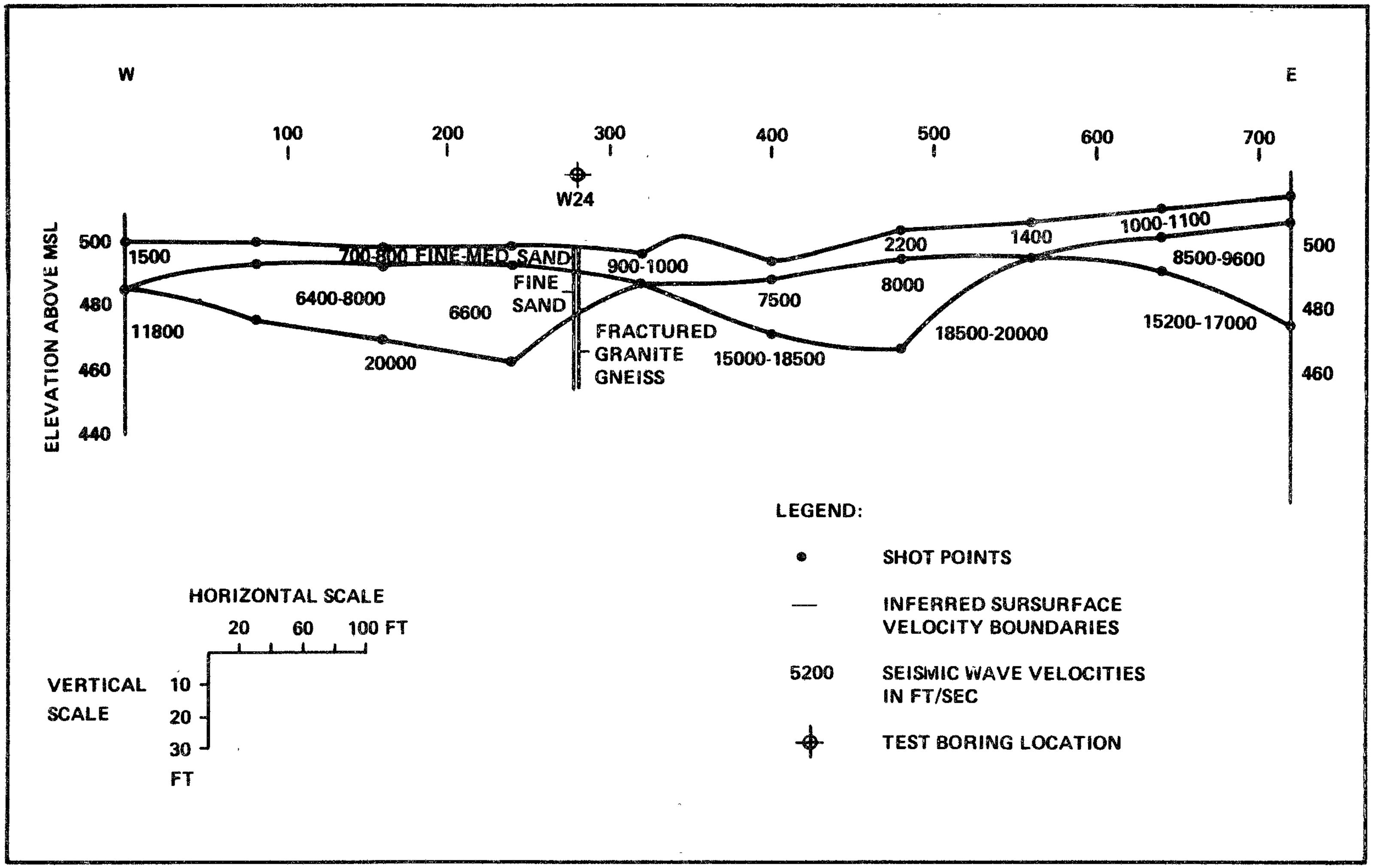
SOURCE: S.A. ALSUP AND ASSOCIATES, INC.

Figure 8. Results of Seismic Refraction Survey: Line 1
(Ground surface represented by top line of figure)



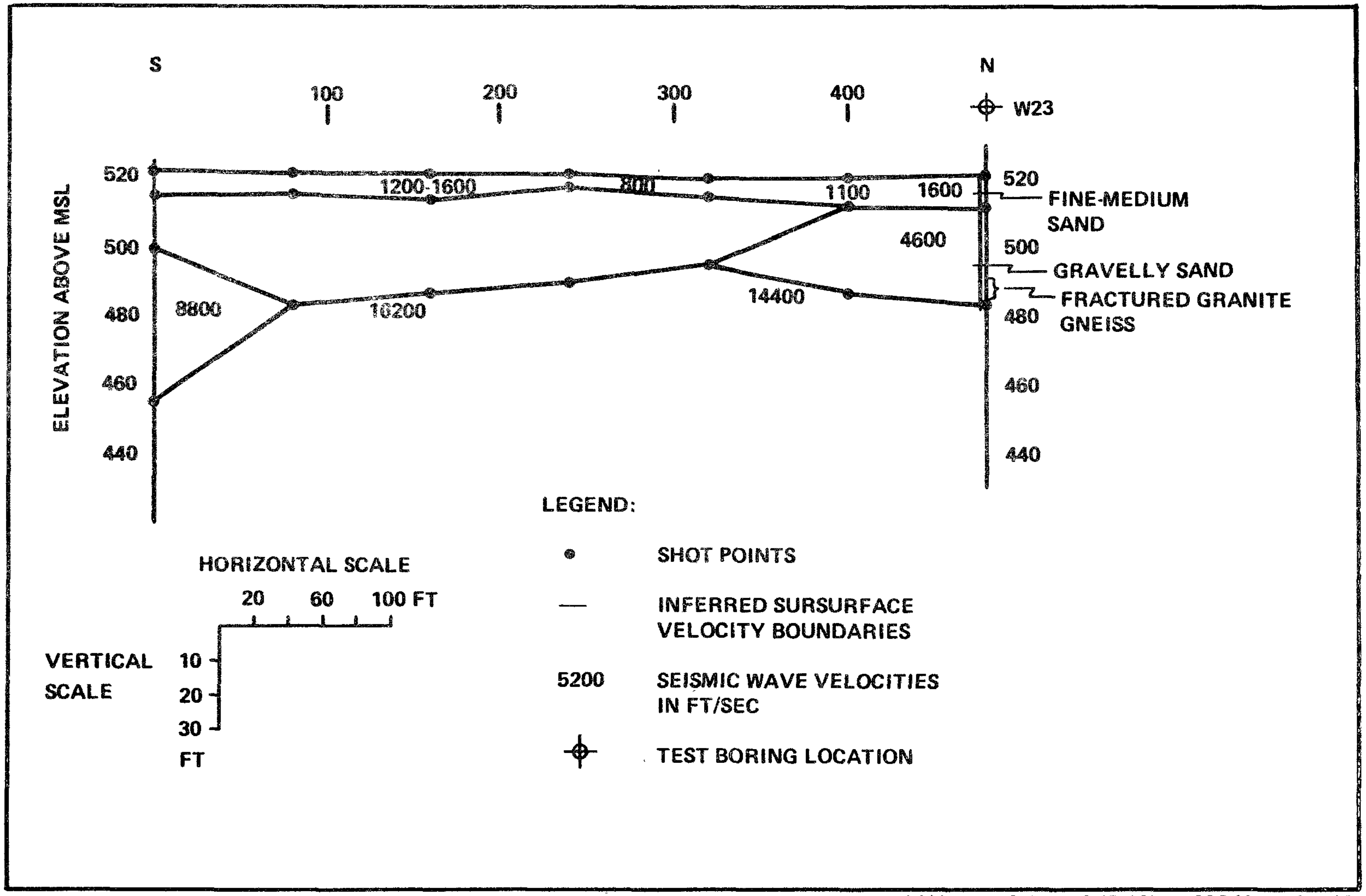
SOURCE: S.A. ALSUP AND ASSOCIATES, INC.

Figure 9. Results of Seismic Refraction Survey: Line 2
(Ground surface represented by top line of figure)



SOURCE: S.A. ALSUP AND ASSOCIATES, INC.

Figure 10. Results of Seismic Refraction Survey: Line 3
(Ground surface represented by top line of figure)



SOURCE: S.A. ALSUP AND ASSOCIATES, INC.

Figure 11. Results of Seismic Refraction Survey: Line 4
(Ground surface represented by top line of figure)

TABLE 8. CORRELATIONS BETWEEN SEISMIC VELOCITIES AND GEOLOGIC STRATA

Compressional Wave Velocity (fps)	Inferred Subsurface Conditions
600 - 2200	Very loose and unconsolidated soil or fill, not saturated with ground water or other fluid, may include ablation tills, very recent sand/gravel deposits.
2400 - 3600	More compact deposits than above, but of intermediate density. Often includes non-saturated coarse sands and gravels, some ablation tills, and some compacted fill materials.
4000 - 5600	Materials of either type above, with ground water saturation. Degree of saturation and permeability generally increases with increasing velocity to the mid-range values, then may decrease because of finer grain sizes in the deposits.
6000 - 8600	Typically dense glacial tills, either with or without ground water saturation. May include deeply weathered or fractured bedrock, with possible marine clays in the lower part of the velocity range.
9000 - 11000	Moderately to weakly weathered or fractured bedrock, may include very dense lodgement tills.
above 11000	Typically very dense to dense sound and competent bedrock units.

Note: There is overlap among the ranges above with regard to the particular type of deposit represented by the compressional wave velocities. Geological interpretation is commonly required for identification and deposit type.

Source: S. A. Alsup and Associates, Inc.

Three well clusters now exist at the Picillo site (W6 and W21, W8 and W24, W25 and W26). One well at each location is screened in the glacial deposits (W6, W8, W25) and the others (W21, W24, W26) are isolated in the fractured bedrock. Each cluster indicates that the fractured bedrock is hydraulically connected to the overlying glacial deposits and that there is a slight downward component of flow (differences in head of one foot or less) from the unconsolidated material into the bedrock. Visual examination of the unconsolidated material during test drilling showed deeper sediments to be very dense and contain less coarse-grained material, while field permeability tests conducted during and following the drilling activities indicated a decrease in the hydraulic conductivity with depth. Table 9 presents a summary of hydraulic conductivity values calculated from borehole permeability tests and water level recovery rates.[1]

As a result of the additional information obtained about the hydrogeologic system, revised estimates can be made regarding the quantity of contaminated ground water flowing away from the site. Table 10 presents the values used for the hydraulic conductivity and the saturated thickness of the aquifer in Phases I and II, in addition to the previous and revised estimates of ground water flow. The values used for saturated thickness for the Phase II estimates were obtained from results of the seismic refraction survey, as well as the test boring logs. The thicknesses given approximate the distance between the water table and competent bedrock. Variations in the saturated thickness due to seasonal fluctuations in the water table (approximately 4 ft) do not significantly affect this analysis because of the inaccuracies involved with interpretation of seismic refraction data. The values used for hydraulic conductivity are taken from Table 9.

The revised estimate for the quantity of ground water flowing away from the site and into the swamp is 10,000 gpd (with $K = 10^{-4}$ cm/sec). This amount is less than the prior estimate, but closer to the average daily recharge of precipitation to the aquifer beneath the site (Phase I calculation of 12,000 gpd).

The water table map shown by Figure 6 indicates that the swamp is the sole discharge area for contamination leaving the dump site. Although the downward gradient in the cluster well near the swamp is slight, the possibility for downward migration of some of the contaminants (and subsequent transport beyond the swamp) cannot be discounted. For this reason it is recommended that a monitoring well screened in the bedrock be installed between the swamp and Whitford Pond.

Examination of a surface topographic map for the region (Figure 12) shows that the dump is located on a three-sided knoll and that hydraulic connection potentially exists with two other surface water bodies: Great Cedar Swamp and Quidnick Reservoir. Great Cedar Swamp flows into Great Grass Pond, which is an additional water source for the cranberry bog fed by Whitford Pond. Quidnick Reservoir is not an active water supply reservoir, but serves as a recreational lake. Although the migration of contamination to either of these two water bodies is considered unlikely because it is counter to the water flow direction indicated by the monitoring wells on the site, monitoring recommendations are included in Section 4 to guard against this possibility.

TABLE 9. SUMMARY OF HYDRAULIC CONDUCTIVITY DATA

Location	Field Test	Unit	Depth Below Surface (ft)	Value (cm/sec)
W24	Borehole Permeability	fine-medium sand, some silt and gravel (glacial till)	10 - 11.5	5.1×10^{-4}
W24	Borehole Permeability	fine sand and silt (glacial till)	20 - 21.75	1.7×10^{-5}
W24	Rising Head	fractured granite gneiss	31.6 - 41.6	4.1×10^{-6}
W21	Rising Head	fractured diabase (?) intrusive	68 - 78	1.8×10^{-5}

TABLE 10. COMPARISON OF PARAMETER ESTIMATES AND QUANTITIES OF GROUND WATER FLOW IN PHASES I AND II

	Phase I Estimate	Phase II Estimate
Elevation Contour 520: Through Dump Area		
K[a] (cm/sec)	10^{-5} to 10^{-2}	10^{-5} to 10^{-4}
b[b] (ft)	9.2	50
Q[c] (gpd)	167 - 167,000	900 - 9,000
Elevation Contour 495: Downgradient from Dump Area (West)		
K (cm/sec)	10^{-5} to 10^{-2}	10^{-5} to 10^{-4}
b (ft)	9.1	30
Q (gpd)	68 - 68,000	400 - 4,000
Elevation Contour 490: Downgradient from Dump Area (North)		
K (cm/sec)	10^{-5} to 10^{-2}	10^{-5} to 10^{-4}
b (ft)	18.3	40
Q (gpd)	91 - 91,000	300 - 3,000
Elevation Contour 490: Downgradient from Dump Area (Northwest)		
K (cm/sec)	-	10^{-5} to 10^{-4}
b (ft)	-	35
Q (gpd)	-	300 - 3,000
Total Downgradient Flow (gpd)	159 - 159,000	1,000 - 10,000

a. K = hydraulic conductivity
b. b = saturated thickness of aquifer
c. Q = quantity of flow

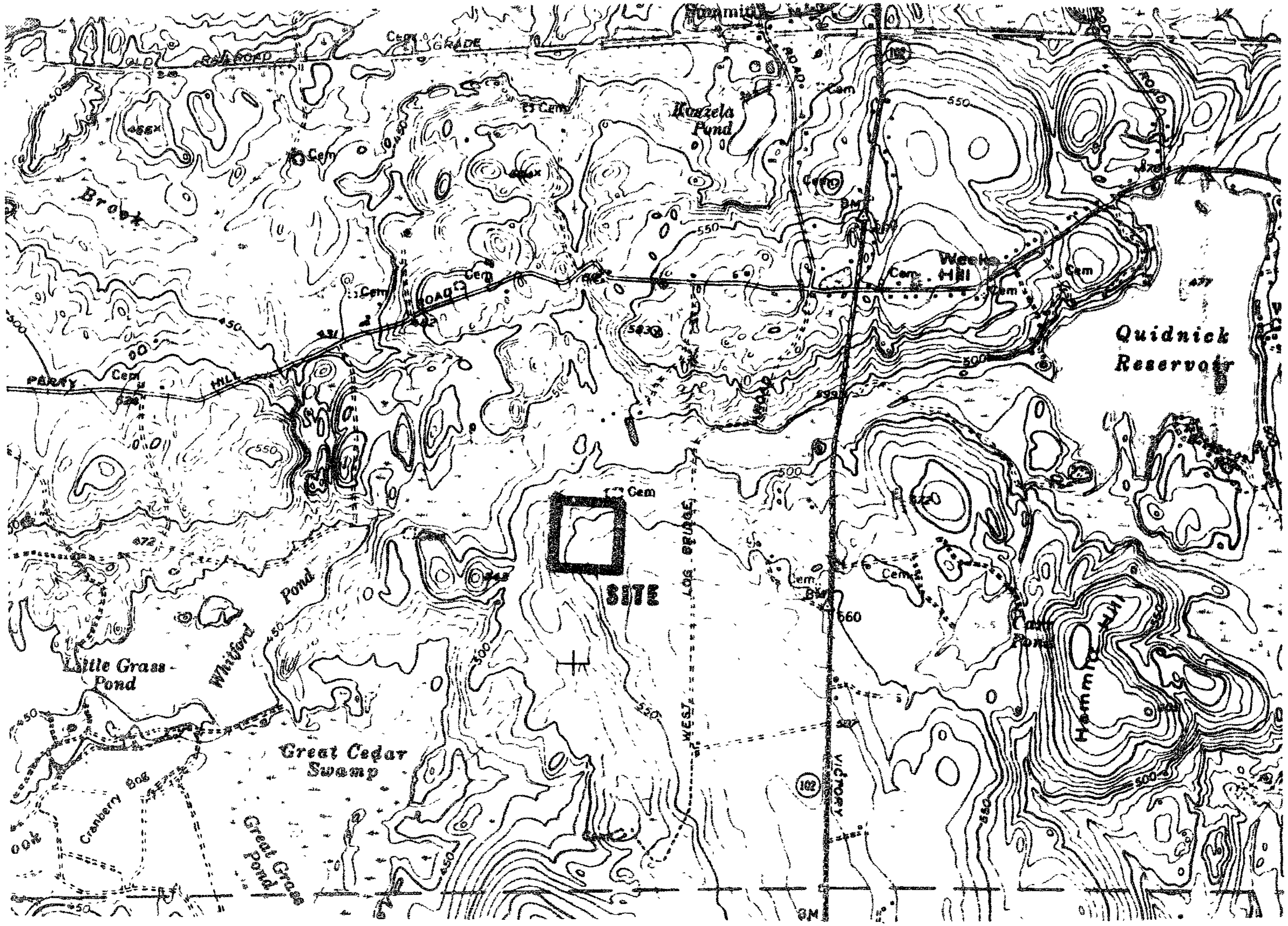


Figure 12. Topographic Map of Region Around Picillo Property

CHEMICAL CONTAMINATION

The results of organic chemical analysis performed on soils and surface and ground waters are presented in Tables 11, 12, and 13. The locations of all sampling stations are shown on Figure 1.

The organic analyses are consistent with what may be expected from a heterogeneous non-point source of pollutants: varying levels of contamination and few discernable trends. The ground water is indeed contaminated with volatile organic chemicals, but the general level of contamination is equivalent to the Phase I results, indicating that the situation has not significantly worsened. The diversity of priority pollutant species likewise is similar to that found in Phase I. An increase in TVO concentrations at wells W18, WA, and WB did occur over the two-week period from June 1 to June 15, 1980, perhaps as a result of the drum excavation activities at the Northeast Trenches.

The following specific conclusions are drawn from the results obtained during Phase II:

- The bedrock zones of the aquifer, with the exception of the vicinity of W23, are either not contaminated or only slightly contaminated with volatile organic compounds, as evidenced by the TVO and priority pollutant results for W21 and W24. This may be due to the relatively low downward gradients of the ground water and lower permeability of the weathered portion of the bedrock in relation to the overlying soil.

- The bedrock zone northwest of the site is contaminated with a diverse assortment of volatile organic pollutants, as evidenced by the analytical results for W23. As discussed in the preceding subsection, the seismic refraction survey shows the presence of a bedrock depression directly upgradient from this region. The effect of the depression may cause contaminated ground water to enter the bedrock zone laterally instead of vertically. This region was believed to be underlain by a diversionary mound in the bedrock, but the Phase II boring program showed that it is instead an area of deep (relative to other areas of the site) ground water flow. Current evidence suggests that the contaminants in the bedrock zone are not likely to travel beyond the swamp. Although the bedrock is fractured, its measured hydraulic conductivity is low, indicating that extensive rock channels in the rock are not present or not connected. Additionally, the bedrock zone is not confined and therefore will discharge to the same region as the water in the unconsolidated deposits (the swamp). The lack of contamination in the shallow and deep wells across the swamp from the dump site (W25 and W26) provide additional data to support the conclusion that ground water flow bypassing the swamp does not occur.

- The results of the Phase I and Phase II organic and inorganic analyses further substantiate the conclusion that the contamination of the ground water is predominantly caused by the presence of volatile organic compounds. The iron levels in all samples except W25 are above

TABLE 11. TOTAL VOLATILE ORGANIC CONCENTRATIONS IN WATER AND SOILS

	TVO Concentration (parts per billion)					
		Soil (approximate depth below surface in feet)				
Station	Water	0-10	10-15	15-20	20-30	30-40
S1	<100					
W14	3,000[c]					
W18	540[a]/1,200[b]					
W21	<100[c]	440		3,600	80	290
W22		530	110/125[d]	375		
W23	16,000[c]	e	445	750	210	
W24	<100[c]	1,060	1,030	180		
W25	315/450[c,d]	350	270			
W26	<100[c]					
WA	23,000[a]/37,000[b]					
WB	26,000[a]/45,000[b]					

Blank Spaces Indicate No Sample Collected

S - surface water sample
W - ground water sample

a. sample taken 7/1/80
b. sample taken 7/15/80
c. sample taken 7/29/80
d. replicate analysis
e. results invalidated due to inconsistencies between field and laboratory sample numbers

TABLE 12. VOLATILE ORGANIC PRIORITY POLLUTANT CONCENTRATIONS IN GROUND AND SURFACE WATERS

Priority Pollutant	Station (concentrations in parts per billion)						
	S1	W14	W21	W23	W24	W25	W26
benzene	NONE DETECTED		NONE DETECTED	380		NONE DETECTED	
1,2-dichloroethane		<1		47	10		
1,1,1-trichloroethane		3,000		4,600	11		
1,1-dichloroethane				88			
chloroform		6,700		2,400	1 to 9		
1,1-dichloroethylene				350			
1,2-dichloropropane		270					
methyl chloride				1,700			
methylene chloride				4,400			
tetrachloethyiene		12		330			
toluene				6,100			1 to 9
trichloroethylene		39		950			
vinyl chloride				520			
trichlorofluoromethane				3,600			
ethylbenzene				1,100			

Blank spaces indicate None Detected

S - surface water sample

W - ground water sample

Samples taken 7/29/80.

TABLE 13. GENERAL INORGANIC CONSTITUENT CONCENTRATIONS IN GROUND AND SURFACE WATERS

Station	Specific Conductivity[a] (µmho/cm)	pH[b]	Inorganic Parameters			
			Total Dissolved Solids (ppm)[b]	Chloride (ppm)[b]	Iron (ppm)[b]	Chemical Oxygen Demand (ppm)[b]
S1	ND	5.9	120	15	1.2	64
W14	800 @ 12°C	6.9	640	5.5	0.4	28
W21	140 @ 13°C	7.7	130	4.0	3.0	73
W23	315 @ 12°C	7.3	290	27	3.0	91
W24	190 @ 13°C	10.0	140	37	1.0	26
W25	80 @ 25°C	7.3	28	5.5	0.2	13
W26	55 @ 19°C	6.9	73	4.5	1.8	83

S - surface water sample
W - ground water sample
ND - not determined

a. field determined
b. laboratory determined

Samples taken 7/29/80.

the drinking water standard of 0.3 mg/1, but the presence of iron in the background wells W21 and W26 indicates that this is a general trend not related to the dump. The only evidence of inorganic pollution is the high pH at well W24, most likely caused by a localized source of caustic substances. An unusually high COD value was found for well W26, but it is concluded that this is due to the presence of natural organic materials, as evidenced by the low TVO results and near absence of volatile priority pollutants (a trace of toluene was found which may have been introduced by drilling or pumping activities).

- Since no water was flowing out of the swamp into Whitford Pond when the samples were taken, it is not possible at the present time to determine conclusively whether or not the swamp acts as a treatment mechanism for the volatile organic contamination of the ground water. A water sample from the swamp (S1) was taken at a location close to the outlet point and this was found to be free of organic contamination. Sampling of surface waters in the proximity of the dump site was done by the U.S. EPA Oil and Hazardous Materials Section on May 5, 1980.* At this time, water was flowing from the swamp into Whitford Pond. A sample taken in the contaminated region of the swamp (station PF02a) shows the presence of assorted chemical contaminants, while a second sample taken at the swamp outlet (station PF03) is free of all contaminants. The two sampling locations are shown on Figure 1. The analytical results from these samples are presented in Table 14. To date, three sampling programs (MITRE Phase I, MITRE Phase II, and EPA) have not indicated that the chemical contamination existing at the eastern edge of the swamp is being carried to Whitford Pond and these data also suggest that volatilization to the atmosphere is responsible for the elimination of pollutants from the hydrologic system. However, due to the low flow conditions which occurred during the July 1980 sampling period, a comprehensive investigation was not possible and the hypothesis that the swamp serves as a treatment mechanism remains not completely validated. It must be emphasized that, although treatment of the swamp outflow is not presently warranted, the swamp waters should be monitored regularly in case future discharge of chemicals to Whitford Pond occurs.

The EPA additionally sampled a stream which would be the potential route of pollutants from the dump site to Quidnick Reservoir. The sampling station is located on Victory Highway, approximately 2000 ft south of the Perry Hill Road Intersection (see Figure 12). None of the organic constituents shown in Table 14 (the sample was not analyzed for inorganic constituents) were found to be present. As in the case of the inlet to Whitford Pond, this stream should be periodically monitored to protect against the possibility that the pollutant migration may be more extensive than the ground water map indicates.

*The other sampling locations were: (1) ponded leachate seep north of site, (2) stream on Perry Hill Road which discharges to swamp, (3) two inlets to Quidnick Reservoir, (4) the cranberry bog downstream from Whitford Pond, (5) the stream outflow (Roaring Brook) from the cranberry bog, and (6) the stream outflow from Arnold Pond, downstream from Roaring Brook. All samples were uncontaminated except the leachate seep which contained measurable amounts of volatile organics.

TABLE 14. RESULTS OF THE U.S. EPA SURFACE WATER ANALYSIS AT EASTERN REGION OF SWAMP AND SWAMP OUTFLOW

Constituent	Concentration in parts per billion	
	Station PF02a	Station PF03
1,1,1-trichloroethane	1,600	ND
trichloroethylene	840	ND
benzene	510	ND
toluene	1,400	ND
methylene chloride	3,700	ND
chloroform	1,000	ND
acetone	NQ	ND
tetrahydrofuran	-	ND
methyl ethyl ketone	NQ	ND
methyl isobutyl ketone	NQ	ND
tetrachloroethylene	250	ND
ethyl benzene	700	ND
xylene isomers	1,700	ND
phenol	5,625	ND
cresol isomers	375	ND
dimethyl phenol isomers	86	ND
o-dichlorobenzene	420	ND
cyanide (in parts per million)	0.02	-
phenol	270	-
silver	2.00	-
arsenic	0.00	-
beryllium	25.0	-
cadmium	75.0	-
chrome	38.0	-
copper	55.0	-
mercury	1.00	-
nickel	738	-
lead	280	-
antimony	0.00	-
selenium	52.0	-
thallium	0.00	-
zinc	70.0	-

NQ - Not Quantitative
ND - Not Detected
- - not analyzed

REFERENCES

1. Hvorslev, M. J., "Time Lag and Soil Permeability in Ground Water Observations." U.S. Army Corps of Engineers Waterways Exp. Sta. Bull. 36, Vicksburg, MS, (1951).

SECTION 4

RECOMMENDATIONS

Section 4 presents recommendations for actions leading to long-term abatement of contamination at the site and for procedures to monitor the effectiveness of the techniques employed.

SUMMARY OF PHASE II INVESTIGATION

It was necessary during the Phase II investigation to resolve the following questions in order to provide a basis for evaluating long-term abatement methods:

- condition and number of buried drums
- condition and topography of bedrock
- effectiveness of the swamp as a treatment mechanism.

Each of the above three items has been addressed in Section 3, and the principal conclusions are summarized below.

Condition and Number of Buried Drums

The excavation of the Northeast Trenches showed that some of the assumptions used for the previous estimates were incorrect. The revised estimate for the remaining buried drums is between 16,700 and 44,700 on a whole (uncrushed) drum basis, the range reflecting different assumed nominal trench depths and densities of drums in place. This range can be narrowed if one were willing to assume the Northeast Trenches are fully representative of the other trenches. Even though approximately 30 percent of the drums in the Northeast Trenches were crushed, this was not taken into account in the above analysis. There is, of course, a danger in extrapolating the mix of percentages of drums containing various chemicals from the Northeast Trenches to the other trenches because the remaining trenches may differ in construction, depth, and contents. It appears from the excavation, nonetheless, that a significant number of the drums contain liquid chemicals which would continue to be released over time if not removed from the ground.

Condition and Topography of Bedrock

As was discussed in Section 3, the bedrock sampling and seismic refraction survey showed that the bedrock is much deeper beneath the site than was previously assumed and that the bedrock surface is very irregular. The bedrock is also highly fractured within the upper 10 to 15 feet, hydraulically connected to the glacial deposits, and cannot be considered an impermeable barrier.

Effectiveness of the Swamp as a Treatment Mechanism

Because of the seasonal low flow conditions, it was not possible to determine whether the ground water pollutants (predominently volatile organic chemicals) completely volatilize in the swamp. However, none of the analytical testing to date has shown the presence of contaminants discharging into Whitford Pond. Continued monitoring of the swamp outflow and the bedrock will be necessary to guard against the possibility that pollutants may discharge during higher seasonal flows.

ABATEMENT OF SITE POLLUTION

The conceptual designs, advantages, disadvantages, and estimated costs of several long-term alternatives were presented in the Phase I report (see Section 1 for reference). The following options were presented:

- no action
- source encapsulation
- leachate collection and treatment (via interceptor trenches)
- removal and disposal of drums and chemicals.

The key advantages and disadvantages of each option are summarized in Table 3 and described in more detail in the Phase I report. In addition, the Phase I report takes into account the following considerations:

- short-term and long-term consequences and impacts of each option
- time-phased implementation of a combination of options
- major assumptions concerning selection and design of each option.

None of the above abatement options was recommended at the conclusion of Phase I because of a lack of certain significant information about the site. Short-term abatement measures were recommended instead, in order to protect the public health while the Phase II study was underway.

Evaluation of Major Alternatives

With the additional knowledge gained from the Phase II investigation, it is possible to evaluate long-term alternatives and make a recommendation on the preferred course of action. Table 15 summarizes this evaluation. Since the recommended course of action became apparent without the necessity of revising cost estimates for each of the alternatives, such estimates are not included in Table 15. However, the cost of each option will now be different from that presented in the Phase I report. Realistically, the potential costs of both the source encapsulation walls and leachate collection trenches would

TABLE 15. SUMMARY EVALUATION OF LONG-TERM ABATEMENT OPTIONS

Long-Term Option	Summary Evaluation
Option 1: Encapsulation	Not Recommended • significant source of chemicals in liquid state (perpetual threat for environmental release) • deep bedrock (high cost) • fractured bedrock (too permeable for secure base)
Option 2: Interceptor Trenches	Not Recommended • deep bedrock (high cost) • irregular bedrock surface (high cost) • fractured bedrock (too permeable for secure base)
Option 3: Drum and Chemical Removal - with continued monitoring of plume and swamp	Recommended • source of contaminants removed • dispersion of contaminants in ground water monitored
No Action Alternative	Not Recommended • significant source of contamination (potential for long-term continuous release) • swamp not proved to be treatment mechanism (potential for spread of contaminants resulting in human contact)

be much larger due to the increased excavation required to reach bedrock. Similarly, the cost of complete drum removal would also be higher due to the revised drum count, greater depth of trenches, and large amount of generated contaminated earth (if the Northeast Trenches are considered representative of the other trenches).

Because a significant source of chemicals remains within the drums buried on the site, the recommended course of action is a carefully conducted program of excavation of drums; disposal of the drums, chemicals, and contaminated soils; and continuous and periodic monitoring of the plume and swamp. This combined approach will remove the source of the chemicals and monitor the dispersion of the contaminants presently in the ground water. If at a later date it is discovered that the swamp does not serve as an effective treatment mechanism for the contaminants in the plume, procedures can be instituted to appropriately treat the swamp effluent. This would be feasible because the swamp outflow to Whitford Pond occurs in a well-defined stream. Access to the stream is provided by a dirt road adjacent to the east edge of the pond (see Figure 1). Any treatment system designed for this outflow stream would have to be sized for maximum seasonal flow rates.

The no-action alternative is not recommended because of the potential for continuous, long-term release of contaminants with the inherent risk of exposure to the public. This exposure may develop from contamination of water supplies and food stocks or may result from an increase in population density within the now-rural contaminated area.

Encapsulation is not a recommended option because of the condition of the source of chemicals and condition of the bedrock. First, since the source of the contamination is now expected to contain a significant amount of liquids, there would be a potential for future release, requiring perpetual vigilance and maintenance. Additionally, the bedrock surface appears to be too fractured to provide an impermeable base and too deep for economic justification of containment walls.

Interceptor trenches are not recommended because of the extreme irregularity of the bedrock surface requiring the use of numerous pumping stations, and also because the rock is too permeable to function as an effective base. Using pumping wells instead of interceptor trenches to collect contaminated ground water may be possible if the swamp does not act as an adequate treatment mechanism, but this is not recommended because of the low hydraulic conductivities of the till and bedrock (10^{-4} to 10^{-6} cm/sec) and the low total flow of contaminated ground water (1000 to 10,000 gpd). A more simple and cost-effective method of collection would involve pumping directly from the stream between the swamp and Whitford Pond as was described above.

Implementation of Preferred Alternative

Table 16 presents general recommendations regarding contractor procurement, safety procedures, working conditions, and field procedures with reference to the preferred long-term abatement alternative, removal, and disposal of drums and chemicals.

Table 16. General Recommendations for Drum Excavation

Procurement of Contractor

- Procure disposal services simultaneously with excavation services
- Obtain written technical approach from excavation contractor including:
    - drum probing and removal procedures
    - logistics of excavation (personnel required, equipment movement, removed soil, and drum placement)
    - procedures for drum sampling and logistics of disposal operations
    - procedures and logistics for treatment or removal of contaminated soil (and establishment of borrow areas if necessary)
    - procedures for protection of drum staging area to avoid generation of contaminated water
    - safety procedures
    - contingency and emergency plans
- Contract on a time-and-materials basis

Safety Procedures and Work Conditions

- Monitor contractor activities by a full-time DEM Site Representative
- Determine "work area" according to air quality where smoking is prohibited and respirators are required; delineate work area with rope fence and signs
- Control access to site of non-contractor personnel (24 hours per day, seven days per week security), escort all visitors, require proper safety equipment within work area
- Establish crew rest area and guard station outside of work area
- Install communications equipment to summon emergency aid and organize fire fighting procedures in advance with fire department personnel
- Require self-contained breathing equipment in trench area
- Require first-aid capability of contractor, particularly the ability to wash off splashed chemicals
- Require periodic monitoring of trench-area air with explosivity meter

Field Procedures

- Use metal detector as a guide to locate drums in the field after preliminary outline of trench has been determined from metal detection and ground-piercing radar surveys
- Address drums individually and with a minimum of physical shock
- Contain and remove all spilled liquids where possible
- Note and record, to the extent feasible, trench depth and construction, and locations of high drum or contaminated soil concentrations in an attempt to validate remote sensing data
- Measure leachability of excavated soil to determine whether it should be classified as a hazardous waste requiring disposal in licensed secure landfill

Disposal services should be procured simultaneously with excavation services so the entire cost of the project can be estimated before initiation and cost estimates can be revised periodically while the project is in progress. The latter action should be taken frequently enough to prevent budget overruns and to guide field decisions concerning contractor scope-of-work. A time-and-materials type of contract is recommended for the excavation in order to better meet unforeseen difficulties and to reduce the incentives for contractor short-cuts in performance of work or safety measures. Technical approach, including safety procedures, disposal methods, and emergency plans, should be a part of all prospective contractors' proposals and serve as the principal criterion for proposal evaluation, in addition to cost.

The safety procedures employed by the contractor should be reviewed and approved prior to project initiation. It is recommended that a "work area" be determined around the excavation area, in which all personnel be required to wear appropriate safety gear. Air quality sampling devices should be used to determine the extent of the work area. The boundaries of the work area should be revised periodically as the project proceeds. It is recommended also that organic vapor respirators be worn within the work area and self-contained breathing devices be worn in the excavation areas. All first-aid equipment should be readily accessible to all crew work areas.

Site access should be restricted and all visitors escorted while within the work area. The site should be guarded (24 hrs/day, 7 days/wk) and the sponsoring agency should have a Site Representative in attendance while the contractor is working. It is recommended that the Site Representative have the following responsibilities:

- monitor progress of contractor
- make field decisions concerning contractor scope-of-work, procedures, and project priorities
- produce project cost projections on a periodic basis and evaluate cleanup progress
- interact (coordinate) with all site visitors and concerned parties and agencies.

By comparison with the situation on a typical construction project, the Site Representative on a major cleanup project plays an unusually broad and critical role. Hazardous waste cleanups are atypical for at least two important reasons: (1) the project is rarely well-defined, the problems are not completely known at the outset, and therefore someone representing the sponsoring agency must be in attendance to make the necessary field decisions or recommendations and to continuously monitor project costs in relation to cleanup priorities and available funds; and (2) cleanup projects have high public visibility, both locally and nationally, with concomitant potential for the spread of misinformation and in some cases undue alarm. Additionally, there is a great deal of interagency involvement (e.g., EPA, state agencies, local fire and police departments) which is most effectively coordinated through a central individual, with appropriate authority or ready access to such.

During the excavation, it is preferred that drums be addressed individually where possible and that the probing, exposing, removing, and transporting activities be conducted with a minimum of physical shock. If rupture of drums does occur, attempts should be made to contain and pump out the spilled liquids to prevent either the mixing of liquids (which may cause potentially dangerous chemical reactions) or the release of liquids to the ground and air. In addition to impermeable clothing and self-contained breathing apparatus, it is recommended that the workers in the trenches wear light-weight body armor to protect against explosions.

An important consideration concerning the excavation of the remaining trenches is the proper decontamination of the soil that is removed along with the drums. Although generally accepted or mandated procedures for treatment and/or disposal of soil contaminated at a site such as Coventry have not been established, periodic analysis of the soil or extracted leachate is recommended to insure that any soil left on-site will not continue to be a significant source of contamination once the drums have been removed. Additionally, the presence of polychlorinated biphenyls (PCBs) further complicates the problem of contaminated soil, since disposal of any liquid or solid substance varies with the concentration of this pollutant. Therefore, periodic chemical analysis of the contaminated soil is recommended to determine whether it can be aerated to remove volatile components and whether there will be significant amounts of leachable components remaining. If the latter is true, the soil will require disposal in a secure landfill.

Table 17 presents general recommendations for procedures to monitor the effectiveness of the alternative chosen to abate site pollution. Although no requirements currently exist for the establishment of a monitoring program at a site such as Coventry, it is essential that both up and downgradient ground water samples and downstream surface water samples be regularly collected and analyzed to insure that the impact of the site upon the environment is lessening and that the public health is unaffected. The recommended monitoring program includes site wells, household wells, the inlets to Whitford Pond, Quidnick Reservoir, Great Cedar Swamp, and the cranberry bog as sampling stations. Volatile priority pollutant and TVO analyses are recommended for the more frequently collected samples, while full priority pollutant scans should be performed on the pond inlet and the cranberry bog at least once a year. It is important that the monitoring program be maintained until the DEM is certain that all of the contaminants have dispersed to safe levels and that no public health threat exists. Until this condition is reached, it is recommended that all public or private use of the dump site, leachate plume area, and swamp be prohibited. It will be necessary to analyze the soil at the dump and the sediment in the swamp in order to determine that the concentration of contaminants has been reduced to safe levels. This sampling program may be performed at the conclusion of the monitoring period.

TABLE 17. GENERAL RECOMMENDATIONS FOR MONITORING EFFECTIVENESS OF PREFERRED ABATEMENT ALTERNATIVE

Sampling Location[b]	Analysis	Frequency	Comments
Surface Water			
inlet to Whitford Pond (on dirt road connecting with Perry Hill Road)	volatile priority pollutants all priority pollutants	each season (every 3 months) once each year	frequent sampling suggested because swamp is surface discharge point for contaminated ground water
inlets to cranberry bog (from Whitford and Great Grass Pond)	all priority pollutants	once each year (before growing season	full priority pollutant scan recommended because of agricultural use
inlet to Quidnick Reservoir (at Victory Highway, approximately 1000 ft south of Perry Hill Road)	volatile priority pollutants	twice each year (spring and fall months)	extensive sampling and analysis not recommended unless shown to be discharge area
inlet to Great Cedar Swamp (approximately 1500 ft west of cemetary at end of West Log Bridge Road)	volatile priority pollutants	twice each year (spring and fall months)	extensive sampling and analysis not recommended unless shown to be discharge area
Ground Water			
wells W6, W8, W14, W15, W19, W23, W24, and Picillo household well	TVO	twice each year (spring and fall months)	W6: upgradient; W14, W15, W8: downgradient, in unconsolicated deposits; W19, Picillo household: downgradient toward Quidnick Reservoir; W23, W24: downgradient, in bedrock, water level elevations should be recorded at time of sampling
household wells (within one mile radius of site)	volatile priority pollutants	once each year	sampling of local household wells addresses primary concerns of nearby residents
monitoring well between swamp and Whitford Pond (on dirt road connecting with Perry Hill Road)	TVO	each season (every 3 months)	well not presently installed; should be screened in soil and bedrock to monitor for subsurface migration of contaminants from swamp to pond
Air Quality			
air quality of swamp and dump site	volatile organic compounds (portable gas chromatograph)	each season (every 3 months)	determine potential harmful effects of air quality with each season and evaluate need to physically restrict access to site or swamp

a. Subject to promulgation of Federal post-closure monitoring regulations concerning uncontrolled hazardous waste sites.
b. See Figure 7 for locations.

APPENDIX A

TABLE OF CONTENTS, LIST OF ILLUSTRATIONS,
AND LIST OF TABLES FROM PHASE I REPORT

HAZARDOUS WASTE INVESTIGATION:
PICILLO PROPERTY, COVENTRY, RHODE ISLAND

TABLE OF CONTENTS

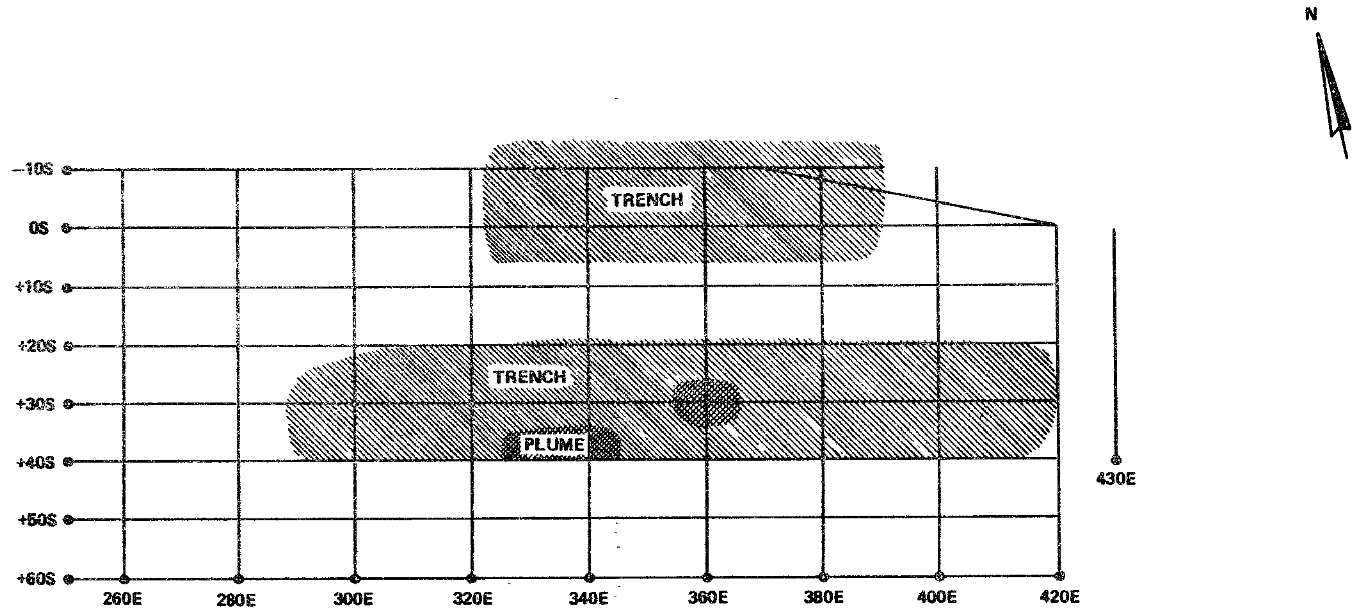
LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (concluded)

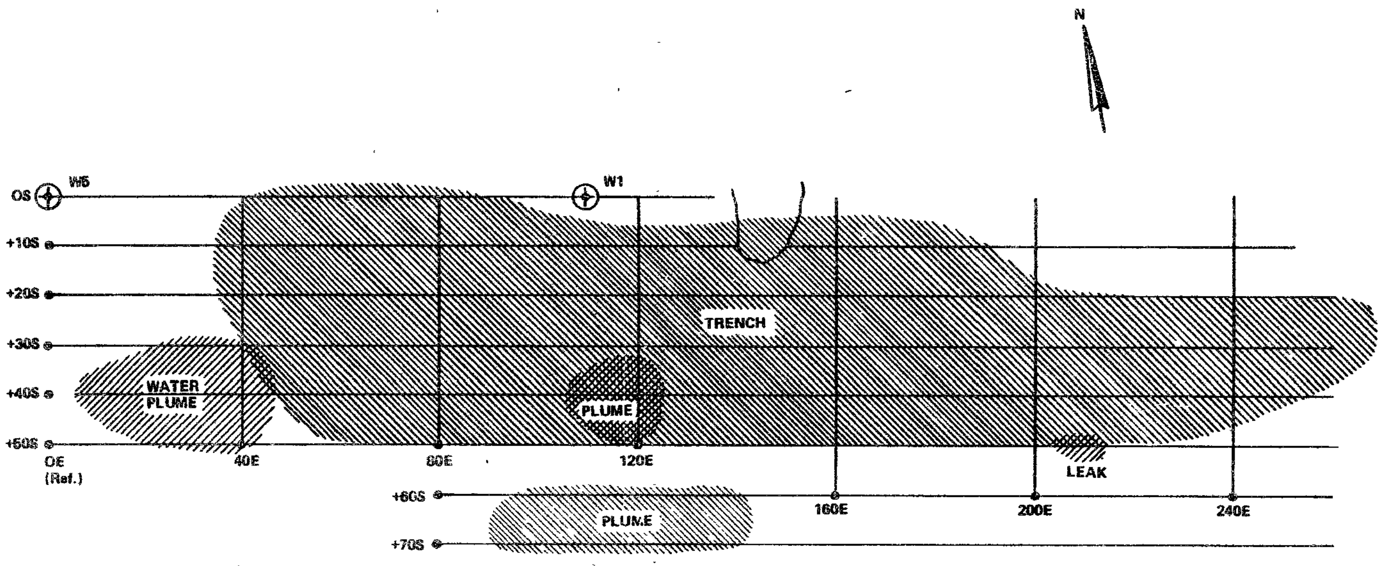
APPENDIX B

THE LOCATION OF BURIED DRUMS AS
DETERMINED BY GROUND-PENETRATING RADAR



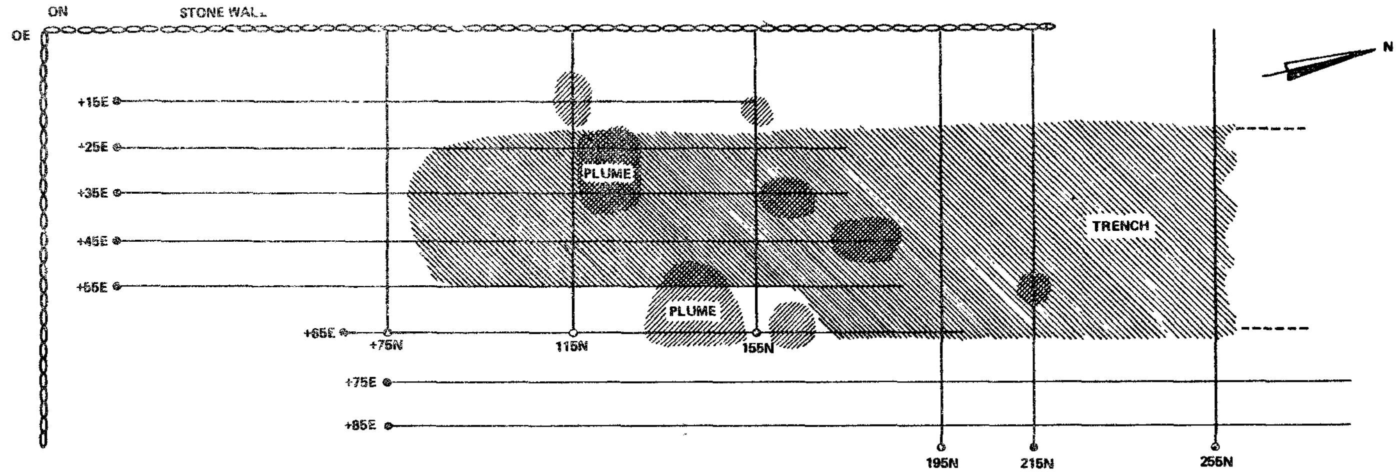
SCALE: 1" = 20'

NORTHEAST TRENCHES



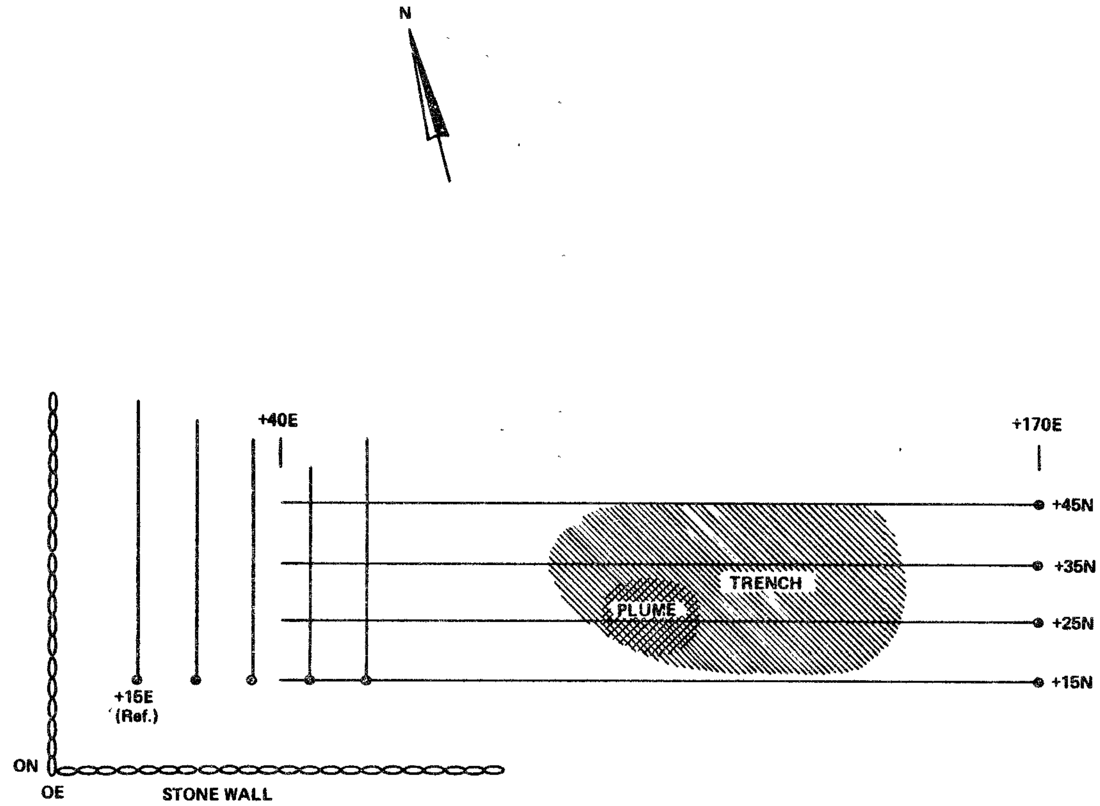
SCALE: 1" = 20'

NORTHWEST TRENCH



SCALE. 1" = 20'

WEST TRENCH



SCALE: 1" = 20'

SOUTH TRENCH

APPENDIX C

MONTHLY VARIATION OF GROUND WATER LEVELS

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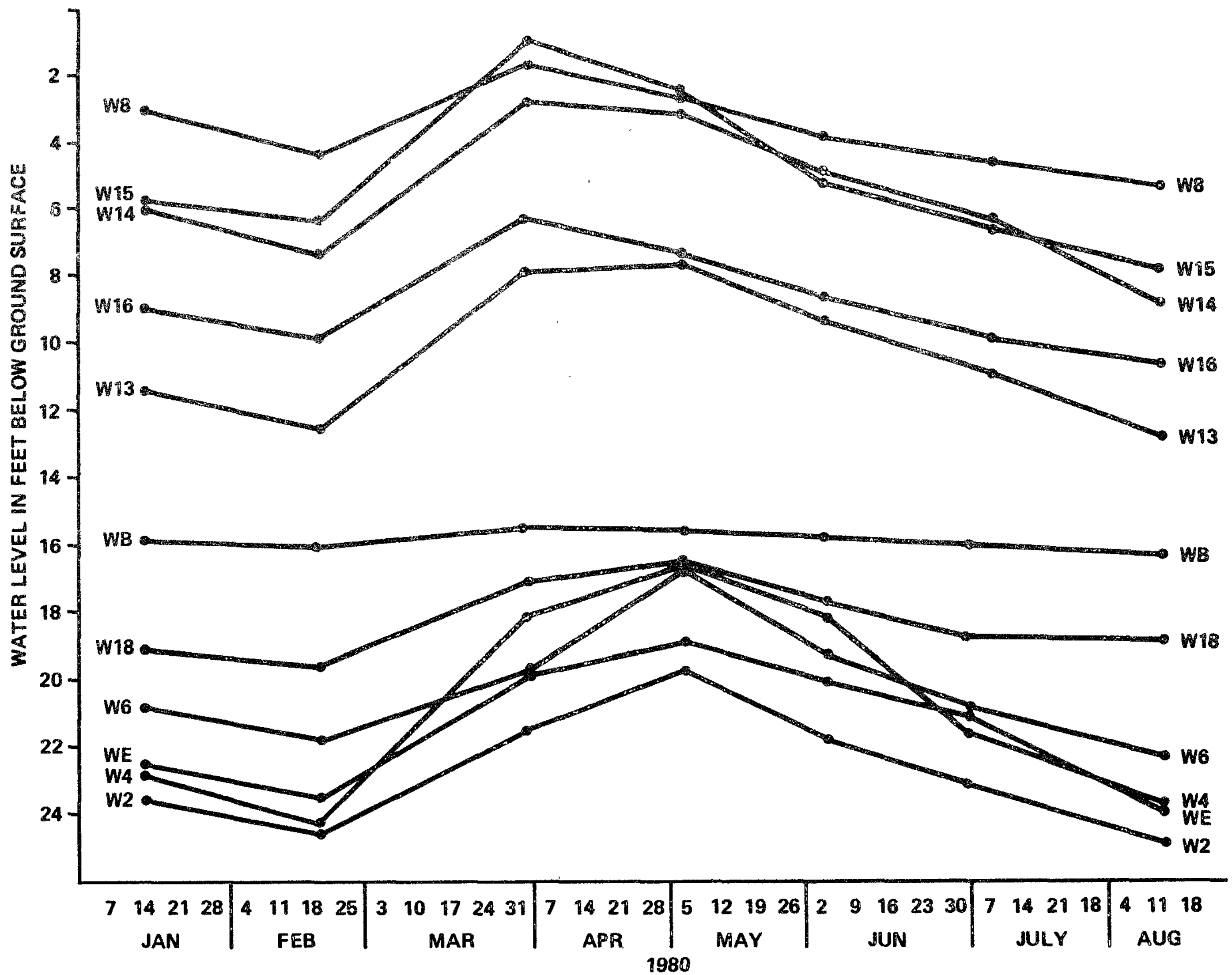

APPENDIX D

TEST BORING LOGS

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PROJECT	LOCATION	DRILLED BY FR	BORING NO. 21
DATE STARTED 6/5/80	INCLINATION	LOGGED BY WP, NC	GROUND EL
DATE COMPLETED 6/12/80	BEARING	CHECKED BY	TOTAL DEPTH 78'3"

EL ft.	DEPTH ft.	SAMPLE TYPE-NO.	SAMPLE BLOWS PER 6"	SAMPLE PEN in	SAMPLE REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
		S1	3 5 5	18	6	6 in OD cont. flight hollow stem auger 0-39.5		Silty sand - fine to v. fine grained, some med-coarse grained sand with fine gravel
	5	S2	23 29 38	18	10			Gravelly silty sand - widely graded, pred. fine-grained. 10-15% non-plastic fine, occ. fine gravel to 1-3/8 in (gray brown) occ. olive gray silt pockets
	10	S3	14 15 26	18	10	(40 cc sample)		Sand - very fine grained, uniform, approx. 5% nonplastic fines stratification not apparent, lt. gray
	15	S4	79 24* 18	18	12			3-12 in Sand - widely graded, clean 40% nonplastic fines occ. angular fine gravel. 0-8 in Silty sand - fine grained, 10-15% med-coarse sand, occ. gray brown fine gravel
	20	S5	77 133 45	18	16	(40 cc sample) wet		8-14 in Fragmented gravel, clean 14-16 in Sandy silt - v. fine grained, occ. med-coarse sand, brown
	25	S6	100/2" 37*/4"	6	5			Gravelly silty sand - widely graded approx. 10-20% nonplastic fines. Locally clean till structure
	30	S7	48 100/4" 32*/2"	12	6	(40 cc sample)		Same as S6 - locally v. fine grained dense till structure, gray brown
		S8						

LEGEND
BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
▽ - Groundwater
S - Split spoon sample

NOTES *Blows of a 300 lb hammer falling 24 in to effect 6 in of penetration

Depth to water table ≃20'

DATE ____ PROJECT NO. 1671V
PAGE 1 OF 3 BORING NO. 21

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GEOTECHNICAL ENGINEERS INC.

PROJECT ______ LOCATION ______ DRILLED BY ______ BORING NO. 21
DATE STARTED ______ INCLINATION ______ LOGGED BY ______ GROUND EL. ______
DATE COMPLETED ______ BEARING ______ CHECKED BY ______ TOTAL DEPTH ______

EL. ft.	DEPTH ft.	SAMPLE TYPE-NO.	SAMPLE BLOWS PER 6"	SAMPLE PEN in	SAMPLE REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
		S8	72 73*	12	12			Gravelly silty sand - approx. 20% non-plastic fines. Sand is pred. fine to v. fine grained, with angular gravel
	40	S9	65 50/1"	6	6	(40 cc sample)		Similar to S8 - gravel fragments, biotite granite stuck in sample shoe, occ. angular gravel
	45	S10	74/1.5" 81*/3.5"	6	6			Similar to S8 - gravelly silty sand angular 3/4" gravel, biotite grains, v. fine-grained sand
	50	NX-1		60	17	49'6"-50' 53'-53'		Boulder - granite gneiss 11" boulder - granite gneiss
	55		75/4 58*/0	4	0			no sample
	60	S11	34 130/3" 60*/3"	12	5			Gravelly silty sand - angular qtz fragments to ½", v. fine-grained Sand, silt than S10
	65	S12	22 39 68	18	18			Decomposed rock - blue gray, dense clayey texture
			23*/0		0			

LEGEND
BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
▽ - Groundwater
S - Split spoon sample

NOTES
*Blows of 300 lb hammer falling 24 in to effect 6 in of penetration

DATE ______ PROJECT NO. 1671V
PAGE 2 OF 3 BORING NO. 21

GEOTECHNICAL ENGINEERS INC

PROJECT	LOCATION	DRILLED BY	BORING NO. 21
DATE STARTED	INCLINATION	LOGGED BY	GROUND EL.
DATE COMPLETED	BEARING	CHECKED BY	TOTAL DEPTH

EL ft.	DEPTH ft.	SAMPLE TYPE-NO.	BLOWS PER 6"	PEN in	REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
		NX2		15	13	69'6"-70'7" (roller bit)		Similar to S12 - blue gray decomposed dense rock, clayey (core barrel sticks)
	75	NX3		51	49	74'6"-78'3" RQD*=57%		Weathered diabasic rock (sill or dike) with few hornblende(?) phenocrysts clayey fillings in fractures
	80							

LEGEND
BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
∇ - Groundwater
S - Split spoon sample

NOTES
*RQD = rock quality designation - % of total length of core recovered greater than 4 in. in length.

DATE ____ PROJECT NO. ____
PAGE 3 OF 3 BORING NO. 21

GEOTECHNICAL ENGINEERS INC

PROJECT	LOCATION	DRILLED BY FR	BORING NO. 22
DATE STARTED 6/13/80	INCLINATION	LOGGED BY NC	GROUND EL.
DATE COMPLETED 6/17/80	BEARING	CHECKED BY	TOTAL DEPTH 41'8"

EL ft.	DEPTH ft.	SAMPLE TYPE-NO.	SAMPLE BLOWS PER 6"	SAMPLE PEN in	SAMPLE REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
		S1	2 4 8	18	6	6 in OD cont flight hollow stem auger 0-15'		Sand - fine-medium grained, occ. coarse, some angular gravel
	5	S2	20 45 37	18	12	wet		Gravelly sand - fine-medium grained subangular gravel to 3/8", little silt
	10	S3	13 18 24	18	16	(40 cc sample)		Silty sand - fine-medium grained frequent biotite, no stratification apparent
	15	S4	13 12 13	18	18	(40 cc sample)		Sand - fine grained, ¼" subangular gravel, upper 12"-gray, lower 6"-brown (running sand)
	20	S5	17 18 28	18	3	(40 cc sample)		Sand - fine grained, 10-20% silt brown
	25	NX1		60	17	RQD = 0		Boulders - granite gneiss
	30	S6	16 51/4" 16*/2" 43*	18	13	32'8"-36'8"		Silty sand - fine-grained, granite fragments to 1"
		NX2		48	39	RQD = 0		

LEGEND

BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
∇ - Groundwater
S - Split spoon sample

NOTES
*Blows of a 300 lb hammer falling 24 in to effect 6 in of penetration

Depth to water table ≃5'.

DATE ______ PROJECT NO. ______

PAGE 1 OF 2 BORING NO. 22

GEOTECHNICAL ENGINEERS INC

PROJECT	LOCATION	DRILLED BY	BORING NO. 22
DATE STARTED	INCLINATION	LOGGED BY	GROUND EL.
DATE COMPLETED	BEARING	CHECKED BY	TOTAL DEPTH

EL ft.	DEPTH ft.	SAMPLE TYPE - NO.	SAMPLE BLOWS PER 6"	SAMPLE PEN in	SAMPLE REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
								Boulders - granite gneiss
	40	NX3		60	60	36'8"-41'8" RQD = 23%		Highly fractured granite gneiss moderately weathered, some breaks rusty

LEGEND
BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
∇ - Groundwater
S - Split spoon sample

NOTES

DATE ______ PROJECT NO. ______
PAGE 2 OF 2 BORING NO. 22

GEOTECHNICAL ENGINEERS INC

PROJECT	LOCATION	DRILLED BY FR	BORING NO. 23
DATE STARTED 6/18/80	INCLINATION	LOGGED BY NC	GROUND EL.
DATE COMPLETED 6/23/80	BEARING	CHECKED BY	TOTAL DEPTH 37'11"

EL ft.	DEPTH ft.	SAMPLE TYPE-NO.	BLOWS PER 6"	PEN in	REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
		S1	3 3 4	18	2	6 in OD cont flight hollow stem auger 0-25'		Silty sand - fine-medium grained 20% coarse sand (rock stuck in sampler)
	5	S2	10 18 22	18	12			Sand - fine-medium grained ½-1" granite fragments 10% silt, 20% med-coarse sand, 70% fine sand
	10	S3	24 27 35	18	18	(40 cc sample)		Gravelly sand - fine-medium grained, ½-1" gravel fragments 10% silt
	15	S4	12 13 16	18	18	(40 cc sample)		Gravelly sand - similar to S3 granite fragments
	20	S5	42/3" 41*/1"	4	4	(40 cc sample) wet		Sand - similar to S3
		S5A	29/3 10*/0	3	3			Unable to spin casing through augered hole - move over 2' - spin casing to 20'9" core to 22'7" - boulders (granite gneiss) S5A - silty fine sand - stratified with fine laminations of silty sand and silt
	25	NX2		60	34	23'11"-28'11" RQD = 15%		
	30	NX3		48	48	28'11"-32'11" RQD = 85%		Fractured granite gneiss - average joint spacing 5" - Fe oxide staining on breaks - some green chlorite (?) filling in breaks. Pegmatite seam (2½"), some healed fractures open during coring
		NX4		60	60	32'11"-37'11" RQD = 77%		

LEGEND

BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
▽ - Groundwater
S - Split spoon sample

NOTES
*Blows of 300 lb hammer falling 24 in to effect 6 in of penetration

Depth to water table ≃23'

DATE ______ PROJECT NO. ______

PAGE 1 OF 2 BORING NO. 23

GEOTECHNICAL ENGINEERS INC

PROJECT	LOCATION	DRILLED BY	BORING NO. 23
DATE STARTED	INCLINATION	LOGGED BY	GROUND EL.
DATE COMPLETED	BEARING	CHECKED BY	TOTAL DEPTH

EL ft.	DEPTH ft.	SAMPLE TYPE-NO.	BLOWS PER 6"	PEN in	REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
		NX4						Fractured granite gneiss
	40							

LEGEND

BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
∇ - Groundwater
S - Split spoon sample

NOTES

DATE PROJECT NO.
PAGE 2 OF 2 BORING NO. 23

GEOTECHNICAL ENGINEERS INC

PROJECT	LOCATION	DRILLED BY FR	BORING NO. 24
DATE STARTED 6/24/80	INCLINATION	LOGGED BY NC, RT	GROUND EL
DATE COMPLETED 7/2/80	BEARING	CHECKED BY	TOTAL DEPTH 42'4"

EL ft.	DEPTH ft.	SAMPLE TYPE-NO.	BLOWS PER 6"	PEN in	REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
		S1	4 6 12	18	8	Spin 4" casing 0-25'		Sand - find-medium, widely graded, 20% coarse, <10% fines granite fragments to 1" (stuck in sampler)
	5	S2	7 11 10	18	2			Sand - silty fine, olive, 40% fine, 30% medium-coarse, 30% pebbles (1/4-1") widely graded
	10	S3	7 15 14	18	5	(40 cc sample)		Olive fine sand - 10%, 30% medium-coarse sand, 15% fine gravel (1 3/4" qtz pebble in sampler nose)
	15	S4	22 23 38	18	10	(40 cc sample)		Olive fine sand - 10% fines, 20% medium-coarse sand, 10% fine gravel and granite fragments (1/4-3/4")
	20	S5	51 65 168	18	12	(40 cc sample)		Olive-brown fine sand - 10% fines, similar to S4, weathered qtz pebbles to 1"
		S6	18 177	12	6			Similar to S5 - red brown fine sand dense, less gravel
	25	S7	50/1" 42*/2"	3	3			Weathered granite fragments
		NX1		60	40	25'3" - 30'3" RDQ = 20%		Highly weathered granite gneiss, joints spaced every 3", qtz seams, filled seams
	30	NX2		60	26	30'3"-35' RQD = 15%		

LEGEND

BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
▽ - Groundwater
S - Split spoon sample

NOTES

*Blows of 300 lb hammer falling 24 in to effect 6 in of penetration

Depth to water table ≃5'

DATE ______ PROJECT NO. ______

PAGE 1 OF 2 BORING NO. 24

GEOTECHNICAL ENGINEERS INC

PROJECT		LOCATION		DRILLED BY		BORING NO.	24
DATE STARTED		INCLINATION		LOGGED BY		GROUND EL.	
DATE COMPLETED		BEARING		CHECKED BY		TOTAL DEPTH	

EL ft.	DEPTH ft.	SAMPLE TYPE-NO.	BLOWS PER 6"	PEN in	REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
		NX3		60	27	RQD = 15%		
						37'4"-42'4"		
		NX4		60	60	RQD = 78%		Granite gneiss - fractured, clean joints
	40							

LEGEND
BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
▽ - Groundwater
S - Split spoon sample

NOTES

DATE		PROJECT NO.	
PAGE 2 OF 2		BORING NO.	24

GEOTECHNICAL ENGINEERS INC

PROJECT	LOCATION	DRILLED BY FR	BORING NO. 25
DATE STARTED 7/3/80	INCLINATION	LOGGED BY NC	GROUND EL.
DATE COMPLETED 7/3/80	BEARING	CHECKED BY	TOTAL DEPTH 14'

EL ft.	DEPTH ft.	SAMPLE TYPE - NO.	BLOWS PER 6"	PEN in.	REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
						6 in OD cont flight hollow stem auger 0-14"		
		S1	13 16 16	18	10	moist		Sand - fine-medium grained, tan, 5% silt, 25% coarse sand and gravel, 1" granite fragment, orange mottling
	5							
		S2	29 27 42	18	10	(40 cc sample) wet		Sand - upper 5" similar to S1 lower 5" gray fine-medium grained sand, 15% silt, 10% coarse sand and gravel, 2-1" granite fragments
	10							
		S3	63 54 100*/4" 31*/2"	18	18	(40 cc sample)		Sand - similar to S2, gray fine-medium, less silt, 20% coarse sand and gravel several 1" granite fragments
	15							

LEGEND
BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
▽ - Groundwater
S - Split spoon sample

NOTES

Depth to water table ≃7'

DATE ______ PROJECT NO. ______
PAGE 1 OF 1 BORING NO. 25

GEOTECHNICAL ENGINEERS INC

PROJECT	LOCATION	DRILLED BY FR	BORING NO. 26
DATE STARTED 7/7/80	INCLINATION	LOGGED BY NC	GROUND EL.
DATE COMPLETED 7/10/80	BEARING	CHECKED BY	TOTAL DEPTH 34'8"

EL ft.	DEPTH ft.	SAMPLE TYPE-NO.	BLOWS PER 6"	PEN in	REC in.	REMARKS ON ADVANCE OF BORING	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
						spin casing to 8'		Sand - tan fine-medium grained (location 4' from B25)
	5							
	10	NX1		60	19	8'7"-13'7" RQD = 0		Boulders-granite gneiss, 8 2-3" fragments
	15					(Roller bit)		Gray fine - medium sand
	20	NX2		60	46	18'5"-23'5" RQD = 91%		Granite gneiss - bluish gray, 4 rusty core breaks, 45% fracture
	25	NX3		60	60	22'6"-27'6" RQD = 77%		Granite gneiss - fractured, rusty breaks, some chlorite(?) fillings
	30	NX4		60	39	27'6"-32'6" RQD = 85%		Granite gneiss - less fractured, cleaner breaks
		NX5		26	42	32'6"-34'8" RQD = 88%		

LEGEND
BLOWS PER 6" - 140 lb. hammer falling 30" to drive a split spoon sampler
PEN - Penetration length of sampler
REC - Length of sample recovered
▽ - Groundwater
S - Split spoon sample

NOTES
RQD = rock quality designation

Depth to water table ≃7'

DATE ____ PROJECT NO. ____
PAGE 1 OF 1 BORING NO. 26

GEOTECHNICAL ENGINEERS INC