Site: Stamina Mills
Break: 3.4
Other: #6942

GHR ENGINEERING
ASSOCIATES, INC.

SEMS Doc ID 6942

REPORT OF PUMP TEST OF THE FORESTDALE WATER ASSOCIATION WELL

STAMINA MILLS SUPERFUND SITE

NORTH SMITHFIELD, RHODE ISLAND

REPORT OF PUMP TEST OF THE FORESTDALE WATER ASSOCIATION WELL
STAMINA MILLS SUPERFUND SITE
NORTH SMITHFIELD, RHODE ISLAND

Prepared For:

United States Army Corps of Engineers
Omaha, Nebraska

For:

United States Environmental Protection Agency
Region I - Waste Management Division

Prepared By:

GHR Engineering Associates, Inc.
109 Rhode Island Road
Lakeville, MA 02347

March 1989

TABLE OF CONTENTS

TABLE OF CONTENTS
REPORT OF PUMP TEST OF THE FORESTDALE WATER ASSOCIATION WELL
STAMINA MILLS SUPERFUND SITE
NORTH SMITHFIELD, RHODE ISLAND

PAGE

SECTION ONE - INTRODUCTION AND BACKGROUND

SECTION TWO - STUDY AREA GEOLOGY, HYDROGEOLOGY AND GROUNDWATER QUALITY

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

PAGE

SECTION FIVE - REDUCTION OF PUMP TEST DATA

SECTION SIX - CONCLUSIONS

REFERENCES

TABLES

TABLE OF CONTENTS (Cont'd)

APPENDICES

TABLE OF CONTENTS (Cont'd)

FIGURES

SECTION ONE

INTRODUCTION AND BACKGROUND

REPORT OF PUMP TEST OF THE FORESTDALE WATER ASSOCIATION WELL
STAMINA MILLS SUPERFUND SITE
NORTH SMITHFIELD, RHODE ISLAND

SECTION ONE - INTRODUCTION AND BACKGROUND

1.10 INTRODUCTION AND BACKGROUND

This Report presents the results of a pump test conducted of the Forestdale Water Association Well located north of the Stamina Mills Site in North Smithfield, Rhode Island. The investigation was performed as part of a Remedial Investigation (RI) by GHR Engineering Associates, Inc. (GHR), under a contract with the Army Corps of Engineers (ACOE), Omaha, Nebraska District. The Stamina Mills RI project is being performed under the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA), with the ACOE in an Interagency Agreement to the U.S. Environmental Protection Agency (EPA), Region 1 to oversee the project.

The pump test was conducted to assess the hydrologic connection between the groundwater under the Stamina Mills Site and the groundwater in a residential area north, hydraulically upgradient of the Site.

The residential area north of the Stamina Mills Site consists of a number of homes with private wells and the Forestdale Association Well which potentially served 27 homes. These wells have not been used for water supply purposes since February 1985 when trichloroethylene (TCE) and other volatile organic compounds were detected in groundwater samples taken from the wells. Presently, groundwater flow from the residential area is to the south towards the Stamina Mills Site and the Branch River. The pump test was performed to evaluate the hypothesis that during the period when the residential wells and the Forestdale Association Well were pumping the direction of groundwater flow was reversed such that the reversal caused contaminated groundwater from the Stamina Mills Site to flow to the pumping wells.

The pump test was conducted according to the ACOE Work Plan Modification of February 17, 1988. This work plan was prepared to supplement RI activities defined in the RI/FS Work Plan of March 18, 1986 under Interagency Agreement No. DW96931313-01-0 of March 27, 1985 between the ACOE and EPA.

1.20 GENERAL SITE DESCRIPTION

The Stamina Mills Site is located in Providence County in the Town of North Smithfield and the Village of Forestdale in Rhode Island. The Site is approximately 14 miles northwest of Providence, Rhode Island, 1.1 miles south of the Rhode Island/Massachusetts border, and approximately half way between Rhode Island State Routes 5 and 146. A Site vicinity map is shown as Figure 1-1. The "Site" encompasses approximately 5 acres and is located on the northern side of the Branch River as shown on Site Plan No. 1 (SP-1). The "study area" for the purpose of the current assessment encompasses the Site and the residential area north of the Site as shown on SP-1.

The North Smithfield region is a moderately populated residential and industrial area. For the most part, industries are concentrated along the Branch River in the villages of Slatersville, Forestdale and Branch Village. Many of the industries are located in former textile mills which were sited along the river to take advantage of water power.

The population of Forestdale within a half mile radius of the Site is approximately 590. The highest populations in the two villages of Forestdale and Slatersville are concentrated north of the Branch River. The area south of the Branch River is sparsely populated. The pump test focused on assessing the hydrologic connection between the Site and the residential area immediately north of the Site as shown on SP-1.

The Forestdale area has a relief of over 200 feet ranging from an approximate 200 foot elevation above National Geodetic Vertical Datum (NGVD) on the Branch River valley floor to hilltops exceeding elevations of 400 feet. The residential area north of the Site is situated at elevations ranging from 240 to 265 feet and slopes toward the south to the Site which is situated at elevations ranging from 200 to 220 feet.

The Branch River flows adjacent to and south of the Site in a west to east direction. The River is impounded by a dam at the Site which was constructed to provide water power to the Mill facility. Impoundment of the River forms of body of water known as Forestdale Pond.

1.30 SITE HISTORY

The Stamina Mills facility began operation in 1824 as the Forestdale Manufacturing Company. The company weaved and finished cotton. A plan produced by the Association of Mutual Insurance Companies in 1899 (1) indicates that the company occupied two main mill buildings with ancillary buildings including a blacksmith shop, an office, a barn, a storage house for waste fabric, and a paint shop.

The Mill continued operation until the Great Depression of the 1930s when the Mill temporarily closed for an undocumented period of time. After the depression, the Mill resumed operation and changed ownership in the 1940s and was re-named Stamina Mills.

In March 1969, Stamina Mills installed a solvent scouring system for use in removing oil and dirt from newly-woven fabric. The system utilized TCE as a solvent. Spent TCE was pumped into stills where the leftover solvent was evaporated and condensed for recycling.

It was reported by a former mill employee, Mr. Manuel Freitas (2) that, in 1969, a spill of TCE occurred when a hose coupling disconnected during the filling of a 5,000 gallon TCE storage tank by a tanker truck. It is reported that the tank was located outside the northeast wall of Mill Building No. 1. Mr. Freitas indicated that as he arrived at the Site of the spill, solvent was seen flowing toward the nearby Branch River (3). Since the solvent appeared to have either washed down to the river or was evaporating, there was no attempt to report or cleanup the spillage (3).

Approximately 3 or 4 months after the spill, workers at the Mills reported a sweet taste in water pumped from the Stamina Mills well (3), located approximately 25 feet from the suspected spill site. Shortly thereafter, following the advice of the Rhode Island Department of Health (RIDOH), Stamina Mills stopped using the well as a source of drinking water, but continued to use it for sanitary purposes. An analysis of water from the Stamina Mills well by RIDOH in 1979 indicated a TCE concentration of 267,000 parts per billion (ppb).

On October 7, 1977 a fire destroyed the mill complex. Since this time the property has been vacant and unused.

Off-Site groundwater contamination by chlorinated volatile organics was first detected in the Forestdale Water Association Well, located approximately 900 feet northwest north of the Site (SP-1), in August 1979 during a statewide survey by the RIDOH. The Forestdale Water Association Well is finished in bedrock at a depth of 250 feet. The well served approximately 50 people living in 28 houses. TCE at 413 ppb and tetrachloroethylene (PCE) at 12 ppb were detected in the initial sample. The RIDOH subsequently expanded its well-testing program in the Forestdale area to include other residential bedrock wells and found TCE at concentrations ranging from 3 ppb to 7,000 ppb in 18 of 51 wells tested.

In 1980 the State of Rhode Island and the Town of North Smithfield financed the installation of a water main through the residential area north of the Site that RIDOH had shown to be affected or could be potentially affected by volatile organic contamination. The water main was connected to the Slatersville-Forestdale Water System, which is supplied with water from a Town-owned well field adjacent to the Slatersville Reservoir.

Between 1979 and 1984 various studies of the well contamination problem in the Forestdale area were completed by several agencies and their contractors. These studies generated extensive data on Site history, Mill operations, solvent use, waste disposal methods, supply well details, well water quality, study area geology, and contaminant migration. A summary of these studies is provided below.

1.40 SUMMARY OF PREVIOUS STUDIES, RESULTS AND REMEDIAL RESPONSES

Several comprehensive studies and a number of limited investigations of the Stamina Mills Site have been prepared by various investigators in the past. The results of these studies provide a substantial amount of historical, geological, hydrological and public health related information from which the remedial investigation can draw. The reports provide detailed information concerning the geology and hydrogeology of the Site and adjacent areas; identification and evaluation of potential on-Site sources of contamination; and estimates of the overall area of impact.

In addition to the formal studies and investigations, various memos, letter reports, news clippings, community relations literature, analytical results and other relevant information were collected from the files of several State and Federal agencies for review.

The following sections present a chronological outline of all available studies and investigations researched during the RI. The condensed outline serves to present the objectives, scope and findings of the studies. It does not, however, provide an evaluation of methods employed, the limitations of the approach or validity of the findings.

1.41 State of Rhode Island Report on Forestdale Well Contamination, Pearce Klazer, Division of Water Resources, Department of Environmental Management, State of Rhode Island, February 1980

This RIDEM inter-office memo report was prepared in response to initial indications from the RIDOH that a public drinking water supply well in the Forestdale section of North Smithfield had been contaminated with chlorinated solvents. The RIDEM investigative report focused on the Stamina Mills Site as the most likely source of TCE contamination since it was known that the Mill used a similar process chemical in its solvent scouring system.

The report compiled its background information primarily from internal Department files and interviews with a former Stamina Mills employee. From these sources it was determined that:

1. Stamina Mills, Inc. adopted a solvent scouring system in March of 1969.

2. The solvent used in the scouring system was trichloroethylene.

3. Spent solvents were pumped from the system to stills where it was evaporated and condensed for recycling.

4. Oil and other contaminants removed by the solvents remained in the stills as still bottoms.

5. It was estimated that about one drum of still bottom wastes were disposed of in the Mill's landfill each day.

6. In the fall of 1970 or 1971 a spill of an estimated 100 to 300 gallons of TCE occurred at the Site during a delivery. There was no attempt to report or clean up the spill.

7. Indications of a "sweet taste and odor" in the Mill's drinking water about 3 to 4 months following the spill prompted the RIDOH recommendation to no longer use its water supply for drinking purposes.

An inspection of the Stamina Mills Site was conducted by the Department. Key features of the Site, including the spill location, solvent storage tank and the source of the Mill's water supply were noted. Additionally, observations of local bedrock outcroppings were made where it was noted that "the bedrock was laminar, having a tendency to be fractured in its direction of lay". Further research revealed that "the bedrock in Forestdale is classified as a metamorphic, and dips or tilts 35° downward from the horizontal and toward the northeast". Based on this information and considering the physical properties of the chemicals in question, a preliminary determination was made that a hydrogeologic connection between the Site and the Mill's supply well potentially existed.

The RIDEM report presented several possible sources of contamination at the Site: introduction into the bedrock of contamination from the Mill's well, which was apparently contaminated by the spill; the landfill where still bottom were disposed; the vapors discharged from the solvent scouring system; the Mill's sewage disposal system; and possible loss of stored solvent during the 1977 fire, which destroyed the Mill complex. Each potential source of contamination identified was evaluated as to its potential impact(s) on the affected well. The source identified first, the Stamina Mills well, was selected as the most "prime suspect in the investigation".

Working from this assumption, the Mill's well was located, measured, and sampled, revealing that the well contained "elevated levels of trichloroethylene and essentially no 1,1,1-trichloroethane and only minor levels of tetrachloroethylene". It was also postulated that rock blasting as part of a sewer project near the Site opened cracks and fissures in the bedrock, thus allowing for the release of chemicals from within the Mill's well.

To evaluate the relationship between the contaminated drinking water wells and the Site, RIDEM compiled and compared data on individual private well depths, TCE levels and the distance from the wells to the identified sources on the Site (well, landfill and sewer interceptor). The data, presented in graphic form, support the theory that contamination of the Forestdale Water Association well by TCE originated from the Stamina Mills Site, with contamination "moving down the bedrock toward the village either directly from the Mill well or by way of the line of sewer excavation". The correlation between well depth, contamination level and distance from the sewer interceptor did not, however, hold for the other contaminants found in minor quantities in the affected wells. To provide explanation for this occurrence, the report theorized that they were introduced locally through disposal of household products in subsurface disposal systems. As support, the report provided a comprehensive listing of common household products containing the chemicals in question.

1.42 Field Investigation Team (FIT) Project Report on October 10, 1980 Sampling Visit to Forestdale, RI, December 1980, TDD No. F-1-8011-06

The FIT Report was prepared by Ecology and Environment, Inc. under contract with the U.S. Environmental Protection Agency. The described purpose of the Site visit was "to obtain samples for possible enforcement actions against Stamina Mills, Inc.", with the objective of obtaining tap water samples for organic analysis from three residences in Forestdale.

The report presents a historical background of the Site generated from excerpts from the State of Rhode Island Report on Forestdale Well Contamination. The field investigators, in addition to collecting tap water samples, interviewed homeowners. Information concerning the families' water use, adverse health effects experienced due to use of contaminated water and comments on conditions of the residents' water delivery system were noted. Further, the investigators recorded the homeowners' recollections of Stamina Mills and its history of operation.

The analytical results from the sampling round revealed the presence of low concentrations (1 to 13 ppb) of four organic compounds; 1,1,1-trichloroethane, TCE, PCE, and methylene chloride. The report concluded that:

1. The low levels of contamination present are unlikely to cause the symptoms described by residents.

2. Plumbing fixtures and furnace coils in the homes are not corroding due to high water acidity as the water was tested to have a neutral pH.

3. Background information indicates a definite potential for organic chemical contamination of all groundwater in the area as a result of former activities at Stamina Mills.

1.43 Forestdale Well Contamination Study, North Smithfield, Rhode Island, Goldberg-Zoino & Associates, Inc., September 1982, File No. A-3036.

Work on this project was undertaken by Goldberg-Zoino & Associates, Inc. (GZA) on behalf of the U.S. Environmental Protection Agency under a contract provided through JRB Associates, Inc. As part of the investigation, eight residential wells north of the Site and two industrial wells, the Stamina Mills well and a well south of the Site, were sampled. Analytical results revealed TCE concentrations ranging from 27 to 8,000 ppb in the eight wells. Trans-1,2-dichloroethylene (25 ppb) and 1,1,1-trichloroethane (1 to 9 ppb) were detected in two of the wells.

The GZA project was completed in five Tasks. Task 1 involved a detailed review of available data on the Site and collection of additional background information. Task 2 consisted of a detailed Site reconnaissance, which included geologic mapping of the study area, an inventory of residential wells in the village of Forestdale, and water quality sampling of selected locations. A number of residential well samples were analyzed as part of this Task to establish existing water quality conditions and for comparison with previous results.

Based on the results of Tasks 1 and 2, including volatile organic screening analyses by GZA, Task 3, an evaluation of potential contaminant sources, was completed. This assessment did not reveal any additional probable source of volatile organic contamination in or near the study area other than Stamina Mills. However, existing information was insufficient to identify the specific source within the Stamina Mills Site or characterize the mechanism of contaminant migration. The remainder of the study was therefore focused on the immediate area of the former Mill Site.

Task 4, the field exploration program, was initiated to address the issues of specific source areas and contaminant migration and to provide subsurface data for documentation. The first phase of the program included a series of test pit excavation to investigate potential source areas within the Stamina Mills Site and a bedrock coring effort to characterize lithologic conditions below the study area. The second phase of the field explorations entailed installation of three deep bedrock wells and execution of a one-day pumping test to investigate potential hydraulic communication between the Mill Site and the contamination wells.

Task 5, data analysis and documentation of results was completed in two stages: (a) an interim report representing project progress, data analysis and documentation of study results; and (b) the final report containing the conclusions drawn from data analysis, identification of probable sources of contamination and documentation of pollutant migration mechanisms.

GZA concluded that the most probable source of the TCE contamination of the Forestdale residential wells is the former Stamina Mills Site, and that other constituents detected in the residential wells probably originated from individual septic systems. The reasons for these conclusions were as follows:

1. The former Stamina Mills was the only facility in the Forestdale area which was known to store or use trichloroethylene. Furthermore, a major spill of TCE involving several hundred gallons of product was reported by a former plant employee.

2. The highest levels of TCE within groundwater in the study area were detected within the former Mill supply well during the GZA sampling program and previous analytical work by the Rhode Island Department of Health.

3. Elevated levels of TCE were found in soils above the water table near the alleged spill area northeast of the Mill structure. The observed distribution of TCE suggested that the origin of this contamination was percolation of contaminated liquids disposed of on or near the ground surface in this area.

4. The bedrock structure, which is expected to exert the primary influence on groundwater flow, is a joint set which strikes west to northwest and dips north to northeast from the Mill Site toward the residential wells at 15 to 40 degrees from the horizontal. These joints represent a preferred direction for groundwater flow and provide a mechanism for transport of contaminants from the Mill Site to the residential supply wells.

5. Water level measurements in certain Forestdale wells and the results of a short-term pumping test indicated the likelihood of pumping-induced groundwater flow northward from the Stamina Mills Site to the residential zone, confirming the existence of a contaminant transport mechanism between these areas.

GZA's final report recommended that additional work be completed to identify and evaluate remedial action alternatives designed to mitigate the contamination and/or provide a potable water supply to affected residents. Further, GZA recommended a more comprehensive characterization of potential source areas within the Site, with particular emphasis placed on the unsaturated zone in the vicinity of test pit TP-9 and the landfill area. It was also recommended that groundwater contamination by constituents other than TCE within the study area be investigated in greater detail.

1.44 Residential Groundwater Sampling of the Stamina Mills Area of Forestdale, Rhode Island, NUS Corporation, June 14, 1984, TDD No. F1-8402-04.

This letter report presents the results of a residential well sampling program conducted by the NUS Field Investigation Team for the U.S.

Environmental Protection Agency. As part of the investigation, NUS/FIT prepared a bedrock fracture and joint survey of the Forestdale area.

NUS collected water samples from seventy-six homes and businesses in the area. The samples were screened by an NUS chemist utilizing a Photovac 10A10 gas chromatograph, having a sensitivity of approximately 0.5 ppb. Concentrations of TCE ranging from 0.1 ppb to greater than 694 ppb were detected in forty-three wells. Concentrations of PCE ranging from 0.3 ppb to 14.2 ppb were detected in forty-two wells, and concentrations of 1,1-dichloroethylene ranged from 1 ppb to 6 ppb in sixteen wells. (NOTE: A cross-reference list of analytical data generated from sampling of monitoring wells on the Site and private off-Site wells for the period of 1979 to 1986 is presented in Appendix I of this GHR Report.) The NUS results revealed:

1. The groundwater from lots adjacent to Main Street and directly northwest of the Stamina Mills Site appear to be the most contaminated by TCE.

2. The groundwater from lots adjacent to Main Street and directly east of the Stamina Mills Site appear to have either no detectable or low levels of contamination by TCE.

3. The Forestdale Water Association well on Freitas Lane supplies water to a limited number of residents in the Forestdale area. Analytical results indicate that this well is contaminated by TCE.

The fracture and joint survey indicated that "major fractures in the bedrock dip from the reservoir (Slatersville) and the Stamina Mills spill site north at an angle of 26 degrees under the Village of Forestdale. These fractures provide a conduit for contaminants to enter local groundwater".

1.45 Magnetometer Survey at the Stamina Mills Site, North Smithfield, Rhode Island, Roy F. Weston, Inc., TDD No. 01-8504-04.

The magnetometer survey report, prepared by Roy F. Weston, Inc. for the Oil and Hazardous Materials Section of the EPA, describes the findings of an investigation to identify possible locations of buried drums and tanks at the Stamina Mills Site.

The magnetometer survey was conducted using a Geometrics Model G816 Proton Magnetometer. Magnetic field intensities, measured in gammas, were recorded from within an established grid layout over the Site. The survey identified several suspect areas of the Site exhibiting high magnetic anomolies (59,000 gamma range).

Based on these findings, five test pit excavations were completed on April 29, 1985. Test pitting in the areas exhibiting the highest magnetic readings obtained on the Site, uncovered a buried tank located east of former Mill Building No. 1 approximately 4 feet below the ground surface. The tank was estimated to be 8,000 gallons in size. A HNU reading of 40 ppm was obtained from within the opening of the tank. The tank was approximately one half full of a thick, black oily substance, which appeared to be a heavy grade fuel oil. Subsequent analysis of the substance indicated that it was a heavy grade fuel oil.

None of the remaining four test pits uncovered buried drums or tanks. Three of the remaining four test pits did, however, encounter soil described as "dark, oily and exhibiting a strong odor". Based on descriptions of the locations of these test pits, provided in the R.F. Weston report, these test pits were apparently excavated in the landfill.

1.50 RESPONSE ACTIONS AND CURRENT STATUS

With the discovery of volatile contamination in the Forestdale Water Association well and in other residential wells in 1979 and 1980, the RIDOH advised residents to boil water used for drinking and cooking. A continuing monitoring program of contaminant levels in residential wells was also instituted by the RIDOH.

In 1980 the State of Rhode Island and the Town of North Smithfield financed the installation of a water main through the residential area north of the Site that RIDOH had shown to be affected or could be potentially affected by volatile organic contamination. The water main was connected to the Slatersville-Forestdale Water System, which was supplied with water from a Town-owned well field adjacent to the Slatersville Reservoir.

Between 1980 and 1984 only 7 of approximately 50 residences who had access to the water main had selected to tie into the public water system. Due to limited funds, the Town was unable to pay for tie-ins from the water main into the residences and most residents selected not to pay an estimated $600 to $1,200 for hooking up to the water main. Residents who did not tap into the water main continued to use untreated water from their wells, boiled water prior to use, installed faucet filters, or selected to use bottled water for consumption.

In September 1984, the EPA purchased bottled water for residents whose homes were not connected to the public water system. Later in 1984 and early 1985 the EPA funded the hook-up of homes to the water main. As of late 1986, 40 of the 50 homes in front of which the water main was installed had elected to tie into the public water supply. Site Plan No. SP-1 indicates which residential wells were inactive (i.e., not used for consumption purposes) at the time of the pump test and which wells were active during the pump test. It is noted that some "inactive" wells are periodically used for irrigation purposes.

SECTION TWO

STUDY AREA GEOLOGY, HYDROGEOLOGY AND GROUNDWATER QUALITY

SECTION TWO - STUDY AREA GEOLOGY, HYDROGEOLOGY AND GROUNDWATER QUALITY

2.10 INTRODUCTION

The geology and hydrogeology of the Stamina Mills Site and the surrounding area have been described in detail in the following studies conducted prior to this report. Richmond mapped the surficial and bedrock geology of the Georgiaville, Rhode Island Quadrangle which includes the Stamina Mills Site (4,5). The surficial geology of a portion of the Blackstone, Massachusetts Quadrangle immediately north of the Site was mapped by Johnson (6). The bedrock geology of the study area is also briefly and generally illustrated in the Rhode Island State and Massachusetts State bedrock geology maps by Quinn (7) and Ratcliff et al (8), respectively. The Site and immediately surrounding area have been the focus of more detailed studies by the State of Rhode Island, Department of Water Resources (3), GZA (9) and NUS (10) relative to TCE contamination of the groundwater.

The following sections provide a brief summary of the geology and hydrogeology of the study area relevant to the pump test. The reader is referred to the above reports for further information regarding study area geology and hydrogeology. The summary that follows provides the reader with an understanding of the conceptual hydrogeologic framework within which the pump test was designed and aids in understanding how the bedrock aquifer reacted when it was stressed during the pump test.

Study area geology and hydrogeology is primarily bedrock-controlled with bedrock typically occuring within 15 feet of the ground surface. Exposed bedrock to the north of the Site and along the bed of the adjacent Branch River indicate that surficial (unconsolidated) materials in the study area constitute a limited medium for groundwater occurrence and transport. The abundance of wells finished in bedrock in the study area supports the observation that groundwater occurs and is available primarily from the bedrock aquifer.

The pump test was conducted to evaluate the response of the bedrock aquifer to pumping because the bedrock aquifer appears to have acted as the primary contaminant transport media by which the private wells became contaminated. Therefore, the discussion that follows focuses on bedrock structure and how that structure controls groundwater movement.

2.20 BEDROCK GEOLOGY

The Stamina Mills Site and its near environment are founded on a complex of schists, gneisses, and quartzite belonging to the Blackstone Series. These rocks are exposed in outcrops over an area extending from 1.5 miles northwest of the Site to the south flank of Woonsocket Hill 2 miles to the south. The Blackstone Series is also exposed 4 miles to the west and 3 miles to the southwest of the Site at Whortleberry Hill. Figure 2-1 displays the regional bedrock geology.

The Blackstone Series rocks were intruded and locally replaced by the Esmond Granite batholith (5). This unit is exposed 0.5 and 1 mile north and west of the Site, and recurs 3 miles to the southeast of the Site as a large north-trending body in contact with the Blackstone Series at Whortleberry Hill. The Esmond Granite is believed to regionally underlie and enclose the remnant Blackstone Series metamorphic units.

Figure 2-2 presents a regional geologic cross-section drawn through the study area from Industrial Highway, 1600 feet south of the Site and 4200' north of the Site to Route 146. The location of cross-section Line A-A' is shown on Figure 2-1. The lithology shown on Figure 2-2 is based upon reported (references 4 through 7) exposed lithology and mapped contacts.

Of primary importance during the hydrogeologic assessment conducted as part of the RI and the pump test discussed in this report, was definition of groundwater migration patterns in the bedrock aquifer. Groundwater migration in the bedrock aquifer at and in the vicinity of the Stamina Mills Site is controlled primarily by the secondary porosity of the rock caused by discontinuities in the rock. These discontinuities may include joints, fractures and faults. Lesser quantities of groundwater may be stored and transmitted in the interstitial spaces of the rock due to primary porosity. Thus, by defining the orientation of fractures and joints and the hydraulic gradient, one is able to begin to assess the direction of groundwater movement in the bedrock aquifer.

The orientation of joints and fractures has been analyzed by a number of field methods and by evaluation of remote sensing imagery. These methods have included:

1. Strike and dip measurements of major joints and foliation in study area outcrops by GZA (9) and NUS (10).

2. A fracture trace analysis conducted as part of the RI to identify from aerial imagery, major lineaments manifesting themselves as surface features which may represent bedrock discontinuities.

3. Coring and retrieval of bedrock cores during the hydrogeologic assessment conducted on the Site as part of the RI.

4. Downhole geophysical profiling of five bedrock wells in the study area conducted prior to and in conjunction with the pump test.

2.21 Strike and Dip Measurements

Strike and dip measurements of joint, fracture and foliation features in outcrops in the study area were completed by GZA in 1984 (9) and later in 1984 by NUS (10). Table 2-1 presents structural measurements made during the NUS and GZA studies. Figure 2-3 is a rose diagram generated using strike measurements respectively of joints and foliation manifested as fractures measured in the field by NUS and GZA. Figure 2-4 is a rose diagram generated using dip measures of joints and foliation measured by NUS and GZA. Figure 2-3 shows four preferred strike orientations. The

TABLE 2-1

STRIKE AND DIP OF MAJOR JOINTS AND FOLIATION MEASURED FROM OUTCROPS IN THE VICINITY OF THE STAMINA MILLS SITE

Page 1 of 2

LOCATION	STRUCTURAL FEATURE	ATTITUDE	REFERENCE
Intersection of Kirby Lane and Main Street	Foliation	N285°E; 22°N	NUS, 1984
231 Maple Avenue	Joint	N10°E; 90°	NUS, 1984
	Joint	N65°E; 85°S	
	Joint	N62°E; 80°S	
	Joint	N0°E; 70°W	
	Foliation	N290°E; 35°S	
	Foliation	N90°E; 42°N	
Intersection of Steel Street and Industrial Drive	Joint	N278°E; 31°N	NUS, 1984
	Joint	N280°E; 90°	
	Foliation	N275°E; 31°N	
	Foliation	N285°E; 27°N	
	Foliation	N300°E; 26°N	
	Foliation	N300°E; 29°N	
Pound Hill Road 1 mile north of Industrial Drive	Joint	N90°E; 90°	NUS, 1984
	Joint	N85°E; 85°S	
	Foliation	N20°E; 24°NW	
	Foliation	N75°E; 27°NW	
	Foliation	N85°E; 26°N	
Industrial Drive 0.2 miles east of Route 5	Joint	N280°E; 30°N	GZA, 1984
	Joint	N300°E; 80°S	
	Joint	N10°E; 80°E	
	Foliation	N280°E; 30°N	
Industrial Drive 0.6 miles east of Route 5	Joint	N290°E; 80°S	GZA, 1984
	Foliation	N60°E; 30°NW	
Industrial Drive 0.7 miles east of Route 5	Joint	N300°E; 25°N	GZA, 1984
	Joint	N20°E; 90°	
	Joint	N300°E; 80°N	
	Foliation	N300°E; 25°N	
Intersection of Pound Hill Road and Route 146	Joint	N300°E; 30°E	GZA, 1984
	Foliation	N300°E; 30°E	
South Flank of Premisy Hill Entrance to Route 146	Joint	N315°E; 40°NE	GZA, 1984
	Joint	N315°E; 80°NE	
	Foliation	N315°E; 40°NE	

TABLE 2-1

STRIKE AND DIP OF MAJOR JOINTS AND FOLIATION MEASURED FROM OUTCROPS IN THE VICINITY OF THE STAMINA MILLS SITE

Page 2 of 2

LOCATION	STRUCTURAL FEATURE	ATTITUDE	REFERENCE
West Flank of Premisy Hill	Joint	N315°E; 48°NE	GZA, 1984
	Joint	N315°E; 80°NE	
	Foliation	N315°E; 48°NE	
South Bank of Branch River at Stamina Mills Site	Joint	N280°E; 30°N	GZA, 1984
	Foliation	N280°E; 30°N	
Intersection of Maple Avenue and Freitas Lane	Joint	N70°E; 90°	GZA, 1984
	Foliation	N320°E; 30°-35°NE	
Intersection of Maple Avenue and Wildwood Road	Joint	N280°-290°E; 30°N	GZA, 1984
	Foliation	N280°E; 30°N	
Intersection of Route 146 and Route 146A	Joint	N90°E; 30°N	GZA, 1984
	Joint	N330°E; 60°E	
	Foliation	N30°E; 15°NW	

two most predominant fracture trends are characterized by strikes trending generally east-west and northwest-southeast. Secondary trends occur in northeast-southwest and north-south orientations. Observations of rock cores taken from the Site, as described in Section 2.23 indicate that the fracture apertures which generally dip between 15° and 35° and are parallel to the foliation planes in the rock are narrower and "tighter" than the apertures of high angle (greater than 45° dip) or vertical fractures observed in the cores. Based on a visual comparison between the apertures of low angle and high angle fractures, it appears that the high angle and vertical fractures would serve as the major water bearing fractures while the fractures associated with foliation plans would serve as minor pathways (compared to high angle or vertical fractures) through which groundwater would migrate. Figure 2-3 shows the strike of foliation planes and joints measured from outcrops. Analysis of the data provided in Figure 2-3 and Table 2-1 shows that most of the foliation planes have low dip angles (less than 45°) while the joints generally have high angle dips. Assuming that these joints are surface representations of water bearing fractures at depth, further analysis of the data on Figure 2-3 indicates that 40 percent of the joints have a northwest-southeast strike, 32 percent have an east-west strike, 16 percent have a northeast-southwest strike and 12 percent have a north-south strike.

Figure 2-4, representing dip directions of joints and foliation measured in outcrops, indicate five dominant dip directions. The predominant dip direction is toward the north with secondary dip directions to the northeast, southeast, southwest and northwest.

Table 2-2 presents an analysis of the average dip angle and percentage of joints versus foliation for each compass quadrangle calculated from Table 2-1 and Figure 2-4.

TABLE 2-2

ANALYSIS OF DIP ANGLES AND PERCENTAGE OF JOINTS AND FOLIATION FOR EACH COMPASS QUADRANT

COMPASS QUADRANT	PERCENTAGE OF JOINTS (J) AND FOLIATION (F)	AVERAGE DIP ANGLE (DEGREES)
NE	J-53 F-47	J-52 F-31
SE	J-100	J-82
SW	J-50 F-50	J-80 F-32
NW	J-50 F-50	J-85 F-25

Table 2-2 indicates that in all cases, the joints have an average dip angle which is higher than the average dip angles of the foliation. Additional analysis of the joint data indicates that 54 percent of the joints occur in the northeast quadrant, 21 percent occur in the northwest quadrant, 17 percent occur in the southeast quadrant and 8 percent occur in the southwest quadrant. Using the rationale that the high angle and vertical joints represent the water bearing fractures, the data presented above indicates that the water bearing fractures dominantly dip toward the northeast and northwest.

2.22 Fracture Trace Analysis

The lineaments shown on Figure 2-5 were identified from aerial imagery of the study area. The lineaments were subsequently classified based upon their orientation related to magnetic north. A rose diagram representing the frequency distribution of lineament orientation is presented as Figure 2-6.

The fracture trace analysis method does not distinguish between lineaments representing foliation versus those representing joints and fractures. Thus, the water bearing fractures in the bedrock are not segregated from the minor water bearing features represented by the foliation. Additionally, the fracture trace analysis was conducted over a regional area which is larger than the area assessed during the pump test. Nevertheless, the fracture trace analysis provides information which is useful in understanding the regional structural geology which is unlikely to vary significantly from the structural geology of the Site and residential area north of the Site.

The rose diagram indicates that there are four preferred lineament orientations within the study area. The most predominant trend is characterized by lineaments trending north-south, with secondary trends observed in northwest-southeast, east-west, and northeast-southwest orientations. The northwest-southeast and east-west lineament trends may be associated with the inferred contact between the Blackstone schists and quartzites as shown on Figure 2-1.

The results of the fracture trace analysis corroborates with the structural geologic information generated by NUS and GZA. Comparison of Figure 2-3 with Figure 2-6, showing the orientation of lineaments based on the fracture trace analysis, indicates that the strike measurements generated by actual field measures are in general agreement with the interpretation of bedrock structure provided by the fracture trace analysis exercise.

2.23 Bedrock Coring

During the RI, bedrock was cored to depths ranging from 35 to 40 feet below the top of rock at MW-1 through MW-9, MW-12, -15 and -16 locations. Rock core logs are provided in Appendix A.

The principal joint set observed in the rock cores exhibited smooth surfaces, approximately parallel to the schistosity and inclined at apparent dips of 15° to 35° to the horizontal. The majority of these joints or partings were located in the upper 15 feet of the bedrock and were generally closely-spaced and tight, displaying little separation, with weathering typically limited to staining of the joint surfaces and rarely penetrating the rock fabric. The aperture of these joints indicate that they are not major water bearing fractures.

A second set of vertical to near-vertical joints was observed locally in the cores. The strike of these discontinuities did not appear to be systematic to the foliation or principal joint set. These joints terminate in intact rock or at the surface of the foliation joints and were typically tight to slightly open but were darkly stained over their surfaces indicating storage and possible migration of groundwater within the joints. A set of vertical joints in moderately hard schist was encountered at depths of 30 to 35 feet in corehole MW-3. These joints included an open sand-filled joint at 32 feet.

The occurrence of the near vertical joints, the sand filled joint, and the fractured nature of the upper 15 feet of the bedrock indicate that good hydraulic communication exists between overlying soils and the bedrock.

2.24 Downhole Geophysics

Prior to conducting the pump test, a downhole geophysical survey of five bedrock wells was conducted. The objectives of the downhole geophysical survey were to:

1. Attempt to correlate the foliation and fracture orientation information generated by near surface methods (outcrop measurements, fracture trace analysis and bedrock coring) with structural information at depth in the bedrock.

2. Attempt to define the locations and orientation of fractures and foliation planes which were suspected to act as contaminant pathways from the Site to the residential wells north of the Site.

3. Identify major water bearing zones providing groundwater to the bedrock wells at which groundwater sampling devices could be installed to monitor groundwater quality during the pump test.

4. Generate information on fracture and foliation orientation which would aid in the interpretation of drawdown data measured in wells during the pump test.

The downhole geophysical survey was conducted in three residential wells, Kenoian, Cross-Reference (CR) #I-2, Freitas, CR#I-12 and Post Office CR#I-31, the Forestdale Water Association Well and the Stamina Mills Wells as shown on SP-1. The downhole geophysical survey consisted of downhole acoustic televiewer and three-arm caliper logging and was conducted by the United States Geologic Survey (USGS) under a cooperative agreement with the USEPA during the period of December 11 to 14, 1987. Temperature logging was attempted but malfunctioning equipment prevented gathering of useful data. To facilitate the introduction of geophysical instruments into the wells, the pumps, electrical cables and piping were withdrawn from the wells on December 7 and 8, 1987.

Downhole acoustic televiewer logging produces a videotape and printout showing fracture zones within the borehole. Since the orientation of the televiewer is magnetically controlled in the borehole and the televiewer records fractures around the complete circumference of the borehole, the orientation (strike direction and dip angle) can be established.

The three-arm caliper logger measures minute differences in borehole diameter as the caliper is drawn from the bottom to the top of the borehole. Increases in borehole diameter may be the result of natural fractures caused by tectonic forces intercepting the borehole or of artificial fractures caused by drilling of the borehole (11).

Under the cooperative agreement with EPA, the USGS was tasked to provide an initial evaluation of the televiewer and caliper logs from the five wells. The results of this evaluation are presented in Appendix B and summarized below. GHR incorporated the results of the initial evaluation in the following discussions of the results of the downhole geophysical survey. Figures B-1 through B-7 in Appendix B were generated through the evaluation. Figures B-2 through B-6 show the caliper and televiewer logs side-by-side with a stereographic projection on which is plotted the strike and dip of all of the fractures identified in the five surveyed wells. Borehole diameter versus depth is plotted on the caliper log. Strike and dip symbols are plotted on the televiewer log to indicate the orientation of the fractures. Figure B-1 is a stereographic projection which contains plots of the strikes and dips of all fractures identified in all five wells. The intent of Figure B-1 is to provide a regional perspective of fracture orientation over the entire study area. Figure B-7 is a stereographic projection which contains plots of the strikes and dips of only fractures identified by the televiewer probe which correlate with spikes on the caliper logs. These fractures were interpreted by the USGS to be the fractures which are likely to be water bearing although the areal extent of the fractures beyond the borehole cannot be determined from the televiewer and caliper logs alone. Additionally, as described in Appendix B, geophysical logging including fluid-resistivity and temperature and vertical flow measurements would be required to determine which fractures identified on Figure B-7 are conducting water.

Further analysis of the results of the downhole geophysics was conducted by GHR in order to determine if there is a correlation between the attitude of fractures identified during the downhole geophysics and the attitude of fractures determined from the fracture trace analysis and measurements from bedrock outcrops. Figure 2-7 was generated by plotting the strikes for all structural features identified during the downhole geophysical survey.

Strike directions of structural features identified on Figure B-7 as likely water bearing fractures, for each 45 degree increments of the compass (i.e., N-S, NE-SW, E-S and NW-SE) were tabulated from the televiewer logs. The total and average number of fractures in each 45 degree increment was then calculated. The results of this evaluation indicated four dominant directions of structural features; the most dominant direction being northeast-southwest (33 percent of the features) with secondary features being aligned northwest-southeast (28 percent), east-west (28 percent) and north-south (11 percent). This analysis is in agreement with the predominant strike directions for all structural features shown on Figure 2-7 which shows the predominant strike direction being northeast-southwest.

The USGS notes in Appendix B that work conducted by the Borehole Geophysics Project in New Hampshire and Arizona (12) indicates that conductive fractures do not necessarily appear different than other prominent fractures on the televiewer logs. Additionally, definition of the orientation of fractures in individual boreholes does not necessarily lead to a definition of the connectivity of fractures from one borehole to another. The work conducted in New Hampshire and Arizona (12) indicates that migration of groundwater through fractures from one borehole to another did not appear to occur along discrete fractures for which the strike and dip were measured, but rather along nearly horizontal fracture zones composed of intersecting fractures with attitudes significantly different than the fractures measured in the boreholes.

It is important to note that the work in New Hampshire and Arizona was conducted in crystalline (igneous) rock which is unlike the metamorphic units in the Stamina Mills study area in that the crystalline units did not show preferred fracture orientations, while the metamorphic units do show preferred fracture orientations. Undoubtedly, when the bedrock aquifer in the study area is stressed by pumping, TCE contaminated groundwater would migrate along the path of least resistance provided by intersecting fractures.

2.25 Summary

Information on the orientation of bedrock features which serve as groundwater migration pathways has been generated by physical measurements of joints and foliation in bedrock outcrops, by a fracture trace analysis and by a downhole geophysical survey in five bedrock wells. Evaluation of the general water bearing characteristics of fractures parallel to foliation planes and of high angle fractures was accomplished by observation of rock cores taken at the Site.

The results of the assessment of bedrock features described above indicate that:

1. The strike of bedrock discontinuities (joints and foliation) is predominantly in northeast-southwest and northwest-southeast directions with minor trends in east-west and north-south directions.

2. The orientation of structural features measured on the ground surface during the strike and dip evaluation and identified during the fracture trace analysis, are in general agreement with the orientation of structural features measured at depth during bedrock coring and the downhole geophysical survey. Therefore, it is concluded that the orientation of structural features at depth which control the migration of groundwater manifest themselves as surface features in bedrock outcrops.

3. Observations of bedrock cores and analysis of structural measurements from bedrock outcrops indicate that the high angle and vertical joint are most likely the water bearing features as compared to the apparently "tight" foliation planes. The joints dip predominantely toward the northeast and northwest.

4. Taken in total, measurements and analysis of bedrock structural features indicate the presence of groundwater migration and contaminant pathways oriented in a northeast and northwest direction from the Site toward the residential area northwest, north and northeast of the Site. When the bedrock aquifer north of the Site is stressed by pumping, these pathways would serve as potential groundwater contamination pathways from the Site toward the residential area.

2.30 HYDROGEOLOGIC SETTING

The study area lies within the watershed of the Branch River, which is the ultimate recipient of most surface water runoff from the residential area to the north of the Site and the Stamina Mills property. The river also receives groundwater discharge from the Site and a portion of the residential area north of the Site. Under non-pumping conditions (of residential wells and the Forestdale Water Association Well), regional groundwater flow is generally toward the Branch River from upland areas along the north and south banks, and then eastward, parallel to the River as shown on SP-1. This interpretation is based upon water table elevations measured in residential and the Forestdale Water Association Wells and monitoring wells and upon considerations of topography and the regional northwest to southeast trend of upland hills and intervening valleys. These data suggest that regional flow directions in the bedrock beneath the Forestdale area and the Stamina Mills Site are toward the southeast under non-pumping conditions. However, the presence of TCE in wells north of the Site suggests that at one time the pumping of individual residential bedrock supply wells and the Forestdale Water Association Well to the north of the Stamina Mills Site produced local reversals in the regional hydraulic gradient. Currently, not all the residential wells are in use; those that are being pumped supply reduced, and in some cases, only seasonal demands (i.e., for watering lawns, etc.). SP-1 shows the active and inactive residential wells in the study area.

2.31 Horizontal Groundwater Movement

Contours of groundwater elevation reflecting data collected in August 1986 during the RI are depicted on SP-1. It is noted that the contours shown on SP-1 were developed from water level measurements taken in both shallow bedrock monitoring wells (screened 10 to 20 feet in bedrock) on the Site and deep (up to 465 feet) open hole bedrock residential wells. Thus, piezometric measurements from some of the on-Site monitoring wells are representative of hydraulic pressures at the top of the bedrock surface while measurements from the residential wells represent an average of the hydraulic pressure over the full depth of the well. The intent of SP-1 is to present a regional perspective of groundwater contours and flow direction relative to the residential area and the Site. The use of measurements from shallow and deep bedrock wells does not have an influence on interpretation of regional groundwater elevation conditions. This has been proven by separate plots of measurements from just the residential wells and the on-Site monitoring wells as shown on SP-1 and of measurements from just on-Site monitoring wells as shown on Figure 2-8. Both SP-1 and Figure 2-8 clearly show groundwater migration under non-pumping conditions toward Forestdale Pond and the Branch River. As suggested by the topography and groundwater elevations across the Forestdale residential area, groundwater flow direction in the bedrock aquifer is to the southwest and south from the area of maximum relief approximately 700 feet to the north of the Site along Maple Street. The hydraulic gradient from the area of maximum relief to the Stamina Mills Site at the time the hydraulic head measurements were taken in bedrock wells was .086 ft/ft.

2.32 Bedrock Hydraulic Conductivity

Bedrock hydraulic conductivity at the Stamina Site was estimated during the RI by packer pressure testing conducted in bedrock coreholes from selected wells. Testing was conducted according to methods outlined in the Earth Manual, 1974 (13). Testing was conducted in coreholes ranging in depth from 10 to 20 feet which were drilled for monitoring well installation on the Site. Results of the packer testing are provided in Table 2-3. Of the forty pressure tests performed as part of the RI, eighteen, or 45 percent, recorded no flow; that is, flow quantities were less than 0.05 gallons per minute (not measurable with the equipment used) and eleven or 27 percent, resulted in hydraulic conductivity estimates of less than 100 feet/yr (0.3 ft/day).

TABLE 2-3

SUMMARY OF HYDRAULIC CONDUCTIVITY
MEASURED BY PACKER TESTS
IN COREHOLES AT THE
STAMINA MILLS SUPERFUND SITE
NORTH SMITHFIELD, RHODE ISLAND

Page 1 of 2

MONITORING WELL NUMBER	TEST INTERVAL (depth-ft)	GEOLOGIC MATERIAL	TYPE OF TEST	HYDRAULIC CONDUCTIVITY (ft/day)
MW-1	16.9' - 21.7'	Bedrock	Packer	1.1×10^{-1}
	19.9' - 24.7'	Bedrock	Packer	6.0×10^{-2}
	24.7' - 29.5'	Bedrock	Packer	5.0×10^{-2}
	29.5' - 34.3'	Bedrock	Packer	5.0×10^{-2}
MW-2	18.4' - 23.2'	Bedrock	Packer	could not seal packer
	19.9' - 24.7'	Bedrock	Packer	5.0×10^{-2}
	24.7' - 29.5'	Bedrock	Packer	5.0×10^{-2}
	29.5' - 34.3'	Bedrock	Packer	5.0×10^{-2}
MW-3	13.5' - 18.7'	Bedrock	Packer	5.38
	15.9' - 20.7'	Bedrock	Packer	5.85
	20.4' - 25.2'	Bedrock	Packer	6.25
	24.9' - 29.7'	Bedrock	Packer	2.0×10^{-2}
	29.4' - 34.2'	Bedrock	Packer	4.19
MW-4	12.0' - 16.8'	Bedrock	Packer	4.0×10^{-2}
	15.6' - 20.4'	Bedrock	Packer	3.0×10^{-2}
	20.1' - 24.9'	Bedrock	Packer	5.0×10^{-2}
	24.6' - 29.4'	Bedrock	Packer	5.0×10^{-2}
MW-5	19.9' - 24.7'	Bedrock	Packer	17.5
	23.9' - 28.7'	Bedrock	Packer	7.6
	28.7' - 33.5'	Bedrock	Packer	1.25
MW-6	24.0' - 28.8'	Bedrock	Packer	7.0×10^{-2}
	28.5' - 33.3'	Bedrock	Packer	5.0×10^{-2}
	33.0' - 37.8'	Bedrock	Packer	2.0×10^{-2}
	37.6' - 42.4'	Bedrock	Packer	3.0×10^{-1}

(continued)

TABLE 2-3 (CONT'D)

SUMMARY OF HYDRAULIC CONDUCTIVITY MEASURED BY PACKER TESTS IN COREHOLES AT THE STAMINA MILLS SUPERFUND SITE NORTH SMITHFIELD, RHODE ISLAND

Page 2 of 2

MONITORING WELL NUMBER	TEST INTERVAL (ft)	GEOLOGIC MATERIAL	TYPE OF TEST	HYDRAULIC CONDUCTIVITY (ft/day)
MW-7	14.2' - 19.0'	Bedrock	Packer	3.0 x 10^{-2}
	18.7' - 23.5'	Bedrock	Packer	3.0 x 10^{-2}
	23.2' - 28.0'	Bedrock	Packer	3.0 x 10^{-2}
	27.7' - 32.5'	Bedrock	Packer	3.0 x 10^{-2}
MW-8	16.3' - 21.4'	Bedrock	Packer	3.0 x 10^{-2}
	20.3' - 25.1'	Bedrock	Packer	4.0 x 10^{-2}
	24.8' - 29.6'	Bedrock	Packer	3.0 x 10^{-2}
	29.3' - 34.1'	Bedrock	Packer	3.0 x 10^{-2}
MW-9	14.0' - 18.8'	Bedrock	Packer	3.0 x 10^{-2}
	18.5' - 23.3'	Bedrock	Packer	3.0 x 10^{-2}
	23.0' - 27.8'	Bedrock	Packer	3.0 x 10^{-2}
	27.5' - 32.2'	Bedrock	Packer	3.0 x 10^{-2}
MW-12	23.11 ' - 27'	Bedrock	Packer	2.5 x 10^{-3}
MW-15	11.61'-16.61'	Bedrock	Packer	15.28
	16.61'-21.61'	Bedrock	Packer	10.29
	21.61'-26.61'	Bedrock	Packer	3.4 x 10^{-3}
MW-16	15.12'-20.12'	Bedrock	Packer	13.3+
	19.62'-24.62'	Bedrock	Packer	14.0+

NOTES

1. Packer pressure test conducted in bedrock corehole using a double level inflatable packer, except in the corehole for MW-12, where a single packer was used.
2. The calculated water pressure required for the test could not be attained due to excessive water loss, therefore the hydraulic conductivity in this corehole is a low estimate.

The highest hydraulic conductivities were calculated for tests run at locations MW-3, MW-3A and MW-5, with conductivities on the order of 6 ft/day to 8 ft/day observed across the upper 15 to 20 feet of rock. A test run across the depth interval 29 to 34 feet at MW-3A, in which an open and sand-filled vertical joint was encountered, indicated a conductivity on the order of 5 ft/day. The low hydraulic conductivity values of the bedrock are in agreement with the low yields of residential wells which are generally less than 10 gpm.

Review of the hydraulic conductivity data presented in Table 2-3 and observations of rock cores as discussed in Section 2.23, indicate the following:

1. Over much of the Site, below the initial 5 feet of relatively fractured bedrock, openings associated with foliation planes are generally tight and are not thought to be carrying significant quantities of water. The hydraulic conductivity of the bedrock below 5 feet ranged from 3.0×10^{-1} ft/day to 7.6 ft/day and averaged 1.0 ft/day. The hydraulic conductivity of the top 5 feet of bedrock ranged from 3.0×10^{-2} ft/day to 17.5 ft/day and averaged 2.8 ft/day.

2. Locally across the Site the upper 15 feet of rock are significantly fractured/jointed as observed in rock cores.

3. Locally, high angle or vertical fracture zones in good hydraulic connection with other fractures are present, providing a vertical path for groundwater flow at the Site.

2.40 GROUNDWATER QUALITY

A number of groundwater sampling and analysis efforts were conducted on and in the vicinity of the Stamina Mills Site by various parties prior to the Remedial Investigation. Results of these groundwater analyses are summarized in Section 1.40 and are briefly discussed below to provide an understanding of the historical distribution of TCE in the groundwater. The results of sampling during the RI and prior to the pump test are discussed to establish pre-pump groundwater conditions.

The earliest sampling was conducted in 1979 when the RIDOH sampled water from the Stamina Mills supply well. Analysis of the water indicated the presence of TCE at a level of 267,000 ppb. Later in 1979, the RIDOH sampled the Forestdale Water Association Well and detected TCE at 413 ppb. An expansion of the sampling and analysis program by RIDOH into residential areas north of the Site revealed that groundwater in 18 of 51 residential wells sampled had levels of TCE ranging from 3 ppb to 7,000 ppb.

In 1980, Ecology and Environment, Inc. sampled water from seventy-six residential wells north of the Site. Levels of TCE and other chlorinated volatiles were detected at levels ranging from 1 to 13 ppb.

In 1982, Goldberg-Zoino and Associates, Inc., as part of an initial hydrogeologic investigation, sampled three monitoring wells installed at the Site, eight residential wells and two industrial wells north of the Site, the Stamina Mills well and a well south of the Site. Analytical results indicated TCE concentrations ranging from 27 to 8,000 ppb.

In 1984, NUS sampled water from seventy-six active and inactive drinking water supply wells in the vicinity of the Site. Screening of samples for the presence of volatile organic constituents indicated concentrations of total volatile organics (TVO's), the majority of which was TCE ranging from 0.1 ppb to greater than 674 ppb in forty-three wells. Levels of TVO's detected as a result of sampling by RIDOH, Ecology and Environment, Goldberg-Zoino and NUS between 1979 and 1984 are shown on Figure 2-9.

A round of groundwater samples were taken from selected on-Site wells and residential wells prior to the pump test. Table 2-4 provides a list of the wells sampled and the analytical results. Figure 4-1 and SP-1 show analytical results for each location sampled prior to the pump test. The wells were sampled prior to the pump test to define baseline groundwater quality conditions prior to the pump test with which to note changes in groundwater quality which may result from pumping of the Forestdale Water Association Well. The pre-pump samples were analyzed in the GHR field laboratory by headspace gas chromatography using an HNU Model 321 as described in Section 3.27 and detailed in Appendix C. Split-samples from the same locations were also submitted to the CLP for confirmatory analysis as shown on Table 2-4.

It is readily apparent, when comparing Figure 2-9 to SP-1 and Figure 4-1, that contaminant concentrations in most of the residential wells north of the Site have decreased since February 1985 when the Forestdale Water Association Well and most of the residential wells ceased pumping. This phenomenon could be viewed as indicative of a reversal of groundwater gradient since 1985 which caused the removal of the source of contamination to the supply wells. Consequently, contaminated groundwater which was drawn into the Forestdale Water Association Well and residential wells began to move toward local and regional areas of groundwater discharge when the pumps were turned off.

It is also evident, as shown on SP-1 and Figure 4-1, that concentrations of TVO's were present in groundwater north of the Site prior to initiation of the pump test. These concentrations are likely the result of residual contamination that was previously drawn from the Site and remains in the groundwater north of the Site as a result of the intermittent pumping of certain residential wells. For instance, it is known that up to the fall of 1987 wells at the J. Freitas and M. Freitas residences were periodically pumped to supply irrigation water. The presence of volatile organics in these wells prior to the pump test may be a result of this pumping or the result of residual contamination remaining in the bedrock aquifer in the residential area.

TABLE 2-4

ANALYTICAL AND GROUNDWATER ELEVATION DATA
RECORDED AT SELECTED INTERVALS DURING THE PUMP TEST
JUNE 15 THROUGH 19, 1988
STAMINA MILLS SUPERFUND SITE
NORTH SMITHFIELD, RHODE ISLAND

		PRE-PUMP TEST			12 HOURS INTO TEST		24 HOURS INTO TEST		36 HOURS INTO TEST		48 HOURS INTO TEST		60 HOURS INTO TEST		72 HOURS INTO TEST		92 HOURS INTO TEST	
SAMPLE LOCATION	SAMPLE DEPTH	CLPA (1.)	321 ANALYSES (2.)	G-WATER ELEV.	321 ANALYSES	G-WATER ELEV.	321 ANALYSES	G-WATER ELEV.	321 ANALYSES	G-WATER ELEV.	321 ANALYSES	G-WATER ELEV.	321 ANALYSIS	G-WATER ELEV.	321 ANALYSIS	G-WATER ELEV.	321 ANALYSIS	G-WATER ELEV.
Stamina Mills Well	SHALLOW INTER. DEEP	1837.0 (3.) 6230.0 15690.0	1746.5 6537.7 15190.0	197.27'	1358.2 9101.9 9183.0	197.13'	1197.8 4964.0 12220.0	197.09'	1757.4 4894.8 8076.9	197.06'	NS (9.) 3707.7 8641.2	197.01'	NS 3725.4 10560.0	196.93'	620.6 3325.2 10269.4	196.89'	426.8 678.5 9150.9	196.77'
I-2 (Kenoian)	SHALLOW INTER. DEEP	NA (5.) NA 3.0(J) (6.)	BDL BDL BDL	207.17'	BDL 1.8 (TR) BDL	195.03'	DRY 1.4 (TR) 1.4 (TR)	192.16'	DRY 1.8 (TR) 2.0 (TR)	192.78'	DRY BDL BDL	187.22'	DRY BDL BDL	185.95'	DRY 1.2 (TR) 1.1 (TR)	178.33'	DRY BDL BDL	170.82'
I-12 (M. Freitas)	SHALLOW INTER. DEEP	BDL 63.0(J) 93.5	BDL 10.5 57.8	208.56'	BDL 24.2 4.1		5.0 45.3 51.1	203.17'	BDL 44.7 50.8	204.01'	3.8 (TR) 31.4 29.3	202.92'	4.1 (TR) 40.2 38.0	201.69'	BDL 15.6 29.1	200.43'	BDL 14.0 12.1	190.16'
I-13 (J. Freitas)	SHALLOW INTER. DEEP	NA NA 3.0(J)	BDL BDL 1.4 (TR) (7.)	209.27'	BDL BDL BDL		BDL BDL BDL	211.13'	BDL BDL 13.5	199.39'	DRY BDL 15.8	196.85'	BDL BDL 32.3	195.23'	DRY BDL 28.5	192.70'	DRY 4.5 (TR)	189.95'
I-28 (Trudel)	SHALLOW DEEP	NA BDL	BDL BDL	209.36'	BDL BDL	206.47'	1.8 (TR) 1.2 (TR)	204.83'	BDL BDL	203.64	BDL BDL	202.43'	BDL BDL	201.05'	BDL BDL	199.67'	BDL	197.53'
I-31 (U.S. Post Office)	SHALLOW INTER. DEEP	BDL BDL BDL	BDL BDL BDL	208.03'	BDL BDL BDL	205.20'	BDL 1.4 (TR) 1.2 (TR)	203.50'	BDL BDL BDL	202.19	BDL BDL BDL	200.92	BDL BDL BDL	199.55'	BDL BDL BDL	198.06'	DRY BDL BDL	196.03'
I-32 (Forestdale Association Well)	SHALLOW DEEP	BDL 2.0(J)	BDL BDL	210.04'	BDL 2.4 (TR)	149.89'	2.1 (TR) 6.0 (TR)	139.21'	1.5 (TR) 7.6	140.27'	BDL 6.0	95'	BDL 7.3	91.35'	DRY 10.6	53.25'	DRY 13.7	42.94'
I-34 (Wheaton)	SHALLOW INTER. DEEP	NA NA BDL	1.2 (TR) BDL BDL	226.79'	BDL BDL BDL	222.83'	BDL BDL BDL	221.16'	DRY BDL BDL	219.12'	DRY BDL BDL	217.17'	DRY BDL BDL	215.19'	DRY BDL BDL	213.33'	DRY BDL BDL	204.73'
I-37 (Lovette)	SHALLOW INTER. DEEP	NA NA 13.0(J)	31.9 5.4 1.2 (TR)	208.68'	50.3 68.1 12.9	206.14'	59.4 67.9 13.4	204.79'	57.0 51.8 10.8	203.55'	31.3 57.4 10.8	202.37'	47.4 47.2 14.6	201.07'	42.3 48.2 9.9	199.72'	21.1 38.9 15.9	197.79'
MW-10A	148'-150'	330,000	242,172	NM	NA	NM	NA	NM	NA	NM	NA	NM	NA	NM	NA	NM	NA	NM
GZA B-1	50'	520 (J)	1,350	196.52'	NA	196.51'	NA	196.54'	NA	196.43'	NA	196.41'	NA	196.40'	NA	196.37'	NA	196.43'
GZA B-3	100'	6	2.9	207.94	NA	204.56'	NA	203.46'	NA	202.21'	NA	200.76'	NA	199.52'	NA	196.13'	NA	196.21'

NOTES

1. Results were determined at a CLP Lab using EPA Method 624.
2. Results are from field screening on an HNU Model 321 portable gas chromatograph.
3. Analytical results are in Parts Per Billion (PPB) and represent a sum total of trichloroethene, tetrachloroethene and 1,2-dichloroethene.
4. Groundwater elevations are in feet above mean sea level (MSL).
5. NA indicates sample not analyzed.
6. (J) indicates results are estimated value.
7. BDL indicates below detectable limits.
8. (TR) indicates results are quantifiable but below method detection limit.
9. NS indicates that the sample was not collected due to sample malfunction.
10. NM = Water table elevation not measured.

SECTION THREE

DESCRIPTION OF PUMP TEST

SECTION THREE - DESCRIPTION OF PUMP TEST

3.10 OBJECTIVE OF PUMP TEST

Previous studies of the Stamina Mills Site and surrounding areas have indicated that the TCE spill at the Site was the source of TCE contamination detected in residential wells north of the Site. This conclusion was based on the premise that when the residential wells north of the Site, including the Forestdale Water Association Well, were actively pumping, that the hydraulic gradient which is toward the Branch River to the south of the Site under non-pumping conditions would be reversed toward the residential area north of the Site. Additionally, the bedrock structure characterized by fractures connecting the Site with the residential area would provide a pathway for migration of TCE from the Site into residential wells.

In order to verify this premise and prove that a hydraulic gradient reversal is possible by pumping north of the Site, a 95 hour pump test of the Forestdale Water Association Well was conducted during the period of June 15 to June 19, 1988. The purpose of the pump test was to create a reversal of the static hydraulic gradient to confirm a hydraulic connection exists between the Site and the Forestdale Water Association Well. The piezometric surface developed during the pump test represents a snap shot of the specific hydraulic conditions that existed during the pump test. However, it is felt that the stress placed on the aquifer during the pump test was similar to the stress placed on the aquifer when the Forestdale Water Association Well was pumping. This premise is based on records of the number of residents using the Forestdale Water Association Well prior to February 1985 when the well was shut down due to contamination and calculations of the total water pumped from the Association Well.

According to records regarding residences holding shares in the Water Association provided to GHR by Paul Lavalle, Superintendent of the Water and Sewer Department in North Smithfield, Rhode Island (14) a total of 27 residences had rights to the water. The Stamina Mills facility also had rights to the water from the Association Well (the water likely served the

Stamina Mills office). According to the 1980 census conducted in the Town of North Smithfield, there is an average of 2.9 residents per household in the Town. Figures on the daily consumption of water per resident range from 75 gallons per day (GPD) (15) to 160 GPD (16). Using an average water consumption rate of 117 GPD, 2.9 residents per household and 27 residences potentially served by the Forestdale Well, it is calculated that the Association Well may have pumped approximately 9,161 GPD. This volume is in reasonable agreement with the 10,080 GPD rate at which the Association Well was pumped (7 GPM) during the pump test.

It is emphasized that the calculations presented above do not take into account possible use of the Association Well by employees of Stamina Mills or the fact that residences other than the 27 potentially served by the Association Well had their own wells which were pumping in conjunction with the Association Well. In fact, records indicate that some of the 27 residences potentially served by the Association Well also had their own wells. The significance of pumping the Forestdale Water Association Well in conjunction with private residential wells prior to February 1985 is that a much steeper hydraulic gradient may have occurred from the Site to the residential area north of the Site, than that realized during the pump test. Thus, the driving force for TCE migration from the Site to the residential wells prior to February 1985 may have been greater than that observed during the pump test.

3.20 PUMP TEST PROCEDURES

The following sections describe the methodology employed for conducting the pump test.

3.21 Selection of Wells to be Monitored

Selection of wells to be monitored (measurements taken of drawdown and recovery and samples taken for water quality) were based on the following criteria:

1. Wells from which samples had shown significant levels of TCE contamination based on past analyses (Stamina Mills, Post Office, Bosco, Trudel, J. Freitas, M. Freitas and Forestdale Water Association well) were chosen since it was suspected that these wells were hydraulically connected with the Site.

2. Wells north of the Site finished deep enough in bedrock to intercept fractures parallel to bedrock foliation which dip toward the north and northeast at angles ranging from 15 to 35 degrees were selected (those cited above plus Wheaton and Kenoian wells).

3. Selected on-Site bedrock monitoring wells (MW-2, -3, -5, -9, -13, -14, -15, -16, B-1, B-2 and B-3) were chosen to allow measurement of a hydraulic gradient reversal in a direction from the Site toward the Forestdale Water Association Well. Logs for these wells are provided in Appendix D.

4. The Tetrault well was chosen as the point at which it was felt that ambient water level fluctuations (unaffected by pumping) would be monitored. The selection of an ambient monitoring point was difficult since a well too far from the Forestdale Water Association Well could not be used since water levels in the wells may have been affected by active wells north, east and west of the Forestdale Water Association Well yet the ambient well could not be too close to the Forestdale Water Association Well since pumping would affect water levels in the ambient well.

5. Finally, wells which were aligned in a northwest-southeast and northeast-southwest direction in respect to the spill area at the Site were selected since the results of the strike and dip measurements, the fracture trace analysis and the downhole geophysical survey indicated the presence of fractures aligned in

these directions which could be contaminant pathways from the Site. These wells, as shown on SP-1, include Lovette CR#I-37, Trudel CR#I-28, Bosco CR#I-7, J. Freitas CR#I-13 and the Post Office CR#I-31.

3.22 Installation of Monitoring and Sampling Instruments, Survey of Wells

Monitoring instruments were installed in eight wells during the period of June 10 to June 14, 1988. The instruments consisted of pressure transducers and data loggers to measure drawdown and recovery and gas-drive groundwater samples to allow sampling of groundwater prior to, during and after the pump test.

Model SDEE-10B transducers and data loggers manufactured by Thor International, were installed in eight wells on June 10, 1988. The eight wells in which these continuous water level recorders were installed are listed on Table 3-1.

Use of the continuous recorders allowed for rapid collection of water level data with extreme accuracy. Water level measurements were taken manually in wells distant from the Forestdale Water Association Well except in the Stamina Mills well in which a transducer/data logger system was installed. The drawdown and recovery measured in the wells was used to provide information of the extent of the cone of depression caused by pumping of the Forestdale Water Association Well. Evaluation of the pump test data with respect to transmissivity and storativity is provided in Section 5.00. The water level information obtained from the data loggers is presented in Appendix H.

Prior to start-up of the step-drawdown pumping test, initial water level readings were obtained on June 9, 1989 at the monitoring locations with a standard, manually operated, electric water level indicator. The data loggers were then secured to the well casings. Before securing the transducers in place, each transducer-recorder was checked for accuracy by lowering the transducer to a predetermined depth. Transducer depths were calibrated with a steel tape. All transducer-recorder systems were found to be functioning properly.

TABLE 3-1

WELLS MONITORED DURING PUMP TEST
STAMINA MILLS SUPERFUND SITE
NORTH SMITHFIELD, RHODE ISLAND

WELL LOCATION		METHOD OF DRAWDOWN/ RECOVERY MEASUREMENT (1)	NUMBER AND DEPTHS (ELEVATIONS) OF GAS-DRIVE SAMPLER PLACEMENT (2)
1)	Stamina Mills	Transducer	3 @ 20' (184.03'), 115' (89.03') and 161' (43.03')
2)	Post Office (I-31)	Transducer	3 @ 58' (186.96'), 97' (147.46') and 178' (66.46')
3)	Forestdale Water Association Well (I-32)	Transducer	1 @ 176' (68.46'), Samples also taken from valve in discharge hose from pump set @ 240' (4.46')
4)	Kenoian (I-2)	Transducer	3 @ 76.5' (191.55'), 111' (157.05') and 194' (74.05')
5)	M. Freitas (I-12)	Transducer	3 @ 84.5' (176.96'), 158' (103.46') and 280' (-18.54')
6)	J. Freitas (I-13)	Transducer	3 @ 86' (171.76'), 160' (97.76') and 230' (27.76')
7)	G. Wheaton (I-34)	Manual	3 @ 49' (215.29'), 92' (172.29') and 166' (98.29')
8)	P. Lovette (I-37)	Transducer	3 @ 50' (177.2'), 105' (122.2') and 295' (-67.8')
9)	B. Trudel (I-28)	Manual	2 @ 57' (181.44') and 141' (97.44')
10)	G. Bosco (I-7)	Transducer	None
11)	G. Tetrault (I-36)	Manual	None
12)	MW-2	Manual	None

TABLE 3-1 (Cont'd)

WELL LOCATION		METHOD OF DRAWDOWN/ RECOVERY MEASUREMENT (1)	NUMBER AND DEPTHS (ELEVATIONS) OF GAS-DRIVE SAMPLER PLACEMENT (2)
13)	MW-3	Manual	None
14)	MW-5	Manual	None
15)	MW-9	Manual	None
16)	MW-13	Manual	None
17)	MW-14	Manual	None
18)	MW-15	Manual	None
19)	MW-16	Manual	None
20)	B-1	Manual	Baseline CLP Sample Only
21)	B-2	Manual	None
22)	B-3	Manual	Baseline CLP Sample Only

(1) Drawdown measurements periodically taken from wells monitored with transducers to confirm transducer recordings.

(2) Pre-pump baseline samples taken from SM Well, I-31, I-32, I-2, I-12, I-13, I-34, I-37, I-28, B-1 and B-3 for Contract Laboratory Program analyses.

Between the period of June 10 and 15, 1988 ambient (pre-pump) groundwater levels were monitored in I-2, -31, -32 and -34 wells on an hourly basis. Ambient water level data was analyzed, background water level data was used to determine if changes in barometric pressure would produce significant changes in water levels. Barometric readings were obtained from the weather station at T.F. Green Airport in Warwick, Rhode Island. The change in barometric pressure over a twenty-four hour period from June 12, 1988 to June 13,1988 was used along with the change in water level in the Forestdale Village Well for the same time period to determine the barometric efficiency (BE) from the following equation (Ferris et. al., 1962) (17):

$$BE = (WB) 100$$

where W is the change in water level and B is the change in barometric pressure expressed in feet of water.

The calculated barometric efficiency was then used to determine whether adjustments in drawdowns that were recorded during the pump test would be required. Barometric changes over twenty-four hour periods during the test were evaluated to determine if the corrections would be significant. The largest change in barometric pressure (0.16 ft of water) occurred between June 17, 1988 and June 18, 1988. This change resulted in a water level correction of 0.027 feet which was considered to be negligible. The barometric efficiency and water level correction calculations are presented in Appendix E.

While the transducers were being installed, the data loggers installed in the eight wells indicated in Table 3-1 were programmed to record drawdown at the following frequency:

Test Time (minutes)	Recording Frequency
0 - 3	6 second intervals
3 - 20	30 second intervals
20 - 60	1 minute intervals
60 - END	1 hour intervals

Prior to pump test termination, the data from the loggers was down loaded into a Psion brand personal computer and the loggers were programmed to record recovery readings at the same frequency as drawdown measurements were recorded.

Gas-drive groundwater samplers were installed in nine wells on June 13 and 14, 1988 to facilitate sampling of wells prior to, during and at the termination of the pump test. A schematic diagram of the gas-drive samplers installed in the wells is provided in Appendix F. Gas-drive samplers were selected for use as sampling instruments for the following reasons:

1. Sampling the gas-drive instrument would not disturb the water column as great as sampling by bailer or by pumping. Thus, potential contaminants in the wells would not be mixed resulting in mixing a composite sample from the entire vertical water column in the well rather than a sample from a discrete fracture zone.

2. Discrete fractured zones in the bedrock, as identified during the downhole geophysical survey, which could be migration pathways from the Site for TCE could be sampled. These discrete fractured zones are identified in Appendix B.

3. Withdrawal of water from the sampling tubes in the gas-drive samplers would not result in fluctuations of water levels in the wells which would be measurable on the transducer/data logger system. For example, in a 6-inch diameter, 300-foot well which contains approximately 440-gallons of water, withdrawal of one volume of water from the gas-drive system with one-half inch sampling tube would result in the removal of approximately .17 gallons of water from the well or .03 percent of the total volume of water in the well.

Prior to conducting the pump test, samples were withdrawn on June 15, 1988 from wells I-2, -31, -32 and -34 (which were also monitored from pre-pump ambient conditions; Section 3.23) to determine if water withdrawal was recorded on the data loggers. It was determined that water withdrawal did not influence water levels enough to be recorded on the data loggers. Results of this test are provided on the water level recording data for pre-pump conditions provided in Appendix C. In addition to measurement of possible water fluctuation during sampling by the transducer system, manual measurements were taken from the wells at the time samples were taken. Changes in water levels were not observed by manual measurement during sampling of the gas-drive systems.

4. Sampling from the gas-drive instruments would be less time consuming than sampling by methods such as bailing or pumping.

5. Sampling from the gas-drive instruments would allow for generation of real time analytical data with which to identify migration of volatile organics in the bedrock aquifer during the pump test.

Appendix F contains a description of the construction of the gas-drive sampling instruments and the methodology by which the instruments are sampled.

Bundles of samplers, two to three per monitored well, were lowered to the depths indicated on Table 3-1. In wells in which downhole geophysics was conducted, gas-drive samplers were installed in the three most fractured zones in the well as determined by the acoustic televiewing logging. In other wells in which downhole geophysics was not conducted, samplers were installed at the bottom of the well, below the water table and at a distance half way between the bottom and shallow sampler. The sampling tubes were secured to the top of the well and each tube was labelled and color coded according to the depth to which it was installed.

The top of the well casings from which measurements were taken were surveyed for location and elevation by GHR on July 29, 1988 and August 3, 1988, respectively. The top of the well casing which was surveyed and from which all measurements were taken was clearly marked with paint.

3.23 Measurement of Pre-Pump Ambient Groundwater Levels

Between the period of June 10 and 15, 1988 ambient (pre-pump) groundwater levels were monitored in I-2, -31, -32 and -34 wells on an hourly basis via transducers and data loggers. These measurements were taken to assess fluctuations in groundwater levels which would occur naturally due to factors such as recharge and changes in barometric pressure and artificial fluctuations caused by groundwater withdrawal by active wells in the vicinity of the Forestdale Water Association Well.

These measurements were used during evaluation of the pump test data to explain anomalies observed in the drawdown and recovery curves caused by pumping of residential wells.

3.24 Discharge Line Installation

Permission was obtained by letter on May 23, 1988 from the City of Woonsocket, Rhode Island Department of Public Works, Pretreatment Division (18) to discharge water pumped from the Forestdale Water Association Well into the sanitary sewer line which is located at the Site. A 4-inch flexible PVC discharge line was installed on June 9, 1988 between the Forestdale Water Association Well and Main Street, then installed below Main Street by way of a storm drain. The end of the discharge line was installed in the sewer line through a manhole structure.

3.25 Step-Drawdown Test

A step-drawdown test was attempted on June 9, 1988 using a 5-horsepower submersible pump which was throttled to pump at 7-gallons per minute. Back pressure was created in the discharge line between the pump and the flow meter and gate valve which exceeded the pressure rating of the hose. As a result, the hose failed and the test was discontinued.

A new smaller capacity pump 2-horsepower pump was installed in the Forestdale Water Association Well on June 12, 1988. The step-drawdown test was repeated on June 14, 1988 at a pumping rate of 10 gpm which was maintained for 1 hour. A maximum drawdown of 32 feet resulted during the test. A drawdown curve was plotted which suggested that the well bore would dewater if the pumping rate of 10 gpm was maintained through the entire pump test. Therefore, the pump rate was throttled down to 7 gpm and maintained at that rate for 2 hours. A drawdown curve plotted for the 7 gpm rate indicated that this rate would not likely dewater the well. Thus, the 7 gpm rate was selected for the pump test.

3.26 Pre-Pump Groundwater Sampling and Analysis

On June 15, 1988, prior to start-up of the pump test, groundwater samples were taken from selected monitoring wells on-Site and the residential wells which were monitored during the pump test. Sampling locations are listed on Table 2-2 and shown on SP-1. Split samples were taken at selected sampling locations with one sample submitted to the on-Site field laboratory for volatile organic analysis on an HNU Model 321 and the other sample submitted to the CLP for confirmation of the on-Site analysis. (The screening method used in the field laboratory is discussed below.) The analysis of pre-pump samples provided baseline groundwater quality data with which to compare samples taken during the course of the pump test to determine if pumping of the Forestdale Water Association Well was causing mobilization of TCE contaminated groundwater from the Site.

3.27 In-Field Volatile Organic Analyses

Water samples collected prior to, during and at the termination of the pump test were analyzed for volatile organic compounds in an on-Site laboratory. The analyses were analyzed by headspace gas chromatography using an HNU Model 321 gas chromatograph equipped with series mounted photoionization and electrolytic conductivity detectors. The field analysis was optimized for the separation and quantitation of the volatile halocarbons dichloroethene, trichloroethene (TCE) and tetrachloroethene (PCE) as part of a laboratory precalibration method evaluation. The minimum detection limit using this procedure is approximately 5.0 ug/l for each of the three target compounds, and by adjusting injection volumes and detector attenuation setting levels of up to 1,000,000 ug/l can be measured. An in-depth discussion of the HNU 321 analytical technique is provided in Appendix C.

In all a total of 304 samples were analyzed during the pump test. Results were computed and made available to the Project Manager within several hours of collection. Twenty-three (23) samples were sent out for volatile organic analysis under the EPA Contract Laboratory Program (CLP). Nineteen (19) of the twenty-three (23) samples were groundwater samples from twelve (12) well locations. Multiple samples (number indicated in parenthesis) from different depths were taken from I-32 (2), I-12 (3), I-31 (3), and the Stamina Mills well (3). One sample each was taken from B-1, B-3, I-2, I-13, I-34, I-28, I-37 and MW-10A. Two duplicate and two blank samples were submitted to the Contract Laboratory Program. Wells B-3, MW-10A and B-1 were not periodically sampled during the pump test, thus analytical results for samples from these wells are not shown on Table 2-2. Eleven (11) of these samples from the Stamina Mills wells (3), I-2 (1), I-12 (2), I-13 (1), Forestdale Water Association Well (1), I-37 (1), B-3 (1) and MW-10A (1) contained detectable levels of volatile organics. Comparable results were obtained by the Contract Laboratory Program and on-Site analyses for nine of these eleven samples. The two samples for which analytical results by Contract Laboratory Program were not comparable to results of the HNU-321 analyses were from I-12 Intermediate and I-37 Deep (Table 2-4). Analytical results by CLP versus HNU-321 of groundwater from I-12 differed by a factor of six while results from I-37 differed by an order of ten. All other analyses compared very well to one another.

The apparent differences in levels of volatile organics in groundwater from I-12 and I-37 may be due to a number of factors including sampling technique, sample bottle to sample bottle variability, and differences in test methods. Overall the field screening method succeeded in detecting the presence of low levels of volatile halocarbons and provided valuable real time data which was used to guide the progress of the pump test.

3.28 Criteria for Termination of Pumping

Prior to the pump test the USEPA, ACOE and GHR jointly established criteria to be used in determining when the pump test should be terminated. Of utmost concern was establishing a criteria to reduce the chance of inducing the migration of TCE contaminated groundwater from the Site to the residential area which could be caused by the anticipated reversal of the hydraulic gradient from south to north. Thus, it was decided that if a reaction to pumping was noted on the Site by drawdown in bedrock well(s) or if a discernable gradient reversal from the Site or just north of the Site along Main Street was reached, then the pump test would be immediately terminated. Alternately, if a one order of magnitude change in TCE concentrations were noted after two consecutive samples were taken during a four hour interval in any of the wells located along Main Street (Post Office, Trudel or Lovette) then the test would be terminated.

It is noted that the pump test was conducted without fear of contaminating an area north of the Site which was uncontaminated prior to the pump test since historical and current analytical data indicated that the groundwater in this area was already contaminated with TCE. The intent of monitoring hydraulic gradients and groundwater quality was to prevent further degradation of groundwater quality in the area of Main Street. Additionally, it is noted that even if TCE contamination from the Site was induced toward the residential area, the health of residents would not be threatened since residents with wells that had been impacted by TCE contamination had been provided with a source of public water.

To ensure that drawdown on the Site or a gradient reversal was expeditiously noted, periodic manual water level measurements (as well as drawdown recorded by the data loggers) were taken from all wells monitored during the pump test. Groundwater samples were withdrawn from all wells monitored on a periodic basis and analyzed for volatile organics in the field laboratory to allow changes in water quality to be noted. The frequency of manual water level measurements and groundwater supply is discussed below.

3.29 Pump Test Procedure

The pump test began at 2100 hours on June 15, 1988. During the test manual water level measurements were taken from all wells on twelve hour intervals and from selected wells on a six hour basis. On the third day of pumping, the pumping rate was increased from 7 gpm to 10 gpm in order to maximize the stress in the aquifer and manual measurements were taken on an accelerated basis of six then four hour intervals in selected on-Site wells and the residential wells bordering Main Street. Drawdown data were corrected to elevations and contours and contoured immediately after each round of measurements were taken.

Groundwater quality was assessed by sampling all the wells in which drawdowns were measured initially. This was performed on a twelve hour basis. Toward the end of the pump test when a gradient reversal was observed, the sampling frequency in selected wells was increased to six then four hour intervals.

Operational checks were made of the transducer and data loggers on twelve hour intervals by comparing the manual water level measurements with read-outs from the data loggers.

At 1400 hours on June 19, 1988, a hydraulic gradient from Main Street just north of the Stamina Mills well to the Forestdale Water Association Well was realized. To reduce the chance that TCE contaminated groundwater from the Site would migrate toward the residential area, the pump test was terminated at 2000 hours on June 19, 1988. A final round of groundwater samples were taken before pump test termination.

Groundwater recovery measurements were taken from June 19 to June 22, 1988 for a total of 69 hours. Measurements were taken by the transducer/data logger systems.

SECTION FOUR

DRAWDOWN AND GROUNDWATER QUALITY DATA EVALUATION

4.10 PRE-PUMP CONDITIONS

Water levels were measured in the Forestdale Water Association Well, eight private wells and seven monitoring wells on the Site on June 15, 1988 just prior to beginning the pump test. With the exception of MW-2 and MW-15 which are respectively located adjacent to Branch River and Forestdale Pond, only deep bedrock wells that could potentially intersect many fractures were used to construct the groundwater elevation and drawdown maps shown as Figures 4-1 through 4-6. Shallow bedrock wells were not used for this purpose because, from review of the drawdown data it is apparent that some of these wells are not in good hydraulic communication with deeper water bearing fractures. Groundwater elevations and contours for pre-pumping conditions are shown on Figure 4-1. The ambient water table map shows the presence of a groundwater high in the vicinity of the Wheaton well with groundwater elevations decreasing radially and uniformly from the well in all directions at approximately the same hydraulic gradient. Table 4-1 lists representative hydraulic gradients that were calculated from Figure 4-1.

TABLE 4-1

PRE-PUMPING HYDRAULIC GRADIENTS

LOCATIONS OF MEASUREMENT	HYDRAULIC GRADIENT (FT/FT)
Wheaton to Kenoian Well	0.035
Wheaton to M. Freitas Well	0.049
Wheaton to Stamina Mills Well	0.044
Wheaton to Tetrault Well	0.029

This data is consistent with the local geology and conceptual model developed in Section 2.32 which concluded that under ambient conditions groundwater is flowing through a distribution of fractures and fissures from the topographically higher areas north of the Stamina Mills Site to local and regional areas of discharge. Groundwater from the vicinity of the Wheaton well flows: a) west and northwest in the direction of a tributary to the Branch River, b) south and southwest in the direction of Forestdale Pond and c) southeast in the direction of Branch River.

Of particular interest in Figure 4-1 is groundwater flow in the vicinity of Forestdale Pond and Branch River. Due to the presence of the dam across the Branch River at Stamina Mills, surface water elevations are 200.67 feet and approximately 185 feet in Forestdale Pond and the Branch River, respectively in these two water bodies. Analysis of the bedrock groundwater contours for this portion of the Site indicate the presence of a north-south trending groundwater divide passing just west of the Trudel well and through MW-3 as shown on Figure 4-1 such that under ambient (non-pumping) conditions groundwater west of this divide flows from topographically higher areas north of Main Street into Forestdale Pond and groundwater east of the divide flows from the pond through a portion of the Site and then into Branch River. In Figure 4-1, there is also a second groundwater divide trending east-west and passing through the Stamina Mills well. This divide distinguishes between groundwater flowing through the Stamina Mills Site from the upland areas and groundwater flowing from Forestdale Pond. This interpretation is consistent with bedrock groundwater contours for August 1986 as depicted in Figure 5-13 of the RI and for groundwater contours developed for October, 1988 and displayed on SP-1.

With respect to Forestdale Pond, this means that west of the divide the pond is receiving groundwater from the bedrock aquifer and east of the divide surface water is leaking into the aquifer through fractures and fissures, passing through the eastern part of the Stamina Mills Site, and flowing into Branch River. These flow conditions and the location and orientation of the groundwater divides changed considerably during the pumping test as the cone of depression for the Forestdale Water Association Well expanded in the direction of these natural recharge boundaries.

4.20 CONDITIONS DURING THE TEST

In order to better understand the hydrogeology of the bedrock aquifer north of the Site under pumping conditions, a series of three (3) groundwater elevation maps at approximately 24 hour intervals (Figures 4-2 through 4-4) were prepared that illustrate the growth of the cone of depression and the reversal in hydraulic gradient that occurs in the direction of the Stamina Mills Site. A fourth map depicting groundwater contours at the end of the pump test is presented as Figure 4-5 and Figure 4-7 depicts total drawdown at the end of the test.

The pump test began at 2100 hours on June 15, 1988 and by 1800 hours on June 16 (21 hours later), the Forestdale Water Association Well (pumping at a rate of 7 gpm) had developed nearly 70 feet of drawdown. By that time a distinct cone of depression, shown on Figure 4-2 as groundwater elevation contours in bedrock, had developed. As can be seen from Figure 4-2, the groundwater contours began to exhibit strong anisotropic properties in specific directions. Comparing Figure 4-2 with the ambient contours shown on Figure 4-1, one can see that the groundwater high near the Wheaton well that existed north of the Site just prior to initiating pumping has disappeared completely and groundwater has begun to migrate in an anisotropic fashion from three directions south of the Forestdale Water Association Well toward the pumping center: 1) northerly in a wide band from the vicinity of the Bosco and Post Office wells, 2) northeasterly from the Lovette well along a narrow path, and 3) from what has been inferred (due to lack of data along Maple Avenue) to be in a westerly direction from the Tetrault well. In examining the contours in Figure 4-2, the almost immediate drawdown in well B-3, located 85 feet east of the Stamina Mills well and 925 feet from the pumping well is evident. The water level in B-3 had declined 4.48 feet in this first 21 hour pumping period and the anisotropic nature of the aquifer, caused by the fractures in the bedrock, is clearly depicted by the shape of the groundwater contours. These flow directions are consistent with the conclusions arrived at in Section 2.20 that suggest that water bearing fractures show some preferred orientations namely northwest-southeast, northeast-southwest and east-west.

Of particular interest to note in Figure 4-2 is the fact that a temporary east-west trending groundwater divide representing the downgradient stagnation point has developed between the Site and the Forestdale well just north of Main Street. This is depicted by the pair of 202 foot contours and the closed 204 foot contour shown on Figure 4-2. The 200 foot contour trending east-west just north of the Stamina Mills well has remained unchanged at this point in time but a second 200 foot contour has appeared north of the Post Office, Bosco and Trudel wells.

By June 17 (46 hours into the pump test), 115 feet of drawdown had developed in the Forestdale Water Association Well. The pumping rate had been increased from 7 gpm to 10 gpm in order to maximize the stress on the aquifer. During this time period, drawdowns in the Kenoian, J. Freitas and Tetrault wells have increased approximately 5 feet at each location while drawdowns in the Lovette, Trudel, Bosco and Post Office wells increased about 2 feet at each well.

Groundwater elevations and contours for this time period are depicted on Figure 4-3 and show that the shape of the water table is essentially the same as that of June 16. The principle difference is that the 204 foot contour that encompassed the Bosco well in Figure 4-2 has disappeared as water levels in that well dropped over 2 feet to an elevation of 203.98 feet. The groundwater divide between the pond and the pumping well is now represented by the closed 202 foot contour which continued to diminish as the cone of depression expanded towards Forestdale Pond.

On June 18, 1988 after sixty-eight hours into pumping test, drawdowns in the aquifer, depicted as groundwater elevation contours on Figure 4-4, have maintained their same anisotropic shape. The cone of depression has continued to expand in the direction of Forestdale Pond and Branch River and in fact has reached the pond just west of the Bosco well. This is evidenced by the fact that groundwater elevations in both the Lovette and Trudel wells have dropped below 200 feet while the pond has remained at 200.67 feet. This means that all of the groundwater west of the north-south groundwater divide depicted on Figure 4-4 is now flowing from the Forestdale Pond to the Forestdale Water Association Well and that a complete reversal of groundwater flow has been achieved on the western portion of the Site.

The 200 foot contour which under ambient conditions was depicted in Figure 4-1 as an inverted V opening in the direction of Branch River now runs east west from the dam towards Lovette's well indicating that the entire northern shore of Forestdale Pond that abuts the Site is recharging the aquifer. From Figure 4-4 it can be seen that a portion of the pond water still flows through the Site into Branch River east of the north-south divide and groundwater in a small portion of the aquifer near the Bosco well also flows towards the Branch River. There continues to exist the remains of an east-west groundwater divide on the eastern part of the Site between B-3 and the Post Office well represented by the 198 foot contour that appears in Figure 4-4 on either side of Main Street in the vicinity of the Post Office well and the contracted 200 foot contour around the Bosco well. Water levels in B-3 continue to decline and water levels in the Stamina Mills well remain unchanged.

4.30 DRAWDOWN AT TERMINATION OF TEST

On June 19, 1988, eighty-nine hours into the pumping test, just prior to shut down, the hydraulic gradient between Forestdale Pond and the Forestdale Water Association Well has increased as groundwater elevations in the Lovette and Trudel wells have dropped almost 2 feet in each well. Figure 4-5 depicts the bedrock groundwater contours for this point in time. The north-south groundwater divide depicted on Figure 4-4 has shifted more than 200 feet to the east past the Stamina Mills well indicating that more of the pond is contributing water to the Forestdale Water Association Well and, more importantly, that most of the Site is within the recharge area of the Forestdale Water Association Well.

Although one source of recharge to the aquifer (Forestdale Pond) had been reached, drawdown in the Forestdale Water Association Well had not stabilized even though the pumping rate had been increased 43 hours earlier. The water level in the Stamina Mills well, which until this point in time had remained unaffected by pumping, has begun to exhibit a drawdown of 0.41 feet while well B-3 located sixty feet east of the Stamina Mills well has dropped a total of 11.74 feet throughout the test. As the drawdown in well B-3 continued to decline throughout the pumping test, the hydraulic gradient between B-3 and the Stamina Mills well appears to have decreased at a uniform rate and reversed direction approximately 80 hours into the pumping test. This is graphically depicted in Figure 4-6 and in the groundwater contours and the inferred flow directions shown in Figures 4-1 through 4-5.

Shortly after this time, because the objective of the pumping test had been achieved, the Forestdale Water Association Well was shut down for fear of causing contaminants at the Site in the vicinity of the spill area to migrate off-Site. A hydraulic gradient between the Stamina Mills well and the Forestdale Water Association Well had been established along a northwest-southeast trending fracture passing through well B-3 and the Forestdale Water Association well.

Figure 4-7 depicts total drawdowns at the end of the pump test. The directions of anisotropy, which represent the orientation of water bearing fractures with respect to pumping the Forestdale Water Association Well, are clearly visible. The shape of the isopleths are similar to the groundwater contour maps already discussed. Because of the drawdown response in the wells that were monitored, the spur in the direction of B-3 suggests the presence of a more transmissive fracture in that direction and consequently a well defined contaminant migration pathway extending from the Site toward the Forestdale Water Association well.

This is consistent with data gathered by GZA when they performed a short duration pumping test on well B-3 in September 1982 (9). After pumping well B-3 at approximately 10 gpm for 2.5 hours, 109 feet of drawdown had been produced in the pumping well and 61 feet of drawdown had been produced in the Post Office well, 165 feet northeast of B-3. The Stamina Mills well showed 0.3 feet of drawdown during the same period of pumping B-3.

There is also shown on Figure 4-7 a spur aligned east-west elongated in the direction of the Tetrault well. This spur may be associated with east-west fracture sets which are associated with the inferred contacts between the Blackstone series quartzites and schists.

4.40 PRE-PUMP GROUNDWATER QUALITY CONDITIONS

Review of the areal distribution of the pre-pumping water quality data, which was analyzed using an HNU-301 and is depicted in Figure 4-1 as total volatile organics (TVO), indicate that, with the exception of the Stamina Mills well which is highly contaminated (15,190 ppb TVO), there are low levels of contamination northwest of the Site in the Lovette well (41.8 ppb TVO) and the M. Freitas well (57.8 ppb TVO). J. Freitas' well and Wheaton's well were the only other wells that had any volatile organics (1.4 ppb and 1.2 ppb, respectively). The presence of low levels of volatile compounds in groundwater hydraulically upgradient and west of the Site suggests that this is residual contamination that was drawn from the Site back to the private wells under a condition of a reversal of the hydraulic gradient between the Site and the private wells when those wells were active. Now that the wells are no longer pumping, the contaminated groundwater is slowly migrating under natural flow conditions to points of groundwater discharge in Forestdale Pond and the Branch River.

Figure 2-9 depicts the historical distribution of TVO's in private wells for four time periods. The figures show that concentrations of organic contamination in the vicinity of the Forestdale Water Association

Well and J. Freitas well were substantially higher than in the Lovette and M. Freitas wells as late as 1984 (Figure 2-9) when many of the private wells were still pumping. This condition changed substantially after most of the private wells had been connected to the public supply in 1986 as can be seen from Figure 4-1 and ambient flow conditions had been restored in the aquifer.

4.50 GROUNDWATER QUALITY CONDITIONS DURING AND AT TERMINATION OF TEST

Of the wells that were sampled throughout the pumping test only the Stamina Mills well and the M. Freitas and Lovette wells had contamination above 10 ppb (TVO) throughout the entire pump test at all sampling depths. The J. Freitas well had trace levels (TR) in the deep sampler at the beginning of the test and began to show concentrations greater than 10 ppb 36 hours into the pump test steadily increasing until the end of the test when a 4.5 ppb (trace concentration) was detected. Similarly, the Forestdale Water Association Well showed below detection level (BDL) to trace (TR) levels at the beginning of the test but by the end of the test 13.7 ppb was being measured in groundwater from the intermediate gas drive sampler. This data is presented in Table 2-4 and Figures 4-8 and 4-9.

Concentrations of TVO's in the shallow and intermediate samples in the Lovette well were measured at 50.3 ppb and 68.1 ppb, respectively, 12 hours into the pump test and steadily decreased to values of 21.1 ppb and 38.9 ppb respectively (Figure 4-8). Levels in the deep sampler at this location remained essentially constant varying between 12.9 ppb and 15.9 ppb. Similarly, concentrations in the intermediate and deep samplers installed in the M. Freitas well were determined to be 63 ppb (J) and 93.5 ppb, respectively, at the beginning of the test. Concentrations in these samplers continued to decrease to 14 ppb and 12.1 ppb by the end of the pump test (Figure 4-8).

The Lovette and M. Freitas wells are hydraulically upgradient relative to the established cone of depression of the Forestdale Water Association Well. Both these latter wells showed increases in TVO concentrations from

1.4 ppb (TR) in the J. Freitas well and BDL in the Forestdale Water Association Well at the beginning of the pump test to 28.5 ppb and 13.7 ppb, respectively, at the end of the test (Figure 4-8). This indicates that as groundwater flow directions were reversed and contaminated groundwater began flowing from the Lovette and M. Freitas wells towards the production well, in the absence of a contaminant source near these wells, concentrations decreased in upgradient wells (Lovette and M. Freitas) and increased in the downgradient wells (J. Freitas and the Forestdale Water Association Well).

It is also interesting to note that although drawdown in the Stamina Mills well remained unchanged until almost the end of the pumping test, as the groundwater flow patterns changed in the vicinity of the Stamina Mills well in response to pumping the Forestdale Water Association Well, concentrations in the shallow and intermediate gas drive samplers in the Stamina Mills well decreased an order of magnitude from the beginning to the end of the pumping test (Table 2-2 and Figure 4-10). TVO concentrations ranged from 1746 ppb, 6537 ppb and 15190 ppb in the shallow, intermediate and deep samples respectively at the beginning of the test and decreased to 427 ppb, 678 ppb and 9151 ppb at the end of the test. One possible explanation for this is that groundwater flow in the vicinity of the Stamina Mills well changed direction from a southeasterly to easterly direction from the beginning to the end of the pumping test as shown in Figures 4-1 and 4-5. As the groundwater divide shifts under the influence of pumping the Forestdale Water Association Well, the source of water passing through the Stamina Mills well changes from a combination of aquifer and pond water at the beginning of the test (Figure 4-1) to all pond water at the end of the pumping test (Figure 4-5) so that a reduction in TVO concentrations in the Stamina Mills well due to dilution from a contaminant free source of water (i.e., Forestdale Pond) may have been realized.

SECTION FIVE

REDUCTION OF PUMP TEST DATA

SECTION FIVE - REDUCTION OF PUMP TEST DATA

5.10 INTRODUCTION

Pumping of the Forestdale Water Association Well was initiated at 2100 on June 15, 1988 with a pumping rate of 7 gallons per minute (gpm). On June 17, 1988 at 1400 hours the pumping rate was increased to 10 gpm in order to maximize the drawdown in the production well thereby maximizing the stress on the bedrock aquifer. Pumping ended and recovery measurements began at June 19, 1988 at 2000 hours. Recovery was monitored until June 22, 1988 at 1200 hours. Recovery data was not used to define aquifer parameters but was collected as a back-up to the drawdown data. This was done in the event of transducer malfunction which may have resulted in the loss of drawdown data.

Water levels were monitored at selected well locations as described in Section 3.00. Automatic water level recorders were installed in observation wells I-2, -7, -12, -13, -31, -34 -37 and the Forestdale Village Well for five days prior to pumping in order to measure ambient (non-pumping) groundwater and to identify any water level fluctuations which may be caused by changes in barometric pressure, recharge due to precipitation or pumping of active wells north of the Forestdale Water Association Well (refer to SP-1). A graph of water levels recorded over the period of June 10, 1988 to June 15, 1988 shows rather sporadic water level fluctuations, particularly in I-2 (see Appendix G). These fluctuations were likely caused by the short term pre-testing (pumping) of the Forestdale Water Association Well conducted on June 11, 13 and 14, 1988 and by active residential wells, particularly in the vicinity north of I-2. Active residential wells are shown on SP-1. It is possible to identify water level fluctuations caused by pumping residential wells north of I-2 because the pumping periods for the residential wells is short relative to the long term constant rate at which the Forestdale Water Association Well was pumped and the resultant drawdown trend due to long term pumping of the Forestdale Water Association Well can be identified. Consequently, the water level fluctuations caused by short term, sporadic pumping of the wells north of I-2 did not affect evaluation of the pump test data.

The water level data recovered from the data loggers was converted to drawdowns and plotted versus time since pumping began on double logarithmic and semilogarithmic graphs. Drawdown versus the square root of time was also plotted on an arithmetic graph for analysis. Drawdown versus time and residual drawdown versus time (recovery) plots are provided in Appendix H. Data analysis is discussed in detail in the following sections.

5.20 DATA EVALUATION

Evaluation of pump test data typically involves plotting drawdown versus time data and matching the test data to theoretical well function curves (type curves) developed for specific aquifer models. Selection of the appropriate type curve is dictated by the conceptual model of the aquifer developed from available subsurface information obtained from soil borings, rock cores, geophysical data, and pressure response data collected from observation wells.

The following aquifer information and general observations of the aquifers response due to pumping were used as a basis for selection of the specific analytical models:

1. The aquifer consists of a fractured phyllitic schist.
2. In general, the bedrock surface is covered with a thin veneer of glacial till.
3. There are two types of porosity associated with the bedrock aquifer. There is a porosity component associated with the intergranular spaces of the rock matrix and bedrock foliations.

There is also a porosity component, which is considered to be more significant in terms of water storage. This second porosity component is associated with the major fracture system.

4. The fracture system, based on measurements taken from bedrock outcrops and downhole geophysical data indicate that the greatest frequency of fractures are oriented northwest-southeast, northeast-southwest and east-west.

5. The reaction time and drawdown rate for the first 100 minutes of pumping is greatest in observation well I-2 located 260 feet from the Forestdale Water Association Well even though there are two observation wells (I-12 and -13) located in close proximity to the production well (245 feet and 190 feet respectively) which did not show the response to pumping that I-2 did. Similar reactions to pumping (i.e., faster and greater drawdown in wells further from the Forestdale Water Association Well than those closer to the Forestdale Water Association Well) were noted during the pump test. These reactions suggest some degree of variability in the hydraulic communication between the Forestdale Water Association Well and observation wells and indicates the bedrock aquifer is acting as an anistropic porous media.

6. A decrease in the drawdown rate is observed in observation wells I-2 and -13 following the initial drawdown period suggesting that in the absence of any recharge, of which there was none, drainage from the porous rock unit is occurring. The decrease in the drawdown rate at observation well I-2 and -13 appears to coincide with the early drawdown periods for the more distant wells I-12, -28, -21 and -37 located in an arc 500 feet to 800 feet from the Forestdale Water Association Well.

Analytical models for evaluation of fluid flow through fractured media can be divided into two categories based on the conceptualization of the fractured formation. The first category of analytical techniques assumes that the aquifer system consists of a two component system, the rock matrix and the fractures. In the two component system, each component of the system is assumed to have separate hydraulic conductivity and storativity values. This concept is known as the double porosity medium theory. Analytical models for evaluation of fluid flow through fractured formations based on the double porosity medium have been developed by various authors (Barenblatt, et. al, 1960 (18); Gringarten and Witherspoon, 1972 (19); Boulton and Streltsova, 1978 (20); Streltsova-Adams, 1978 (21) and Gringarten, 1982 (22). Jenkins and Prentice, 1982 (23) developed a method for predicting fracture orientations from pump test data. Analytical models developed using this theory assume either that the rock matrix is broken by the fractures into randomly distributed blocks or that the system consists of a regular pattern of blocks.

The second conceptual theory for fluid flow in fractured formations is based on the assumption that the flow through porous blocks makes no significant contribution to the total flow. Fluid flow is assumed to be strictly through individual fractures and is simulated by a system of pipes or horizontal planes. The fractures are described by parameters such as aperture size, roughness, friction coefficient and hydraulic radius. Type curves solutions are not available for this type of analysis, thus the previous model was used for data evaluation.

Based upon the review of the core sections, geophysical data, fracture trace analysis and drawdown data, the conceptual model of the bedrock aquifer north of the Stamina Mills Site more closely fits the double porosity model rather than the individual fracture model. At the Site, one "porosity component" consists of the high and vertical angle fractures which are believed to be the major water bearing fractures and the second "porosity component" is provided by a combination of the tight low angle fractures parallel to foliation planes and porosity provided by the rock matrix. Additionally, since the individual fracture model requires very detailed fracture characteristics, the definition of which is beyond the realm of a field investigation, the double porosity model was selected to evaluate the pump test data.

In order to calculate values of transmissivity and storativity from the pump test data, various analytical models, based on the double porosity theory were used in data analysis and interpretation. A brief discussion of the theory of fluid flow in fractured formations and a synopsis of the assumptions and applicability of each of the analytical models is presented below.

5.30 THEORY OF FLUID FLOW IN FRACTURED ROCK SYSTEMS

Hydraulic properties and fluid flow behavior in fractured bedrock aquifers differ from that of uniformly porous aquifers in that flow in fractured formations is anisotropic and is strongly controlled by the presence of discontinuities such as fractures, joints, fissures and bedding in the rock. In this type of medium, fluid storage is controlled by the intergranular porosity of the rock matrix. Fractures generally exhibit rapid response to sudden changes in hydraulic pressure in the formation since the fracture permeability is typically several orders of magnitude greater than that of the porous blocks and the fracture porosity is typically less than the porosity of the blocks. The resultant pressure differential between the fractures and blocks resulting from pumping water from the formation drives water from the porous blocks into the fissures. Thus, there are two porosities and two different hydraulic conductivities involved in the response of a fractured aquifer to pumping. This condition is referred to as the double-porosity medium condition. Strelstova-Adams (21) provides a detailed discussion of the theory and the various type curve methods of analysis based on this aquifer condition.

When a system is highly fractured it is likely that the pumping well will intersect at least one of the fractures. Given that condition, if the hydraulic conductivity of the fracture is much greater than the permeability of the rock matrix, the response of the aquifer will differ from that predicted by the double porosity models presented by Barenblatt (18), Boulton and Strelstova (20), and Streltsova-Adams (21) and the fracture system can be analyzed as an equivalent anisotropic system (19,20). Anisotropic analysis of fractured bedrock is based on the assumption that the aquifer possesses directional permeability properties with the maximum hydraulic conductivity being in the direction of the fracture system while the minimum permeability is in the direction of the rock matrix. This method of analysis produces values of the mean transmissivity ($\sqrt{Tf\ Tm}$) where Tf is the transmissivity of the fracture and Tm is the transmissivity of the matrix.

Gringarten and Witherspoon (19), Gringarten (22) and Jenkins and Prentice (23) have developed methods of analysis for this extreme case of anisotropy where the pumping well intersects a vertical or horizontal fracture having a hydraulic conductivity several orders of magnitude greater than the hydraulic conductivity of the rock matrix. The fracture acts as an extended production surface of the well and groundwater flow from the fracture is linear and laminar towards the production well. The pump test data was evaluated utilizing this approach. Presentation of this evaluation is provided in Section 5.40.

5.31 Double Porosity Models

As previously discussed in Section 3.00, the majority of water transmitted through the bedrock aquifer in the study area is believed to be through vertical and high angle fractures. However, groundwater contribution to wells from the fractures associated with foliation planes and from the rock matrix itself cannot be ignored. Therefore, various double porosity fracture flow analyses were utilized in evaluating the pump test data to provide a range of transmissivity and storage coefficient volumes. A brief description of each solution technique and the associated data analysis are provided in Section 5.31.1. Interpretation of the analytical results is provided in Section 5.32.

5.31.1 Steady State Random Block and Fissure Model

Barenblatt, et. al. (18), developed an analytical model which assumes that the fractured rock aquifer is confined and that the porous rock is broken into blocks of irregular size and shape by the fractures. The fractures are interconnected and the drainage rate from the porous blocks into the fractures is proportional to the pressure differential between the two components of the model. Additional assumptions are that:

1. The blocks are isotropic.
2. The production well has no storage capacity and penetrates both porous blocks and fissures.
3. The change in the volume of liquid due to compression of the fractures is negligible when compared with the change in fluid volume coming from the porous blocks.
4. Fluid flow from blocks to fractures is steady state.
5. The change in fluid volume in the blocks due to flow out of the blocks is negligible in comparison to the change in fluid volume due to liquid expansion.
6. The blocks are not recharged.

Solutions to the Barenblatt model generate a series of logarithmic type curves for the fissure portions of the fractured aquifer. From the matching process of observed time-drawdown data, the transmissivity of the fracture and the storage coefficient of the porous rock can be calculated. Because the model is based on the assumption that flow from the blocks to the fracture is steady state and that the change in the volume of liquid due to compression of the fractures is negligible when compared with the change in fluid volume coming from the porous blocks, the Barenblatt et. al. model is only valid for the latter periods of pumping after which flow from the rock matrix and the fractures has reached a quasi-steady state condition.

The data plots and calculations for data analysis using the Barenblatt model are presented in Appendix I. A summary of the results are given in Table 5-1.

TABLE 5-1

RESULTS OF PUMPING TEST DATA ANALYSIS USING BARENBLATT MODEL

Well	Radial Distance to the Forestdale Water Association Well r (ft)	Tf[1] (ft /d)	Sb[2] (dimensionless)
I-2	265	no match point	------
I-12	245	89.4	3.8 E-5
I-13	190	89.4	1.2 E-5
I-28	675	76.6	3.6 E-5
I-31	790	89.4	1.1 E-6
I-37	570	71.5	3.8 E-5

1. Transmissivity of the fracture.
2. Storage coefficient of the porous block.
3. Aquifer parameters were not calculated for the Stamina Mills well since drawdown in the well was 0.45 feet.

The time-drawdown data for observation well I-2 could not be matched to any of the type curves for this model. The calculated storage coefficient values for the block portion of the aquifer system are, as one would expect, very low and consistently within the range of 1. 10^{-5} to 4 x 10^{-5}. The low storage coefficient indicates that the rock matrix is of low primary porosity and storage capacity. The calculated transmissivity values range from 71.5 square feet per day (ft^2/d) to

89.4 (ft^2/d). Although the range in values is not great, the calculated values could be suggesting some degree of anisotropy within the fracture system. The maximum transmissivity calculated is in the direction of I-12, -13 and -31 and the minimum value of transmissivity is in the direction of I-37.

5.31.2 Transient Random Block and Fissure Model

A time-dependent double porosity model for randomly fractured formations, described by Streltsova-Adams (21), is based on the assumption that the porous blocks contribute to the fracture flow by their elastic response to the artesian pressure differences at points within and outside the porous blocks. Analytical solutions obtained from which type curve solutions are characterized by r/B values for specified values of N_F where,

$$N_F = 1 + (S_b/S_F)$$

S_b and S_F are the storage coefficients for the porous block and fractures, respectively. A series of type curve solutions for drawdowns in the fractured and block portions of a fractured formation for N=10 are presented by Streltsova-Adams (21) and were used to calculate the transmissivity and storage coefficient of the fractured portion of the aquifer. The storage coefficient for the block portion can also be calculated if the saturated thickness of the aquifer is known. The type curves developed for the fractured portion are sufficiently different from that of the porous block such that the shape of the data plots can be used to determine which set of type curves is most appropriate. These curves were used to analyze the pumping test data obtained from observation wells I-12, I-31, I-28, I-2, I-37, and I-13. The analytical results are presented in Table 5-2. The calculation sheets are presented in Appendix J.

TABLE 5-2

RESULTS OF RANDOM BLOCK AND FISSURE MODEL ANALYSIS

Well	Radial Distance r (ft)	Tf (ft²/d)	Sf (dimensionless)
I-2	265	11.9	7.1 E-6
I-12	245	82.5	6.1 E-3
I-13	190	71.5	1.1 E-5
I-28	675	51.1	4.7 E-6
I-31	790	38.3	4.6 E-5
I-37	570	63.1	1.0 E-5

The shape of the time-drawdown curves for observation wells I-12, -13 and -31 (see Appendix J) are typical of porous block forms which resemble the Theis curve. The shape of the time-drawdown curves for observation wells I-2 and I-37 resemble fracture flow form. Due to the limited data available for I-28 a qualitative assessment of the portion of the aquifer system tapped by this observation well could not be determined.

The transmissivity values calculated using the Streltsova method range from 11.2 ft^2/d to 82.5 ft^2/d. This range is slightly less than that calculated using the Barenblatt method. However, both methods indicate that the maximum transmissivity for the wells evaluated is in the direction of I-12 and I-13.

5.31.3 Two-Layer Block and Fissure Model

Boulton and Streltsova (20) (1978) devised an alternative method of analysis of the double porosity media by replacing the irregular network of blocks and fractures of the Barenblatt model with a regular pattern of block and fissure units.

The ideal formation is made up of blocks (rock matrix) separated by horizontal fissures. This network is assumed to extend without limit in all horizontal directions. The block units representing the porous rock mass have a thickness (2H) equal to the average thickness of the actual blocks. The fracture units have a thickness of (2n) equal to the average thickness of the actual fractures. The model assumes that 2h is much less than 2H. Additional model assumptions are:

1. The block and fracture units are compressible.

2. Flow in the fractures is horizontal and flow in the blocks is vertical.

3. There is no contact resistance to flow between the blocks and fractures.

4. Both flow in the blocks and fractures obeys Darcy's Law.

5. There is no well bore storage.

6. The thickness of the fracture is small compared to that of the block.

7. The pumping well draws water from both the porous block and the fracture layers at a constant rate.

Utilizing this approach, a complex analytical solution is obtained from which the type curve solutions are calculated for both confined and unconfined aquifer conditions. The type curve solutions are characterized by various ratios of fissure storativity and transmissivity to block transmissivity and storativity. The type curves developed for b = 0.1, where b = TbSf/SbTf, and C = 1, where C = Tb/Tf for the block and the fracture portions of a water table aquifer were used to analyze the pumping test data. As with the random block and fissure methods, the shape of the type curves for the porous block portion are sufficiently different from that of the fissure portion such that the shape of the drawdown plots on logarithmic paper can be used to determine which type curve set is the most appropriate to select. The data plots and calculation sheets for data analysis are presented in Appendix K. A summary of the results for the 2-layer model are given in Table 5-3.

TABLE 5-3

RESULTS OF PUMPING TEST DATA ANALYSIS USING THE TWO LAYER BLOCK AND FISSURE MODEL

Well	Radial Distance r (ft)	$T^{F}1$ (ft²/d)	$S^{F}2$ (dimensionless)
I-2	265	23.8	8.6 E-5
I-12	245	71.5	2.6 E-4
I-13	190	63.1	5.8 E-5
I-28	675	53.6	1 E-6
I-31	790	53.6	2.1 E-5
I-37	570	39.7	3.3 E-5

1. Transmissivity for the fractured portion of the aquifer.
2. Storage coefficient for the fractured portion of the aquifer.

The shape of the drawdown plots for observation wells I-2 and I-37 best fit the fractured portion type curves whereas the other observation well data was best fit to the block portion. This is consistent with analysis using the Streltsova technique. A comparison of the transmissivity and storativity values calculated using the two-layer model and the previously discussed models indicates that the results are fairly consistent.

5.31.4 Anisotropy Models

Papadopulos (24) produced a method for determining the drawdown distribution around a pumping well from an anisotropic, homogeneous porous aquifer. The method produces values and directions of transmissivity in the principal directions of anisotropy using curve matching of time drawdown data from at least three observation wells. Gringarten and Witherspoon (19) later extended the Papadopulos model for use in fractured formations. Gringarten and Witherspoon theorized that the hydraulic conductivity should increase when the fractures are parallel to the direction of flow whereas there should be no change in hydraulic conductivity due to fractures at right angles to the direction of flow. As a result, the maximum hydraulic conductivity should be representative of the fracture system, while the minimum hydraulic conductivity would reflect the effects of the rock material.

Gringarten and Witherspoon (19) developed idealized models that described the fluid flow behavior of a well for the extreme case of anisotropy were the production well intersects a single vertical or horizontal fracture. One characteristic of these solutions is that, for highly conductive fractures, a log-log plot of drawdown versus time yields a straight line with an early time slope of 0.5. This half unit slope indicates linear flow from the porous block into the fracture. The half unit slope may not be evident, however, if the well has a large storage volume. Drawdown in a well with a large storage volume is characterized by a unit slope at early time. When drawdown versus the square root of time data are plotted on a double arithmic scale, the half unit slope appears as a straight line. The plots of drawdown data versus square root of time are presented in Appendix I. The early straight line plots are clearly evident for observation wells I-12, -13, -31 and -37.

Gringarten (22) suggests that this straight line is indicative of non-radial or linear flow, where the fracture is acting as an extended well with drainage into the fissure from the rock matrix. Following the straight line portion of the curve is a transition slope following which psuedo-radial flow commences. The logarithmic plot type curve follows this curve at this latter time. This suggests that the Jacobs method of analysis can be applied to the late time data where psuedo-radial flow commences. This method has been used the resultant T and S values using Jacob's approximation appear in Table 5-4 along with the Gringarten-Witherspoon results.

The groundwater contour maps developed from water level data collected during the pumping test (Section 4.00) suggest that the aquifer is highly anisotropic. The relatively narrow and extended contours may be indicative of high angle fractures with specific orientations. For this reason the vertical rather than horizontal fracture type curves were used to evaluate the pumping test data. The vertical fracture method of analysis yields values of the geometric mean transmissivity ($\sqrt{TfTm}$), and if the storage coefficient of the aquifer is known, a value of Tf/Xf^2 (where Tf is the transmissivity in the direction parallel to the fracture, Xf^2 is half the length of the fracture).

The transient response of water levels in observation wells depends upon the location of the observation well with respect to the pumping well and the transmissivity ratio. To compensate for the observation well location, Gringarten and Witherspoon prepared a series of type curves for vertical fractures with observation wells located parallel (0°), perpendicular (90°) and at a forty-five degree (45°) angle to the fracture. Selection of the appropriate type curve for each observation well was made based upon review of the map of total drawdown (Figure 4-7). The drawdown plots for the observation wells were then matched to the selected curve. The results of the data analysis are presented on Table 5-4. The data plots and calculation sheets are presented in Appendix L.

TABLE 5-4

RESULTS OF PUMPING TEST DATA ANALYSIS USING GRINGARTEN AND WITHERSPOON METHOD OF ANALYSIS AND JACOBS STRAIGHT LINE METHOD

	Radial Distance	Tm⌉ (ft²d)			Jacobs Method	
Well	r (ft)	0°	45°	90°	T (ft²d)	S
I-2	265	NA	38.3	42.9	26.1	4.8 E-5
I-12	245	32.5	71.5	NA	49.5	3.5 E-4
I-13	190	53.6	42.9	NA	37.4	1.5 E-4
I-28	675	41.3	33.5	NA	31.3	2.4 E-5
I-31	790	51.1	39.7	NA	39.2	2.5 E-5
I-37	570	35.8	NA	NA	85.2	1.1 E-4

1. Mean transmissivity ($\sqrt{TmTf}$) calculation for the various observation well locations relative to the fracture.
2. NA indicates data curve did not match solution curve for given fracture angle.

The analytical results using the single fracture technique show a wide variation of mean transmissivity values for the various observation well locations. The only observation wells for which the time-drawdown data matched one of the type curves at nearly all points were I-31 and I-37. Both of these data curves best matched the type curve for observation wells located parallel to the fracture. Previously discussed model analyses have consistently suggested that observation well I-37 is located in a major water bearing fracture. The straight line plot of drawdown versus square root of time suggests that both I-31 and I-37 are located on a fracture.

Evaluation of the drawdown data using the straight line method of analysis yielded calculated transmissivity values that are generally lower than the values calculated from previously discussed models. However, it should be noted that the straight line portions of the curves used in the matching process did not meet the $U \leq 0.02$ requirement for this method of analysis. This is likely due to the extended pumping times required (greater than 2,000 minutes), given the relatively large radial distances of the observation wells from the production well (i.e., U is directly proportional to radial distance and inversely proportional to time).

5.32 Discussion of Results of Data Analysis

The pump test data collected from six observation wells located at various radial distances and directions from the Forestdale Water Association Well was evaluated using five different analytical techniques. All techniques were based on the double porosity theory which assumes that the aquifer system consists of a network of fractures and porous rock matrix. Each component of the aquifer system is assumed to have a different value of hydraulic conductivity and storativity. The flow mechanism in the aquifer system is a process of pressure equalization between the blocks of the rock matrix and the fractures.

A summary of the analytical results is presented in Table 5-5. The range of transmissivity values calculated for any given observation well using the Barenblatt, Random Block and Fissure, and the Two Layer Block and Fissure models within a multiple of two and the calculated storativity values are within two orders of magnitude. The transmissivity values calculated using the Gringarten and Witherspoon model and the Jacobs straight line method resulted in consistently lower transmissivity values than the block and fissure approach. This is due to the fact that the Gringarten and Witherspoon model and the Jacobs technique calculate values of mean transmissivity ($\sqrt{TxTy}$) whereas the previously discussed model calculate values for the fracture portion only. It is reasonable to expect that the mean transmissivity of fractured igneous/metamorphic aquifers would be lower than the transmissivity of the fracture portion due to the fact that the fluid transport capabilities of the rock matrix is much lower than that of the fractures.

5.40 PREDICTION OF FRACTURE ORIENTATIONS FROM DRAWDOWN DATA

As has been discussed in the previous sections, fractured bedrock aquifers behave differently from porous media when stressed by pumping. Groundwater in porous overburden material exhibits a more or less radial drawdown pattern around the pumping well, whereas groundwater in bedrock aquifers which possess fractures showing preferred orientations, displays linear drawdown patterns parallel to major water bearing fractures during pumping. The map of total drawdown (Figure 4-6) displays just such a linear drawdown pattern.

Jenkins and Prentice, 1982 (23) developed a method for determining the location of a concealed fracture in a linear bedrock aquifer system using drawdown data from two observation wells on the same side of a fracture. This method has been applied to fractured linear systems in New Mexico, Mendocino and Placer Counties, California (25) and in New Hampshire (26).

TABLE 5-5

SUMMARY OF AQUIFER PARAMETER CALCULATIONS

WELL ID	AQUIFER PARAMETER	BARENBLATT (1)	RANDON BLOCK AND FISSURE (2)	TWO LAYER BLOCK AND FISSURE (2)	GRINGARTEN (4)			JACOBS (5)
					0	45	90	
I-12	T	89.4	82.5	71.5		71.5		49.5
M. Freitas	S	3.8 E-5	6.1 E-3	2.6 E-4				3.5
I-31	T	89.4	38.3	53.6	51.5	39.7		39.2
Post Office	S	1.1 E-6	4.6 E-5	2.1 E-5				2.5
I-28	T	76.6	51.1	53.6		35.5		31.3
Trudel	S	3.6 E-5	4.7 E-6	1 E-6				2.4
I-13	T	89.4	71.5	63.1		42.9		37.4
J. Freitas	S	1.2 E-5	1.1 E-5	5.8 E-5				1.5
I-2	T		11.9	23.8		38.3	42.9	26.1
Kenoian	S	NO MATCH POINT	7.1 E-6	8.6 E-5				4.8 E-5
I-37	T	71.5	63.1	39.7	35.8			85.2
LOVETTE	S	3.8 E-5	1.0 E-5	3.3 E-5				1.1 E-4

1. Transmissivity is for fracture portion (sq. ft./day) and storage coefficient is for block portion.
2. Transmissivity of the fracture portion (sq. ft./day) and storativity is for fracture portion.
3. Transmissivity of the fracture portion (sq. ft./day) and storativity is for fracture portion.
4. Transmissivity coefficient is a mean value.
5. Transmissivity and storativity are mean values.

Analysis of linear flow in a fractured rock aquifer using the Jenkins and Prentice method assumes the following:

1. An infinite, homogeneous, isotropic, confined aquifer containing a long, finite, fully penetrating, vertical fracture having infinitesimal width.
2. The fracture has no storage capacity.
3. Resistance to flow within the fracture is negligible.
4. Flow within the fracture is laminar and linear toward the pumped well.
5. Flow within the aquifer is laminar and linear toward the planar production surface of the fracture, and the flux through the production surface is constant and uniform along the entire length of the fracture.

Obviously, the assumptions outlined above describe an "ideal" aquifer. As with the assumptions used for flow analysis in porous media (i.e., homogeneous, isotropic, radial flow, conditions), certain hydrologic and structural conditions in fractured rock do not strictly adhere to the assumptions outlined above. Since analytical methods are not available to account for non-ideal aquifer conditions (and field methods do not exist for generating the level of data needed to analyze such aquifers) it is acceptable to use methods that somewhat simplify the aquifer system. For instance, in the assumptions provided above, the assumption that an aquifer could contain a single major fracture without fracturing the adjacent rock is unlikely. Nevertheless, aquifer tests have been conducted that indicate that aquifers do approach these idealized conditions at least in the vicinity of the pumped wells under certain circumstances (23).

The Jenkins and Prentice method of determining fracture location was applied to the drawdown data from the pump test conducted in the Forestdale Water Association Well. The method was applied to ascertain if fracture orientations determined using the method correlated with orientations determined from strike and dip measurements, the fracture trace analysis and the downhole geophysical survey (Section 2.20) and in turn if the predicted orientations were in agreement with the alignment of total drawdown contours (Figure 4-7). Applying the Jenkins and Prentice method to the bedrock aquifer in the study area is justified for the following reasons:

1. Arithmetic plots of drawdown versus time of pump test data resulted in a single straight line plot indicating the existence of linear flow.

2. Preliminary analysis of drawdown data indicated that drawdowns were greatest in wells which were believed (based on bedrock structure data available prior to the pump test) to be located in fractures originating from the Site and passing through or near the Forestdale Water Association Well.

3. The results of the strike and dip measurements, the bedrock coring and the downhole geophysical survey (Section 2.20) suggested that the major water bearing fractures were of the high angle or vertical variety.

4. The bedrock structure data (Section 2.20) suggested that groundwater was transported in a number of fractures; not a single fracture as the Jenkins and Prentice method assumes. To overcome this assumption, a number of fracture orientations were predicted using drawdown data from two sets of observation wells. This method of analysis produced a range of possible fracture orientations.

Fracture orientations were predicted using the following formula:

$$\theta_2 = \tan^{-1} \left[\frac{r_1 \sqrt{to_2} \quad \sin \Delta\theta_1}{r_2 \sqrt{to_1} - r_2 \sqrt{to_2} \cos \Delta\theta_1} \right.$$

where: r_1 = distance from observation well No. 1 to pump well.

r_2 = distance from observation well No. 2 to pump well.

to_1 = intercept time of drawdown with the line of zero drawdown from a for observation well No. 1 from a plot of drawdown versus $\sqrt{t}$

to_2 = same as above for observation well No. 2.

$\Delta\theta$ = angle between radial lines drawn from pumping well to observation wells No. 1 and 2.

$\Delta\theta_2$ = angle between radial line from pumping well and observation well No. 2 to predicted fracture through the pumping well.

Solving for $\Delta\theta_2$ and adding to $\Delta\theta$ yields the angle between the radial line from the pumping well to observation well No. 1 and the fracture. Finally, solving for:

$$X_1 = r_1 \quad \text{Sin } \theta_1$$

and

$$X_2 = r_2 \quad \text{Sin } \theta_2$$

where: X_1 = distance from observation well No. 1 to fracture

X_2 = distance from observation well No. 2 to fracture

yields radial distances perpendicular to the fracture, from the two observation wells.

Calculations of predicted fracture orientations are provided in Appendix J. Predicted fractures are shown on Figure 5-1.

The orientation of the predicted fractures are in reasonable agreement with the bedrock structure data and with the drawdown contours in that northwest-southeast, north-south and northeast-southwest striking fractures are predicted. The east-west striking sets of fractures which were measured in the field and suggested by the alignment of drawdown contours near the Tetrault well were not predicted by the Jenkins and Prentice method. The inability of the method to predict this fracture may have been caused by a lack of data points (observation wells) east of the pumping well. Another explanation for not identifying the east-west fracture is the premise that the east-west fractures do not directly intercept the pumping well. Instead, drawdown in the east-west fractures is realized as drawdown occurs in the north-south fractures to which the east-west fractures are connected at more or less right angles.

SECTION SIX

CONCLUSIONS

SECTION SIX - CONCLUSIONS

6.10 CONCLUSIONS

Based on the results of the pump test of the Forestdale Water Association Well described herein, the following conclusions were developed.

1. Previous studies of the Stamina Mills Site, including studies by GZA, NUS and RIDEM as detailed in Section 1.40, have indicated that TCE contamination in groundwater in the residential area north of the Site resulted from pumping of the Forestdale Water Association Well in conjunction with residential wells prior to February 1985. The migration of TCE originating in the spill area, from the Site into the groundwater in the residential area north of the Site was caused by pumping of the Forestdale Well and residential wells which reversed the natural hydraulic gradient which under non-pumping conditions is to the south, but under pumping conditions is toward the residential wells north of the Site.

2. The pump test described herein was conducted to verify that a hydraulic connection between the Site and the residential area north of the Site exists such that groundwater will migrate from the Site toward the residential area when the bedrock aquifer north of the Site was stressed by pumping. TCE, the contaminant involved in the spill of 1969 and consistently detected in groundwater samples from the Site and the residential area, was used as a tracer to show the hydraulic connection between the Site and the residential area.

3. While the pump test reflected a specific set of hydraulic conditions, it is believed, based on estimates of historical water usage before the Forestdale Water Association Well and

private wells became contaminated, that the pumping rate maintained during the pump test is representative of pumping conditions prior to 1975.

4. Groundwater under the Site and in the residential area is stored and transmitted primarily in the bedrock aquifer, since the overburden deposits are thin or absent. The bedrock aquifer consists of metamorphic rock units which show preferred orientations of fractures and joints in which groundwater is stored and transmitted. In order to understand the pathways by which groundwater migrates through the bedrock aquifer the orientation of joints and fractures was analyzed by a number of field methods and evaluation of remote sensing imagery. These methods have included: strike and dip measurements of major joints and foliation in bedrock outcrops, a fracture trace analysis, visual analysis of bedrock cores and downhole geophysical profiling of bedrock wells.

5. Fracture orientation data generated by strike and dip measurements, the fracture trace analysis and the downhole geophysical survey is in reasonable agreement and indicates three strong fracture trends northwest-southeast, northeast-southwest and an east-west trend. This data indicates that there are pathways created by individual or intersecting fractures by which contaminated groundwater under the Stamina Mills Site can migrate northward toward the residential area if a hydraulic gradient from south to north existed and the fractures have permeabilities which are sufficient to allow migration of groundwater.

6. Contamination of groundwater by TCE under the Stamina Mills Site and in the residential area was first identified in 1979. Subsequent sampling and analysis of groundwater from residential wells north of the Site and the Stamina Mills Supply Well between 1980 and 1984 continued to show levels of TCE in groundwater.

During the RI in 1986 and 1988 analysis of groundwater samples from the Site and the residential area continued to show levels of TCE contamination. Concentrations of TCE were present in the groundwater under the Site and in the groundwater north of the site prior to initiation of the pump test. These concentrations are likely the result of residual contamination that was previously drawn from the Site and remains in the groundwater north of the Site as a result of intermittent pumping of certain residential wells.

7. A 95 hour pump test of the Forestdale Water Association Well was conducted during the period of June 15 to June 19, 1988. During the pump test drawdown (and subsequent recovery) measurements were taken in twenty-two wells and groundwater samples were periodically taken from multiple depths in nine wells and analyzed on-Site to provide rapid quantification of TCE concentrations. Prior to the pump test, it was determined that the pump test would be terminated if one of the following conditions were observed: 1) A discernable hydraulic gradient reversal from the Site or just north of the Site such that a gradient from the Site to the north was observed, 2) A reaction to pumping manifested by drawdown in on-Site bedrock wells was observed, or 3) A one order of magnitude change in TCE concentrations were noted after two consecutive samples were analyzed from any residential well immediately north of the Site.

8. Prior to the pump test, groundwater migration as defined by piezometric head measurements shown on Figure 4-1, was from the residential area north of the Site was toward Forestdale Pond and the Branch River south of the residential area. As shown on Figure 4-2, Twenty-four hours after commencement of pumping the Forestdale Water Association Well had developed nearly 70 feet of drawdown and a distinct cone of depression displaying the anisotropic character of the bedrock aquifer had developed.

Groundwater began to migrate northerly from the Bosco and Post Office wells, northeasterly from the Lovette well and westerly from the Tetrault well. During the twenty-four hours of pumping the water level in well B-3 located on-Site dropped 4.48 feet.

As shown on Figure 4-4, sixty-eight hours after pumping began, the cone of depression caused by pumping of the Forestdale Water Association well reached Forestdale Pond, one recharge boundary for the aquifer. At this time a complete reversal of groundwater migration from the Site to the Forestdale Water Association Well was achieved on the western portion of the Site.

Eighty-nine hours into the pump test the hydraulic gradient between Forestdale Pond and the Forestdale Water Association Well continued to increase as shown on Figure 4-5. Drawdown in the Forestdale Water Association Well had not stabilized indicating that the hydraulic gradient between the residential area and the Site would continue to steepen until the cone of depression intercepted the Branch River. The water level in the Stamina Mills well exhibited a drawdown of 0.41 feet while B-3 exhibited a drawdown of 11.74 since the pump test began. The pump test was terminated ninety-five hours into the test for fear of causing TCE to migrate from the Site into the residential area. As shown on Figure 4-5 the pump test was successful in verifying a hydraulic gradient reversal from the Site to the residential area and thus proving a hydraulic connection between the groundwater under the Site and groundwater in the residential area.

9. Analysis of groundwater samples during the pump test indicated as shown on Figures 4-8 and 4-9, minor fluctuations of TCE levels in wells. The fluctuations were caused by transport of residual TCE in the residential area in response to hydraulic gradient changes between residential wells caused by pumping the Forestdale Water Association Well. Monitoring of groundwater quality did not indicate that the pump test caused migration of TCE from the Stamina Mills Site.

10. The methods of analyzing the pump test data assume that there are two porosity components associated with the bedrock aquifer. One porosity component is associated with the fracture system. The second porosity component is associated with the intergranular structure of the rock matrix and the fissures parallel to the bedrock foliation. The use of this method is justified by the character of the bedrock underlying the Site as described in detail in Section 2.20. Specifically, the rock has joints and fractures and discontinuities associated with foliation planes.

11. The drawdown data generated during the pump test indicates that the bedrock aquifer is strongly anisotropic which causes the hydraulic response to be faster and greater at some well locations with slower and/or less response in other areas.

12. Analysis of the pump test data indicates transmissivity values ranging from 11.3 sq. ft./day in the vicinity of I-2 (Kenoians well) to 89.4 sq. ft./day in the vicinity of I-12 (M. Freitas' well), I-31 (Post Office well) and I-13 (J. Freitas' well).

13. As shown on Figure 5-1, there is good correlation between piezometric data measured during the pump test and the rock structure determined by measurements of strike and dip in bedrock outcrops, in coreholes geophysically logged and lineament trends identified during the fracture trace analysis. Collectively, these data show that the bedrock aquifer is anisotropic in nature and displays prominent structural features (joints and fractures) oriented northeast-southwest and northwest-southeast from the Site to the Forestdale Water Association well. A prominent east-west structural feature is also evident.

14. Based on the hydrogeologic and groundwater quality information generated by previous investigations and the results of the pump test it is concluded that there is good hydraulic communication

between the Site and the residential area north of the Site and the TCE spill which occurred at the Stamina Mills Site contributed to the TCE contamination that has been detected in groundwater from the Forestdale Water Association well and private residential wells north of the Site.

REFERENCES

REFERENCES

1. Association of Mutual Insurance Companies, Plan of the Stamina Mills Facility, North Smithfield, Rhode Island, 1899.

2. Freitas, Manuel, Personal Communication with members of GHR Project Team, April 21, 1986.

3. Rhode Island Department of Environmental Management, Interoffice Memo from Pearce M. Klazer to W. Edward Wood, February 1, 1980.

4. Richmond, G.M., Surficial Geology of the Georgiaville Quadrangle, Rhode Island, USGS, 1953.

5. Richmond, G.M., Bedrock Geology of the Georgiaville Quadrangle, Rhode Island, USGS, 1952.

6. Johnson, K.E., Groundwater Map No. 19 - Rhode Island Parts of the Attleboro, Blackstone, Franklin, Oxford, and Uxbridge Quadrangles, Rhode Island Water Resources Coordinating Board and the USGS, 1962.

7. Quinn, A.W., Bedrock Geology of Rhode Island, USGS Bulletin No. 1295, 1971.

8. Ratcliff, N.M., Goldsmith, R. et al, Bedrock Geology Map of Massachusetts, USGS, 1983.

9. Goldberg-Zoino & Associates, Inc., Forestdale Well Contamination Study, North Smithfield, Rhode Island, September 1982.

10. NUS Corporation, Residential Groundwater Sampling of the Stamina Mills Area of Forestdale, Rhode Island, June 14, 1984.

11. Keys, W.S. and MacCary, L.M., Application of Borehole Geophysics to Water-Resources Investigations, USGS Technical Water-Resources Inventory, Book 2, Chapter E1, 1981.

12. Paillet, F.L., Hess, A.E., Cheng, C.H. and Hardin, E., Characterization of Fracture Permeability with High Resolution Vertical Flow Measurements During Borehole Pumping, Groundwater v.25, No. 1, pp. 28-40.

13. U.S. Bureau of Reclamation, U.S. Department of the Interior, Earth Manual, 2nd Edition, 1974.

14. Written Communication, Paul Lavallee, Superintendent of Water and Sewer Department, North Smithfield, Rhode Island to Gerard Martin, GHR Engineering Associates, Inc., records regarding use of Forestdale Water Association Well, October 26, 1988.

15. Metcalf and Eddy, Wastewater Engineering: Collection and Pumping of Waste Water, 1981.

16. McGraw-Hill, Water Resources and Sewage, Water Resources and Environmental Engineering, Fifth Edition, 1979.

17. Ferris, J.G., D.B. Knowles, R.H. Brown, and R.W. Stallman, 1962, Theory of Aquifer Tests, USGS Water-Supply Paper 1536-E.174pp.

18. Written Communication, Adel Banoub, City of Woonsocket Department of Public Works Pretreatment Division to Jeffrey Gram, GHR Engineering Associates, Inc., regarding disposal of pump water, May 23, 1988.

18. Barenblatt, G.E., Zheltov, I.P. and Kochina, I.M., 1960, Basic Concepts in the Theory of Seepage of Homogeneous Liquids in Fissured Rocks, J. Appl. Math. Mech. (USSR) 24(5), 1286-1303.

19. Gringarten, A.C. and Witherspoon, P.A., 1972, A Method of Analyzing Pumping Test Data from Fractures Aquifers in Proceedings, Symposium on Percolation in Fissured Rock: Stuttgart, International Society of Rock Mechanics, v.3, p.B1-139.

20. Boulton, N.S. and Stelstova, T.D., 1978, Unsteady Flow to a Pumped Well in an Unconfined Fissured Aquifer, J. Hydrol., 37, pp. 349-363.

21. Strelstova-Adams, T.D., 1978, Well Hydraulics in Heterogeneous Aquifer Formations in Chow, V.T. ed., Advances in Hydrosciences, v.11, pp.357-423.

22. Gringarten, A.C., 1982, Flow-Test Evaluation of Fractures Reservoirs, Geological Society of America, Special Paper 189.

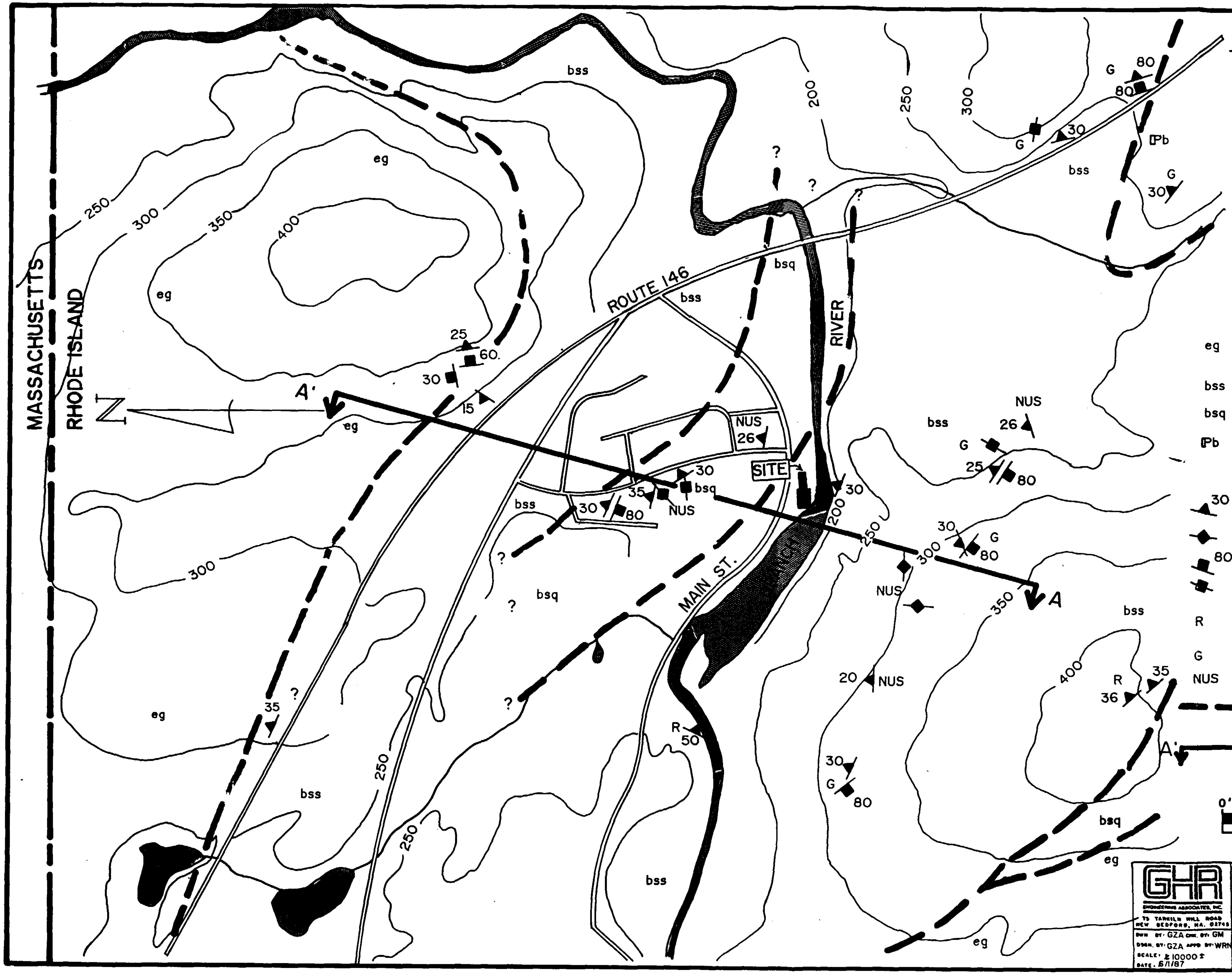
23. Jenkins, D.N. and Prentice, J.D., 1982, Theory of Aquifer Test Analysis in Fractured Rocks Under Linear (Nonradial) Flow Conditions, Groundwater, v.20, No. 1, pp. 12-21.

24. H. Papadopulos, S.S., 1965, Nonsteady Flow to a Well in an Infinite Anisotropic Aquifer in Proceedings, Dubrovnik Symposium on Hydrology of Fractures Rocks, v.1, pp. 21-31.

25. Lewis, D.C. and Burry, R.H., Hydraulic Characteristics of Fractured and Jointed Rock, Groundwater, v.2, No. 3, pp. 4-9.

26. McGlew, P.J. and Thomas, J.E., Determining Contaminant Pathways in Fractured Bedrock in Proceedings of the 5th National Conference on Management of Uncontrolled Hazardous Waste Sites, November 7-9, 1984, Washington, D.C.

FIGURES



NOTES

1. BASE MAP DEVELOPED FROM USGS BLACKSTONE MA-RI, AND GEORGIAVILLE, RI QUADRANGLE MAPS: ORIGINAL SCALE 1": 24000'
2. LITHOLOGY AND GEOLOGIC STRUCTURES WERE COMPILED FROM EXISTING DATA AND PUBLISHED GEOLOGIC MAPS. CONSULT TEXT FOR DETAILS AND REFERENCES
3. BASE PLAN PREPARED BY GOLDBERG-ZOINO ASSOCIATES, INC. SUBCONTRACTOR TO GHR

LEGEND

BEDROCK LITHOLOGY

eg	ESMOND GRANITE AND/OR SCITUATE GRANITE GNEISS
bss	BLACKSTONE SERIES QUARTZ-BIOTITE SCHIST
bsq	BLACKSTONE SERIES QUARTZITE
Pb	BELLINGHAM COHGLOMERATE

STRUCTURAL NOTATION

30	STRIKE AND DIP OF SCHISTOSITY/FOLIATION
◆	STRIKE OF VERTICAL SCHISTOSITY
80	STRIKE AND DIP OF FRACTURE
■	STRIKE OF VERTICAL FRACTURE
R	RICHMOND OBSERVATIONS, 1952
G	GZA OBSERVATIONS, 1982
NUS	NUS OBSERVATIONS, 1984
— —	APPROXIMATE OR INFERRED LITHOLOGIC CONTACT
A'–A	EXTENT AND ORIENTATION OF REGIONAL SECTION SEE FIGURE NO. 5-2 FOR DETAILS.

0' 10,000' 30,000'

APPROXIMATE SCALE

GHR
ENGINEERING ASSOCIATES, INC.
75 TARKILN HILL ROAD
NEW BEDFORD, MA. 02745

DWN BY: GZA CHK. BY: GM
DSGN. BY: GZA APPD BY: WRN
SCALE: 1" = 10000'±
DATE: 5/1/87

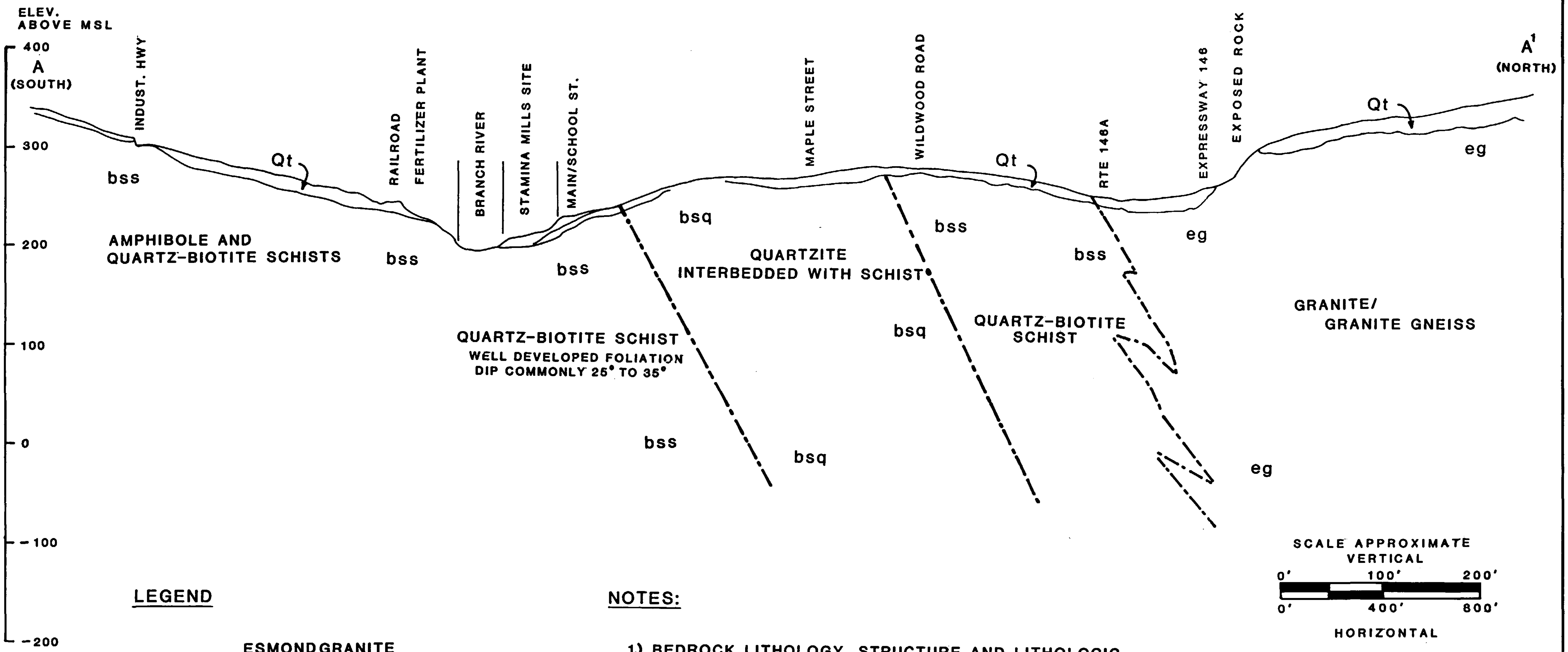
PROJECT
STAMINA MILLS
REMEDIAL INVESTIGATION

CLIENT
U.S. ARMY CORPS
OF ENGINEERS

DWG. TITLE
FIGURE 2-1
AREAL AND
STRUCTURAL GEOLOGY

PROJECT NO.

DWG. NO.



LEGEND

eg	ESMOND GRANITE (REPORTED "HYBRID GRANITE GNEISS")
bss	BLACKSTONE SERIES SCHISTS (UNDERLYING MILLSITE AND VILLAGE)
bsq	BLACKSTONE SERIES QUARTZITE (REPORTED LOCALLY INTERBEDDED WITH SCHISTS)
Qt	GLACIAL TILL, OUTWASH SEDIMENTS AND ARTIFICIAL FILLS
— - —	APPROXIMATE CONTACT BETWEEN UNITS

NOTES:

1.) BEDROCK LITHOLOGY, STRUCTURE AND LITHOLOGIC CONTACTS INFERRED FROM THE GEOLOGY AND GROUNDWATER RESOURCES OF THE GEORGIAVILLE RI. USGS QUADRANGLE BULLETIN NO.4 DATED 1951 BY RICHMOND AND ALLEN, PLATES 1-3.

2.) REFER TO FIGURE NO. 2-1 FOR LOCATION OF PROFILE A-A'.

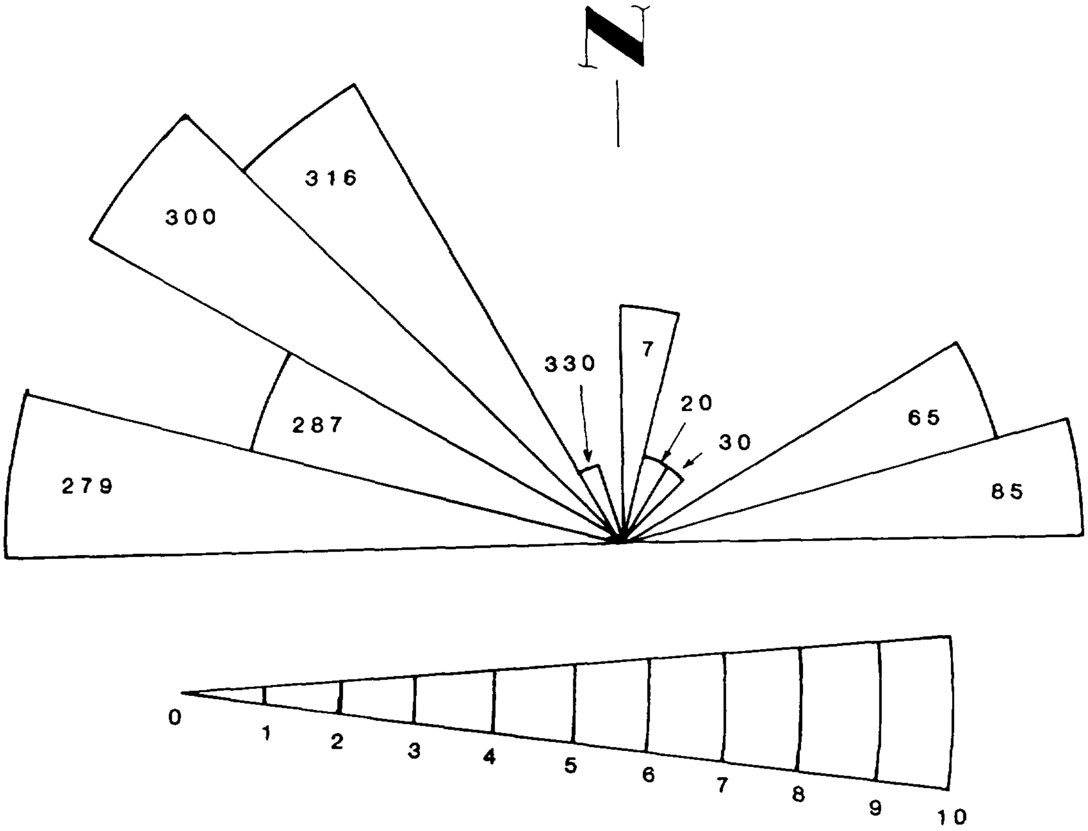
GHR
ENGINEERING CORPORATION
75 TARKILN HILL ROAD
NEW BEDFORD, MA. 02745

DWN. BY: BDM CHK. BY: WRN
DSGN. BY: GM APPD. BY: JJG
SCALE: AS NOTED
DATE: 4/27/87

PROJECT
STAMINA MILLS
SUPERFOUND SITE

CLIENT
U.S. ARMY CORPS
OF ENGINEERS

DWG. TITLE FIGURE 2-2
REGIONAL GEOLOGIC
CROSS-SECTION
PROFILE A-A'



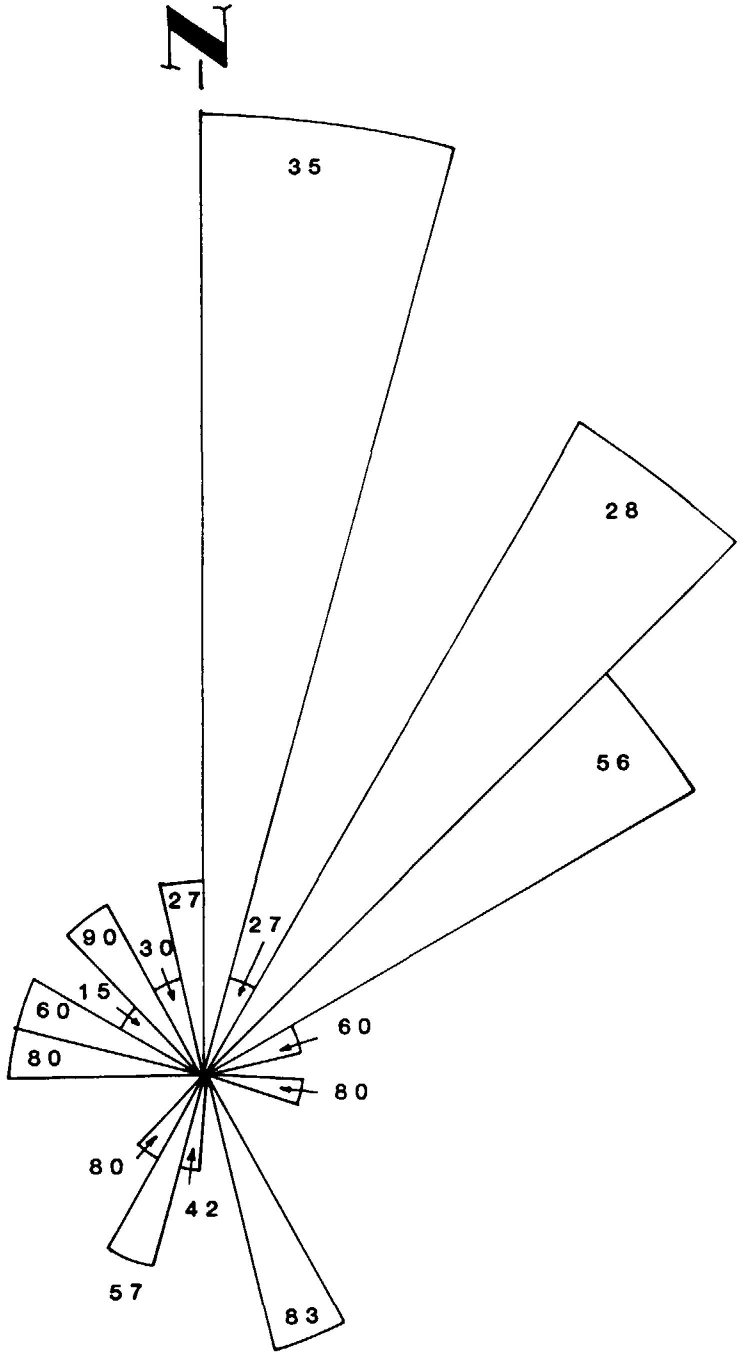
SCALE

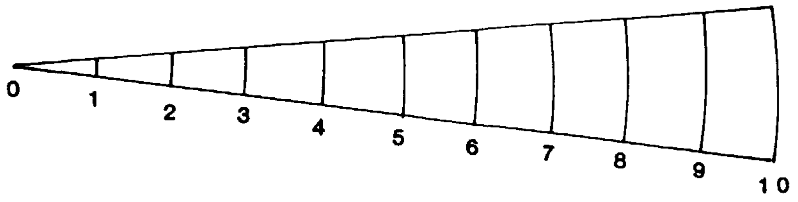
NUMBER REPRESENTS AMOUNT OF LINEAMENTS IN A CLASS

FIGURE 2-3

ROSE DIAGRAM DEPICTING STRIKE ATTITUDE OF JOINTS AND FOLIATION IN THE VICINITY OF THE STAMINA MILLS SITE

NOTES:
1.) ROSE DIAGRAM DEVELOPED FROM MEASUREMENTS MADE IN THE FIELD AT BEDROCK OUTCROPS.
2.) DIP OF THE STRUCTURAL FEATURE WAS NOT CONSIDERED AS A FACTOR.
3.) NUMBER IN WEDGE REPRESENTS MEAN OF CLASS.
4.) AZIMUTH IS RELATIVE TO MAGNETIC NORTH.
5.) STRIKES MEASUREMENTS COMPILED FROM NUS (7) AND GZA (9) REPORTS.
6.) REFER TO TABLE 5-1.





SCALE

NUMBER REPRESENTS AMOUNT OF DIPS IN A CLASS

NOTES:

1.) ROSE DIAGRAM DEVELOPED FROM MEASUREMENTS MADE IN THE FIELD AT BEDROCK OUTCROPS BY GZA (9) AND NUS (7)

2.) NUMBER IN WEDGE REPRESENTS MEAN DIP FOR THAT CLASS.

3.) DIRECTION OF DIP MEASURED RELATIVE TO TRUE NORTH AND WAS CALCULATED FROM THE STRIKE DIRECTION.

GHR
ENGINEERING CORPORATION
75 TARKILN HILL ROAD
NEW BEDFORD, MA 02745

DWN BY KF CHK BY: WN
DSGN BY GM APPD BY JG
SCALE: AS SHOWN
DATE 12/19/86

PROJECT
STAMINA MILLS
REMEDIAL INVESTIGATION

CLIENT
U.S. ARMY CORPS
OF ENGINEERS

DWG. TITLE FIGURE 2-4
ROSE DIAGRAM DEPICTING DIP DIRECTION AND AVERAGE INCLINATION OF JOINTS AND FOLIATION IN THE VICINITY OF THE STAMINA MILLS SITE

GHR

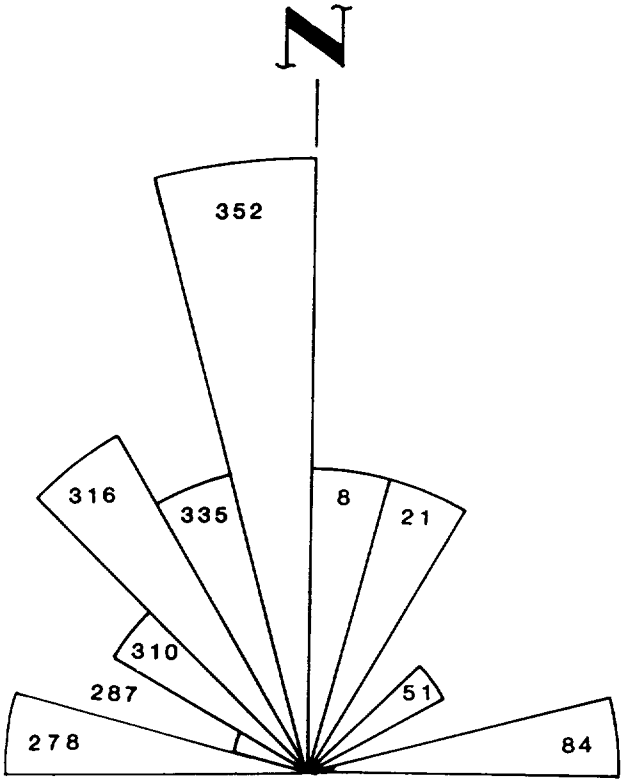
75 TARKILN HILL ROAD
NEW BEDFORD, MA. 02745

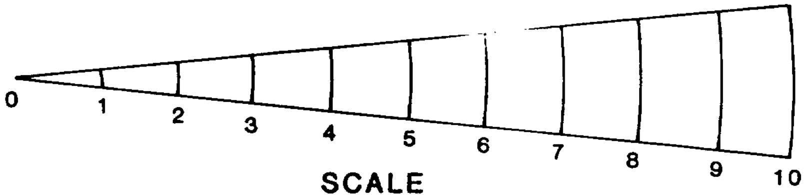
DWN BY: GZA CHK. BY: WN
DSGN. BY: GZA APPD BY: JG
SCALE: 1" = 800'
DATE: 12/19/86

PROJECT STAMINA MILLS REMEDIAL INVESTIGATION

CLIENT U.S. ARMY CORPS OF ENGINEERS

DWG. TITLE FIGURE 2-5
FRACTURE TRACE ANALYSIS





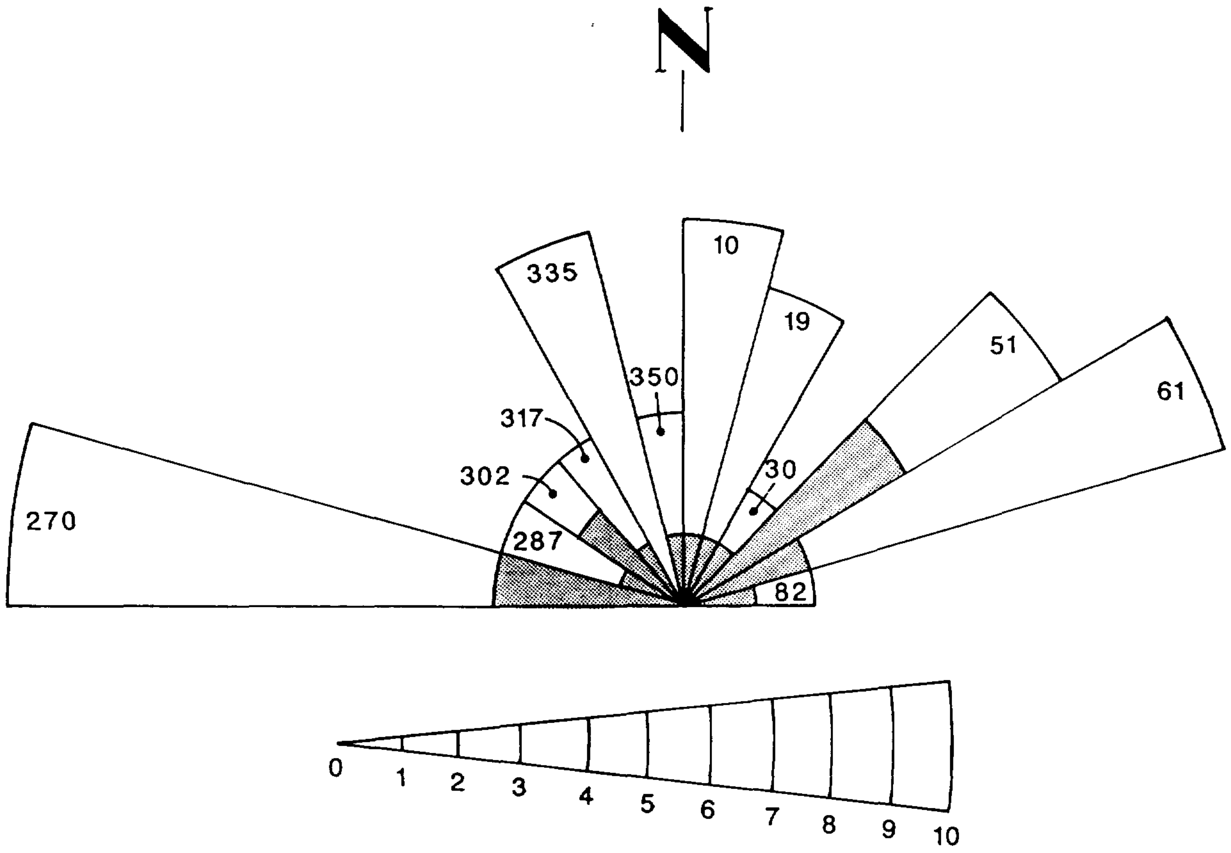
SCALE

NUMBER REPRESENTS AMOUNT OF LINEAMENTS IN A CLASS

FIGURE 2-6

ROSE DIAGRAM OF LINEAMENT AZIMUTHS DETERMINED BY FRACTURE TRACE ANALYSIS

NOTES:
1. ROSE DIAGRAM DEVELOPED FROM SINGLE - IMAGE AERIAL PHOTO OVERLAYS OF THE SITE
2. LINEAMENT LENGTH WAS NOT CONSIDERED AS A FACTOR
3. NUMBER IN WEDGE REPRESENTS MEAN OF CLASS.
4. AZIMUTH IS RELATIVE TO MAGNETIC NORTH



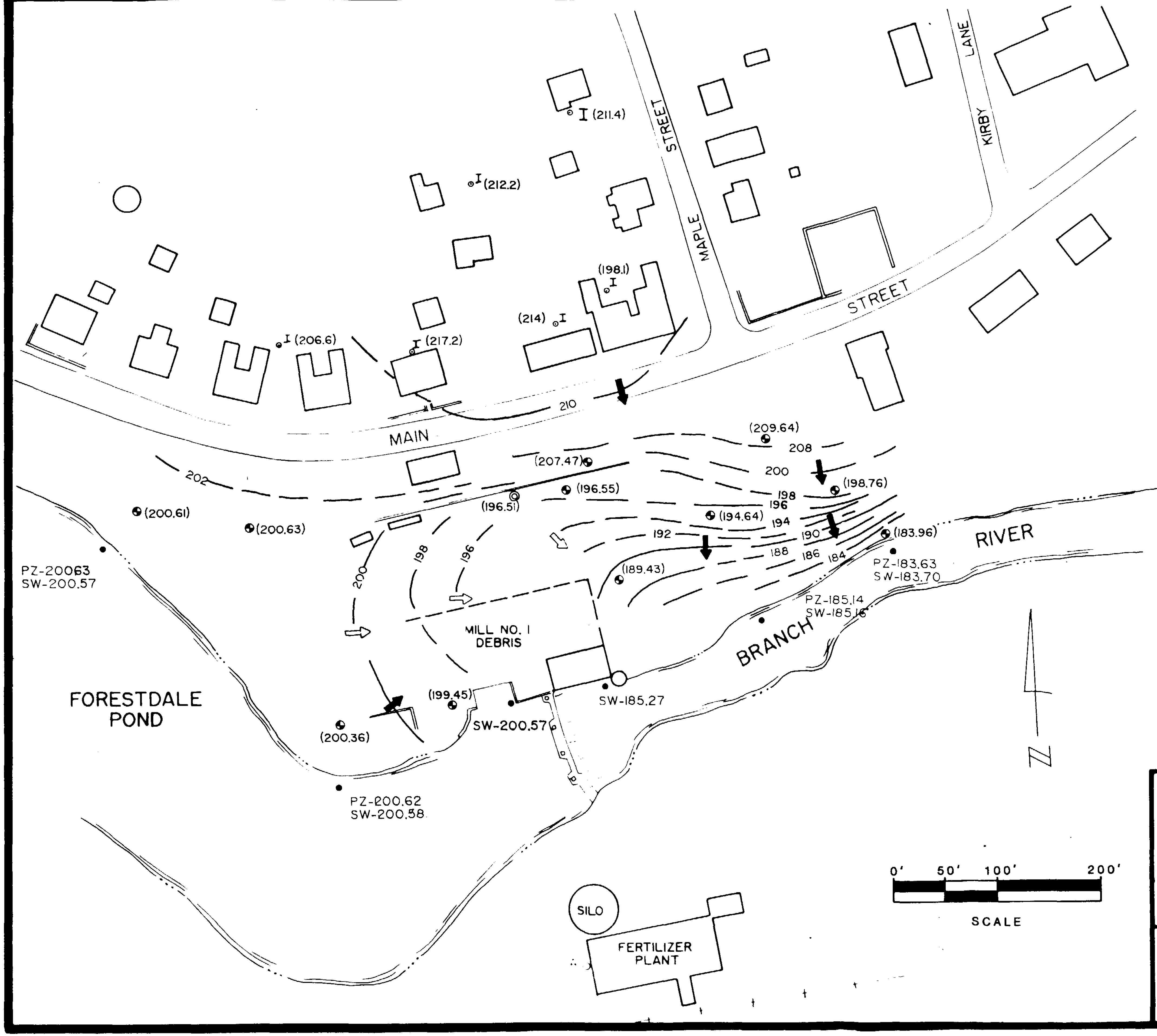
SCALE

NUMBER REPRESENTS AMOUNT OF PLANER STRUCTURAL FEATURES IN EACH CLASS

FIGURE 2-7

ROSE DIAGRAM DEPICTING STRIKE ATTITUDE OF PLANER STRUCTURAL FEATURES INTERSECTING FIVE BEDROCK WELLS IN THE VICINITY OF THE STAMINA MILLS SITE

NOTES:
1.) ROSE DIAGRAM DEVELOPED FROM MEASUREMENTS TAKEN FROM THE ACCOUSTIC-TELEVIEWER LOGS FROM WELLS I-2, I-12, I-31, I-32 AND THE STAMINA MILLS WELL. WHITE AREA REPRESENTS TOTAL NUMBER OF PLANER FEATURES. SHADED AREA REPRESENTS FEATURES THAT APPEAR TO BE OPEN FRACTURES.
2.) DIPS OF THE PLANER FEATURES ARE NOT SHOWN.
3.) NUMBER IN WEDGE REPRESENTS MEAN STRIKE OF THAT CLASS.
4.) AZIMUTH IS RELATIVE TO MAGNETIC NORTH.



NOTES:

1. GROUNDWATER ELEVATIONS ARE CALCULATED FROM WATER LEVEL MEASUREMENTS MADE IN AUGUST, 1986. FLUCTUATIONS IN GROUNDWATER LEVELS MAY OCCUR DUE TO FACTORS NOT ACCOUNTED FOR AT THE TIME THE MEASUREMENTS WERE MADE.
2. GROUNDWATER CONTOURS DEPICTED ARE BASED ON INTERPOLATIONS BETWEEN WIDELY SPACED POINTS. ACTUAL SUBSURFACE CONDITIONS MAY VARY FROM THOSE SHOWN.
3. REFER TO SITE PLAN NO. 6 FOR ADDITIONAL NOTES AND LEGEND.

LEGEND

⊕ MW-9 (209.64)	GROUNDWATER ELEVATION
PZ-200.62 SW-200.58	- GROUNDWATER ELEVATION IN PIEZOMETER SURFACE WATER ELEVATION
200 ⇩	GROUNDWATER CONTOUR AND FLOW DIRECTION (CONTOUR DASHED AND ARROW OPEN WHERE INFERRED)

GHR

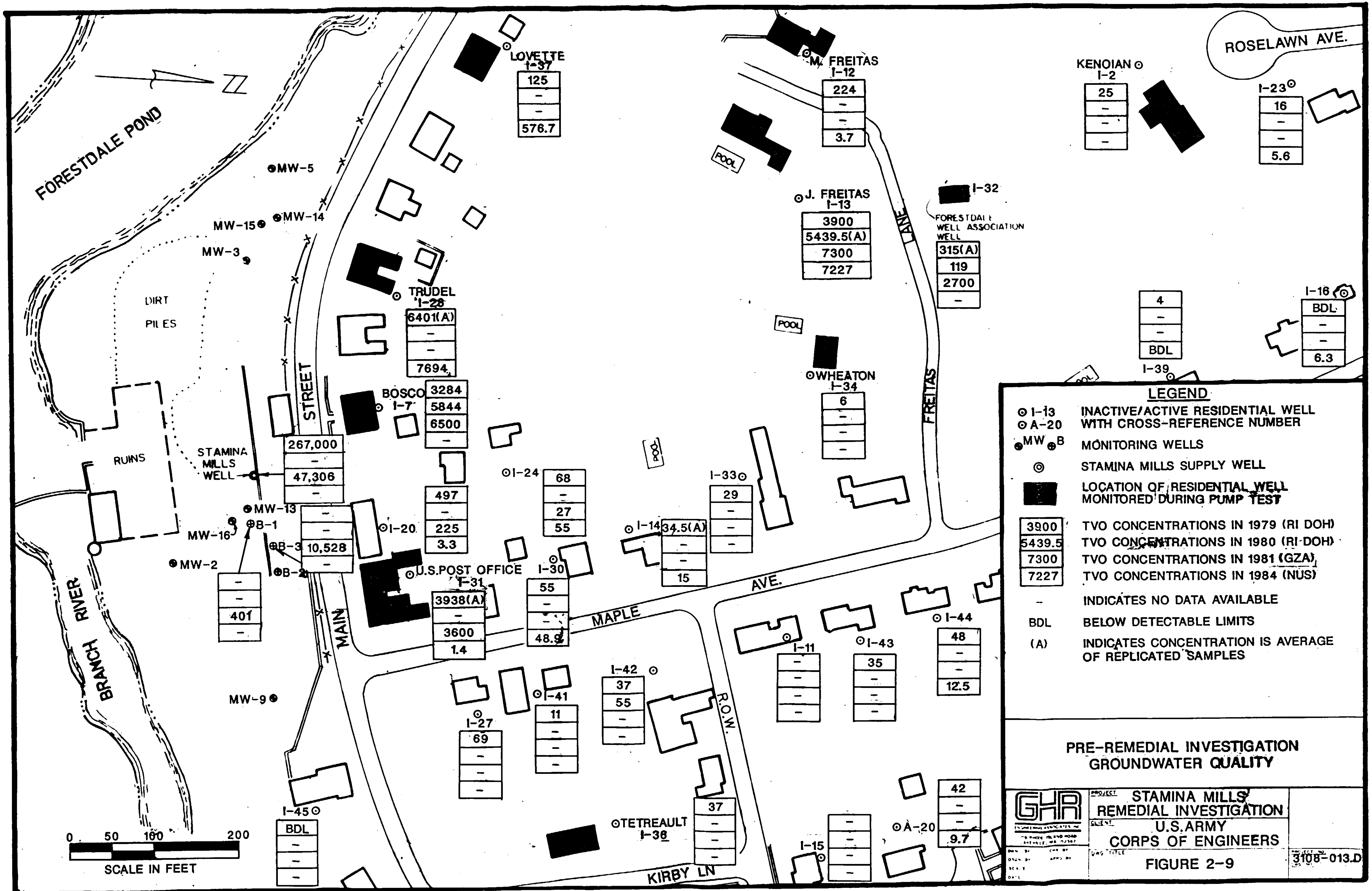
[illegible] ROAD
NEW BEDFORD, MA [illegible]

DWN. BY CJR CHK BY WRN
DSGN BY GM APPR. BY JJG
SCALE 1":100'
DATE 4/27/87

PROJECT
STAMINA MILLS
REMEDIAL INVESTIGATION

CLIENT
U.S. ARMY CORPS OF ENGINEERS

DWG TITLE FIGURE 2-8
GROUNDWATER CONTOUR
ELEVATIONS FROM BEDROCK WELLS
AT THE STAMINA MILLS SITE
(ELEVATIONS AS OF 8/86)



PRE-REMEDIAL INVESTIGATION
GROUNDWATER QUALITY

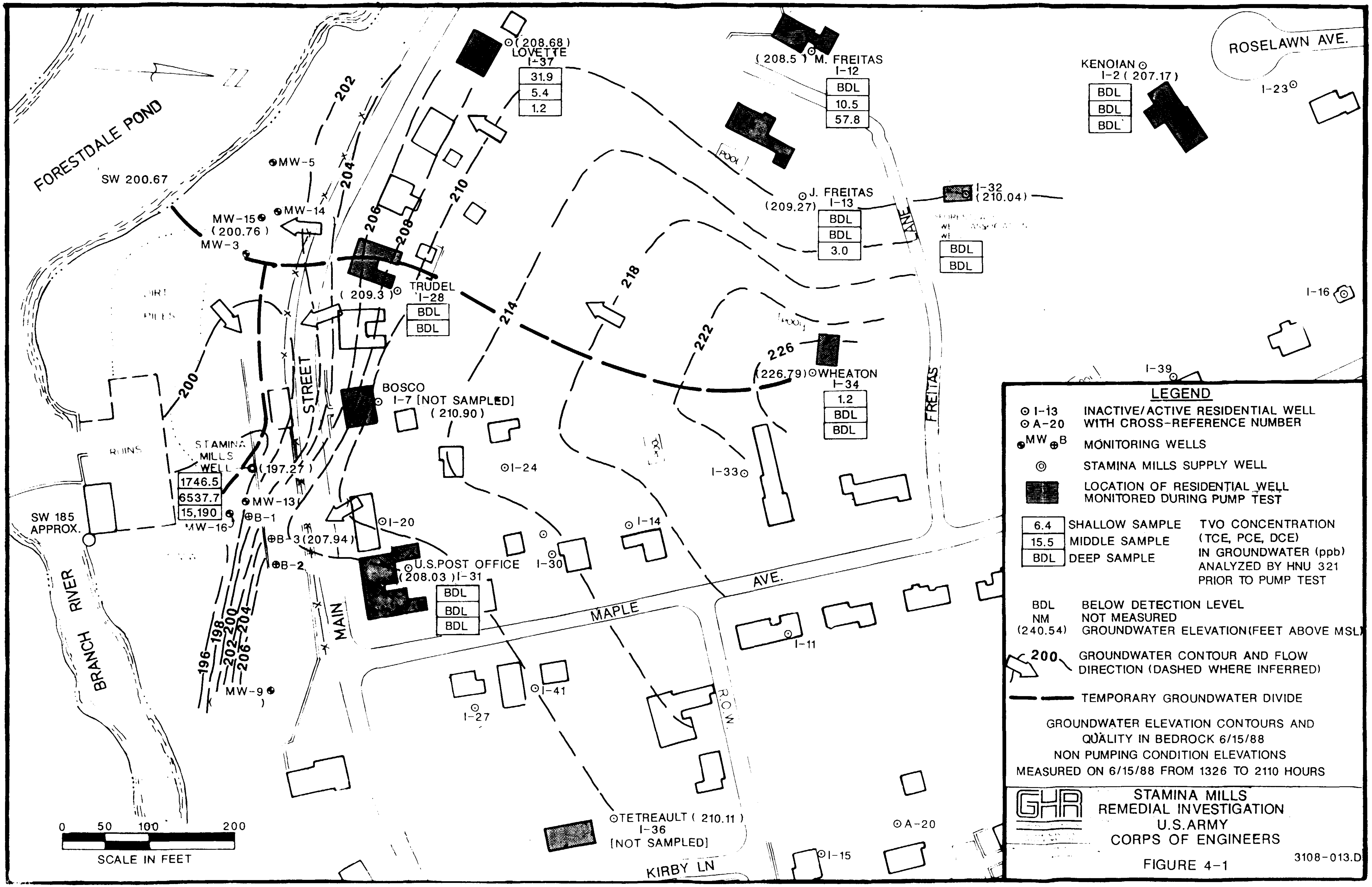
GHR

PROJECT STAMINA MILLS
REMEDIAL INVESTIGATION

CLIENT U.S.ARMY
CORPS OF ENGINEERS

DWG TITLE FIGURE 2-9

PROJECT NO. 3108-013.D

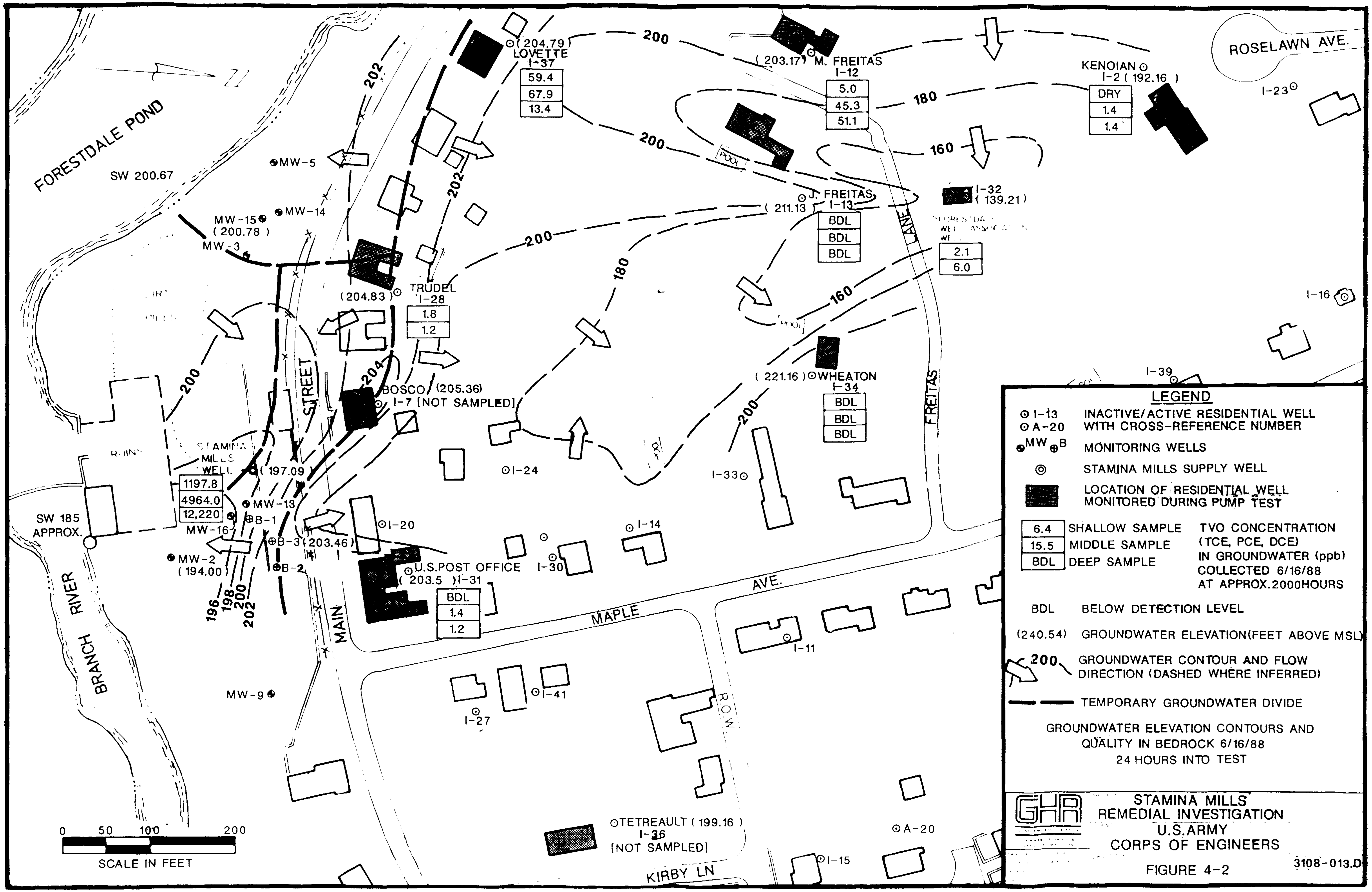


GROUNDWATER ELEVATION CONTOURS AND QUALITY IN BEDROCK 6/15/88
NON PUMPING CONDITION ELEVATIONS
MEASURED ON 6/15/88 FROM 1326 TO 2110 HOURS

STAMINA MILLS
REMEDIAL INVESTIGATION
U.S.ARMY
CORPS OF ENGINEERS

FIGURE 4-1

3108-013.D



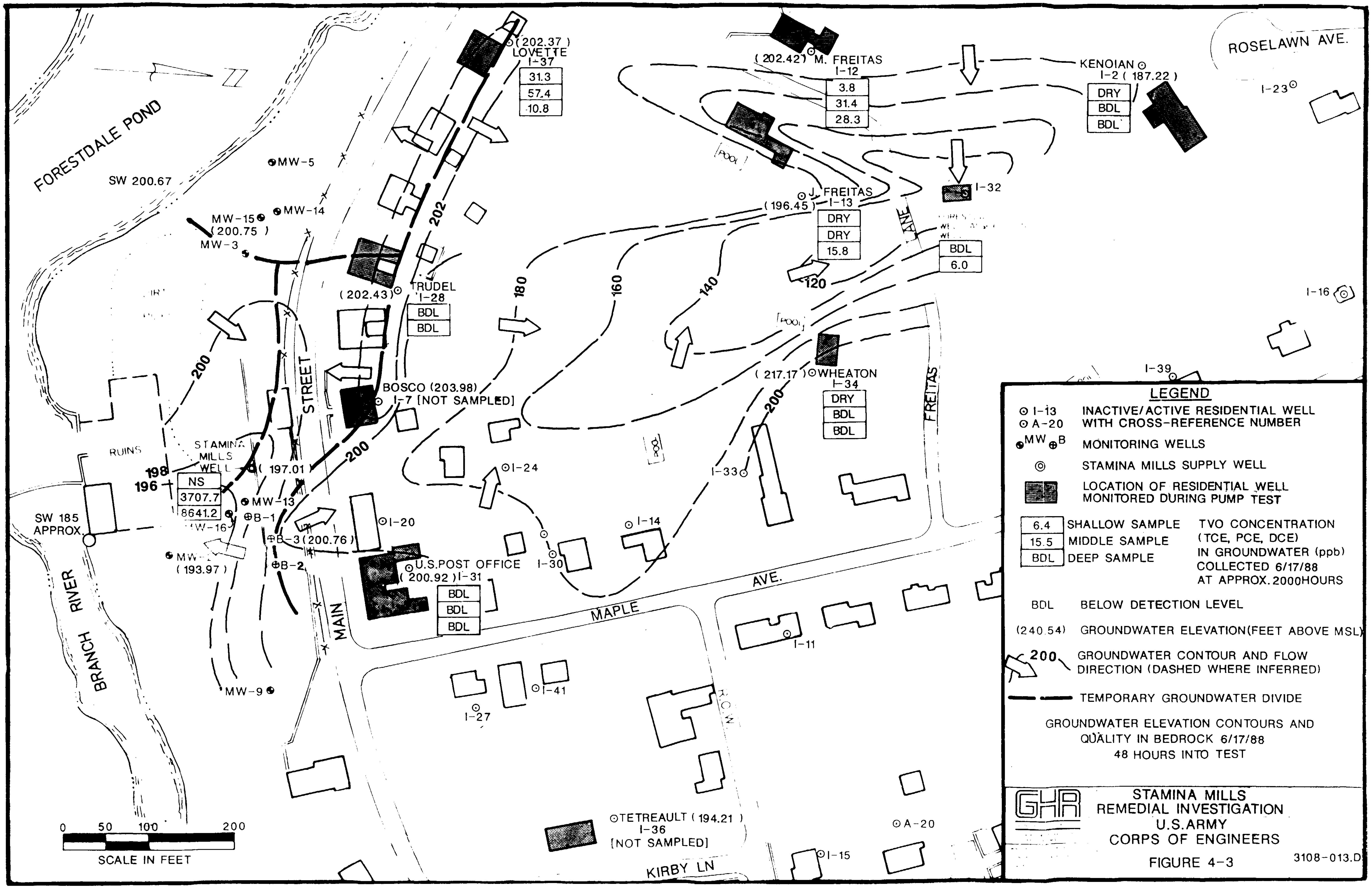
GROUNDWATER ELEVATION CONTOURS AND QUALITY IN BEDROCK 6/16/88
24 HOURS INTO TEST

GHR

STAMINA MILLS
REMEDIAL INVESTIGATION
U.S.ARMY
CORPS OF ENGINEERS

FIGURE 4-2

3108-013.D

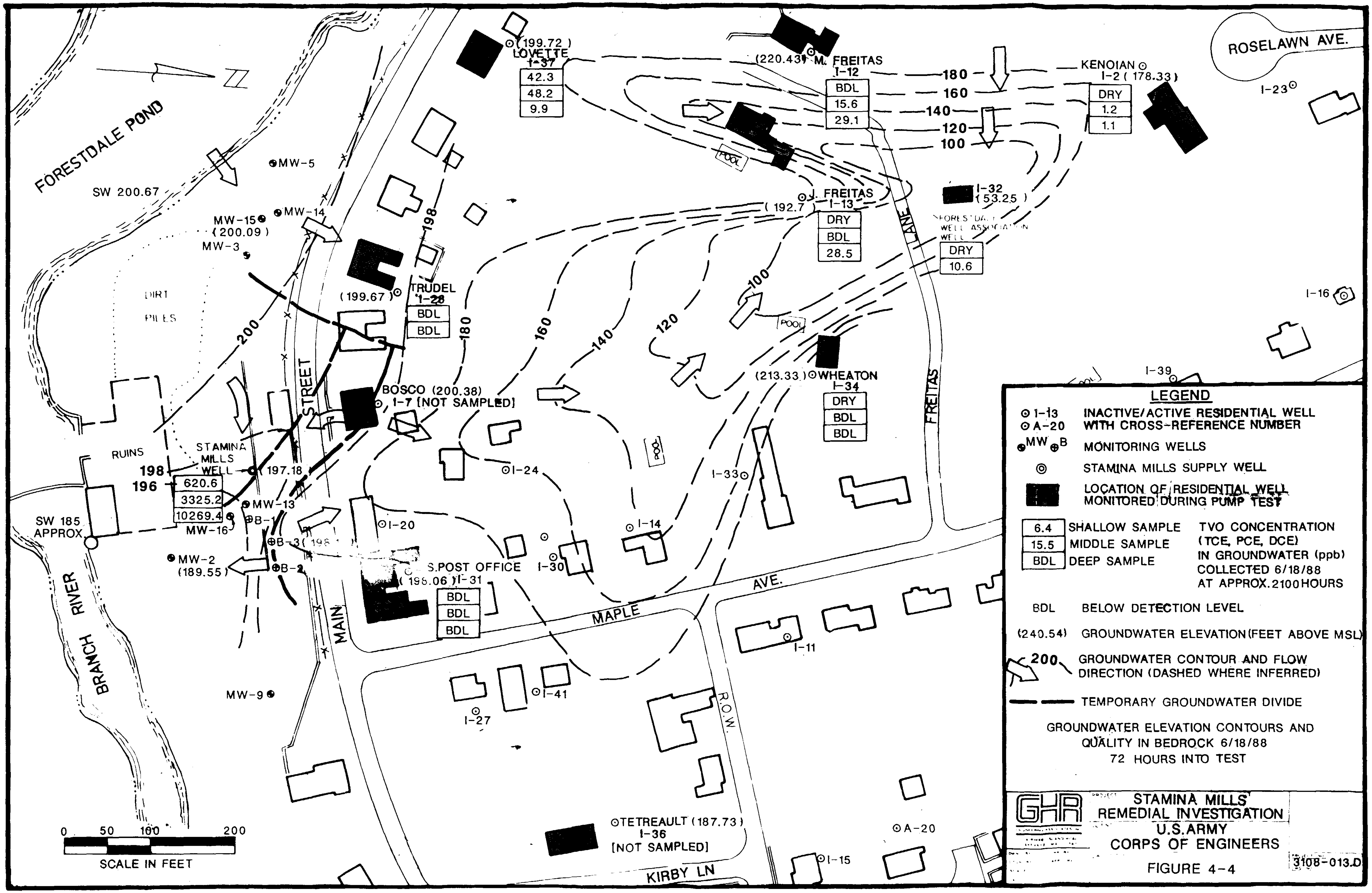


GROUNDWATER ELEVATION CONTOURS AND QUALITY IN BEDROCK 6/17/88 48 HOURS INTO TEST

STAMINA MILLS
REMEDIAL INVESTIGATION
U.S.ARMY
CORPS OF ENGINEERS

FIGURE 4-3

3108-013.D

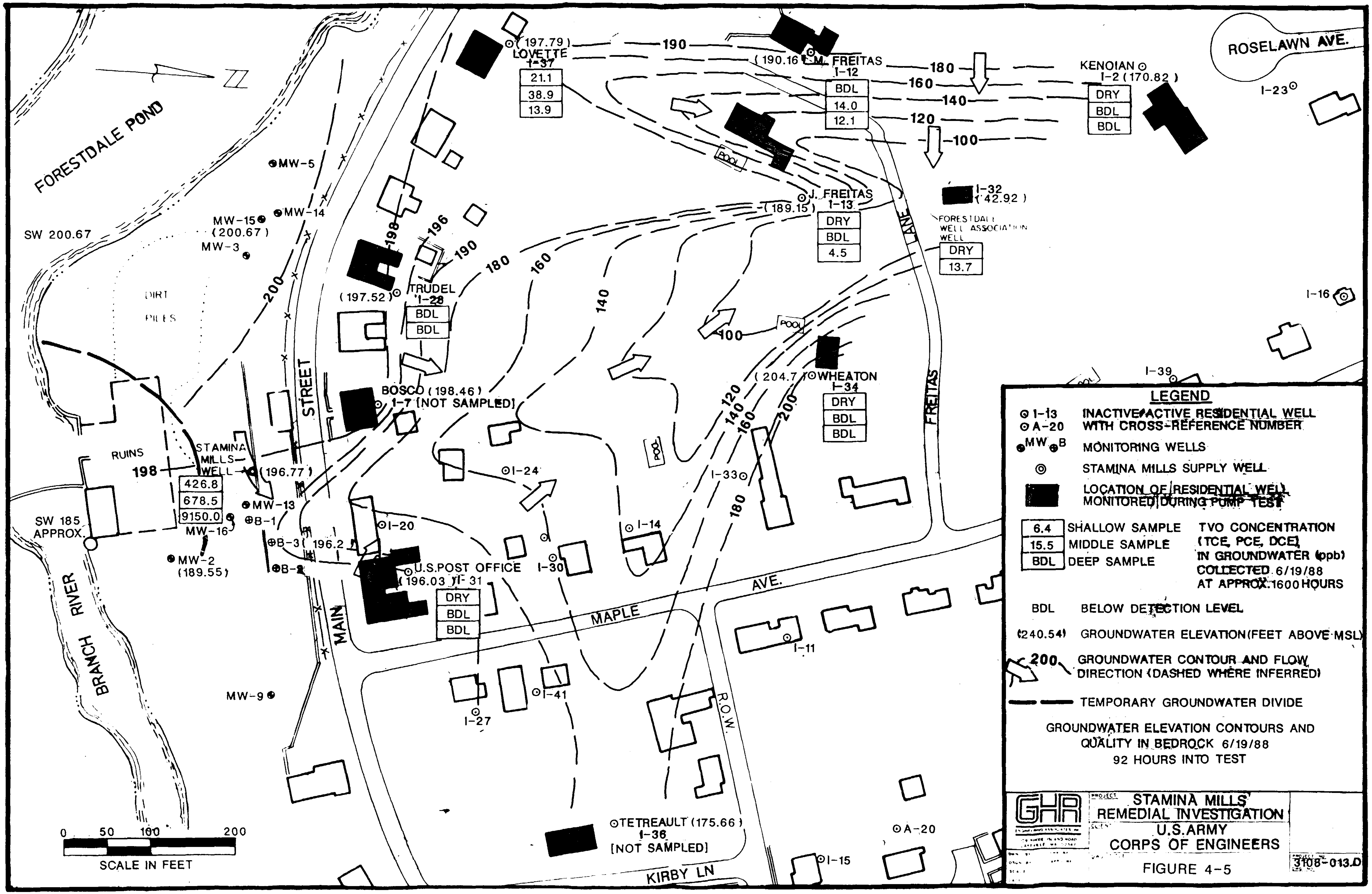


GROUNDWATER ELEVATION CONTOURS AND QUALITY IN BEDROCK 6/18/88
72 HOURS INTO TEST

STAMINA MILLS
REMEDIAL INVESTIGATION
U.S.ARMY
CORPS OF ENGINEERS

FIGURE 4-4

3108-013.D



GROUNDWATER ELEVATION CONTOURS AND QUALITY IN BEDROCK 6/19/88
92 HOURS INTO TEST

FIGURE 4-5

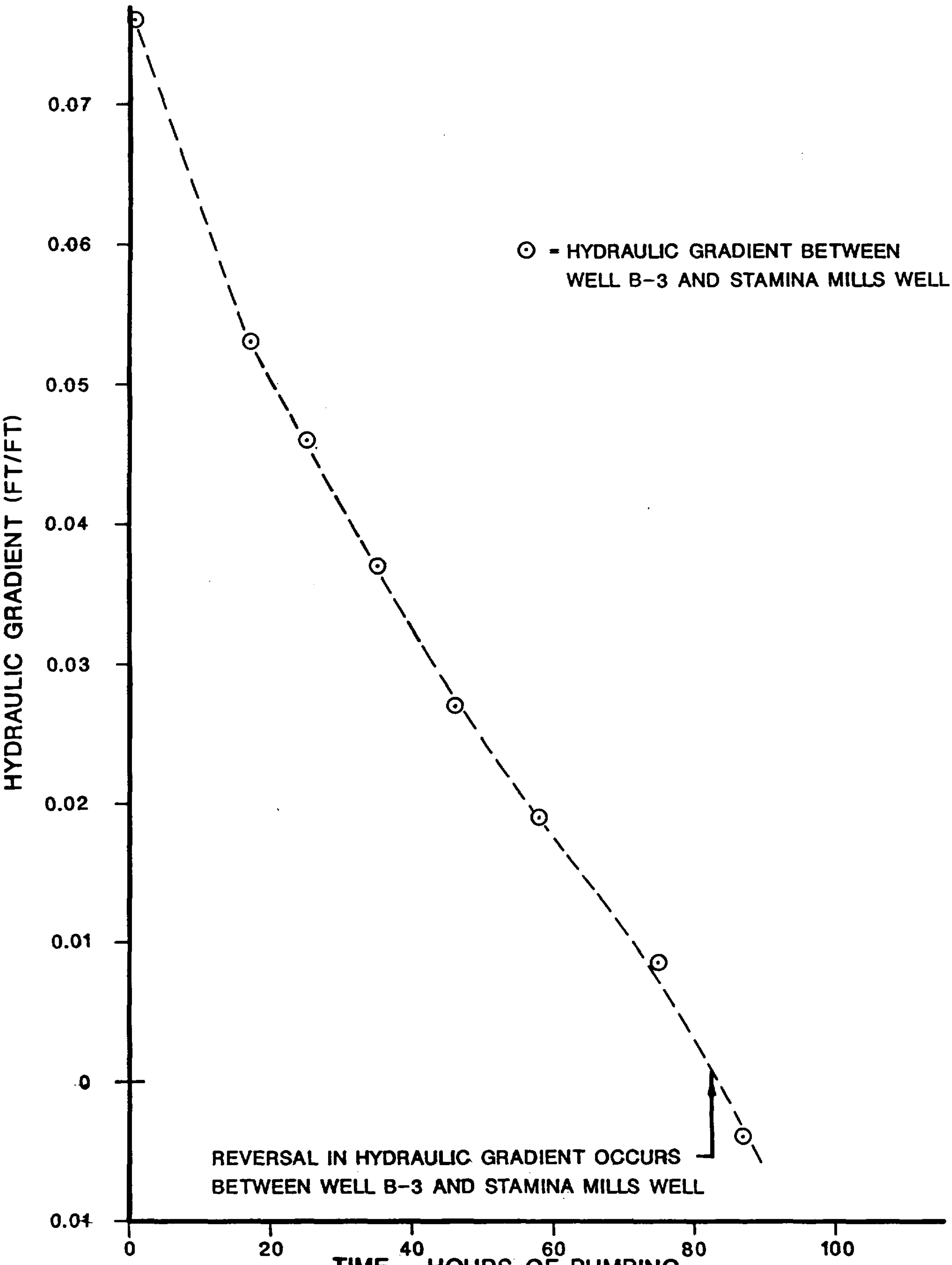
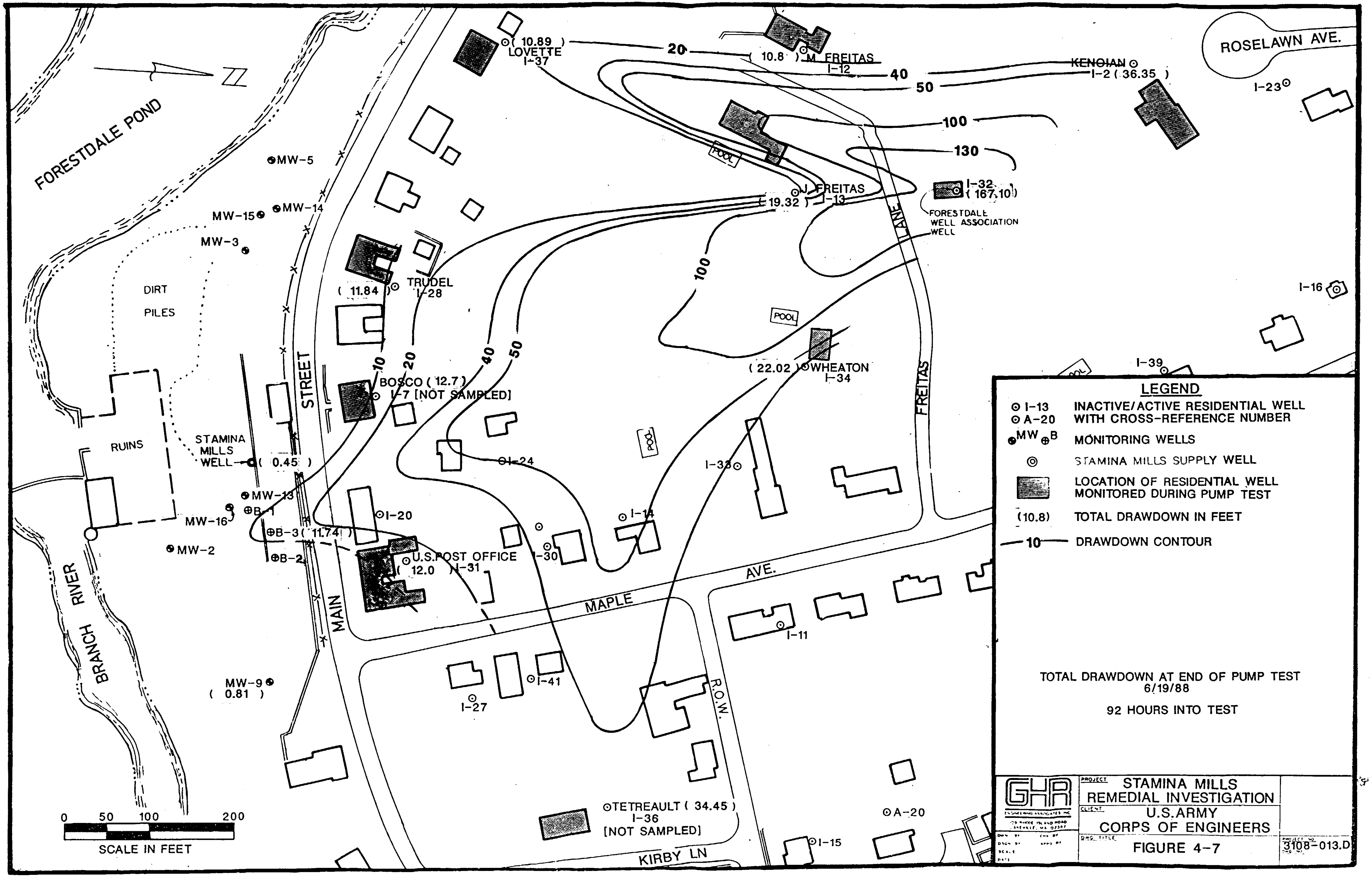


FIGURE 4-6

PLOT OF HYDRAULIC GRADIENT BETWEEN B-3
AND STAMINA MILLS WELL DURING PUMP TEST

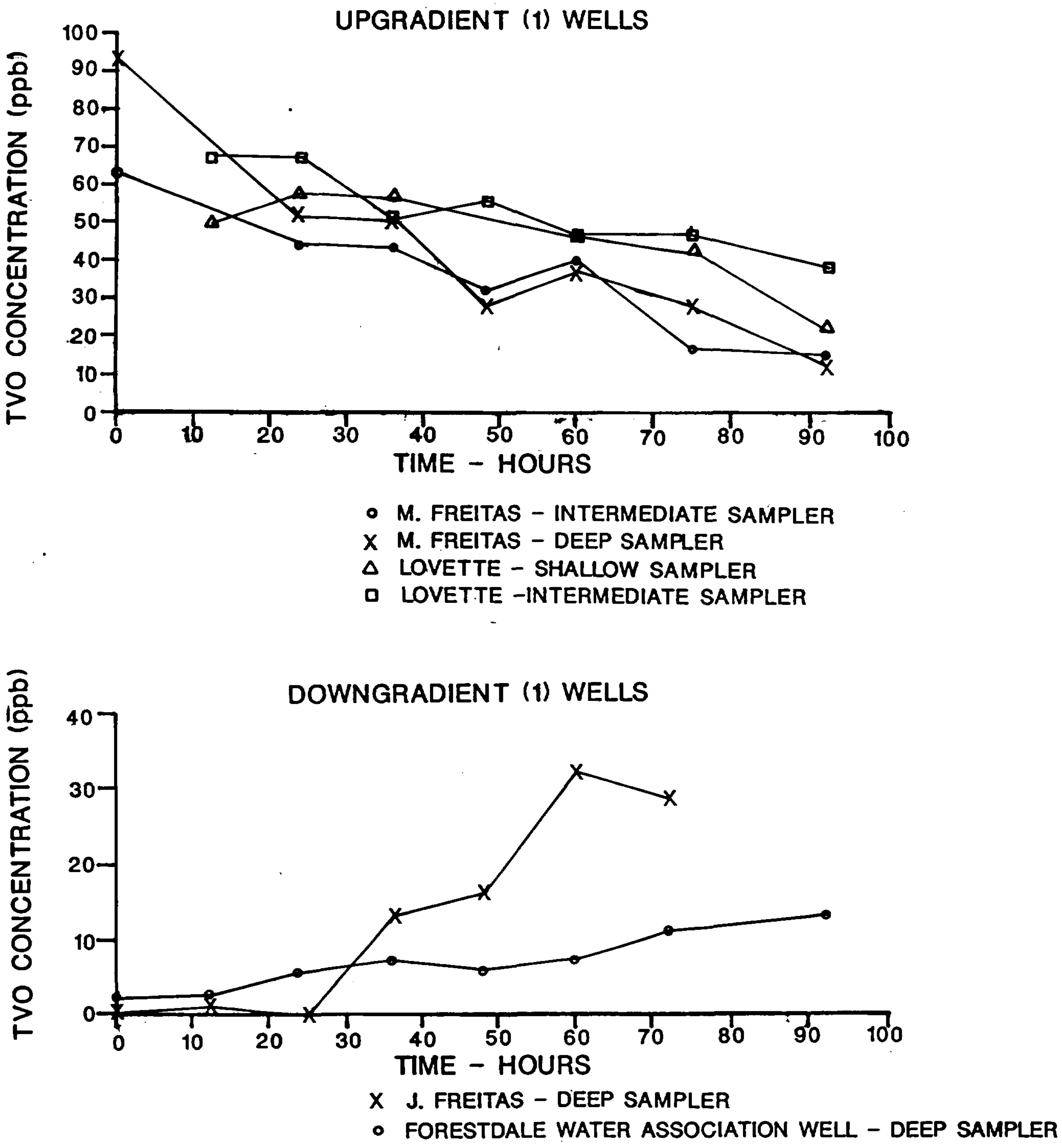
GHR



TOTAL DRAWDOWN AT END OF PUMP TEST
6/19/88

92 HOURS INTO TEST

PROJECT STAMINA MILLS REMEDIAL INVESTIGATION
CLIENT U.S. ARMY CORPS OF ENGINEERS
DWG. TITLE FIGURE 4-7
PROJECT NO. 3108-013.D



NOTES: 1. DOWNGRADIENT AND UPGRADIENT IS RELATIVE TO THE FORESTDALE WATER ASSOCIATION WELL WHICH WAS PUMPED.

FIGURE 4-8

TVO CONCENTRATIONS AT SELECTED WELL DEPTHS IN FOUR RESIDENTIAL WELLS

GHR

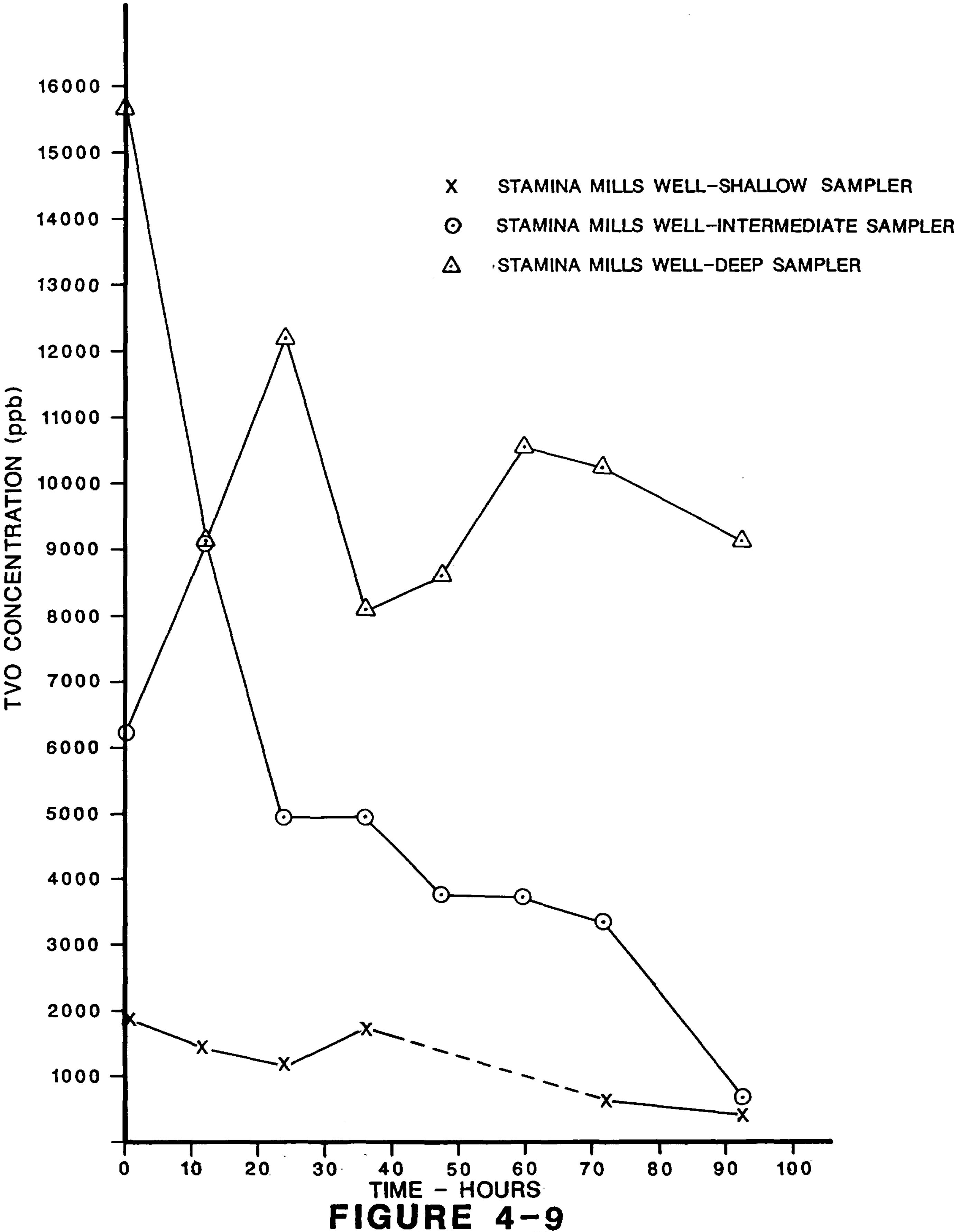
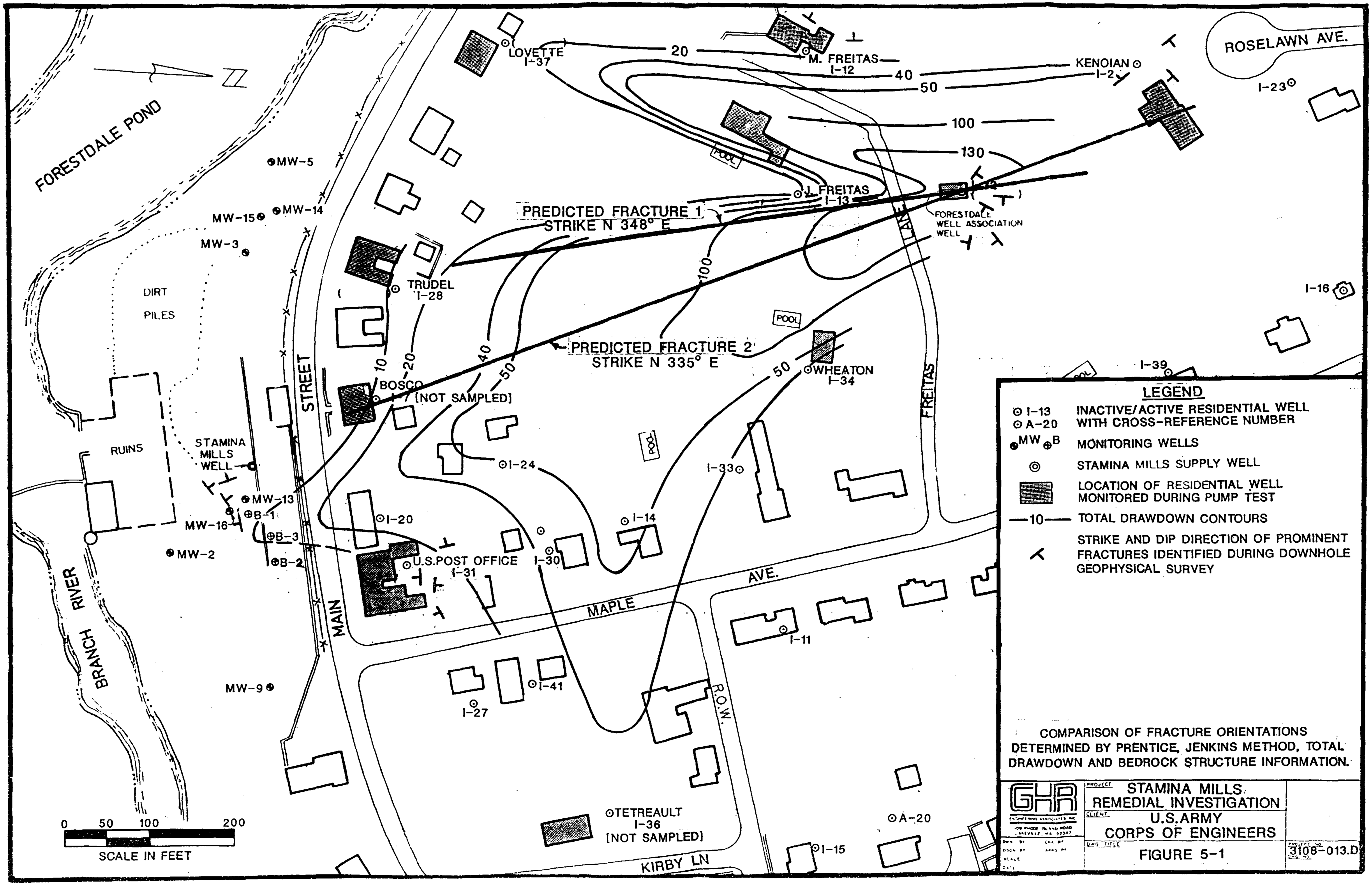


FIGURE 4-9

TVO CONCENTRATIONS IN THE STAMINA MILLS WELL



COMPARISON OF FRACTURE ORIENTATIONS DETERMINED BY PRENTICE, JENKINS METHOD, TOTAL DRAWDOWN AND BEDROCK STRUCTURE INFORMATION.

GHR

PROJECT STAMINA MILLS REMEDIAL INVESTIGATION

CLIENT U.S.ARMY CORPS OF ENGINEERS

DWG. TITLE FIGURE 5-1

3108-013.D

APPENDIX A

ROCK CORE LOGS

ROCK CORE LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 1
LOCATION Refer to Site Plan
SHEET No. 3 OF 5
JOB No. 3108019
DATE(S) 6-5 to 6-9-86

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm/psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
14	C-1	40.8		31				J	Rock is fresh, competent. Joints are parallel to foliation, surfaces slightly stained	14.0' to 20.1': Moderately hard medium to locally coarse grained medium light grey gneissic Quartz-Biotite Schist, local Pegmatite zones Color Code: N6 Moderately well-developed foliation dipping 20 to 25 °.	
15			2.8					D J J			
16			2.8					J		Pegmatite 16.5' - 17.2'	
17			3.7				16.9' to 21.7'	J D			
	C-2	60		38		0.2/18	K= 0.11 F/D				
18			4.3					J	18' to 19.5': Secondary set of right angle (80) to vertical joints intersecting foliation joints. Surfaces stained but rock is intact.		
19			3.3					J			
20			3.5				19.4' to 24.7'			20.1 to 37.4 Moderately hard, medium-grained light to medium light grey Quartz-Biotite SCHIST. Color Code: N6 to N7 Well developed Schistose foliation.	
21			2.5			Less Than 0.05/16	K < .06 F/D No Flow	D D D			
22								D			

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Cored from 14.0 ft to 37.4 ft with high volume of water return throughout.
2. Packer pressure tested rock zone from 16.9 ft to 34.2 ft.

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 1
LOCATION Refer to Site Plan
SHEET No. 4 OF 5
JOB No. 3108019
DATE(S) 6-5 to 6-9-86

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE		CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC AND DESCRIPTIVE LOG		NOTES
	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE	(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
22	C-2		3.5					D D			
	C-3	60		33					Healed quartz-filled joint	Moderately hard, medium grained Quartz-Biotite SCHIST.	
23			2.5						23.3' to 24.5' and at 26.8': 23' to 29.5': Foliation joints are moderately spaced tight, and surfaces exhibit oxidation staining.		
24			3.0				24.7' to 29.5'		Rock fabric is intermittently stained throughout, but is intact and competent.		
25			2.5			0.1/19	K < 0.5 F/D	D	29' to end of Recovery: Rock is fresh intact. Moderately hard to medium hard with increasing Biotite content and foliation development with depth.		
26			2.5					D D	Breaks are principally mechanical along foliation.		
27			2.7					D			
	C-4	60.5		85							
28			3.0								
29			2.7					D D			
30								D			

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 1
LOCATION Refer to Site Plan
SHEET No. 5 OF 5
JOB No. 3108019
DATE(S) 6-5 to 6-9-86

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
30												
	C-4	60	2.0	85			29.5' to 34.3'	D D			Quartz-Biotite SCHIST	
								D D			Local Pegmatite Zones at 32.5',33.5', 37.0'	
31								D				
			2.3			less than 0.05						
						19.7	K < 0.05 ft/ day No Flow	J				
32			2.5					J				
	C-5							D D		Pegmatite		
33		60	2.8	72				D D				
								D		Pegmatite		
34			3.5					D D D D D				
35										Pitted Pegmatite at 35.0'	--- 35'	
			3.5					D D D D			Medium hard, medium grained, medium light grey Quartz-Biotite Schist	
36											Strongly Foliate	
			1.8					D J			Color Code N6	
37			3.2							Hard Pegmatite Zone		
										Bottom of Exploration	37.4 Ft.	
38												

LEGEND:

J-JOINT	S-SLICKENSIDE
T-FAULT	D-DRILLING BREAK
F-FOLIATION	M-MINERALIZATION ZONE
B-BEDDING	WX-WEATHERED ZONE
C-CONTACT	K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 2
LOCATION
SHEET No. 3 OF 6
JOB No. 3108019
DATE(S) 6-9-86 to 6-10-86

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST ppm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
11	C-1 11 to 14.4'	7		0				ZONE OF CORE LOSS 11' to 13.7'		Probable SAPROLITE Decomposed ROCK to 13.7 Ft, Recovered 0.6' of 3.4' core run	9.7' to 13.7': SAPROLITE Decomposed Quartz-Biotite SCHIST of BLACKSTONE SERIES	
12			1.8									
13			1.2								13.7' to 21.6': Moderately hard, medium-grained, light grey Quartz-Biotite SCHIST with local Pegamtite Zones. Color Code N7.	
14			1.2			13.7 to 18.4 Not	ft ft Tested			High angle, tight joint. Surfaces are lightly stained. Rock generally fresh.		
	C-2	30	13.0									
15				23				D			Moderately developed schistosity dipping approximately 20°.	
								J				
16			4.0					J J J		Zone of tight to slightly open fractures through pegmatite. Stained, but rock is hard.	16.2' to 18.5': Coarse-grained Quartz and Feldspar Pegmatite Zone	
17	C-3	34.5	4.0	45								
18			5.0					J J J		18.5' to 21.4': Rock generally fresh.		
19			4.0									

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:
1. Cored from 11 ft to 14.4 ft through Saprolite; top of firm rock at 13.7 ft. Cored 14.4 ft to 37.0 ft.
2. Packer pressure tested rock zone from 18.4 ft to 34.3 ft.

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-2
LOCATION
SHEET No. 4 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/ DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
19	C-3	34.5					18.4' to 23.2'	J		18.5' to 21.4': Rock generally intact. Joints are tight, slightly stained. Rock fabric intermittently stained.	Quartz-Biotite SCHIST Moderately developed Foliation.	
								J				
			4.0			FLOW AROUND PACKERS COULD NOT SEAL						
20								D				
	C-4	60	3.3	26				D D D				
21						19.9' to 24.7':		J		21.4' to 23.6': Rock is moderately weathered. Joints are close at 1/2" to 1", tight. Surfaces and rock fabric exhibit staining.	21.4' to 23.6' Soft to medium-hard, medium grained BIOTITE SCHIST. Greyish Black. Color Code N2. Strong platy foliation dipping 10 ° to 20 ° .	
						<0.1/22.7	K < .05 F/D	J J				
22			3.0									
23			3.0							23.5' to 24.1': High angle, tight joint, Rock fabric stained throughout.	23.6' to 31.4' Moderately hard, medium-grained, light grey Quartz-Biotite SCHIST. Foliation moderately to well-developed, dipping approximately 20 ° .	
24			2.0			24.7' to 29.5':				24.5' to 25.8': Tight, vertical to high angle joint; darkly stained surface.		
						less than 0.05/22	K < .05 F/D	VJ				
25			2.0									
	C-5	60		72		No	Flow					
26			3.8					D		26' to 29': Rock is intact, fresh throughout. Staining limited to joint surfaces.		
								J				
27			1.6					D				

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

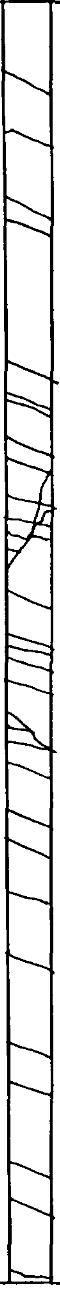
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-2
LOCATION
SHEET No. 5 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH



SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC AND DESCRIPTIVE LOG			NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm psi	K ft/day	TYPE OF FRACTURE	GRAPHIC LOG	(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
27	C-5	60		72				J D			Moderately hard, Quartz-Biotite SCHIST.	
28			1.6					D J				
29			1.6			29.5 34.3 less than 0.05	' to ':	J J D D J		Oxidation Staining Throughout		
30			2.0			22.9	K < 0.5 F/D					
	C-6	57		70				J J D D		Tight, high angle to vertical joint with foliation joints terminating on surface. Slight Weathering.		
31			2.0				No Flow	J		31.4' to 32.1': Rock is soft, pitted. Weathering extends into rock fabric with remineralization and decomposition of biotites.	31.4' to 32.2' Pegmatite and Severely Weathered Schist	
32			3.7					J J D			32.2' to end of recovery: 37.0' Moderately hard, medium grained, medium light grey, gneissic Quartz-Biotite SCHIST. Moderately to well-developed foliation dipping approximately 20 ° . Color Code: N6	
33			2.5					D		33.3' to 37.0': Fresh, intact rock throughout.		
34			1.8					D D D				
35			2.0					D				

LEGEND:

J-JOINT	S-SLICKENSIDE
T-FAULT	D-DRILLING BREAK
F-FOLIATION	M-MINERALIZATION ZONE
B-BEDDING	WX-WEATHERED ZONE
C-CONTACT	K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 2
LOCATION
SHEET No. 6 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV.

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE		CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
35	C-7	24		100				D		Intact, fresh rock throughout.	Gneissic SCHIST	
36			2.0									
								D				
			2.2					D				
37										Bottom of Exploration:	37.0'	
38												
39												
40												
41												
42												
43												

LEGEND:

- J-JOINT
- T-FAULT
- F-FOLIATION
- B-BEDDING
- C-CONTACT
- S-SLICKENSIDE
- D-DRILLING BREAK
- M-MINERALIZATION ZONE
- WX-WEATHERED ZONE
- K-PERMEABILITY

TYPE OF SAMPLE:

- C-CORE
- S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 3
LOCATION
SHEET No. 3 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

	SAMPLE		CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP		GRAPHIC AND DESCRIPTIVE LOG		
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm / psi	K ft/day	TYPE OF FRACTURE	GRAPHIC LOG	(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
11	C-1 10.9' to 15.2'	46.2		58				J		TOP OF ROCK 10.8 FT 10.9' to 15.2' Two predominant joint orientations 1) Parallel to bedding or schistosity (10 to 20° dip) 2) Vertical to 70 °±.	10.9' to 23.6': Very light to light grey, medium grained, moderately hard Quartz-Biotite Schist. Color Code: N8 to N7. Schistose foliation dips 10° to 20°. Relict bedding typically parallel to schistosity with occasional fine (1/8") layers dipping as much as 30°.	
12			2					J J				
13			2					D D		Joints are typically tight, with weathering limited to moderate surface staining.	Locally pitted.	
14			1.3 2.3			15.1' to 19.9':		D				
15	C-2 15.2' to 20.2'	60	1.7	20		6.5 / 12.8	K=5.1 F/D			15.2' to 18.0': Zone of discoid fragments commonly 1/2 inch thick, typically tight and intersected by high angle (70° to vertical joints). Rock surface is pitted and friable, appears to have been eroded by drilling water or natural flow.		
16												
17			1.5			17.1' to 21.9': 7.2 / 11.9	K=6.1 F/D					
18			1.5					D		18.3' & 18.5' to 18.8': Vertical joints		
19												

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT

S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Cored from 10.9 ft to 35.7 ft with no wash water return.
2. Packer pressure tested rock core zone from 15.1 ft to 30.9 ft.

ROCK CORE LOG

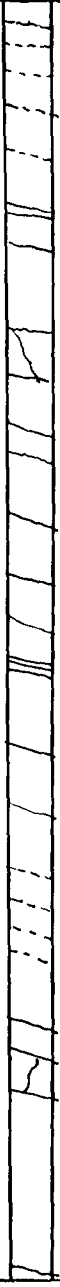
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 3
LOCATION
SHEET No. 4 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV.

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
19	C-2	60	2.3	20				D D D		19.0' to 31.7': Zone of intact, but brittle rock: Numerous drilling breaks parallel to schistosity foliation. Occasional tight joints typically parallel to foliation.	Moderately hard Quartz-Biotite Schist	
								D				
20			2.2					D				
	C-3	56.4						D D				
	20.2' to 24.8'			85								
21			1.6			21.2' to 26.4':		D				
								J D D				
22			1.9			0.1 15A	K < 0.07 F/D	D				
								D J J D				
23			2.3					J				
								J			23.6'to 35.7' Medium grey to medium dark grey, medium grained, moderately hard spotted Quartz-Biotite gneissic schist. Schistosity dips 20 ° to 30 °. Relict bedding is horizontal to parallel to schistosity Color Code: N6 to N5	
								D				
24			3.2					D D D D D				
			2/0.6'					J				
25	C-4 24.8' to 28.1'	39.6		85				J				
								D				
26			3.7									
								D				

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

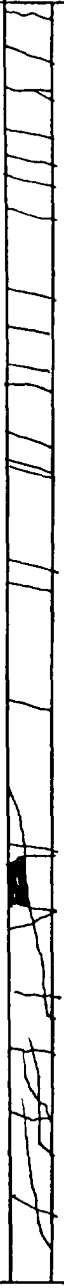
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 3
LOCATION
SHEET No. 5 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV.

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
27	C-4 24.8' to 28.1'	39.6	3.3 4.3	85		26.1 30.9 .27 22.5	' to ':	D D J J D		19.0' to 31.7': Intact but brittle and locally pitted rock. Joint surfaces are typically fresh.	Moderately hard Quartz-Biotite Schist	
28	C-5 28.1' to 32.2'	49.2	3.5	75			K = .12 F/D	D D D J D				
29								J J J				
30			4.0					J D				
31			3.3					J		31.7' to 34.5': Zone of high angle to vertical joints. Generally tight. Sand filled joint encountered at 32 ft ±.		
32	C-6 C-7 32.3' to 35.7'	1 40.8	JAMB	0 40								
33			4.2					J J				
34			5.2					J				

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT

S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-3
LOCATION
SHEET No. 6 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
35	C-7		4.5								Moderately hard Quartz-Biotite Schist	
		40.8						D				
				40				D				
			5.7/ 0.4'					D				
										End of Exploration 35.7'		

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT

S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-3A
LOCATION
SHEET No. 3 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE		CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
9										Top of Firm Rock 9.6'±		
10	C-1	44.4		57						Foliation joints are typically tight, moderately spaced and slightly stained. Rock fabric is fresh and competent.	9.6' to 24.1': Medium to moderately hard, medium grained, light grey, Quartz-Biotite SCHIST Color Code N7	
			4.8									
11												
			3.1								Well-developed foliation dipping 20° to 25°.	
12												
			4.1									
13												
			2.0							Zone of 0.6 ft Core loss		
14						13.5' to 18.7'						
	C-2	10.8		90								
						7.7 14.4	K = 5.4 F/D	D				
15			1.8					D		Secondary joints are vertical, tight and fresh		
	C-3	42		54				D				
16			2.0									
						15.9' to 20.7'						
								D D				
						7.6 13.1	K = 5.9 F/D	D				
17			1.3					D				

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:
1. Cored from 9.6 ft to 38.4 ft with continuous loss of drilling water.
2. Packer pressure tested rock core zone from 13.5 ft to 34.2 ft.

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 3A
LOCATION
SHEET No. 4 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV.

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	ppm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
17	C-3										Quartz-Biotite SCHIST	
		42		54				D				
								D				
18			1.7			7.7 14.4	K = 5.4 F/D					
								J		Slightly open		
19			1.5							Zone of 1.5 ft		
						7.6 13.1	K = 5.9 F/D			Core Loss. Rock is soft, friable. Probable sand seams. Silty fine sand at top of core		
20			1.5									
	C-4											
		61.2		52								
						20.4 25.2	' to '					
21			2.0							Vertical fracture 21.2' to 22'. Rock is fresh, but sandy fill in fracture, open 1/8".		
						7.5 12.1	K = 6.3 F/D					
22			1.5									
								D				
23			2.2									
										SAND filled fragmented joint zone		
24			2.0								24.1'	
								D D D D			GNEISSIC SCHIST	
			5.2									
25												

LEGEND:

- J-JOINT
- T-FAULT
- F-FOLIATION
- B-BEDDING
- C-CONTACT
- S-SLICKENSIDE
- D-DRILLING BREAK
- M-MINERALIZATION ZONE
- WX-WEATHERED ZONE
- K-PERMEABILITY

TYPE OF SAMPLE:

- C-CORE
- S-SPLIT SPOON

NOTES:

ROCK CORE LOG

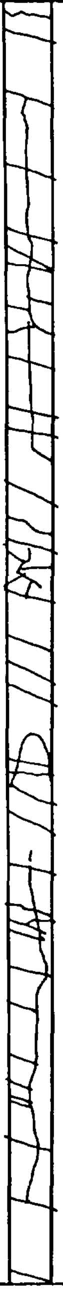
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 3A
LOCATION
SHEET No. 5 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV.

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm / psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
25	C-5	49		22		24.9 29.7	' to '	D D D		Recovered 1' of Silty fine SAND, top of core run. 25.5' to 27.5':	Moderately hard to hard, medium grained, gneissic Quartz-Biotite SCHIST.	
26			2.2			<.05 22.6	No Flow K < .02 F/D			Tight, vertical fracture. Rock is fresh.	Color Code N6. Moderately well-developed foliation/relict bedding, Dipping 20 ° to 25 °	
27			4.5									
28			4.2					D D		Fractured		
29	C-6	60	7.0	42		29.4 34.2	' to '	D D D			Two predominant point sets 1) Foliation joints dipping 20 to 25 ° 2) Irregular tight to slightly open vertical joints.	
30			1.6			7.5 18	K = 4.2 F/D	D		30.3' to 32.4': Vertical fracture Tight, joint surface heavily stained. Rock weathering to 1/16" ±.	Fragmented zone	
31			2.8									
32			3.2									
33			2.2					D				

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

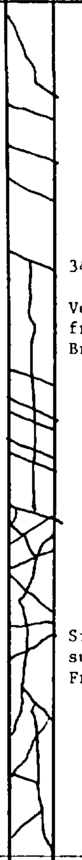
BORING No. MW-3A
LOCATION
SHEET No. 6 OF 6
JOB No. 3108019
DATE(S)

GHR

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/ DIP	GRAPHIC AND DESCRIPTIVE LOG			NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE	GRAPHIC LOG	(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
33	C-6						K = 4.2 F/D				GNEISSIC Quartz-Biotite SCHIST.	
			2.2					D				
34	C-7							D J				
		50.4		9		Not 34.2 38.4 Due Side Coll and/ SAND FILL	Tested ' to ' to wall apse or			34.6' to 36.3': Vertical fracture zones fragmented. Brittle Rock		
35			4.2					VJ				
36			3.2									
37			2.5							Silty fine Sands on fracture surfaces. Fragmented Core Recovery.		
38			2.5 1.5/ 0.3'									
										End of Exploration 38.4 Ft		
39												
40												

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 4
LOCATION
SHEET No. 3 OF 5
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
9.2	C-1									Top of Rock 8.0 Ft		
	9.2' to 12.7'	22.8		14						9.2' to 11.5': Zone of 1.6' Core Loss of	Moderately hard, light-grey, medium grained Quartz-Biotite SCHIST throughout of BLACKSTONE SERIES ROCKS	
10			7.0							Severely weathered and remineralized Biotite rich zone. Disced and Fragmented Recovery		
11			3.3							11.5' to 12.2': Fragmented core return. Vertical joint through foliation joints.	Bedding parallel to well-developed foliation dipping 25° to 30° throughout.	
								J				
12			6.0					J				
			3.2/.5'			12.0 16.8 Less Than	' to ':					
	C-2					0.05	K <					
13	12.7' to 17.7'	60		32		13.7	.04 F/D No Flow	J D J		13.5' to 14.5':		
			6.3							Zone of closely spaced, tight foliation joints exhibition oxidation staining (rust orange) throughout core.		
14								J J J				
			5.8					J				
15												
						15.6 20.4 less than	' to '	D		70 ° to 80 ° joint across foliation joints, tight, slightly stained.		
			3.5			0.05	K <					
16						18.2	.03 F/D	D				
			3.1					D D D D				
17								D				

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

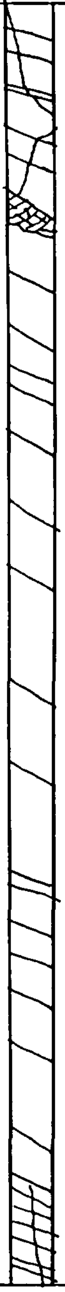
BORING No. MW- 4
LOCATION
SHEET No. 4 OF 5
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
17.2	C-2		3.2			15.6' to 20.4'				17' to 18.5': Zone of high angle, tight joints across foliation joints. Entire rock fabric exhibits oxidation staining.	Quartz-Biotite SCHIST Same	
						0.05 18.2	K < .03 F/D					
18	C-3 17.7' to 22.7'	55.2	2.2	63						18.5' to 18.7': Severely weathered, friable rock. 18.7' to 23.9':	Foliation well-developed, dipping 25 ° to 30 ° throughout	
19								D D D D		Rock is intact, brittle, with moderately to widely spaced tight foliation joints. Joint surfaces are fresh, exhibiting only slight oxidation staining.		
20			3.3			20.1' to 24.9'		J J				
21			3.2			less than 0.05 10,7	K = .05 F/D	J J				
22			3.7 3.7					J D				
23	C-4 22.7' to 27.7'	58.8		58				D J D		23.9' to 25.2': Oxidation stained through rock fabric		
24			4.2					D J J		24.5' to 25.3': Vertical, tight joint.	24.5' to 26.2': Coarse-grained Pegmatite with Schist weathered to Silty Fine Sand	
25			1.8					D				



LEGEND:
- J-JOINT
- T-FAULT
- F-FOLIATION
- B-BEDDING
- C-CONTACT
- S-SLICKENSIDE
- D-DRILLING BREAK
- M-MINERALIZATION ZONE
- WX-WEATHERED ZONE
- K-PERMEABILITY

TYPE OF SAMPLE:
- C-CORE
- S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-4
LOCATION
SHEET No. 5 OF 5
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV.

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
25.2	C-4					24.6 29.4	' to ':			Fragmental Pegmatite Zone	Quartz-Biotite Schist	
			4.0							25.3' to 25.8', with rock decomposed to fine sand and silt from 25.8' to 26.2'.		
						Less Than					Same	
26						0.1	K < .05 F/D					
			6.1			20.6				26.2' to end of recovery: Intact, brittle rock with widely spaced tight foliation joints		
27								J				
			4.0					D				
	C-5							D				
28	27.7' to 32.7'	60		85							28.3' to 28.7':	
			4.3							Pegmatite Zone with tight vertical fracture	Quartz Pegmatite Zone with deformation of foliation at contacts.	
29								J				
								D				
			4.7								Quartz-Biotite Schist,	
30						29.4 32.7	' to '	D			Same	
						NotT	ested					
			3.3									
31												
			3.5									
32								D				
								D				
			5.0									
33										End of Exploration 32.7 Ft.		

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

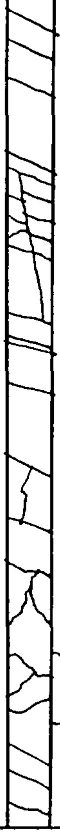
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-5
LOCATION
SHEET No. 3 OF 6
JOB No. 3108019
DATE(S) 6-3-86 to 6-5-86

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm/psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
14	C-1					Rock Zone from 14' to 17' not tested due to Side wall Collapse				Top of Firm Rock: 13.8: 14' to 16.7': Fragmented core recovery of hard Quartz-vein of Quartz-Biotite Schist.	14 to 16.7' Hard Quartz Pegmatite in Quartz Biotite Schist	
15		15	1.5	0								
16	C-2									Rock is typically fresh, unweathered, and brittle.	16.7' to 22': Medium grained, moderately hard, light grey Quartz-Biotite Schist	1.
17		51.5	2.0	31						Foliation joints are tight, only slightly weathered throughout, locally intersected by secondary set of high angle (60 ° to 70 °) to vertical fractures, tight, typically slight staining on joint surfaces.	Color Code N-7. Moderately well-developed Schistosity, dipping 20 ° to 25 ° throughout.	2.
18			2.5					D			Local Pegmatite Zones	
19			2.0					D D				
20			2.0			19.9' to 24.7'						3.
	C-3					30/17.3	K = 17.5 F/D					
21		59	2.0	25						Pegmatite Zone 21.0 to 21.4'		
22								D				

LEGEND:

J-JOINT	S-SLICKENSIDE
T-FAULT	D-DRILLING BREAK
F-FOLIATION	M-MINERALIZATION ZONE
B-BEDDING	WX-WEATHERED ZONE
C-CONTACT	K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Lost wash water at 16.0 ft. No return throughout rock coring.
2. Packer assembly blocked at 15.5 ft. Drilled NW casing to 17.0 ft; Borehole clear to 36 ft.
3. Pressure tested rock hole from 19.9 ft. to 33.5 ft.

ROCK CORE LOG

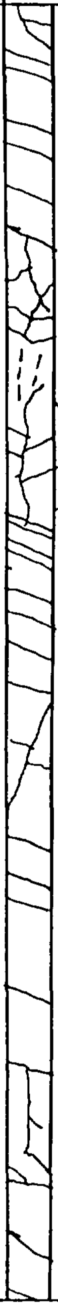
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-5
LOCATION
SHEET No. 4 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
22	C-3					19.9' to 24.7'					22.0' to end of recovery: Moderately hard, medium-grained medium-light grey gneissic Quartz Biotite Schist. Color Code N6	
								D				
			2.5					D D				
		59		25								
23								D D				
			2.0							23.5' to 24.0': Fragmented but fresh rock	Moderately well-developed foliation throughout, dipping 20 ° to 25 °.	
24						23.9' to 28.7'				24' to 25.2': Vertical, tight fractures slight staining at 24.8' to 25.2'		
			1.3			13.7 17.9	K = 7.6 F/D					
25												
			2.4					D D				
26	C-4							D D		Widely spaced, tight foliation joints.		
								D				
		57.6	2.3	52				D				
27												
			2.5									
								D D				
28												
			2.0									
29						28.7' to 33.5'						
			2.7			3.0 24.2	K= 1.25 F/D					
30												

LEGEND:
- J-JOINT
- T-FAULT
- F-FOLIATION
- B-BEDDING
- C-CONTACT
- S-SLICKENSIDE
- D-DRILLING BREAK
- M-MINERALIZATION ZONE
- WX-WEATHERED ZONE
- K-PERMEABILITY

TYPE OF SAMPLE:
- C-CORE
- S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 5
LOCATION
SHEET No. 5 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
30	C-4		2.0			28.7 33.5	' to '	J			Gneissic Quartz-Biotite Schist	
	C-5					3.0 24.2	K = 1.25 F/D			Fresh, competent rock. Tight, moderately spaced foliation joints.		
31			3.0									
		56.4		21								
32			3.7									
33			3.3									
34			3.0									
			3.0							Fragmented Zone		
35	C-6											
36			2.5									
		56.4		50						36.2' to 37.1': Pegmatite		
37			3.0									
38			3.0									

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-5
LOCATION
SHEET No. 6 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	GRAPHIC AND DESCRIPTIVE LOG (ROCK DESCRIPTION)	NOTES
38	C-6										Gneissic Quartz-Biotite Schist	
		56.4		50				D				
39			4.5					D				
										Pegmatite		
			4.3									
40										End of Exploration 40.0 Ft.		

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT

S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

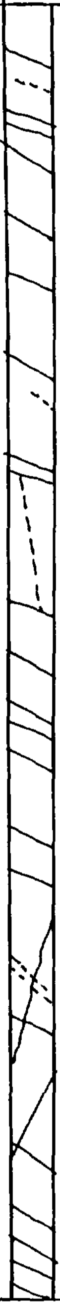
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 6
LOCATION
SHEET No. 3 OF 5
JOB No. 3108019
DATE(S) 6-11 to 6-12-86

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
21.4	C-1 21.4' to 25.3'	46.8						J		Top of Firm Rock 21.4' 21.4' to 34.4': Rock is intact, fresh. Foliation joints are tight, with slight staining on surfaces.	21.4' to 40.6': Moderately hard, medium-grained, medium light grey Quartz-Biotite Gneissic Schist Color Code: N6	1.
22			2.3	81				J J J J				
23			3.3					J		Pitted at 23.7'	Localized Pegmatite Zones.	2.
24			3.3			24.0' to 28.8'		J J		Local, tight high-angle to vertical jointing	Foliation is moderately well-developed dipping approximately 20°.	
25			2.6			0.15 20.7	K < .07 F/D	J J J J J		Pitted Pegmatite Zone		
26	C-2 25.3' to 30.3'	60	3.0					J J				
27			3.1	60				J				
28			3.1			28.5' to 33.3'		D J				
29			3.3			Less Than 0.1 20.2	K < .05 F/D	D J J				

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT

S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Cored from 21.4 ft to 45.4 ft with high volume of water return throughout.
2. Packer pressure tested rock zone from 24.0 ft to 42.4 ft.

ROCK CORE LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

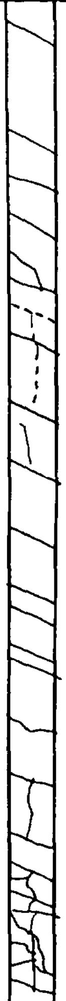
BORING No. MW- 6
LOCATION
SHEET No. 4 OF 5
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
29.4	C-2					28.5 33.3	' to '	J		21.4' to 34.4': Intact fresh rock. Foliation joints are typically tight.	21.4' to 40.6': GNEISSIC SCHIST with Localize of Pegmatite Zones	
						less than	K <	D				
30			3.5			0.1	.05	D				
	C-3					20.7	F/D	J				
		58.6		43				J				
31	30.3' to 35.3'							J		Pegmatite Zone at 31.0'		
			3.0									
								J				
32								J				
			4.3							Pegmatite		
								J				
33			4.1			33.0 37.8	' to '	J				
								J				
						Less Than	No Flow					
34						0.05	K <	D				
			4.3			24.1	0.2 F/D			34.4' to 40.6': Rock zone is hight fractured through coarse grained Pegmatite. Fracture surfaces, and rock fabric are typically stained, with local friable zones	34.4' to 40.6': Pegmatite Zone in Gneissic Schist	
								J				
								J				
								J				
35												
			4.7									
	C-4											
		60		18								
36	35.3' to 40.3'		4.1									
37			4.8									



LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

RÖCK CORE LOG

GHR

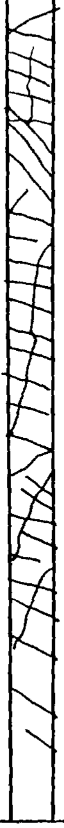
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 6
LOCATION
SHEET No. 5 OF 5
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm/psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	GRAPHIC AND DESCRIPTIVE LOG (ROCK DESCRIPTION)	NOTES
37.4	C-4	60		18		37.6' to 42.4'				30.4' to 40.6': Highly fractured through Pegmatite zone. Rock fabric and joint surfaces are stained. Rock fabric locally friable.		
38			4.7								Pegmatite Zone in Gneissic Schist	
39			4.1			0.7 21.4	K = .3 F/D					
40	C-5		4.0							40.6' to 45.0': End of Recovery: Completely fragmental core recovery. Tight closely spaced foliation joints intersecting high angle to vertical fractures at 41' to 41.4', 41.8' to 43.0' and 43.9' to 44.2'. Weathering limited to slight staining on joint surfaces	Moderately hard, medium grained, light grey Quartz-Biotite Schist. Well-developed foliation dipping approximately 20 °. Local Pegmatite	
41	40.3' to 45.3'	55	3.5	0								
42			2.8									
43			3.7									
44			2.3									
45			4.2							Bottom of Exploration 45.3'		

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-7
LOCATION
SHEET No. 3 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV.

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm / psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	GRAPHIC AND DESCRIPTIVE LOG (ROCK DESCRIPTION)	NOTES
	C-1									Top of Firm Rock 10.2 Ft.		1.
11		19.2	5.2	0								
12						Not Test	ed			Pegmatite zones are fractured. Breaks appear tight, weathering exhibited by staining only. Rock fabric is intact.	12.2' to 13.5': Quartz Pegmatite	
	C-2											
13		37.1	7.4	43							10.8' to 35.3': Moderately hard, medium-grained, medium light grey Gneissic Quartz-Biotite Schist. Color Code N6. Moderately well-developed foliate structure, dipping 25 ° to 30 °. Local Pegnatite Zones	
14			4.7			14.2' to 19.0'						
15			4.5 3.7			Less Than 0.05	No Flow K < .03 F/D			15' to 17': Fractured Pegmatite		
	C-3					18.9						
16		58.8	4.8	48								
17			4.3					D D J		17' to 21': Foliation joints are tight, moderately spaced. Staining of rock fabric to 1/2" above and below joint planes. Rock is intact.		
18			3.7					J				
19								J				

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Cored from 10.8 ft to 35.3 ft with high volume of wash return throughout.
2. Packer pressure tested rock core zone from 14.2 ft to 32.5 ft.

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-7
LOCATION
SHEET No. 5 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm/psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
27	C-5											
		60.6	4.2	83		27.7 32.5	' to ':			Foliation joints are tight, moderately to widely spaced. Slight staining on surfaces only.	Gneissic Quartz-Biotite Schist	
28												
			4.0			0.06 17.4	K < 0.03 F/D	D				
								D				
29			4.0					D				
								J				
								J				
30			3.8					D				
	C-6							J				
31		60		86								
			4.3					D				
								D				
32			4.5					D				
						Not Test	ed	J				
								J				
33			4.2					J				
								D				
								D				
34			3.2					D				
								D				
35												

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

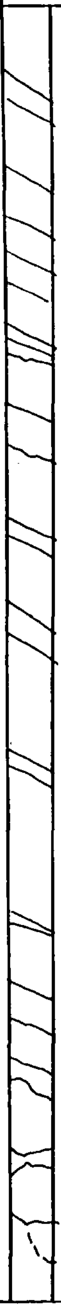
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 7
LOCATION
SHEET No. 4 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV.

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
19	C-3					18.7 23.5	' to ':	D			Gneissic Quartz-Biotite Schist	
			4.2			Less Than		D				
20						0.05	No Flow	J				
			3.3			16.9	K < .03 F/D	J J J				
	C-4											
21		56.4		73						21': open foliation joint with Clayey SILT fill (1/2")	21'	
			2.7					J		21' to 22': Foliation joints are tight, but rock fabric is pitted to 1/16" along surfaces.	Soft, medium grained Greyish, black Biotite Schist	
								D			Color Code N2	
22											22'	
			3.3					J J			Gneissic Quartz-Biotite Schist	
23												
			5.0			23.2 28'	' to	J				
						Less Than						
24						0.05	No Flow					
			5.2			21.3	K < .03 F/D	J		Pitted along joint plane		
25												
			4.2					D				
	C-5											
26		60.6		83							26' to 26.5'	
			4.5								Pegmatite Coarse-grained.	
27												

LEGEND:

J-JOINT	S-SLICKENSIDE
T-FAULT	D-DRILLING BREAK
F-FOLIATION	M-MINERALIZATION ZONE
B-BEDDING	WX-WEATHERED ZONE
C-CONTACT	K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

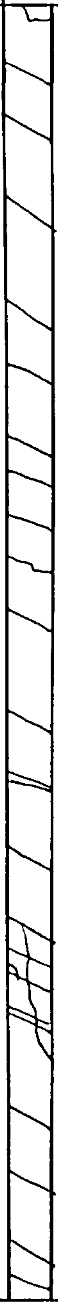
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-7
LOCATION
SHEET No. 5 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

	SAMPLE		CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
27												
	C-5											
		60.6	4.2	83		27.7 32.5	' to ':			*Foliation joints are tight, moderately to widely spaced. Slight staining on surfaces only.*	*Gneissic Quartz-Biotite Schist*	
28												
			4.0			0.06	K <					
							0.03					
						17.4	F/D	D				
								D				
29												
			4.0					D				
								J				
								J				
30												
			3.8					D				
	C-6							J				
31		60		86								
			4.3					D				
								D				
32												
			4.5					D				
								J				
						Not Test	ed	J				
33								J				
			4.2									
								D				
								D				
34												
			3.2					D				
								D				
35												

LEGEND:

J-JOINT	S-SLICKENSIDE
T-FAULT	D-DRILLING BREAK
F-FOLIATION	M-MINERALIZATION ZONE
B-BEDDING	WX-WEATHERED ZONE
C-CONTACT	K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-7
LOCATION
SHEET No. 6 OF 6
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
35	C-6							D				
			4.2					D				
										Bottom of Exploration 35.3'		

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT

S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 8
LOCATION
SHEET No. 4 OF 5
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	GRAPHIC AND DESCRIPTIVE LOG (ROCK DESCRIPTION)	NOTES
22			2.2			20.3 25.1	' to '				20.4' to 25.2' Biotite-Schist Well-developed platy foliation. Exhibiting relict bedding (horizontal to 30°) locally truncated by schistose foliation dip of 20 ° to 30 °. Color Code N5	
	C-3	60.6		62		Less Than .05 13.9	K < .04 F/D			22' to 24': Closely spaced 1/2" to 1" discoid fragments, tight. Stress relief or fresh tight joints.		
23			2.2							23' to 24': Moderately weathered and remineralized rock. Core surface is pitted		
24			1.8					D				
						24.8 29.6	' to '					
25			1.9			Less Than .05 16.3	No Flow K < .03 F/D	D D D			25.2' to 32.3' Moderately hard, medium grained spotted, gneissic Quartz-Biotite Schist. Bedding foliation and schistosity dipping 20 to 30 °. Color Code: N6 Local coarse, grained Pegmatite zone with contact deformation of schistosity at 26.3' to 27.1'.	
26			3.0					J D				
27	C-4	60	5.5	69				J D J				
28			6.8					J J		28' to 29': Locally pitted: along healed vertical fracture surfaces		
29			5.5					J J				
30												

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

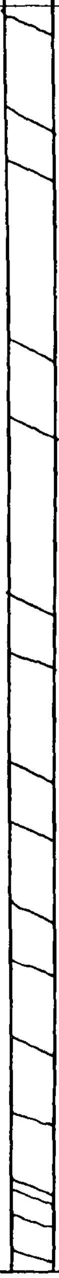
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-9
LOCATION
SHEET No. 3 OF 5
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
INCLINATION Vertical
CORE TYPE NV-2
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH



DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
11.0										Top of Rock 10.8 Ft.		
	C-1 11.3' to 15.3'	46.8		100							11.3' to 30.3' Moderately hard, medium-grained medium light grey, gneissic Quartz-Biotite Schist. Moderately, well-developed foliation dipping at 25 ° to 30 °. Localized Pegmatite	1.
12			3.3					J J		Tight		
										Fresh, intact rock. Widely spaced foliation joints are tight and exhibit only slight straining.		
13			4.1					D				
14			4.2			14.0' to 18.7':		J				
15			4.1			Less Than 0.05	No Flow	D D				
	C-2	60		100		17	K < .03 F/D					
16			4.3					D D				
17			4.8					D D				
18			4.8					D J				
19								D D D				

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Cored from 11.3 ft to 35.1 ft; intermittent loss of wash water at 28 ft, with return and generally high volume throughout.
2. Packer pressure tested rock core zone from 14.0 ft to 32.3 ft.

ROCK CORE LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 8
LOCATION
SHEET No. 5 OF 5
JOB No. 3108019
DATE(S)

GHR

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm / psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
	C-4					29.3 34.1	' to '				25.2' to 32.3': Gneissic Quartz-Biotite Schist.	
30		60	4.5	69				J D				
						Less Than	No Flow					
31			5.7			.05 17.3	K < 0.03 F/D	J J J				
32			4.5					D				
	C-5	60		54				J D D		Slightly open, soft friable weathered rock at contact.	32.3' to 34.0': Soft, greyish black, medium to fine grained Biotite Schist. Foliation dipping 20 ° to 30 °. Moderately hard, friable on joint surfaces Color Code N2	
33			2.5					J J J				
34			3.0					J D		Tight, vertical joint truncated on foliation joint surfaces	34.0' to 37.1': Medium hard, light grey, spotted gneissic Schist, locally intruded by coarse grained Pegmatite at 34.9' to 35.6' and 36.8' to end of core recovery. Foliation dipping 30 ° to 35 °. Color Code: N6	
35			5.2									
36			7.0					J D D		Tight joint, dipping 30 ° to 35 °, parallel to foliation		
37			8.3							Bottom of Exploration 37.1 Ft		
38												

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

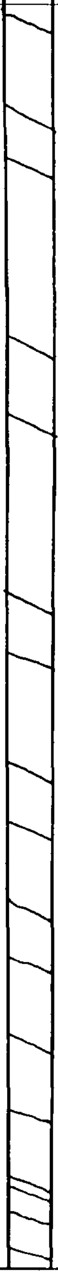
PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW-9
LOCATION
SHEET No. 3 OF 5
JOB No. 3108019
DATE(S)

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
11.0										Top of Rock 10.8 Ft.		
	C-1										11.3' to 30.3'	1.
	11.3' to 15.3'	46.8		100							Moderately hard, medium-grained medium light grey, gneissic Quartz-Biotite Schist.	
12								J		Tight		
			3.3					J				
										Fresh, intact rock. Widely spaced foliation joints are tight and exhibit only slight straining.	Moderately, well-developed foliation dipping at 25 ° to 30 °.	
											Localized Pegmatite	
13			4.1					D				
14			4.2					J				
						14.0 18.7	' to ':					
15								D				
			4.1			Less Than 0.05	No Flow	D				
	C-2											
		60		100		17	K < .03 F/D					
16								D				
			4.3					D				
17								D				
			4.8					D				
								D				
18								J				
			4.8									
								D D D				
19												

LEGEND:

- J-JOINT
- T-FAULT
- F-FOLIATION
- B-BEDDING
- C-CONTACT
- S-SLICKENSIDE
- D-DRILLING BREAK
- M-MINERALIZATION ZONE
- WX-WEATHERED ZONE
- K-PERMEABILITY

TYPE OF SAMPLE:

- C-CORE
- S-SPLIT SPOON

NOTES:

1. Cored from 11.3 ft to 35.1 ft; intermittent loss of wash water at 28 ft, with return and generally high volume throughout.
2. Packer pressure tested rock core zone from 14.0 ft to 32.3 ft.

ROCK CORE LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

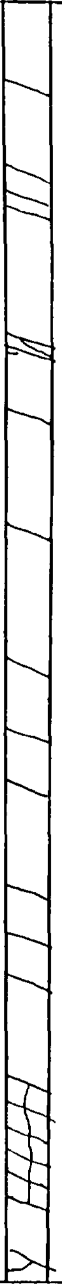
BORING No. MW- 9
LOCATION
SHEET No. 4 OF 5
JOB No. 3108019
DATE(S)

GHR

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm / psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
19	C-2		4.4			18.5 23.3	' to ':	D		Fresh intact rock to 24.7 Ft. Foliation joints are tight, and surfaces only slightly stained.	Gneissic Quartz-Biotite Schist 11.3' to 30.3'	
20						Less Than	No Flow	D D				
	C-3	60		96		0.05 15.1	K < .03 F/D					
21			4.1					J J				
22			4.5					D				
23			4.3			23' 27.8	to ':	J D				
						Less Than	No Flow	D				
24			5.8			0.05 16.4	K < .03 F/D	J J				
25			5.2					D		24.7' to 26.5': Foliation joints intersect vertical fracture at 25.8 to 26.6'±. Rock fabric intermittently oxidation stained.		
	C-4	57.6										
26			3.1					J J				
27												

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 9
LOCATION
SHEET No. 5 OF 5
JOB No. 3108019
DATE(S)

GROUND ELEV.
TOP OF CASING ELEV.

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE
DEPTH

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm/psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
27	C-4		2.8			27.5 32.3	' to ':	J J		Intact rock		
								D		27.9' to 28.3':	27.9' to 28.3'	
28			3.7			Less Than	No Flow	J J		Tight fractures in local Pegmatite	Coarse-grained Pegmatite.	
						0.05 17	K < .03 F/D			Foliation joints are tight, only slightly stained.		
29			3.8					J J				
30			3.5					J		30.35' to 31.3':	30.3'	
	C-5	60		70						Discoid fractures along foliation. 1/2" to 1".	Moderately hard, medium-grained, medium light-grey, Quartz-Biotite Schist, with well-developed foliation and bedding dipping 20 ° to 30 °.	
31			4.8					J				
32			3.3					J D		Stained rock fabric at 32.0'		
						32.3 Bott of Zone	' om Test	D		Rock is intact, locally minor pitting		
33			3.3					D D				
34			3.3					D				
35			3.7					D D		Bottom of Exploration 35.1	Ft.	

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, Rhode Island
CLIENT U.S. Army Corps of Engineers
GHR FIELD GEOLOGIST Mike Sherrill (GZA)
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 8
LOCATION
SHEET No. 3 OF 5
JOB No. 3108019
DATE(S)

GHR

GROUND ELEV. -
TOP OF CASING ELEV. -

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE DEPTH

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/ DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
13.6 14	C-1			0						Top of Rock 12.4'		
	13.6' to 17.2'	41.4								13.6' to 20.4': Core recoveries of discoid pieces typically 1/4" to 1/2" in thickness.	13.6' to 20.4': Moderately hard, medium-grained, light grey, Blackstone Series Quartz-Biotite Schist.	1.
15			2.0									
			2.3							Breaks are tight, fresh, to only slightly stained and largely represent stress relief and/or mechanical breaks of brittle, strongly foliage rock.	Relict bedding parallel to schistosity. Dipping at 10 to 20° .	2.
16											Color Code N7	
			5.2			16.3' to 21.1'						
						.05	No Flow					
17			3.8/.6'			15.6	K < .03 F/D					
	C-2 17.2' to 22.1'	60		0								
18			6.2							18.0' to 20.0': Zone of low angle 15° to 20° tight joints, parallel to schistosity at 1" to 2" spacing. Joint surfaces are stained and exhibit remineralization.		
19			4.0							High angle (70° to 80°) joint intersected by foliation joints at 18.6' to 19.3'.		
20						20.3' to 25.1'					20.4' to 25.2': Medium soft to hard, medium grained, medium grey Biotite Schist.	
			1.8				No Flow					
						.05	K < .04 F/D					
21						13.9						
			1.3									
22												

LEGEND:

J-JOINT	S-SLICKENSIDE
T-FAULT	D-DRILLING BREAK
F-FOLIATION	M-MINERALIZATION ZONE
B-BEDDING	WX-WEATHERED ZONE
C-CONTACT	K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Cored from 13.6 ft to 37.1 ft, high volume of wash water return maintained throughout.
2. Packer pressure tested rock core zone from 16.3 ft to 34.1 ft.

ROCK CORE LOG

GHR

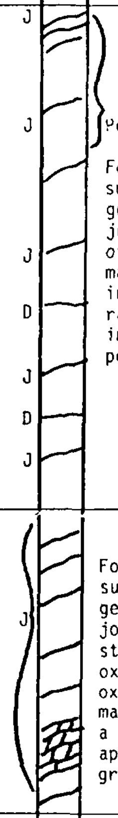
PROJECT STAMINA MILLS SUPERFUND SITE - PHASE II
ADDRESS Forestdale, N. Smithfield, RI
CLIENT Army Corps of Engineers
GHR FIELD GEOLOGIST Gerard Martin
BORING CONTRACTOR Guild Drilling Co.
FOREMAN A.Whitaker

BORING No. MW-12
LOCATION Refer to Site Plan
SHEET No. 3 OF 3
JOB No. 3108018.A
DATE(S) 5-23-88 to 5-24-88

GROUND ELEV. - 204.5
TOP OF CASING ELEV. - 206.65

CORE SIZE 2-inch
CORE TYPE NV-2
INCLINATION Vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE 6/28/88 DEPTH 18.93

	SAMPLE		CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP		GRAPHIC AND DESCRIPTIVE LOG		
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE	GRAPHIC LOG	(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
20										Refer to Boring/Monitoring Well Log, MW-12 for Description of Overburden		
	C-1 (20.5- 24.5)	42	4.0	8%				J				
21												
			5.0					J		Pegmatite		
22										Foliation joints are sub-horizontal to gently dipping, many joints, minor amounts of iron oxide and manganese oxide staining. Spacing of joints range from .5 to 1.5 inches, except in the pegmatite zone.	Soft, fine to medium grained, light gray, Quartz-Bictite Schist Moderately foliated color code N6	
			4.0					J				
23							$2.5x10^{-3}$	D				
			4.0					J				
24								D J				
	C-2 (24.5- 27)	30	5.0	0%								
25										Foliation joints are sub-horizontal to gently dipping, some joints are peruasively stained with iron oxide and manganese oxide. Few high mangle joints within a fracture zone at approx. 26' from the ground surface.	Moderately soft, fine to medium grained, light gray (color code N6), Quartz-Biotite Schist with minor amts. of altered ferro-magnesium mineral (possibly garnet). Moderately foliated	
			5.0					J				
26												
			2.0 for 6"									
27										Bottom of exploration at 27'		
28												
29												
30												

LEGEND:

J-JOINT	S-SLICKENSIDE
T-FAULT	D-DRILLING BREAK
F-FOLIATION	M-MINERALIZATION ZONE
B-BEDDING	WX-WEATHERED ZONE
C-CONTACT	K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Refer to Note 1, Monitoring Well Log MW-12 for installation Log.

ROCK CORE LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE - PHASE II
ADDRESS FORESTDALE, N. SMITHFIELD, RI
CLIENT U.S ARMY CORP OF ENGINEERS
GHR FIELD GEOLOGIST GERARD MARTIN
BORING CONTRACTOR GUILD DRILLING COMPANY
FOREMAN A. WHITAKER

BORING No. MW-15
LOCATION Refer to Site Plan
SHEET No. 4 OF 4
JOB No. 3108018.A
DATE(S) 5/26/88 to 5/27/88

GROUND ELEV. = 211.6
TOP OF CASING ELEV. - 213.56

CORE SIZE 2 inch
CORE TYPE NV-2
INCLINATION vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE 6/28/88 DEPTH 12.95

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm/psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
19												
20	C-4 (20-25')	59"	5.0	40%						Some low angle to sub-horizontal joints, few display any staining. Few of the joints contain silt and clay.	Soft, fine to medium grained, light grey to dark blue-grey (layered) Quartz-Biotite Schist. Little chloritized biotite and muscovite, and trace amounts of altered garnet.	
21			5.0				.0034					
22			4.5									
23			6.0									
24			7.0									
25	C-5 (25-29')	48"	5.0	58%						Few low to subhorizontal fractures with little or no staining. Few fractures contain silt and clay.	Soft, fine to medium grained, light grey to blue grey, Quartz-Biotite Schist, with minor amounts of muscovite.	
26												
27												
28												
29										Bottom of exploration at 29'		

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

ROCK CORE LOG

PROJECT STAMINA MILLS SUPERFUND SITE - PHASE II
ADDRESS FORESTDALE, N. SMITHFIELD, RI
CLIENT U.S ARMY CORPS OF ENGINEERS
GHR FIELD GEOLOGIST GERARD MARTIN
BORING CONTRACTOR GUILD DRILLING COMPANY
FOREMAN A. WHITAKER

BORING No. MW-15
LOCATION Refer to Site Plan
SHEET No. 3 OF 4
JOB No. 3108018.A
DATE(S) 5/26/88 to 5/27/88

GROUND ELEV. * 211.6
TOP OF CASING ELEV. * 213.56

CORE SIZE 2 inch
CORE TYPE NV-2
INCLINATION vertical
BEARING

GROUNDWATER LEVEL READINGS
DATE 6/28/88 DEPTH 12.95

DEPTH	SAMPLE TYPE AND No.	SAMPLE IN. OF REC.	CORE TIME MIN/FT	R.Q.D. %	R.Q.D. GRAPHIC	PACKER TEST gpm/psi	PACKER TEST K ft/day	STRIKE/DIP TYPE OF FRACTURE	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG (FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	NOTES
9	C-1 (9-10')	8"	3.0	0%						Foliation joints, sub-horizontal to high angle, pervasive iron-pyrolucite staining	Soft, fine to medium-grained, light grey Quartz-Biotite Schist, Moderately foliated	
10	C-2 (10-15')	58"	4.0	35%						Pegmatite Zone	Soft to hard, fine to medium-grained, light grey Quartz-Biotite Schist. Biotite is locally chloritized, trace to minor amounts of altered garnet throughout section	
11			4.5									
12			5.0				15.28			Some low to subhorizontal fractures within mid-section of core, very little staining. High angle fractures between 14.5 and 15 feet are pervasively stained with iron and manganese oxide.	Pegmatite Zone in top 2-feet of core composed of Quartz, feldspar and muscovite.	
13			5.0									
14			7.0									
15	C-3 (15-20')	55"	4.0	52%						Pervasively Iron Stained	Soft, fine to medium grained Quartz-Biotite Schist. Biotite is locally chloritized, minor amounts of altered garnet.	
16			4.5									
17			4.0				10.29			Few low to subhorizontal fractures one high-angle fracture, (at approximately 16') pervasively stained with iron and manganese oxide. An 8-inch zone of low angle fractures at 18' is pervasively stained with iron and manganese oxide.		
18			5.5									
19			7.0									

LEGEND:

J-JOINT	S-SLICKENSIDE
T-FAULT	D-DRILLING BREAK
F-FOLIATION	M-MINERALIZATION ZONE
B-BEDDING	WX-WEATHERED ZONE
C-CONTACT	K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Refer to monitoring well log MW-15 for description of overburden and monitoring well installation log.

ROCK CORE LOG

GHR

PROJECT Stamina Mills Superfund Site-Phase I
ADDRESS Forestdale, N. Smithfield, R.I.
CLIENT US Army Corps of Engineers
GHR FIELD GEOLOGIST Gerard Martin
BORING CONTRACTOR Guild Drilling Co.
FOREMAN A. Whitaker

BORING No. MW-16
LOCATION Refer to Site Plan
SHEET No. 3 OF 4
JOB No. 3108018.A
DATE(S) 6/1/88 to 6/2/88

GROUND ELEV. - 207.6
TOP OF CASING ELEV. - 209.89

CORE SIZE 2 inch
CORE TYPE NV-2
INCLINATION vertical
BEARING --

GROUNDWATER LEVEL READINGS
DATE 6/28/88 DEPTH 16.12

SAMPLE			CORE TIME	R.Q.D.		PACKER TEST		STRIKE/DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
DEPTH	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
										Refer to Boring/Monitoring Well Log Mw-16 for description of overburden.		1.
13	C-1 (13-16.5')	41'	3.0	81%	█					Some low to sub-horizontal joints with little iron oxide and manganese oxide staining.	Soft, fine to meduim grained, light grey, Quartz-Biotite Schist with minor amounts of muscovite and altereded garnet, moderately foliated.	
14			3.5		█							
15			3.5		█		13.37					
16			3 for 6"		█							
	C-2 (16.5-20.5	48"	3.0	33%	█					Many low to high angle fractures, high angle fractures are located from 19 to 20.5 feet.	Soft, fine to meduim grained. light grey, Quartz-Biotite Schist, with little muscovite and and alterered garnet, moderately foliated.	
17			3.0		█							
18			3.5		█							
19			3.5		█					Abundant iron and manganese oxide staining in high angle joints and fractures.		
20	C-3 (20.5-21.5)	48"	3.5	31%	█		14.07			Many low to high angle joints and fractures, abundant iron oxide and manganese oxide staining on high angle joints and fractures.	Soft, fine to medium grained, light grey, Quartz-Biotite Schist with little muscovite and alterered garnet.	
21			3.5		█							
22					█							

LEGEND:

J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT

S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:

C-CORE
S-SPLIT SPOON

NOTES:

1. Refer to monitoring well log MW-16 for installation log.

ROCK CORE LOG

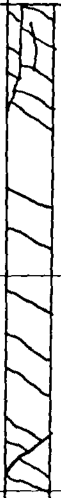
PROJECT Stamina Mills Superfund Site-Phase I
ADDRESS Forestdale, N. Smithfield, R.I.
CLIENT US Army Corps of Engineers
GHR FIELD GEOLOGIST Gerard Martin
BORING CONTRACTOR Guild Drilling Co.
FOREMAN A. Whitaker

BORING No. MW-16
LOCATION Refer to Site Plan
SHEET No. 4 OF 4
JOB No. 3108018.A
DATE(S) 6/1/88 to 6/2/88

GROUND ELEV. 202.6
TOP OF CASING ELEV. 209.89

CORE SIZE 2 inch
CORE TYPE NV-2
INCLINATION vertical
BEARING --

GROUNDWATER LEVEL READINGS
DATE 6/28/88 DEPTH 16.12

DEPTH	SAMPLE		CORE TIME	R.Q.D.		PACKER TEST		STRIKE/ DIP	GRAPHIC LOG	GRAPHIC AND DESCRIPTIVE LOG		NOTES
	TYPE AND No.	IN. OF REC.	MIN/FT	%	GRAPHIC	gpm psi	K ft/day	TYPE OF FRACTURE		(FRACTURE DESCRIPTION)	(ROCK DESCRIPTION)	
22			3.5		▮					Abundant iron oxide and manganese oxide staining.		
23			4.0		▮							
24	C-4 (24.5-26.5)	24"	3.0		▮					Pegmatic zone Some low to subhorizontal Joints, little or no iron oxide at manganese oxide staining	Soft, fine to mediu grained, light gray Quartz-Biotite Schist, with minor amounts of muscovite and alterered garnet, moderately foliated	
25			3.5		▮							
26					▮					Bottom of exploration at 26.5'.		
27												

LEGEND:
J-JOINT
T-FAULT
F-FOLIATION
B-BEDDING
C-CONTACT
S-SLICKENSIDE
D-DRILLING BREAK
M-MINERALIZATION ZONE
WX-WEATHERED ZONE
K-PERMEABILITY

TYPE OF SAMPLE:
C-CORE
S-SPLIT SPOON

NOTES:

APPENDIX B

RESULTS OF DOWNHOLE GEOPHYSICS SURVEY

United States Department of the Interior

TAKE PRIDE IN AMERICA

GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
P.O. Box 1669
Albany, New York 12201
(518) 472-3107

NEW YORK DISTRICT

RECEIVED
MAR
WRD

March 9, 1988

Mr. John Zannos
U.S. EPA Region I
HSS JFK Federal Building
Boston, Massachusetts 02203

Dear Mr. Zannos:

This letter summarizes the borehole-geophysical data collected by the U.S. Geological Survey at the Stamina Mills site in North Smithfield, Rhode Island. In December 11-14, 1987, the Borehole Geophysical Services Unit completed caliper and acoustic-televiewer logs in the Stamina Mills well and wells I-2, I-12, I-31, and I-32 (fig. 1). Construction information and logged intervals of these wells are presented in table 1.

The depth, strike, and dip of planar structural features intersecting the wells were determined from the acoustic-televiewer logs (table 1). An example of the determination of the strike and dip of a planar structural features from a televiewer log is presented in figure 2. Logs and sterographic projections of the strike and dip data are presented in figure 3. Caliper logs that were digitally recorded also are presented in figure 3.

Many planar features identified on the acoustic-televiewer logs probably are foliation or other structural planes and are not open fractures. Planar features that are open fractures typically appear as continuous dark bands or lines on the televiewer logs and correlate with spikes on the caliper logs. Features that appear to be open fractures are differentiated in table 1 and figure 3 and presented on a sterographic projection in figure 4.

Additional borehole geophysical data including fluid-resistivity and temperature logs and vertical flow-measurements would be needed to determine which of the fractures that appear to be open are conductive. Research in crystalline bedrock by the Borehole Geophysics Project in New Hampshire[1] and the New York District in southeastern New York indicates that the fractures that are conductive do not necessarily appear different than other prominent fractures on the televiewer logs. Apparently, the connectivity of a fracture with others in the local fracture network determine if the fracture is a significant part of the ground-water flow system.

---

[1] Palliet, F.L., Hess, A.E., Cheng, C.H., and Hardin, E., 1987, Characterization of fracture permeability with high-resolution vertical flow measurements during borehole pumping: Ground Water, vol. 25, no. 1, p. 28-40.

The research at the New Hampshire site also has shown that the definition of directional permeability in fracture-flow systems from fracture strike and dip measurements may not be straightforward. At the site, conductive fractures intersecting four closely spaced wells dipped eastward and westward at angles greater than 45 degrees. However, the most probable hydraulic connection between the wells appears to be a nearly horizontal fracture zone composed of intersecting fractures with attitudes significantly different than that of the zone.

If you have any question concerning the enclosed information, please give me a call at FTS 562-2825.

Sincerely,

John H. Williams

John H. Williams
Hydrologist

JHW/dlw
Enclosures

TABLE 1.--Construction and logged intervals of the wells and strike and dip of intersected planar structural features.

Well	Well depth (feet)	Casing depth (feet)	Casing diameter (inches)	Logged interval (feet-feet)		Date	Planar structural feature			
				Caliper[1]	Acoustic televiewer		Depth[2] (feet)	Strike direction	Dip direction	Dip angle (degrees)
Stamina Mills	200	18	8	11-200R	13-164	12/14/87	$\underline{20}$	S15E	S75W	46
							22	S25E	S65W	44
							25	S	W	24
							72	S	W	31
							73	S	W	37
							111	S60W	N30W	37
							112	S60W	N30W	37
							$\underline{115}$	S50W	N40W	56
							116	S55W	N35W	67
							$\underline{155}$	S60W	N30W	66
							$\underline{161}$	N80E	S10E	73
I-2	238	--	6	14-238	59-237	12/11/87	70	N45W	N45E	22
							$\underline{111}$	N60W	N30E	22
							113	W	N	22
							124	N	E	17
							$\underline{124.5}$	N45E	S45E	22
							134	N45W	N45E	17
							151	N30W	N60E	22
							161	N65E	S25E	17
							181.5	N55E	S35E	27
							187	E	S	11
							$\underline{194}$	S40E	S50W	19
							198	S30E	S60W	22
							216	S20E	S70W	24
							222	E	S	45
							226	E	S	63
							234	S5E	S85W	22
I-12	454	--	6	11-451	53-449	12/14/87	$\underline{84.5}$	S	W	10
							$\underline{158}$		Horizontal	
							$\underline{160}$	S50W	N40W	75
							219	S30W	N60W	10
							249	S20E	S70W	17
							313.5	S70E	S20W	22
							345.5	N75E	S15E	63
							366.5	S15W	N75W	31
							415	S10W	N80W	22
I-31	234	18	6	11-227R	35-227	12/11/87	46.5	N85E	S5E	72
							51	E	S	25
							$\underline{55}$	W	N	22
							$\underline{58}$	W	N	66
							$\underline{64.5}$	S15W	N75W	71
							67	N20E	S70E	45
							84	W	N	51
							$\underline{97}$	E	S	24
							110	S10E	S80W	66
							119	E	S	21
							130.5	E	S	11
							$\underline{178}$	N60E	S30E	63
I-32	700?	30?	10	11-246R	46-244	12/12/87	59	N25E	S65E	21
							64	N20E	S70E	31
							$\underline{67}$	N5E	S85E	18
							130	S60W	N30W	17
							139	N60W	N30E	21
							$\underline{158}$	N55W	N35E	84
							$\underline{176}$	N30E	S60E	21
							181	N65E	S25E	38
							191	N55E	S35E	17
							204	N60E	S30E	37
							206	W	N	66
							$\underline{218}$	N50E	S40E	17
							224	N25W	N65E	69
							$\underline{230}$	S75E	S15W	21

---

[1] R indicates recorded on digital tape.

[2] Underline indicates feature appears to be an open fracture.

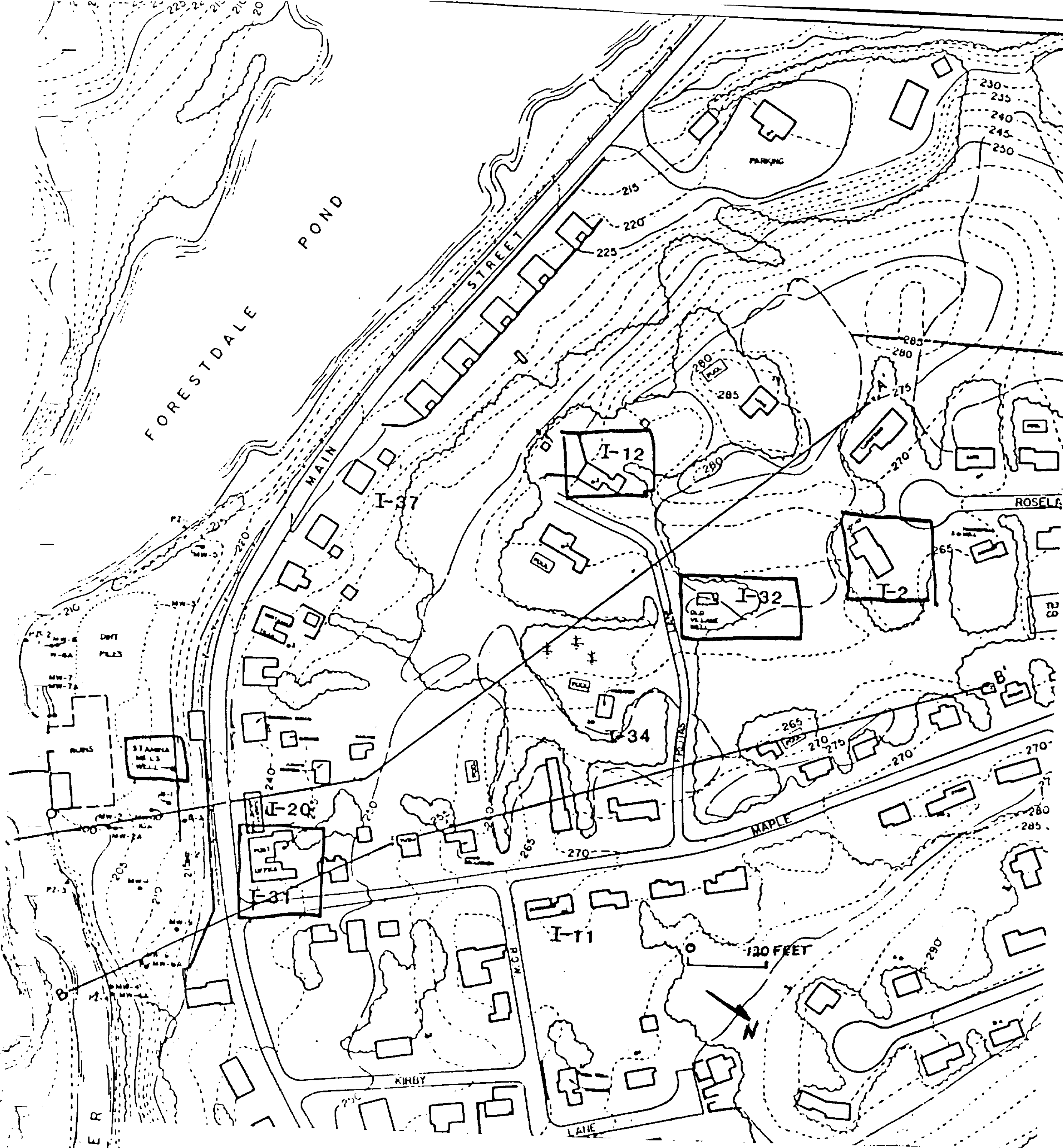
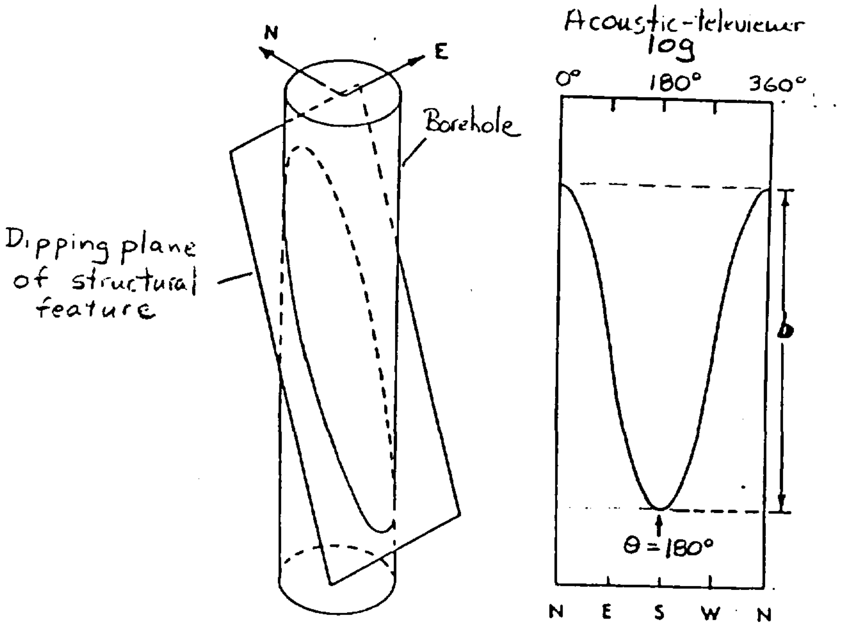


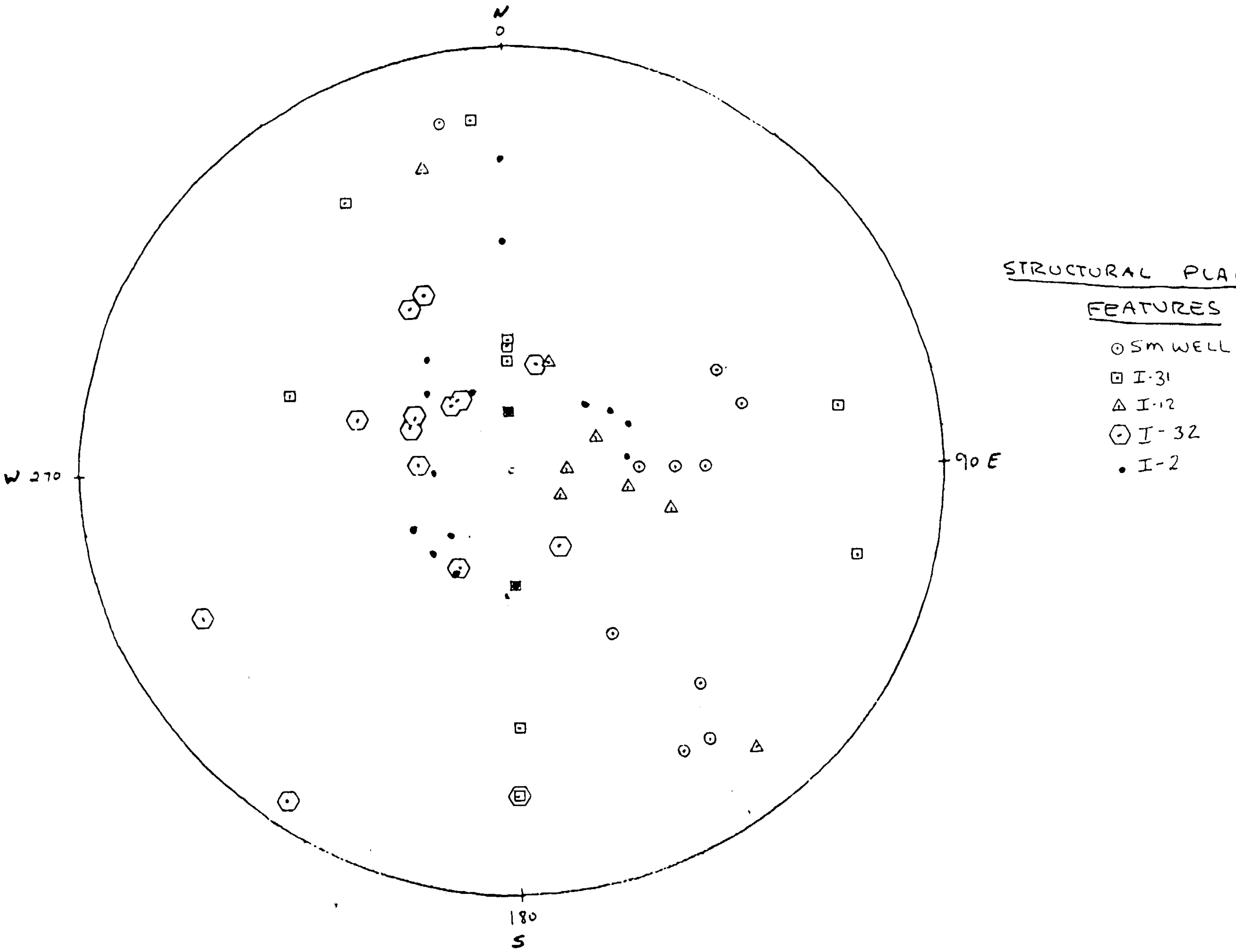
Figure 1.--Location of well sites at which caliper and acoustic-televiewer logs were collected.

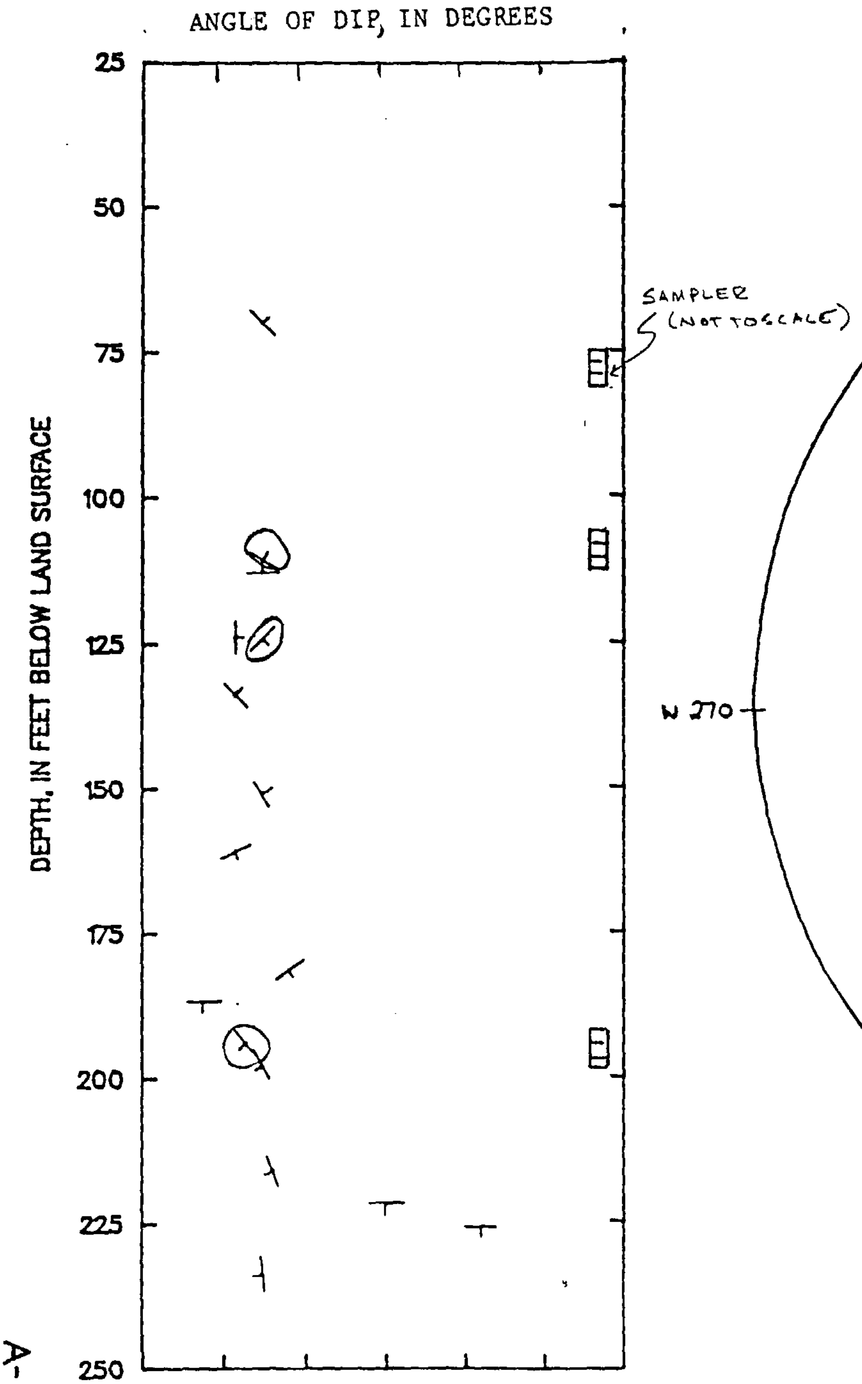


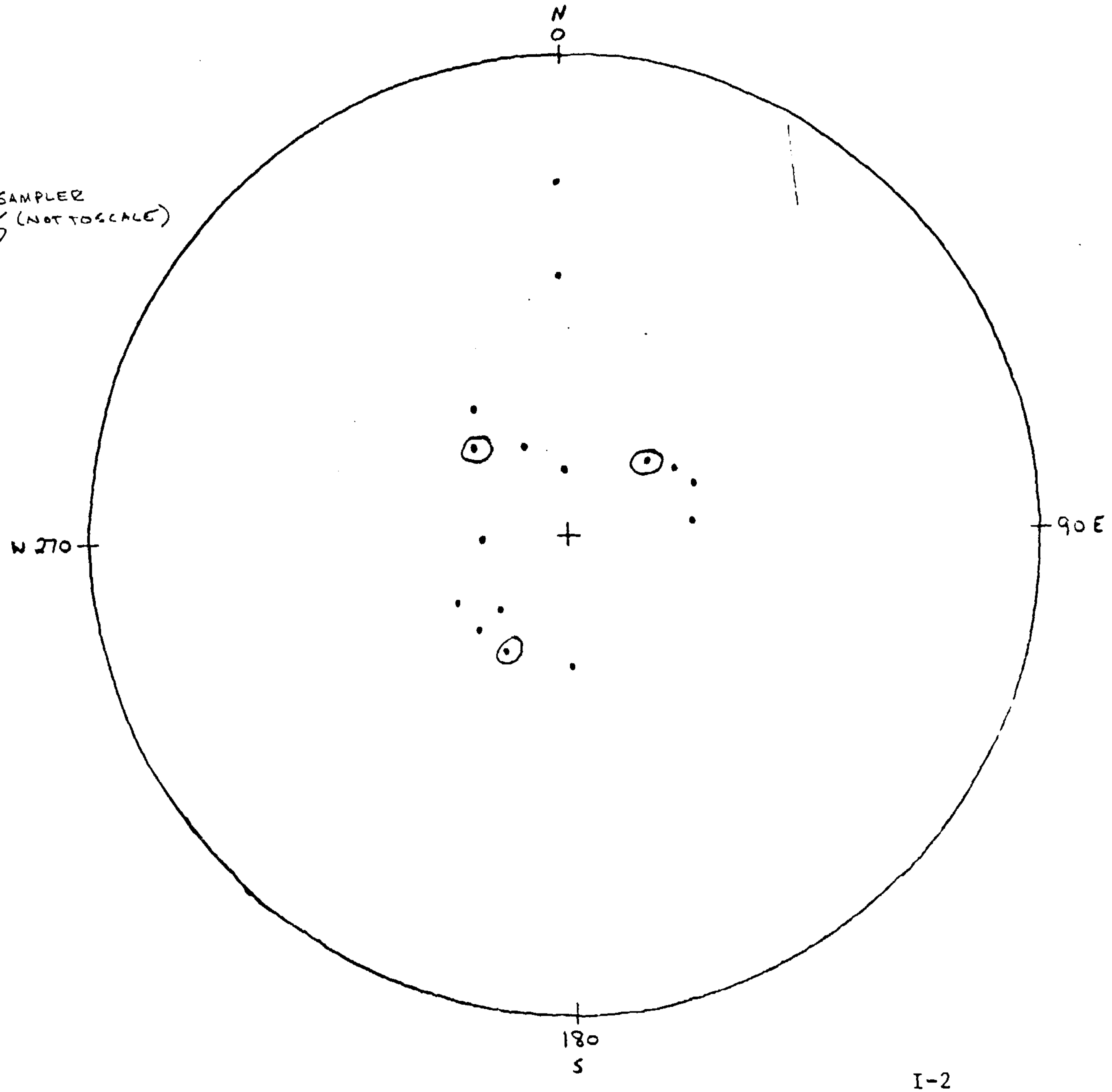
$$\text{Strike} = \theta - 90°$$
$$\text{Dip} = \tan^{-1}\frac{b}{\text{diameter}}$$

Figure 2.--Determination of the strike and dip of a planar structural feature from an acoustic-televiewer log.

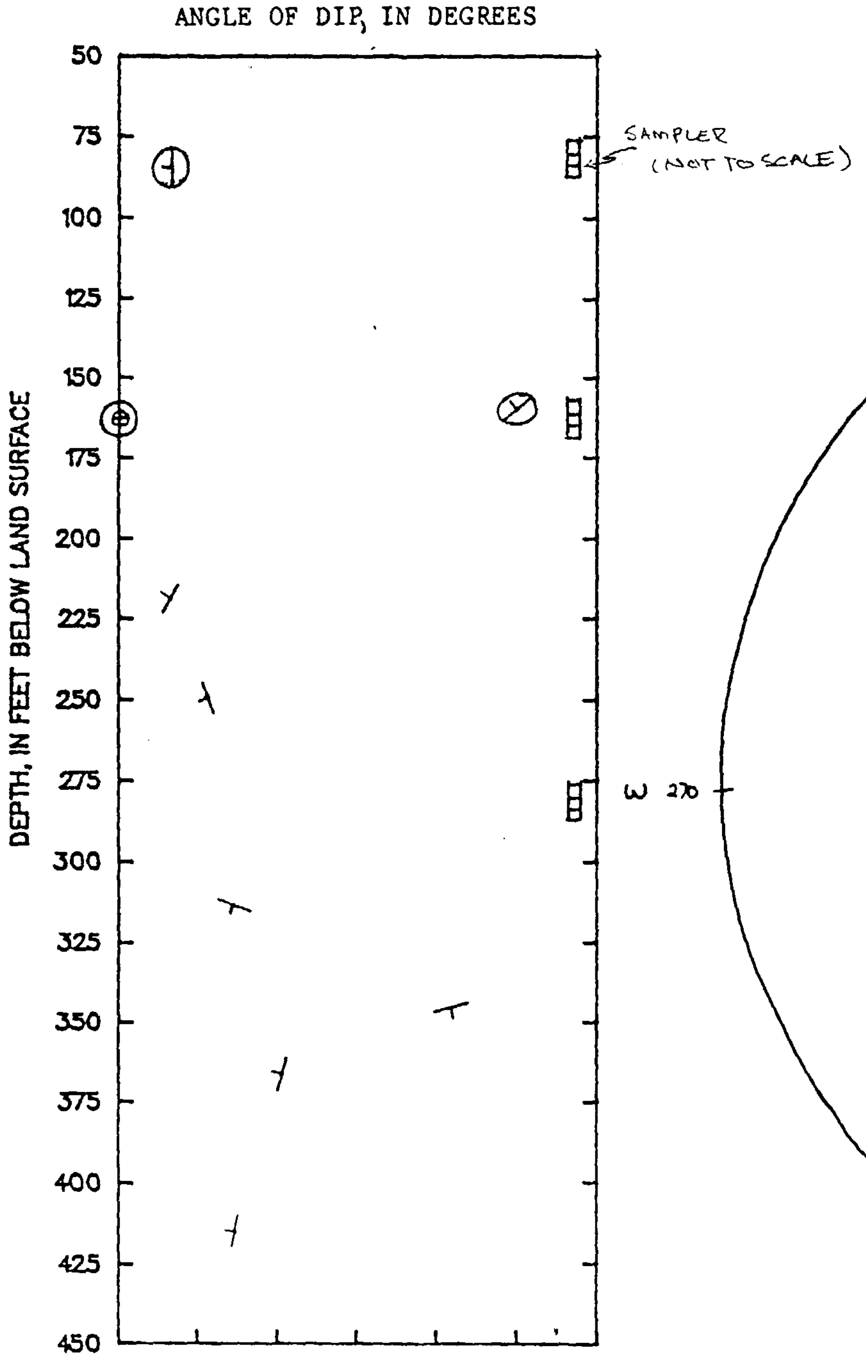
STRUCTURAL PLANER FEATURES

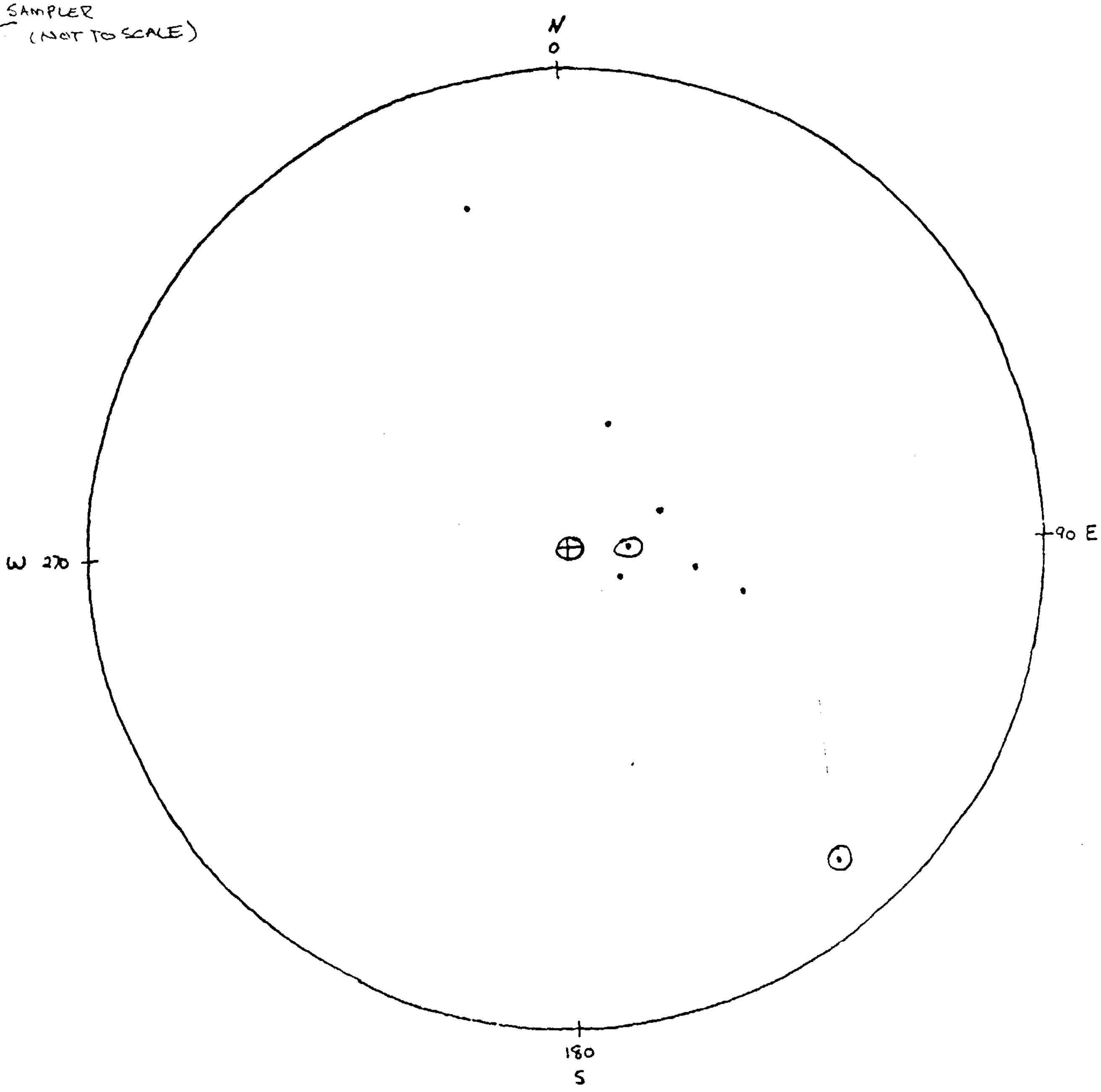



ANGLE OF DIP, IN DEGREES
DEPTH, IN FEET BELOW LAND SURFACE
25
50
75
100
125
150
175
200
225
250
SAMPLER (NOT TO SCALE)

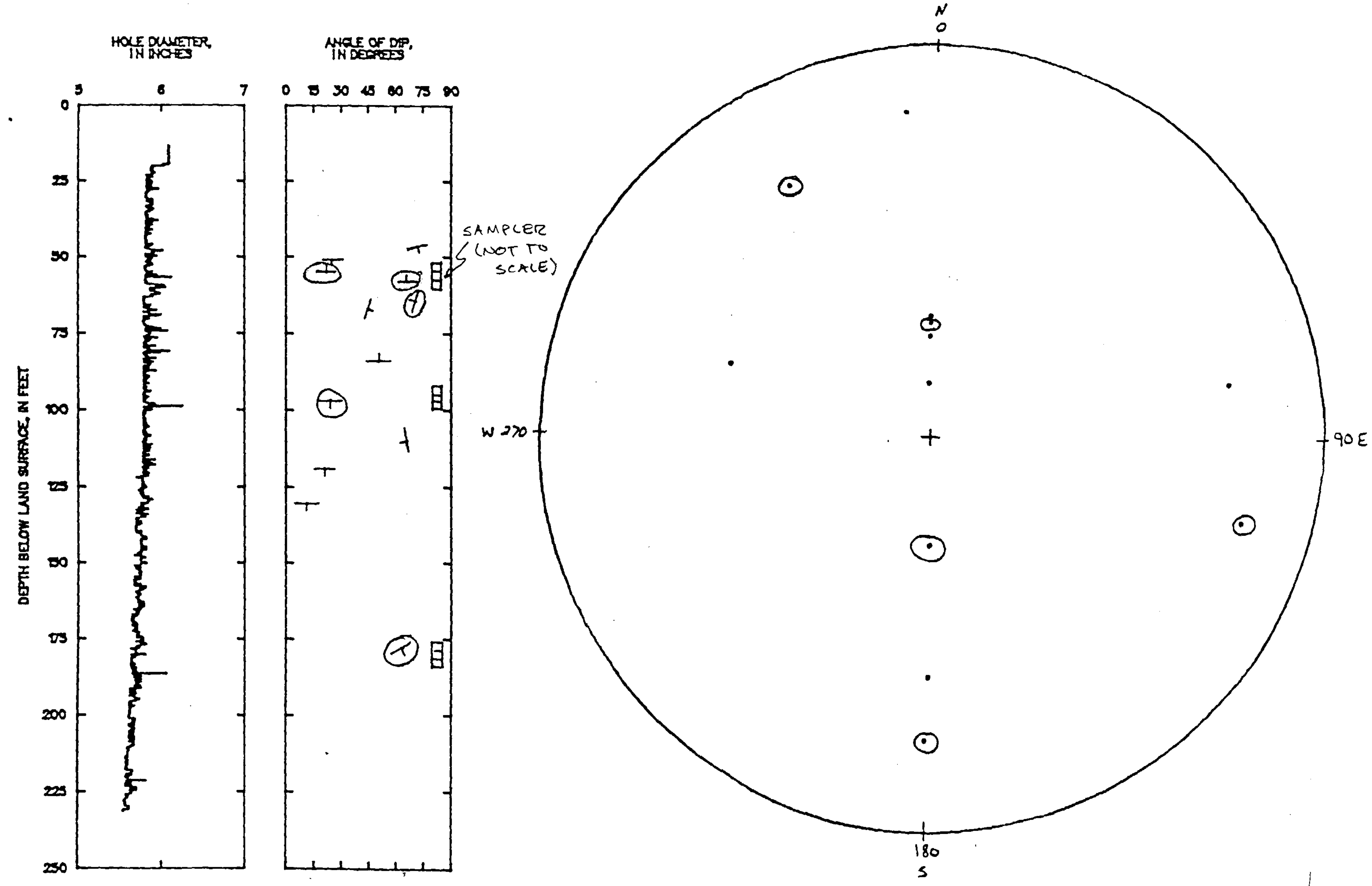

N
0
90 E
180
S
W 270

I-2

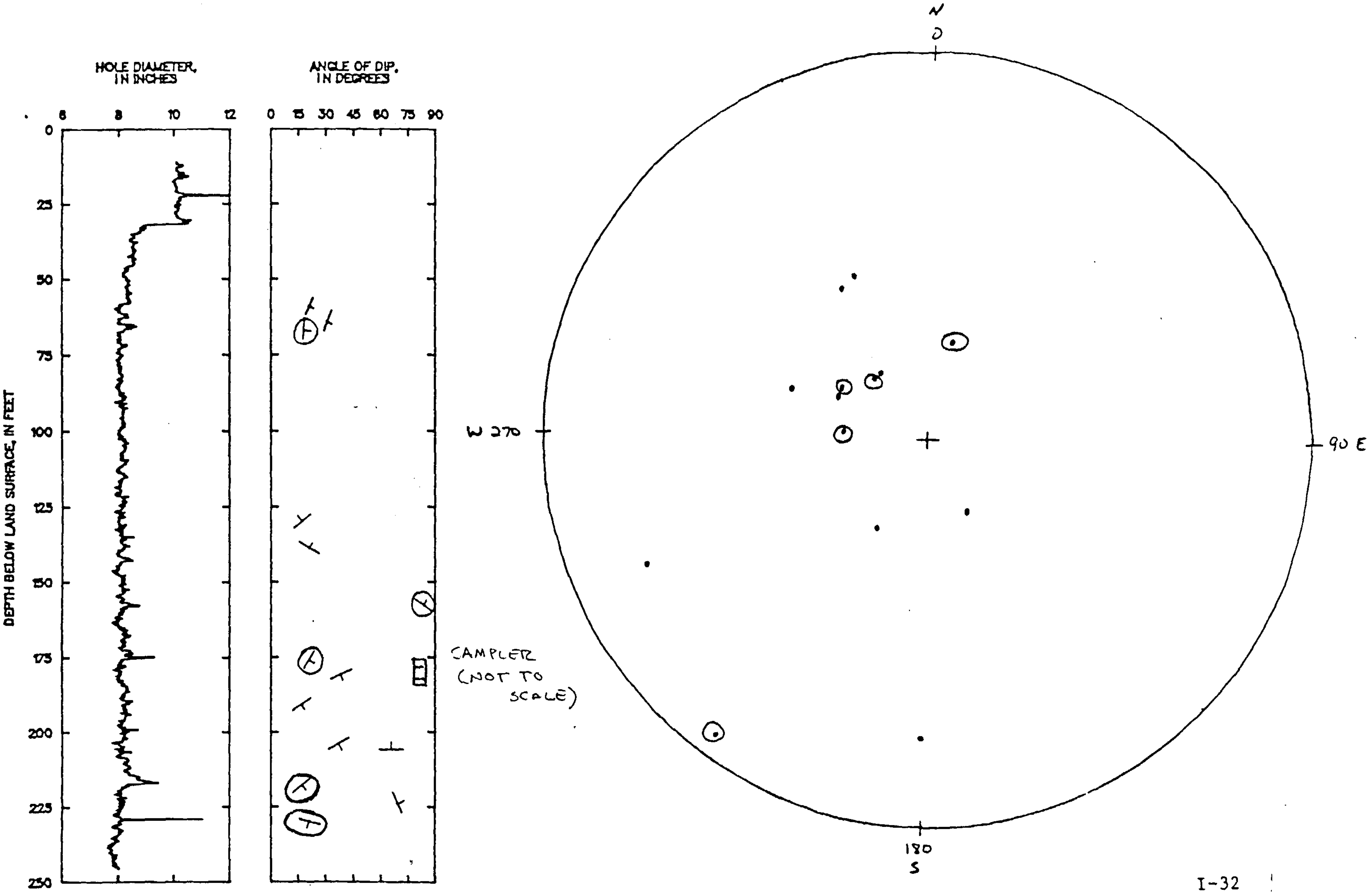

ANGLE OF DIP, IN DEGREES
DEPTH, IN FEET BELOW LAND SURFACE
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
SAMPLER
(NOT TO SCALE)


N
0
90 E
W 270
180
S

I-12


HOLE DIAMETER, IN INCHES
5
6
7
ANGLE OF DIP, IN DEGREES
0
15
30
45
60
75
90
DEPTH BELOW LAND SURFACE, IN FEET
0
25
50
75
100
125
150
175
200
225
250
SAMPLER (NOT TO SCALE)
N
0
W 270
90 E
180
S

I-31


HOLE DIAMETER, IN INCHES
6
8
10
12
ANGLE OF DIP, IN DEGREES
0
15
30
45
60
75
90
DEPTH BELOW LAND SURFACE, IN FEET
0
25
50
75
100
125
150
175
200
225
250
SAMPLER (NOT TO SCALE)
N
0
90 E
180
S
W 270

I-32

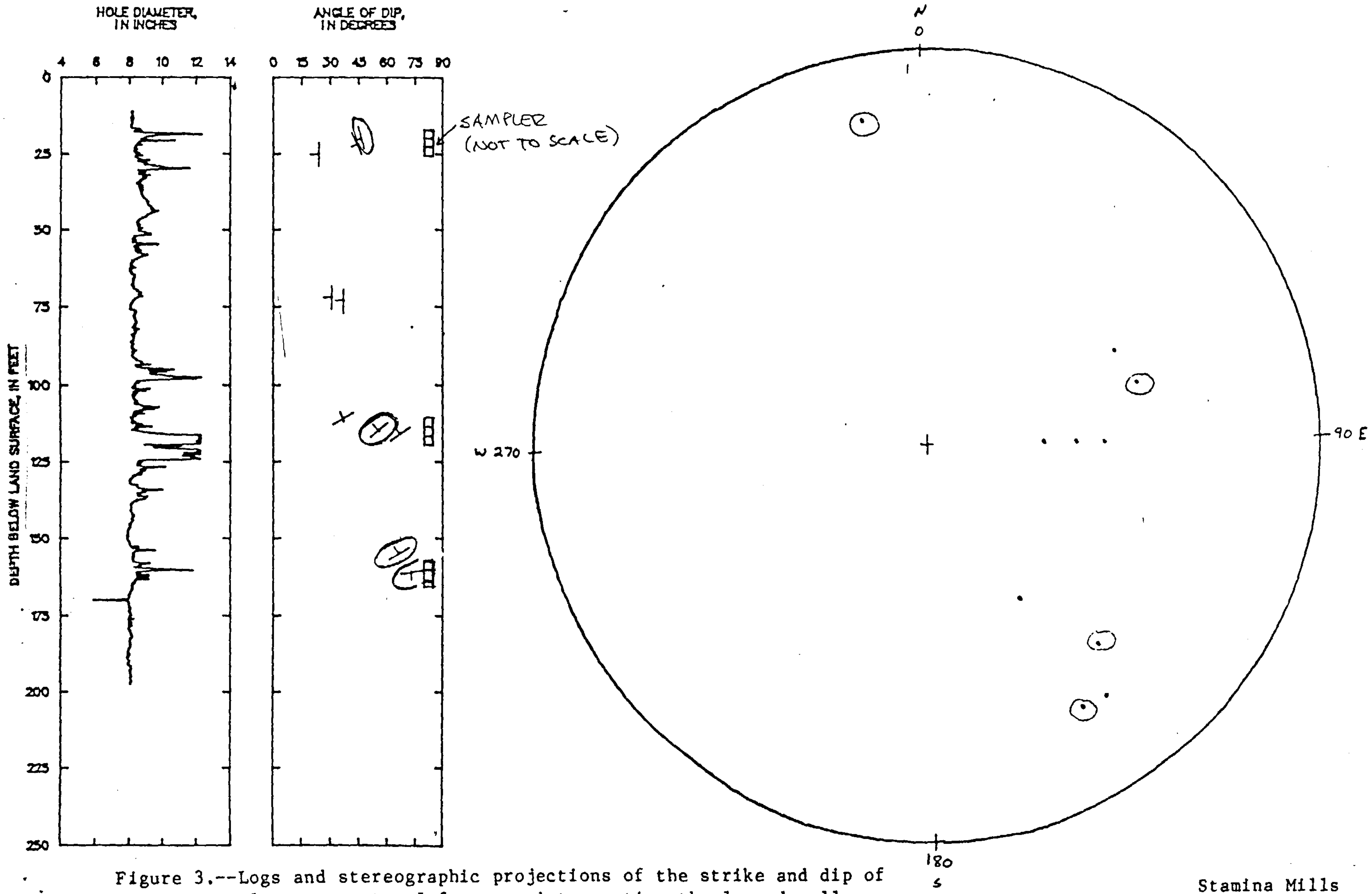


Figure 3.--Logs and stereographic projections of the strike and dip of planar structural features intersecting the logged wells. Caliper logs that were digitally recorded are included. Planar features that appear to be open fractures are circled.

Stamina Mills

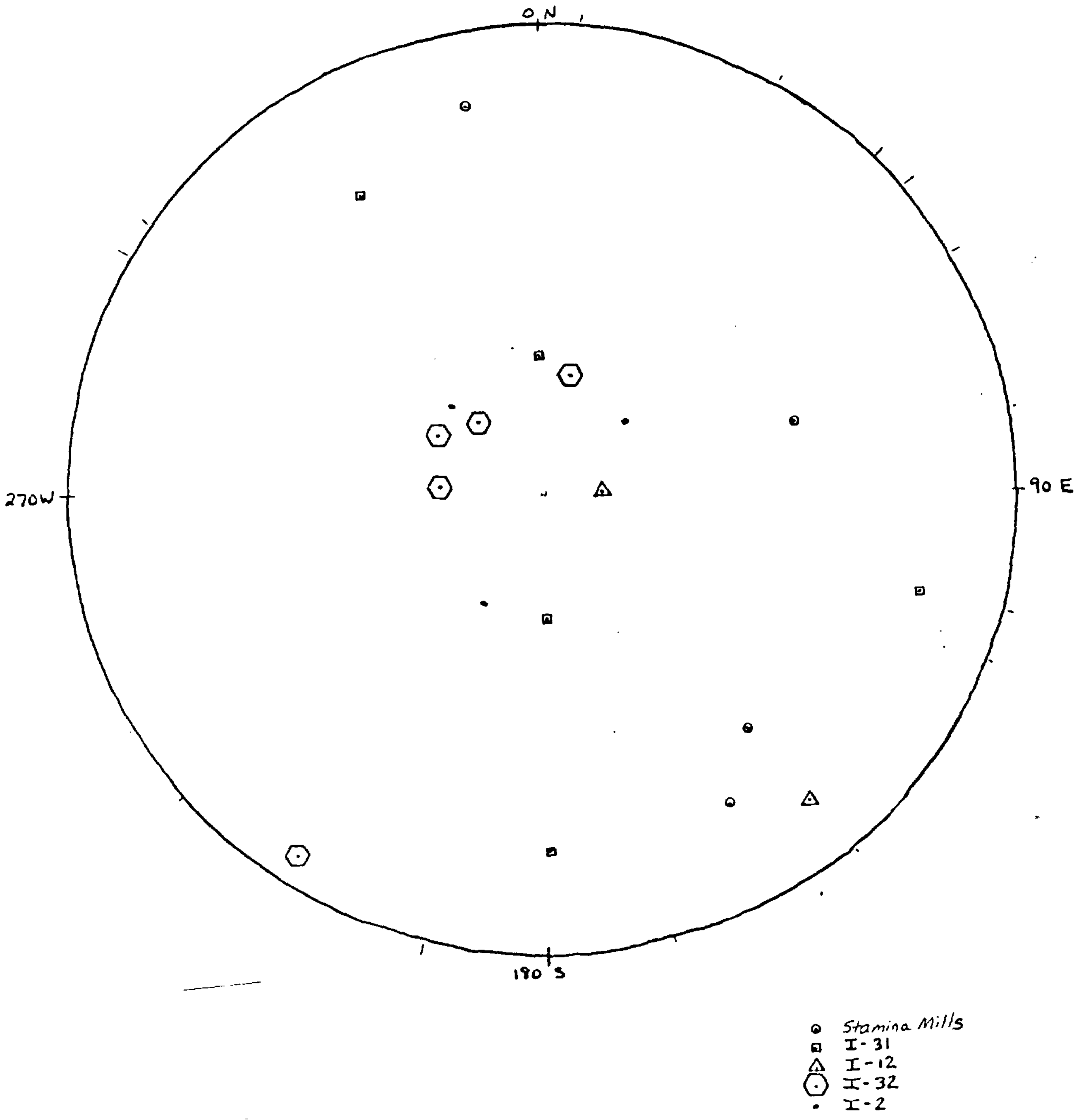


Figure 4.--Stereographic projection of the strike and dip of the planar structural features that appear to be open fractures

E

Characterization of Fracture Permeability with High-Resolution Vertical Flow Measurements During Borehole Pumping

by F. L. Paillet , A. E. Hess , C. H. Cheng , and E. Hardin

Reprinted from the January-February 1987, Volume 25, Number 1 issue of *Ground Water*

Characterization of Fracture Permeability with High-Resolution Vertical Flow Measurements During Borehole Pumping

by F. L. Paillet[a], A. E. Hess[a], C. H. Cheng[b], and E. Hardin[b]

ABSTRACT

The distribution of fracture permeability in granitic rocks was investigated by measuring the distribution of vertical flow in boreholes during periods of steady pumping. Pumping tests were conducted at two sites chosen to provide examples of moderately fractured rocks near Mirror Lake, New Hampshire and intensely fractured rocks near Oracle, Arizona. A sensitive heat-pulse flowmeter was used for accurate measurements of vertical flow as low as 0.2 liter per minute. Although boreholes were spaced at intervals ranging from 10 to 50 meters, acoustic televiewer logs showed little direct continuity of individual fractures from borehole to borehole in either the moderately fractured rocks or intensely fractured rocks. Results indicated that nearly all inflow and outflow to boreholes occurred by means of one or two discrete fractures in both cases. These fractures did not appear very different from other prominent fractures indicated on televiewer and resistivity logs for these boreholes. Hydraulic connections between boreholes apparently were composed of conduits formed by the most permeable portions of intersecting fractures. Most flow in the moderately fractured rocks occurred at isolated fractures at a depth of about 45 meters indicating a nearly horizontal zone of fracture permeability composed of orthogonal, steeply dipping fractures. Previous studies have identified a zone of horizontal permeability in the lower part of the boreholes in the intensely fractured rocks, but flowmeter tests indicated that flow also entered and exited individual boreholes by means of one or two steeply dipping fractures. These results indicate zones of fracture permeability in crystalline rocks are composed of irregular conduits that cannot be approximated by planar fractures of uniform aperture, and that the orientation of permeability zones may be unrelated to the orientation of individual fractures within those zones.

INTRODUCTION

Recent concern with radioactive waste disposal, migration of toxic solutes in ground water, and earthquake mechanisms has increased interest in the hydrogeology of fractured crystalline rocks. Natural and induced fractures can serve as conduits for ground water in otherwise nearly impermeable rocks; yet, fracture systems are difficult to define on the basis of information obtained from outcrops or a few exploratory boreholes. Theoretical studies have defined the cubic law relating fracture aperture to effective permeability (Snow, 1968). However, limited studies of the permeability of natural fracture systems indicate that fractures probably cannot be described as thin, uniform layers of fluid, although fracture permeability still may be related to the effective permeability of an equivalent single fracture of given aperture. Even if a definite law relating fracture width to permeability is available, the most effective method for accurately measuring fracture openings in boreholes is not apparent. Photographic or impression packer images of fractures intersecting a borehole represent fracture faces that were subjected to drilling damage, and to subsequent borehole stress-concentration fields. Fractures are naturally variable, so it also is uncertain whether the observed aperture is representative of the fracture within the vicinity of the borehole. All of these factors serve to highlight the importance of assessing the effective permeability of fractures in situ.

At present (1986) the most effective method for measuring in situ permeability is local pumping tests after isolation of sections of the borehole by means of downhole packers. This method is time-consuming, and requires complicated equipment and lengthy tests. Leakage of water due to poorly seated packers and propping of fracture openings by increased pressures during injection tests may

---

[a] U.S. Geological Survey, Borehole Geophysics Project, MS 403, Box 25046, Denver Federal Center, Denver, Colorado 80225.

[b] Earth Resources Laboratory, MIT, 42 Carlton St., Cambridge, Massachusetts 02142.

Received June 1986, revised August 1986, accepted September 1986.

Discussion open until July 1, 1987.

affect fracture properties during the test. Even if packers seat properly and if fractures are not forced open during the measurement process, few researchers can agree as to the correct method to model the flow field induced by the pressure test. These considerations indicate that there exists a critical need for new methods to determine local in situ fracture permeability using the access provided by exploratory boreholes.

The measurement of fracture permeability in the vicinity of boreholes would be improved considerably if a sensitive flowmeter was available to measure the flows into or out of boreholes under an imposed flow field. Such a sensitive flowmeter for very low velocities has been reported by Dudgeon *et al.* (1975) and Hess (1982, 1985). This flowmeter has been used to identify natural connections between fracture systems along boreholes (Keys, 1984; Hess, 1985; Paillet and Hess, 1986). Successful results in these studies depended upon the fortuitous existence of vertical hydraulic head gradients resulting from substantial recharge and negligible hydraulic connections between two or more independent fracture-permeability systems. In more general cases, an induced flow system might be imposed during a pumping test, and then the flowmeter used to identify flow rates into and out of individual fractures. This paper reviews a test of this concept at two sites where there is already independent information about fracture permeability.

LOCATION OF THE TEST SITES

Two sites were selected for initial tests of the low velocity flowmeter. The study site at Mirror Lake located near West Thornton, New Hampshire, contains a set of closely spaced boreholes more than 100 m in depth (Figure 1). This site was selected because fracture frequency was moderate. Individual fractures and sets of fractures were expected to project from one borehole to the other with little ambiguity. However, even under the conditions of moderate fracture density and close borehole spacing, fractures proved surprisingly difficult to project across the boreholes (Paillet, 1985). The Mirror Lake site was considered ideal because of the additional hydrogeological data available for Mirror Lake and the adjacent Hubbard Brook watershed (Winter, 1984; Likens, 1985).

The second site selected for flowmeter measurements during pumping was the University of Arizona Fractured Rock Hydrology Research Site near Oracle, Arizona (Figure 2). This site was chosen because hydrogeological background information was nearly as well documented as that of the Mirror Lake site (Jones *et al.*, 1985), and eight closely spaced boreholes were available. The boreholes at the Oracle site offered an important contrast to those at the Mirror Lake site, because the weathered granitic rocks at the Oracle site contain a nearly continuous distribution of intersecting fractures, which is almost equivalent to a continuous distribution of intergranular porosity.

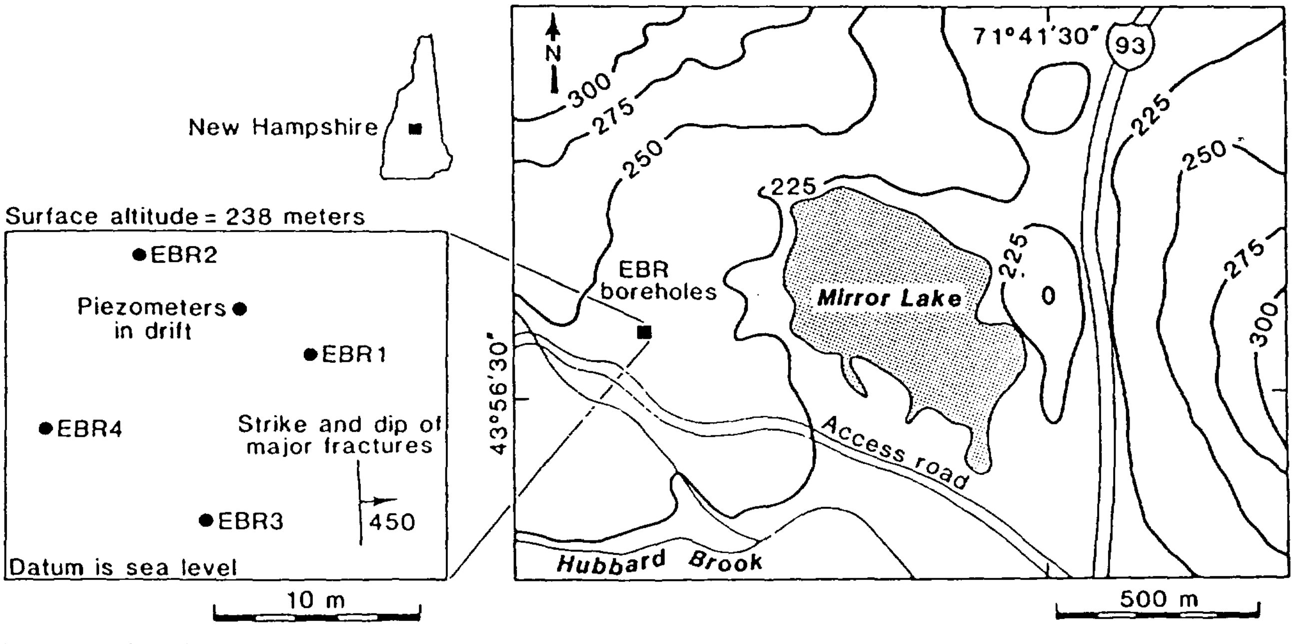


Fig. 1. Location of test boreholes EBR1, EBR2, EBR3, and EBR4 near Mirror Lake, New Hampshire.

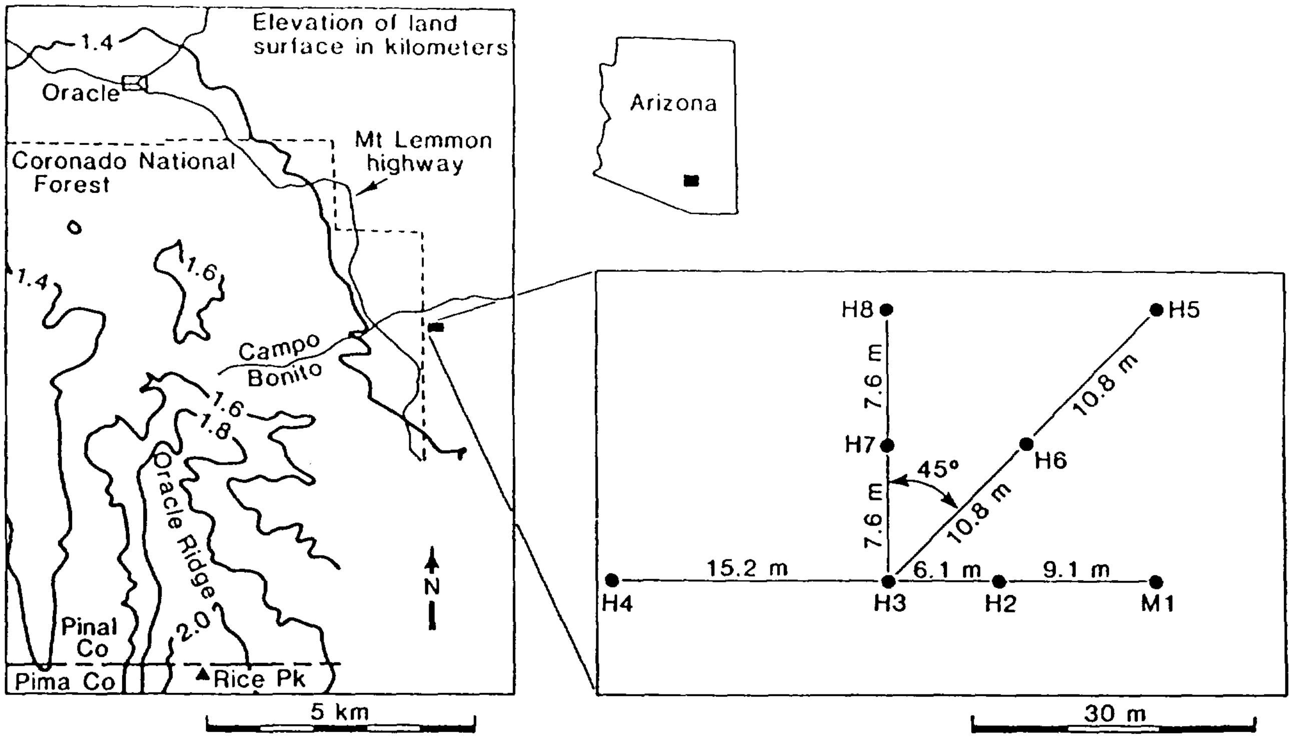


Fig. 2. Location of test boreholes M1, and H2-H8 near Oracle, Arizona (modified from Jones *et al.*, 1985).

Borehole acoustic-televiewer logs were available for some of the boreholes, and additional televiewer logs of the remaining boreholes were obtained as part of this study. Another important reason for selecting this site was the existence of additional information about fracture permeability obtained by packer tests (Hsieh *et al.*, 1983). Diameter, total depth, drilling method, and casing depth for the boreholes at Mirror Lake and Oracle sites are given in Table 1.

Table 1. Mirror Lake, New Hampshire and Oracle, Arizona Borehole Data

Borehole No.	*Diameter (cm)*	*Total depth (m)*	*Type*	*Casing depth (m)*
Mirror Lake Boreholes:				
EBR1	15.0	107.0	Air percussion	16.5
EBR2	15.0	107.0	Air percussion	16.5
EBR3	15.0	107.0	Air percussion	16.5
EBR4	15.0	229.0	Air percussion	17.0
Oracle Boreholes:				
M1	17.0	91.0	Air percussion	18.0
H2	11.5	91.0	Air percussion	18.0
H3	17.0	91.0	Air percussion	18.0
H6	11.5	76.0	Air percussion	19.0
H7	10.0	76.0	Rotary core	20.0

DOWNHOLE EQUIPMENT

The borehole acoustic televiewer (Zemanek *et al.*, 1969) and the heat-pulse flowmeter (Hess, 1984) were the primary downhole instruments used in this study. The borehole acoustic televiewer logging system provides a photographic image of the pattern of borehole wall reflectivity using a pulsed acoustic source of about 1.3 mHz. Televiewer logs were used to identify the depths at which fractures intersect the borehole, along with fracture strike and dip (Figure 3). Representative intervals of televiewer logs from the Mirror Lake and Oracle boreholes are shown in Figure 4. These logs show the steeply dipping, isolated fractures typical of the boreholes at the Mirror Lake site and the dense network of intersecting fractures typical of the boreholes at the Oracle site. The televiewer log provides qualitative indications of fracture aperture; however, the televiewer image of fracture openings in the borehole wall is broadened by convolution with an acoustic beam of about 12 mm diameter, and represents the fracture after possible drilling damage. Various factors that need to be considered in relating apparent fracture aperture on televiewer logs to fracture permeability are described by Keys (1979) and Paillet *et al.* (1985).

2.0 / 3.785 = .53

Table 2. Pumping Test Data

Well No.	*Test type*	*Observation wells*	*Test date*	*Test length (hr)*	Gal/Min	*Rate*
EBR4	Pumping	EBR4	August 21, 1985	8	.53	2.0 l/min
EBR4	Pumping	EBR1, EBR2, EBR3	August 22, 1985	10	.79	3.0 l/min
M1	Injection	H2, H6, H7	March 16, 1985	10		5.5 l/min
H3	Pumping	H2, H6, H7	March 17, 1985	8		Variable

of inner tube rubber fitted around the flowmeter in such a way as to block flow in the annulus. However, such flow blockage was never perfect. Laboratory tests indicated that the skirted flowmeter provided calibrated borehole discharges somewhat less than one-half of the actual discharge because of flow leakage around the outside of the flowmeter. Repeat measurements also were somewhat variable because distortion of the flowmeter skirt produced slightly different degrees of sealing in the annular space on different measurements. For these reasons, the flow rates measured with the skirted flowmeter have been treated as lower limits of the actual borehole flow. These values may be compared to upper limits on local borehole flow rates obtained from the known discharge in pumped boreholes, and the measured decline of water level in casing in observation boreholes.

PUMPING TESTS AT MIRROR LAKE, NEW HAMPSHIRE

The pumping tests at the Mirror Lake site were run over a two-day period by pumping borehole EBR4 at a constant rate, and making flowmeter and hydraulic-head measurements in all four boreholes. Flow rates were measured in borehole EBR4 with the unskirted flowmeter on the first day, and in the other three boreholes on the second day using the flowmeter with flow concentration skirt. The constant discharge was increased on the second day, because discharge from the adjacent nonpumped boreholes was assumed to be somewhat less than the inflows into the pumped borehole at any given discharge. The pump was turned off overnight after the first pumping test; hydraulic heads recovered to nearly the pretest levels prior to the second day of pumping. Other details on the pumping tests at the Mirror Lake site are given in Table 2.

Hydraulic-head measurements during both days of pumping indicated that relatively steady hydraulic-head differences developed between the three observation wells and the pumped well within one hour after the start of pumping. Hydraulic heads in all four boreholes then declined at approximately the same rate for the rest of the day. Measurements of downflow in casing during the first hours of pumping on August 22, 1985, indicated that downflow in the three observation boreholes accounted for approximately one-half of the discharge from the pumped borehole. The measured hydraulic-head differences were about .55 m for flow between boreholes EBR1 and EBR3 and the pumped borehole, and .12 m between borehole EBR2 and the pumped borehole.

Although multiple sets of fractures were indicated on the televiewer logs for the EBR boreholes, the flowmeter measurements indicated that all inflow to borehole EBR4 entered at a single fracture, and that all outflow from boreholes EBR1 and EBR3 existed at similar fractures. In borehole EBR2, additional flow entered the borehole at a point a few meters below the single fracture conducting most of the outflow. Results of the flowmeter measurements during both days of the pumping tests at the Mirror Lake site are given in Figure 5. The results indicate that inflow

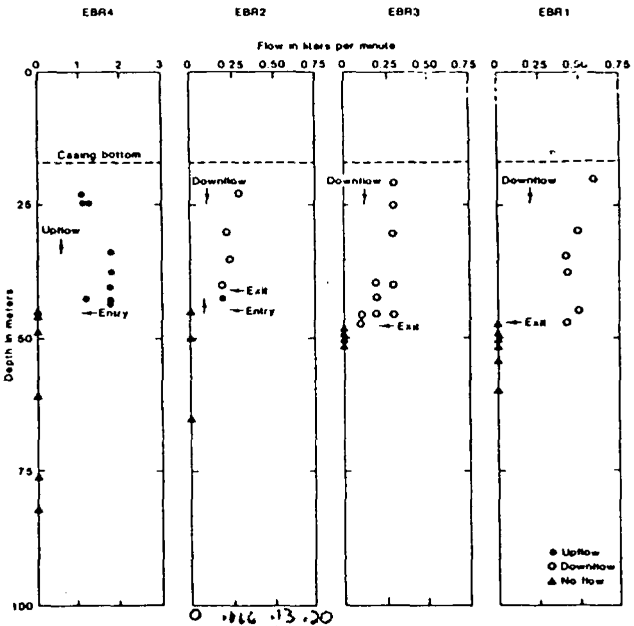


Fig. 5. Measured flow distributions in the EBR boreholes during the pumping test.

Fractures
1 in 118'

or outflow in all four boreholes occurred at a depth of 40 to 45 m. However, inspection of televiewer logs indicates that the hydraulic connection between boreholes does not occur by means of a single fracture, because all fractures shown to produce or accept flow dip at angles greater than 45°.

The lack of televiewer log correlation for the intervals of the EBR boreholes known to be transmitting water during the pumping test is demonstrated in Figure 6. Orientations and depths of the fractures clearly indicate that the connections between the EBR boreholes cannot be represented as a single fracture plane. Water-transmitting fractures dip at angles greater than 45° with some fractures dipping east, and other fractures dipping west. The best model that could be used for this fracture-flow system is a nearly horizontal zone of fracture permeability composed of intersecting fractures that have orientations far different than that of the fracture zone. Inspection of the complete televiewer logs for the EBR boreholes does not indicate an obvious maximum frequency of fractures intersecting the boreholes at a depth of about 45 m. The only apparent trend is one of gradually decreasing fracture frequency with depth. The thickness of the permeable zone is not well-defined by the televiewer logs for individual boreholes, but is estimated to be about 5 m on the basis of the variation in depth of the producing fractures in Figures 5 and 6.

The most probable interpretation of the fracture flow system connecting the EBR boreholes is summarized in Figure 6, showing the strike and dip of fractures intersecting the boreholes projected into the plane connecting boreholes EBR4 and EBR1. The relative size of the fracture opening apparent on the televiewer logs is indicated by the width of the line representing the fracture in Figure 6. The projections demonstrate the lack of correlation of fractures between boreholes. Water flow in fractures is modeled as conduction along an irregular conduit consisting of interconnected parts of numerous fractures.

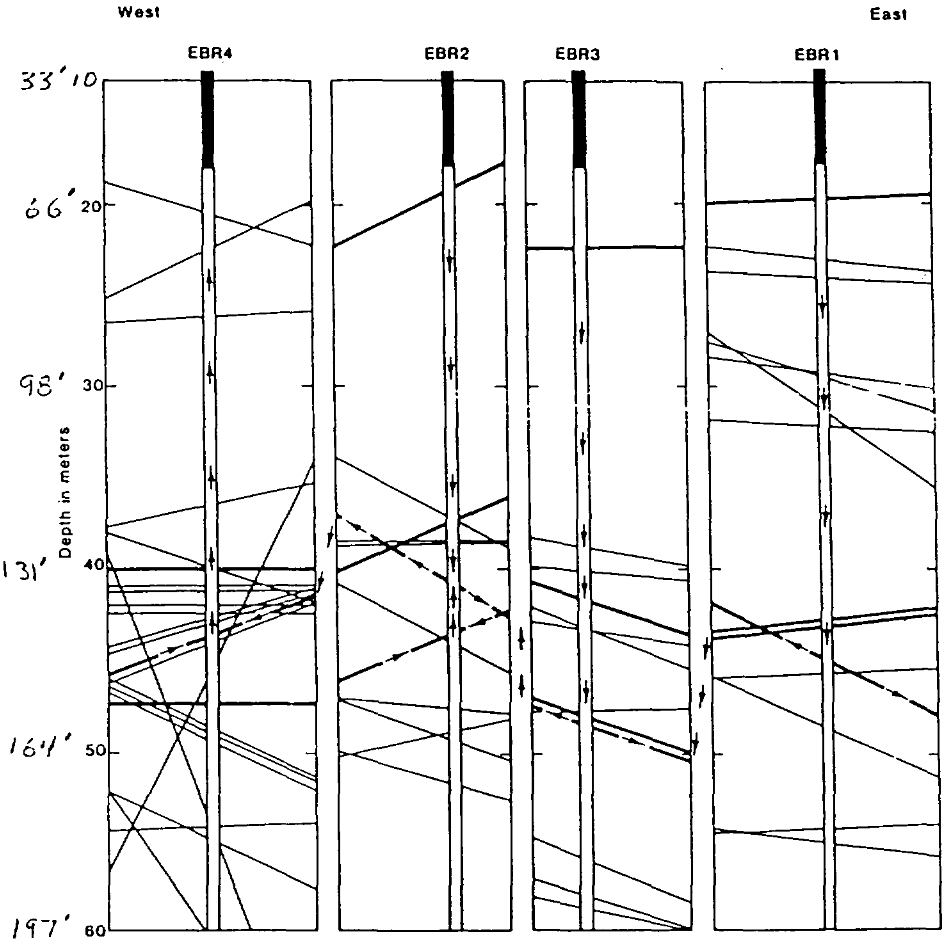


Fig. 6. Projection of fractures in the plane connecting boreholes EBR4 and EBR1, illustrating probable flow path between boreholes; note that vertical scale compression reduces apparent dip of fractures in the figure.

INJECTION TEST IN BOREHOLE M1 AT THE ORACLE SITE

After making a few measurements to insure that no natural flow occurred in the boreholes at the Oracle site before the start of pumping, flow between boreholes was induced by packing off the portion of borehole M1 below a depth of 60 m, and injecting at a steady rate of 5.5 l/min below the packer. Water levels in the other boreholes at the Oracle site were monitored after the start of injection. Rates of rise in nearby boreholes were monitored throughout the test period under the assumption that the flow field would evolve as the cone of hydraulic-head elevation around borehole M1 continued to enlarge with time. The hydraulic-head data did not indicate the rapid approach to steady hydraulic-head differences between boreholes that we observed at the Mirror Lake site. This was expected because the intensely fractured rock at the Oracle site was assumed to provide significant transient storage so that fracture porosity might not be small in comparison to water stored in the boreholes.

In those cases where changes appeared in the flow field with time during the flowmeter measurements, flowmeter data were adjusted to correspond to the measurements made at one particular time. This adjustment was done by fitting a smooth exponential curve to the decreasing rates of inflow or outflow from the casing estimated from hydraulic-head data during the pumping injection tests. Flowmeter values were adjusted according to the equation:

$$Q^* = Q(F^*/F) \qquad (1)$$

where Q is the original flowmeter measurement, F^* is the casing flow at some reference time, and F is the corresponding value of casing flow obtained from the fitted curve at the time of the flowmeter measurement.

The first flow measurements at the Oracle site were made using an unskirted version of the flowmeter with a 6.34-cm diameter measurement section in the 11.4-cm diameter borehole H2. For the injection test using borehole M1, the flowmeter-adjustment procedure was equivalent to adjusting the measured flows to what the flow would have been had the casing continued to fill at the rate of about 4 l/min. This is equivalent to using the maximum value of upflow in casing for the flowmeter measurement adjustment. Unadjusted flowmeter measurements for all depths above the major fracture at a depth of 81.6 m in borehole H2 are superimposed on the curve of decreasing inflow to the casing in Figure 7. These are individual flowmeter measurements made at various depths in borehole H2 above the depth at which all measurable flow was determined to enter the borehole. Much of the scatter in flowmeter measurements may be due to the decrease in flow rates with time, and not from additions to the upward flow associated with other fractures above 81.6 m. Measurements made at all depths below 81.6 m indicated no detectable flow.

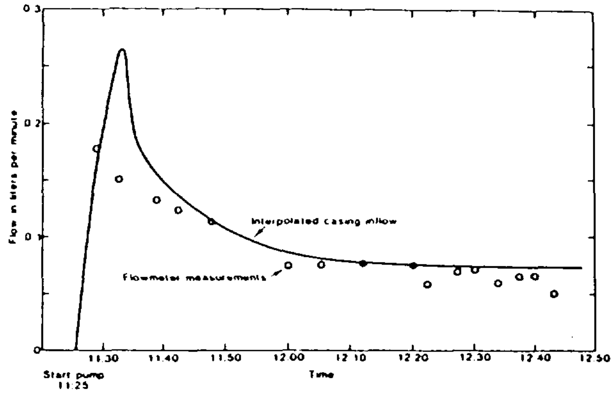


Fig. 7. Comparison of interpolated casing inflow determined from rate of water-level rise with flowmeter measurements in borehole H2 during injection test at the Oracle site.

Normalized flow rates for borehole H2 during injection in borehole M1 are given as a function of depth in Figure 8a. Some scatter occurs in the measurements at depths above 81.6 m, but this scatter is not much greater than that obtained from repeat measurements at a depth of 61 m at the

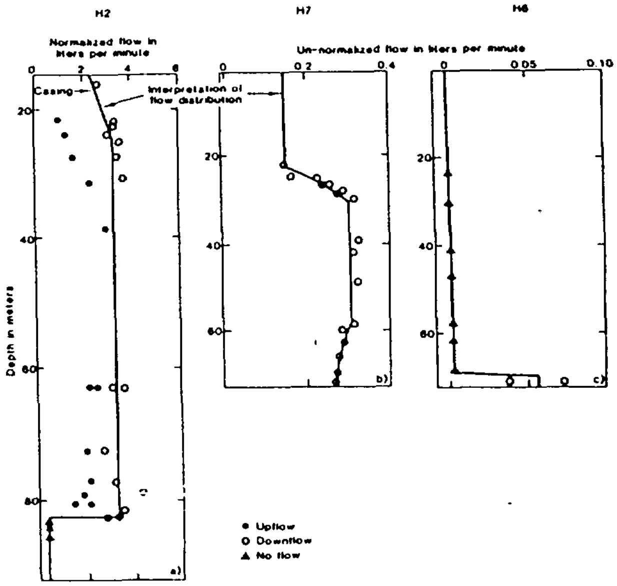


Fig. 8. Measured flow distributions in boreholes at the Oracle site: (a) normalized upward and downward flow in borehole H2 during injection in borehole M1 and pumping in borehole H3; and (b and c) boreholes H6 and H7 during pumping in borehole H3.

start and end of the flowmeter logging. At the reference time, a constant, upward flow rate of about 4.0 l/min appears to have occurred with flow entering via the single large fracture at a depth of 81.6 m and filling the upper casing at that same flow rate.

PUMPING TEST IN BOREHOLE H3 AT THE ORACLE SITE

Flowmeter experiments were continued after the system had recovered from the injection test by pumping from borehole H3. The original intent had been to create a constant drawdown in the pumped borehole; however, the borehole was unintentionally dewatered, and the pump was shut off during the test. The pump was subsequently turned on to maintain an approximately constant drawdown in borehole H3, but this irregular program of pumping made estimates of water levels in the casing much more difficult to approximate by a continuous curve. The total amount of hydraulic-head difference that could be created by completely dewatering the pumped well also was substantially less than that hydraulic-head difference available during the injection below the packer. Therefore, induced flow rates were much lower.

Outflow from borehole H2 during pumping was very similar to outflow during the injection test, except that the flow rates are much lower because of the much lower driving hydraulic heads. All of the flow exited through the major fracture at a depth of 81.6 m. The data also may indicate that downflow entered at fractures above 37 m.

Most flow exited borehole H7 very close to the bottom. This depth was below the lowest depth attained with the flowmeter, and below televiewer log coverage. Therefore, the flow must have exited directly from the bottom of the hole, or within 0.3 m of the bottom. An additional small amount of downflow apparently exited at the large fracture set near 60 m in depth. A substantial quantity of flow entered the borehole at major fractures above a depth of 30 m with the rest of the downflow originating from drainage of the casing.

Outflow from borehole H6 was similar to outflow from borehole H7 in that most of the flow exited very close to the bottom of the hole. The exact exit point was assumed to be a fracture, but these depths were below televiewer log coverage. In this case, most flow appeared to enter by means of fractures between depths of 70 and 76 m rather than coming out of storage in casing. These measurements were made rather late in the day after the start of the experiment, and water levels already had stabilized far below the casing in borehole H6.

CHARACTER OF PRODUCING FRACTURES

The individual fractures at the Mirror Lake and Oracle sites identified as producing water in the pumped wells or accepting water in observation wells adjacent to pumped boreholes were steeply dipping fractures within nearly horizontal zones of permeability. In all cases where the producing or accepting fractures were identified on televiewer logs at Mirror Lake, the fractures appeared as prominent, apparently open fractures with dip angles greater than 45 degrees. However, no single producing fracture appeared to provide a direct hydraulic connection between pumped and observation boreholes.

Considerable information on the distribution of fracture permeability in the vicinity of the boreholes at the Oracle site is given by Hsieh *et al.* (1983) and Jones *et al.* (1985). These authors identified a zone of horizontal permeability below a depth of 80 m in borehole H2, and intersecting boreholes H3, H4, and M1. This fracture interval was interpreted as a fault or shear zone. However, the results of our flowmeter tests indicated that all flow entering borehole H2 in this interval entered from a single fracture at a depth of 81.6 m. The televiewer log for this fracture indicates a dip of (approximately) 60° to the east, so that this fracture intersects borehole H3 at a point far above the permeable zone, and extends below the bottom of borehole M1. This fracture is interpreted as a fracture splaying off the major horizontal zone, and may not be especially permeable where it extends beyond that zone. There are several possible fractures apparent in the televiewer log of borehole H3 that could be the projection of this fracture. However, none of these possible projections of the fracture in borehole H2 appears to be as large.

Televiewer logs for the producing and accepting fractures at the Mirror Lake site are shown in Figure 9. The televiewer log for the major producing fracture in borehole H2 at the Oracle site is compared to other geophysical logs in Figure 10. The fractures illustrated in Figures 9 and 10 are all major fractures, but they do not appear different from other prominent fractures on the televiewer logs. Inspection of the geophysical logs in Figure 10 for borehole H2 at the Oracle site and of other geophysical logs for the boreholes at the Mirror Lake site given by Paillet (1985) indicates that no unusual characteristics occur that could be used to identify these fractures as being especially permeable. These appear to be conductive fractures similar to other fractures intersecting the boreholes, but that are connected favorably to fractures identified in adjacent boreholes. This finding appears to confirm the conclusions given by Long *et al.* (1982) that fracture connectivity

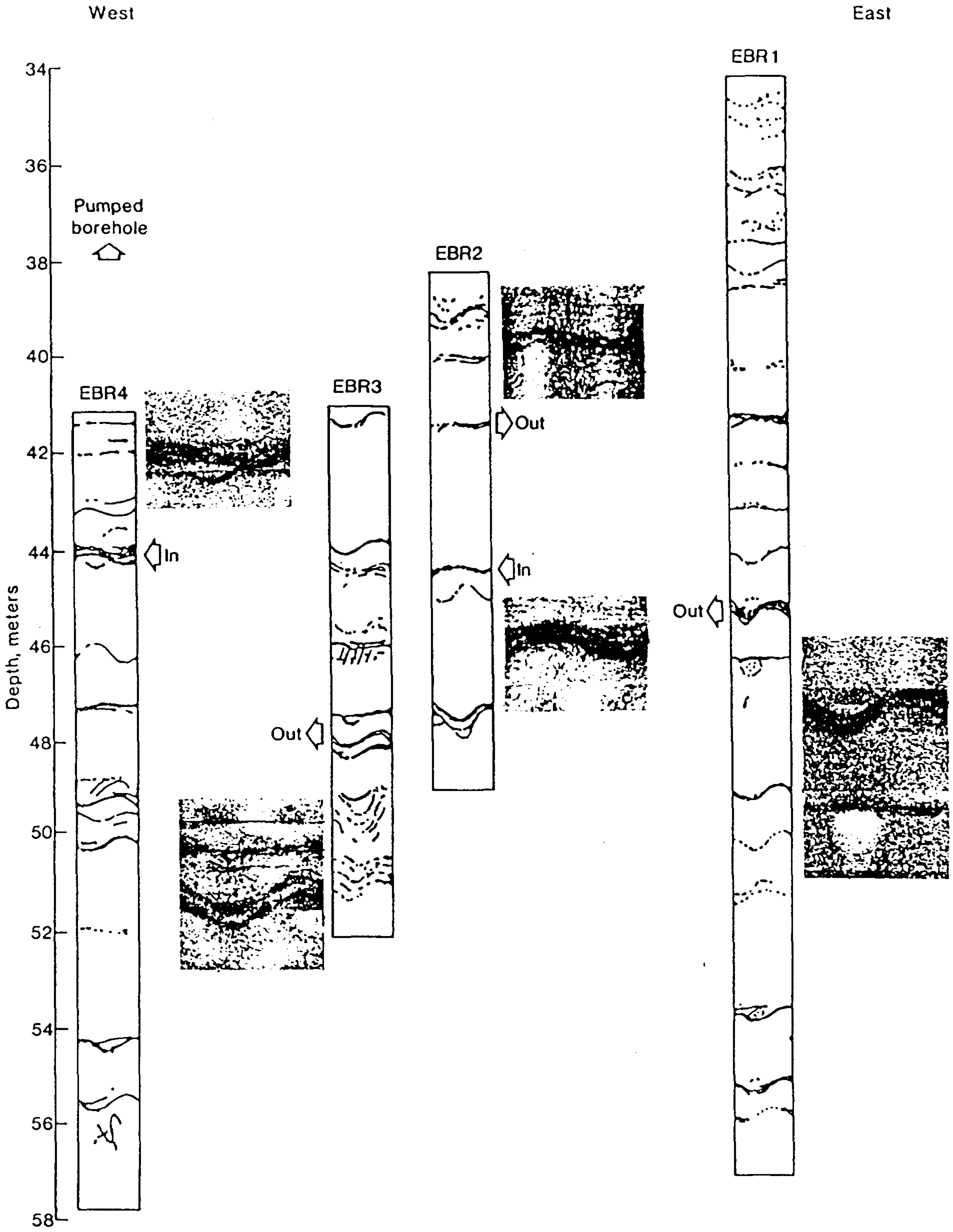


Fig. 9. Televiewer logs of producing and accepting fractures in boreholes at the Mirror Lake site.

and orientation within the large-scale fracture network are more significant than fracture aperture at a given point in a rock mass.

One remaining question about the fracture permeability system at the Mirror Lake site was the nature of the permeability system in the region beyond the immediate EBR borehole area. This scale problem was addressed by running a surface to borehole seismic survey in the vicinity of the EBR boreholes (vertical seismic profile or VSP; Paillet and Turpening, 1984). The survey was run using the method given by Huang and Hunter (1982) and Hardin and Toksoz (1984) in which signals from a surface source are detected at loca-

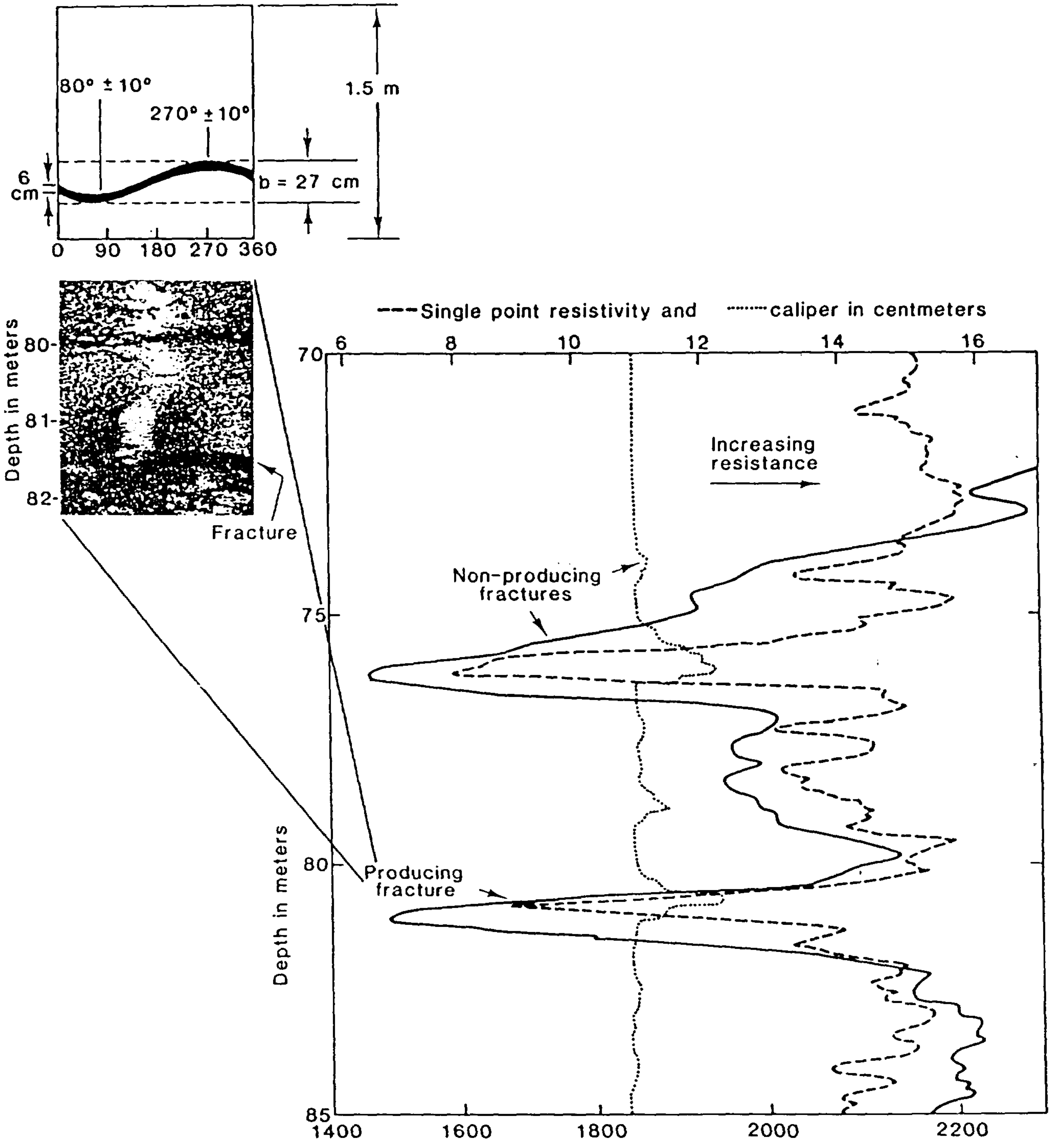


Fig. 10. Televiewer log for the producing fracture in borehole H2 at the Oracle site compared to caliper and resistivity logs.

tions within the borehole. The quantitative results of this survey still are being analyzed, but uncorrected field data indicate that a horizontal zone of permeability is present in the EBR area. The seismic traces indicate the generation of a strong tube wave at a depth of about 45 m in borehole EBR4. The seismic energy detected by the VSP hydrophone is characterized by an acoustic wavelength of about 100 m; therefore, the properties of rocks are averaged for at least 100 m around the borehole array. Although permeability values have not been calculated from the VSP data, the permeability zone identified from the flow tests extends for some distance away from the EBR boreholes.

MODELING FRACTURE FLOW AT MIRROR LAKE SITE

The transient nature of the flow system at Oracle made flow modeling very difficult. However, the nearly constant head differences between various EBR boreholes maintained during the pumping test at the Mirror Lake site indicated that the fracture flow might be modeled as quasisteady flow in a fracture zone from the observation wells into the pumped borehole. Two simplified flow models were used: (1) a single, horizontal fracture connecting all four boreholes; and (2) a tortuous, cylindrical conduit connecting individual pairs of boreholes. A single, infinite, fracture plane probably is not a good model for the individual fractures intersecting the EBR boreholes, but may be a reasonable approximation to a horizontal fracture zone. The tortuous flow conduit also may represent a reasonable approximation to a flow path consisting of the most permeable segments in a network of intersecting fractures. In either case, application of simple flow models can provide at least qualitative indication of the size of apertures of individual fracture segments comprising the horizontal permeability zone detected at the Mirror Lake site.

The first model involved pairs of pumping and observation boreholes, separation D, and borehole radius R in which flow towards the discharge well was conducted by a confined aquifer of transmissivity T. The solution for the transmissivity for the case of steady flow into a well of known radius is (Davis and DeWeist, 1966):

$$T = Kb = Q \ln(D/R)/2\pi H \qquad (2)$$

where K is hydraulic conductivity, b is the vertical thickness of the fracture or fracture zone, and H is hydraulic-head difference between observation and discharge wells.

Fracture-zone transmissivity can be related to the effective aperture of an equivalent single fracture using the equation for laminar flow between two parallel plates. The average flow in such a fracture is proportional to the square of the aperture and the hydraulic-head gradient driving the flow. The expression for the permeability within the fracture is:

$$K = (\rho g b^2)/12\mu \qquad (3)$$

where ρ is the density of water, g is the acceleration of gravity, b is the aperture of the equivalent fracture, and μ is the viscosity of water. Substituting this expression into the equation for transmissivity gives the well-known cubic law:

$$T = Kb = (\rho g b^3)/12\mu \qquad (4)$$

or

$$b = (12\mu T/\rho g)^{1/3} \qquad (5)$$

Results from the application of this model to the pumping test for the three EBR boreholes discharging into borehole EBR4 are given in Table 3. Two of the results (flow out of boreholes EBR1 and EBR3) indicate approximately the same effective fracture aperture (0.07 cm). The third case (flow out of borehole EBR2) indicates somewhat greater permeability, giving an effective single-fracture aperture of 0.12 cm. In both cases, the calculated single-fracture apertures provide an approximation of the size of the fracture openings that appear to be conducting the flow between boreholes.

The second model is based on the formula for laminar flow in cylindrical tubes. The effective length of the flow path between boreholes is assumed to be greater than D, the separation between boreholes. In applying the model, flow conduit tortuosity has been taken as 2.0. The relationship between discharge and conduit radius becomes:

$$Q = (\pi R^4/8\mu)(\rho g H/2D) \qquad (6)$$

where R is the radius of the flow conduit.

Results from the second model calculations also are given in Table 3. These values indicate that cylindrical tubes from 1.0 cm to 2.0 cm in diameter would be required to conduct flow between the EBR boreholes at the head differences and discharge rates measured during pumping tests at the Mirror Lake site. These flow conduit diameters are not completely realistic, but the model of individual flow conduits consisting of passages between asperities within the most permeable segments of intersecting fractures more likely applies to the

Table 3. Results of Fracture Flow Models

Borehole pairs	*Borehole separation (m)*	*Head difference (m)*	*Q (l/min)*	*T (cm²/s)*	*b (cm)*
Infinite Flat Fracture of Uniform Aperture:					
EBR1 and 4	14.1	.55	11.4	2.86	.07
EBR3 and 4	10.0	.55	11.4	2.69	.07
EBR2 and 4	10.0	.12	11.4	12.35	.12
					R (cm)
Cylindrical Flow Conduit of Known Tortuosity:					
EBR1 and 4	14.1	.55	11.4		.71
EBR3 and 4	10.0	.55	11.4		.65
EBR2 and 4	10.0	.12	11.4		.96

EBR boreholes than the first model does. The actual flow field probably consists of several such tortuous conduits, each only a fraction of 1.0 cm in diameter.

CONCLUSIONS

The flowmeter pumping tests at Mirror Lake, New Hamphsire and Oracle, Arizona provide surprisingly similar results in spite of the fact that these test sites were selected to represent the two extremes of fracture network density. Results of both tests indicate that a major proportion of the flow between closely spaced boreholes was conducted by complex conduits composed of intersecting fractures. In both cases, the televiewer logs and other geophysical data indicate that the fractures intersecting the borehole at the point where most water enters or exits during pumping or injection tests are similar to other prominent fractures that may be permeable, but that do not take part in the flow system. None of the major conducting fractures appears to provide a direct connection between boreholes; all major conducting fractures apparently vary in effective hydraulic aperture within distances as short as 10 m. Even though televiewer logs were used to provide qualitative indications of the distribution of fractures along the length of the borehole at the Mirror Lake and Oracle sites, the location of the permeable zones identified from pumping and injection tests were not readily apparent in the observed fracture distributions.

The model of fracture conductivity that appears to apply to both the Mirror Lake and Oracle sites is the model of flow conduits provided by the intersection of short, permeable fracture segments. These conduits probably are best modeled as flow tubes embedded in an intersecting fracture network. The results at both the Mirror Lake and Oracle sites demonstrate that the orientation of the zones of maximum permeability may be quite different from the observed strike and dip of the individual fracture segments that compose that fracture zone. Such a degree of complexity was not expected when this project was being planned. Both sites were selected because observation wells were so closely spaced, and individual fractures were expected to project with little change within distances as short as 10 m. The results obtained here appear to support the theoretical results obtained by Long *et al.* (1982) on the statistical nature of flow through random fracture networks; these results also are consistent with the complexity of fracture hydraulics reported for a Canadian shield study site by Davison (1984).

ACKNOWLEDGMENTS

The authors appreciated the efforts of Professor S. P. Neuman and Professor E. S. Simpson of the University of Arizona in setting up work at the Oracle site. Steve Silliman was especially helpful in arranging equipment for pumping and injection tests. The vertical seismic profile work conducted by the MIT Earth Resources Laboratory was supported by National Science Foundation Grant EAR83-12945.

REFERENCES

Davis, S. N. and R.J.M. DeWeist. 1966. Hydrogeology. Wiley, NY. 463 pp.

Davison, C. C. 1984. Monitoring hydrologic conditions in fractured rock at the site of Canada's underground research lab. Ground Water Monitoring Rev. v. 4, pp. 95-102.

Davison, C. C., W. S. Keys, and F. L. Paillet. 1982. Use of borehole geophysical logs and hydrologic tests to characterize crystalline rock for nuclear waste storage. Whiteshell Nuclear Research Establishment, Manitoba and Chalk River Nuclear Laboratory, Ontario, Canada. ONWI-418. 103 pp.

Dudgeon, W. E., M. J. Green, and W. J. Smedmore. 1975. Heat-pulse flowmeter for boreholes. Water Research

Center, Medmenham, Marlow Bucks, England. Tech. Rept. TR-4. 69 pp.

Hardin, E. and M. N. Toksoz. 1984. Detection and characterization of fractures from generation of tube waves. Society of Professional Well Log Analysts Annual Logging Symposium, 26th, Dallas, Tex., Proc. pp. III-II21.

Hess, A. E. 1982. A heat-pulse flowmeter for measuring low velocities in boreholes. U.S. Geol. Surv. Open-File Rept. 82-699. 40 pp.

Hess, A. E. 1984. Use of a low velocity flowmetering the study of the hydraulic conductivity of fractured rock. National Water Well Association Conference on Surface and Borehole Geophysics in Ground-Water Exploration, San Antonio, Tex., 1984, Proc. pp. 812-832.

Hess, A. E. 1985. Identifying hydraulically-conductive fractures with a low-velocity borehole flowmeter. Canadian Geotech. Jour. v. 23, no. 1, pp. 69-78.

Hsieh, P. A., S. P. Neuman, and E. S. Simpson. 1983. Pressure testing of fractured rocks—a methodology employing three-dimensional hole test. U.S. Nucl. Reg. Comm., Wash. DC. NUREG/CR-3213. 176 pp.

Huang, C. F. and J. A. Hunter. 1981. A seismic tube wave method for the in-situ estimation of rock fracture permeability in boreholes. Society for Exploration Geophysicists Annual International Meeting, 51st, Los Angeles, California. November, Technical Program Abstracts. pp. 414-415.

Jones, J. W., E. S. Simpson, S. P. Neuman, and W. S. Keys. 1985. Field and theoretical investigation of fractured crystalline rock near Oracle, Arizona. NUREG Topical Report. CR-3736. 104 pp.

Keys, W. S. 1979. Borehole geophysics in igneous and metamorphic rocks. Society of Professional Well Log Analysts Annual Logging Symposium, 20th, Tulsa, Okla., Proc. pp. 001-0026.

Keys, W. S. 1984. A synthesis of borehole geophysical data at the Underground Research Laboratory, Manitoba, Canada. U.S. Dept. of Energy, Wash., DC. BMI/OCRD-15. 43 pp.

Likens, G. E. 1985. An ecosystem approach to aquatic ecology. Mirror Lake and Its Environment. Springer-Verlag, New York. 444 pp.

Long, J.C.S., J. S. Remer, C. R. Wilson, and P. A. Witherspoon. 1982. Porous media equivalents for networks of discontinuous fractures. Water Resources Research. v. 18, pp. 645-658.

Paillet, F. L. 1983. Acoustic characterization of fracture permeability at Chalk River, Ontario. Canadian Geotech. Jour. v. 20, no. 3, pp. 468-476.

Paillet, F. L. 1985. Geophysical well log data for study of water flow in fractures in bedrock near Mirror Lake, West Thornton, New Hampshire. U.S. Geol. Surv. Open-File Rept. 85-340. 27 pp.

Paillet, F. L. and A. E. Hess. 1986. Geophysical well log analysis of fractured crystalline rocks at East Bull Lake, Ontario, Canada. U.S. Geol. Survey, WRIR 86-4052 [in press].

Paillet, F. L. and W. S. Keys. 1984. Applications of borehole geophysics in characterizing the hydrology of fractured rocks. NWWA/EPA Conference on Surface and Borehole Geophysical Methods in Ground Water Investigations, San Antonio, Tex., Proc. pp. 743-761.

Paillet, F. L., W. S. Keys, and A. E. Hess. 1985. Effects of lithology on acoustic televiewer log quality and fracture interpretation. Society of Professional Well Log Analysts Annual Logging Symposium, 26th, Dallas, Tex., 1985, Proc. pp. JJJ1-JJJ31.

Paillet, F. L. and Roger Turpening. 1984. Borehole and surface to borehole applications in fracture characterization. Society of Exploration Geophysicists Annual International Symposium, Atlanta, Georgia, Proc. pp. 333-335.

Snow, D. T. 1968. Rock fracture spacings, openings, and porosities. Jour. of Soil Mechanics of the Foundations Division of the Am. Soc. of Civil Engrs. v. 94, pp. 73-91.

Winter, T. C. 1984. Geohydrologic setting of Mirror Lake, West Thornton, New Hampshire. U.S. Geol. Surv. Water-Resources Investigations Rept. 84-4366. 68 pp.

Zemanek, Joseph, R. L. Glenn, S. V. Holcomb, L. J. Norton, and A.J.D. Strauss. 1969. The borehole televiewer—a new logging concept for fracture location and casing inspection. Jour. of Pet. Techn. v. 21, no. 12, pp. 762-774.

• • • • •

Frederick L. Paillet is Project Chief, Borehole Geophysics Research Project, Water Resources Division, Denver, Colorado. He obtained his B.S. and M.S. degrees in Mechanical Engineering at the University of Rochester prior to entering active military service as a Civil Engineering Officer in 1970. He subsequently completed requirements for a Ph.D. at the University of Rochester in 1974 under a United States Air Force scholarship. Paillet then spent two years as a faculty member with the Department of Geology, Wright State University, Ohio, before joining the U.S. Geological Survey in 1978.

Alfred E. Hess is an Electronic Engineer with the Water Resources Division of the U.S. Geological Survey in Denver, Colorado, where he develops instruments and techniques for borehole geophysical investigations. After receiving a B.A. in physics from Columbia Union College, Mr. Hess was employed as an engineering physicist for the Radio Standards Division of the National Bureau of Standards where he developed radio frequency standards and supporting instrumentation.

C. H. Cheng is a Principal Research Scientist at the Earth Resources Laboratory in the Department of Earth, Atmospheric, and Planetary Sciences at the Massachusetts Institute of Technology. He is the project leader of the Full Waveform Acoustic Logging Consortium at M.I.T. He received a B.Sc. in Engineering Physics from Cornell University in 1973 and a Sc.D. in Geophysics from M.I.T. in 1978. He has been with M.I.T. since 1978. His research interests include elastic wave propagation in a borehole, geophysical inversion theory, fracture identification, and physical properties of rocks.

E. A. Hardin participated in the research described in this report in partial fulfillment of the SM degree from the Department of Earth and Planetary Sciences, M.I.T., 1986. He obtained his B.S. degree in Applied Geophysics from the University of Utah in 1978. He is currently employed by Science Applications, Inc. in Las Vegas, Nevada, where his major interests include the geologic isolation of chemical and nuclear wastes, and geophysical applications in site characterization.

APPENDIX C

HEADSPACE GAS CHROMATOGRAPH ANALYSIS PROTOCOL

SUMMARY OF GC VOLATILE ORGANICS SCAN

1.0 INTRODUCTION

The Gas Chromatographic Volatile Organics Scan is a very useful tool which provides a rapid and economical means of identifying areas of contamination or the extent of contamination of volatile organic compounds in the environment. Following this initial survey, those areas identified as requiring more in-depth testing and analysis can be studied utilizing more definitive analytical techniques.

GHR has two means of screening for volatile organic compounds in environmental media; the organic vapor analyzer (HNU PI 101) for in-field use and the other, portable gas chromatographs (HNU 301) for use in either an in-house laboratory setting or as part of a mobile lab. The Volatile Organics scan provides useful information in characterizing both the type and extent of contamination. GHR currently has two portable gas chromatographs, one equipped with a photoionization detector (PID) and a flame ionization detector (FID), the other having an electrolytic conductivity detector (ECD) and a PID. This combination of detectors allows the chemist to characterize both halogenated and aromatic compounds as well as gases in water, soil and soil gas samples.

2.0 THEORY

2.1 Headspace Partitioning

Use of the static headspace technique for the analysis of water and soils allows large numbers of samples to be screened in a short period of time. The technique involves analysis of the headspace above a sample by means of direct injection of an aliquot of the headspace on to the GC. The term headspace refers to the air volume in a container which has been partially filled with a liquid and/or solid. For screening purposes, it is desirable to maintain the headspace volume at between 25 and 50 percent of the total volume of the container.

The composition of the headspace is directly attributable to the physical and chemical properties of the compounds in the sample as well as the concentrations present. As a result of such properties as vapor pressure and solubility, compounds partition between the vapor phase and the sample media until an equilibria is established. To assure that equilibria has been established in a reproducible manner, all samples and standards must be brought to ambient temperature and agitated prior to withdrawing an aliquot for analysis. Because of the reliance on this equilibria, this is not the method of choice when analyzing for compounds with boiling points greater than 125°C.

2.2 Chromatographic Separation

The HNU 301 is a full-function portable gas chromatograph enabling full chromatographic separation of organic compounds. Chromatographic separation is a physical process in which the individual compounds present in a sample successively absorb and desorb onto the packing materials present in a chromatographic column. As a result of their physical and chemical properties, the compounds of interest will have varying affinities for the packing material and thus will separate based upon the length of time they are retained by the column. The chromatographic column on which the separation take place is comprised of a mobile and a stationary phase. The mobile phase consists of the carrier gas which is used to carry the sample through the chromatographic column. The stationary phase consists of an absorbent distributed as a thin film on the surface of a solid support of porous particles packed into the GC column. The various organic compounds that may be contained in a sample will be absorbed and desorbed differently by the stationary phase of the column. As these compounds are desorbed from the stationary phase, the mobile phase will carry them through the column to the detector.

As a result of the separation achieved in the column, a distinct fingerprint pattern (elution) will be obtained with each compound being detected at a specific time.

This is known as the retention time and each compound will have a characteristic retention time based upon its physical properties and the properties of the selected chromatographic column.

2.3 Compound Identification

Data produced by a chromatographic scan can be used to both identify and quantify the detected compounds. Identification is performed by means of the elution order and time of particular peak produced by the detector. The retention time of a peak is compared to the known retention times of various standards that have been previously run and are contained in a standards library. Another means of identification and confirmation is the response of the compound across the two detectors of the GC. A particular compound will have a relative difference in response based on its properties in relation to two detectors. This relative difference is expressed by the ratio of the response on detector 1 vs. the response of the compound on detector 2. Quantification is achieved by comparing the peak response to the response of a known standard after identification is complete.

3.0 ANALYSIS

3.1 Introduction

The infield analysis of volatile organic compounds is performed using headspace partitioning and retention time identification. The operating conditions under which samples are analyzed are kept constant on the GC itself. Each sample encounters the same chromatographic conditions as all previous samples and standards. The various media analyzed (soil, water, soil gas) are also analyzed using the same GC conditions. This enables the analyst to analyze the various media at the same time, and minimizes the down time of the instrument.

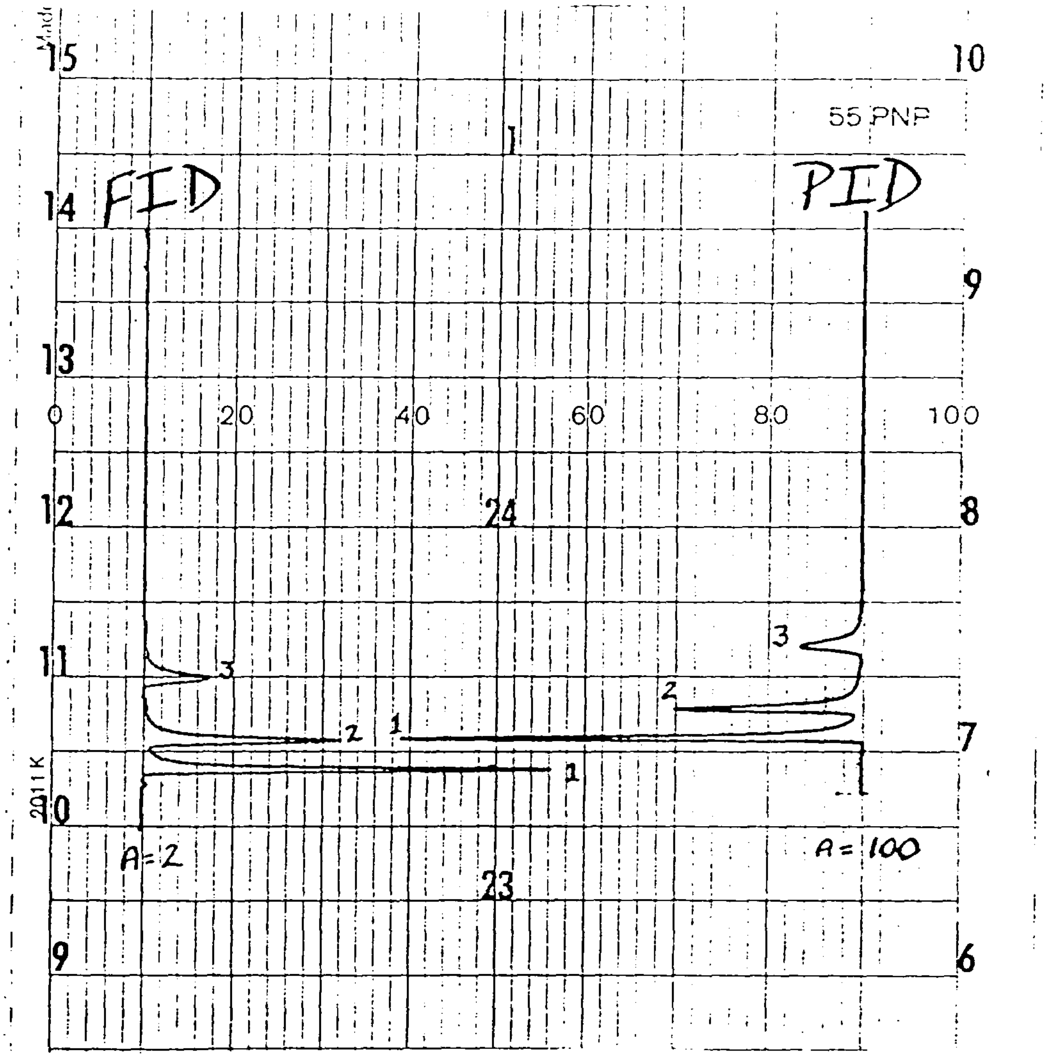
Although the three (3) media are analyzed under the same GC conditions, each media has its own preparatory method for analysis. Each stage has been designed to maximize detection and minimize analysis time. This allows for the quickest possible turn around and highest quality data. Each method of analysis and preparatory stage has its own method of quantification of compounds. Quantification is based upon standards that have gone through the same preparatory method and analyses.

3.2 GC Operating Conditions

Selected conditions of gas chromatography are based on the detection of volatile aliphatic and aromatic hydrocarbons. The sensitivity of the GC to the specific organic compounds depends on the type of chromatographic column, operating temperature and the type of detectors employed. Variations in conditions are made for those samples containing heavy petroleum products (i.e., fuel oil, diesel, etc.). The standard conditions are as follows:

Gas chromatograph: HNU Model 301 Equipped with FID and PID
Column: 3% SP-2100 on 80/100 Carbopak B 1/4" x 6' Stainless Steel.
Injector/Detector Temperature: 180°C.
Oven/Column Temperature: 60°C. Isothermal
Carrier Gas: Nitrogen @ 18 ml/min.
Backpressure: 10 psi
Chart Speed: 1 cm/min.

These conditions will allow excellent separation while keeping run time at a minimum. Figures 3-1 through 3-5 are sample chromatograms which show typical chromatographic patterns encountered.

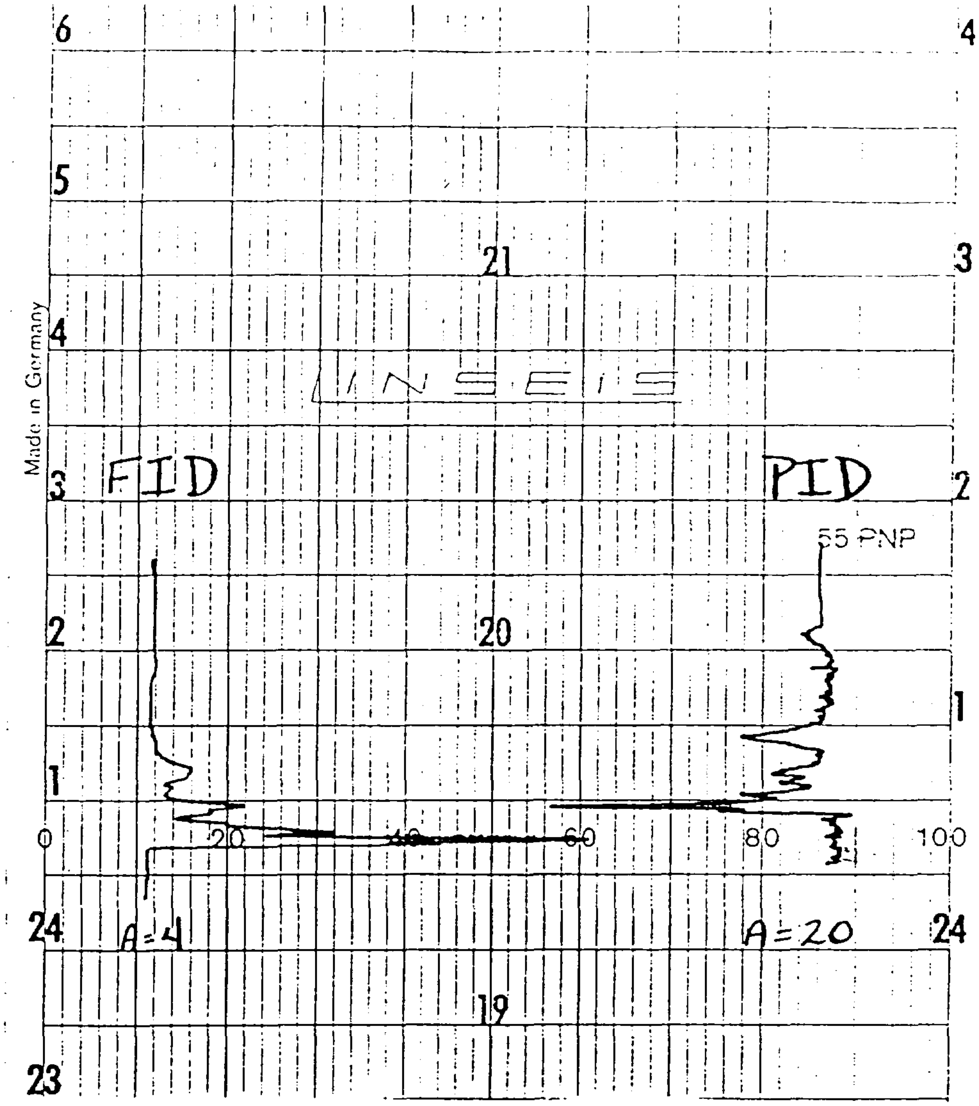


100 ul injection each:

1. Trans 1,2 Dichloroethene 1.28 ppm
2. Trichloroethene 1.20 ppm
3. Tetrachloroethene 0.70 ppm

80/100 Carbopack B/3% SP2100, 6'x¼" OD Stainless Steel, injector/detector temperature 180°, oven/column temperature 60°, backpressure 10 psi, chart speed 1 cm/min.

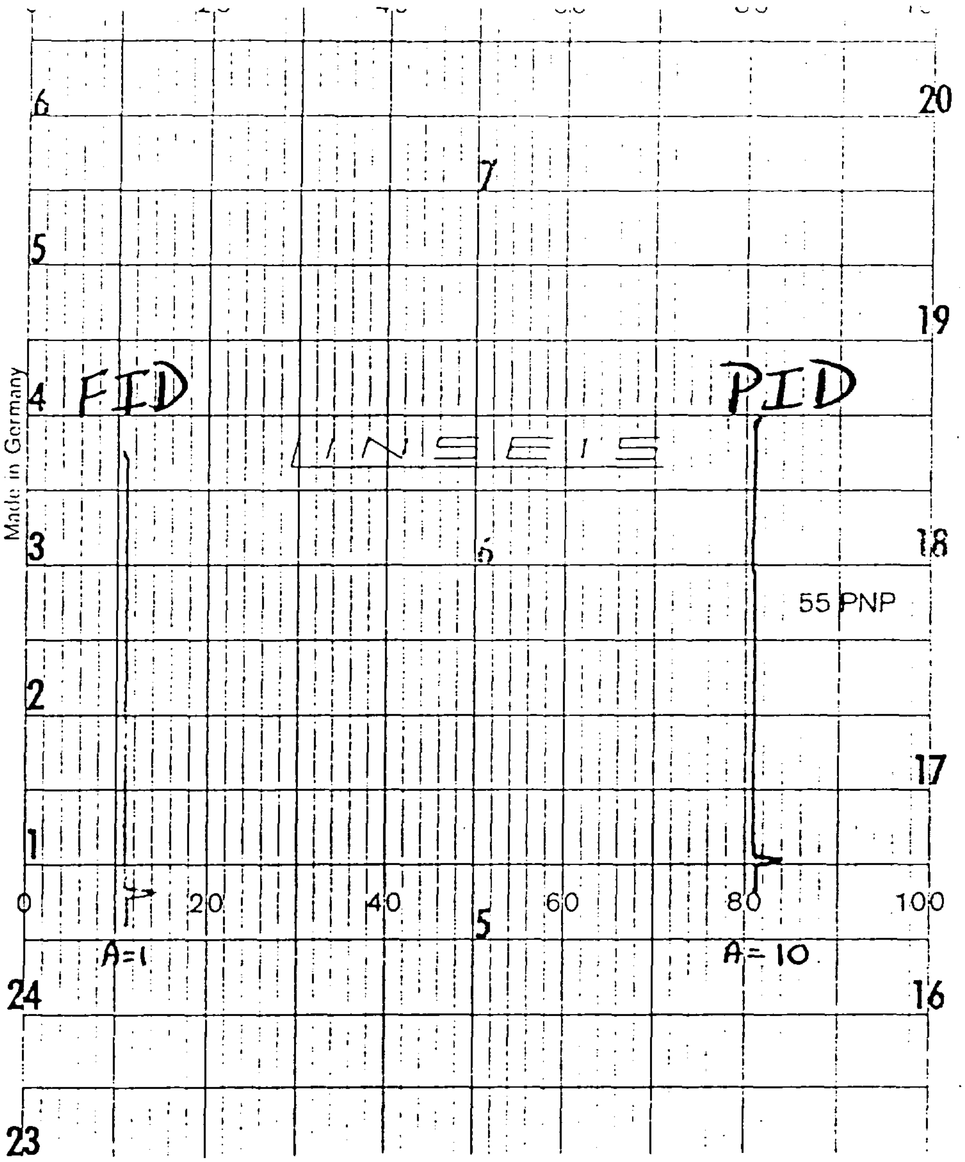
FIGURE 3-1



100 ul injection of 0.90 ppm Gasoline

80/100 Carbopack B/3% SP2100, 6'x¼" OD Stainless Steel, injector/detector temperature 180°, oven/column temperature 60°, backpressure 10 psi, chart speed 1 cm/min.

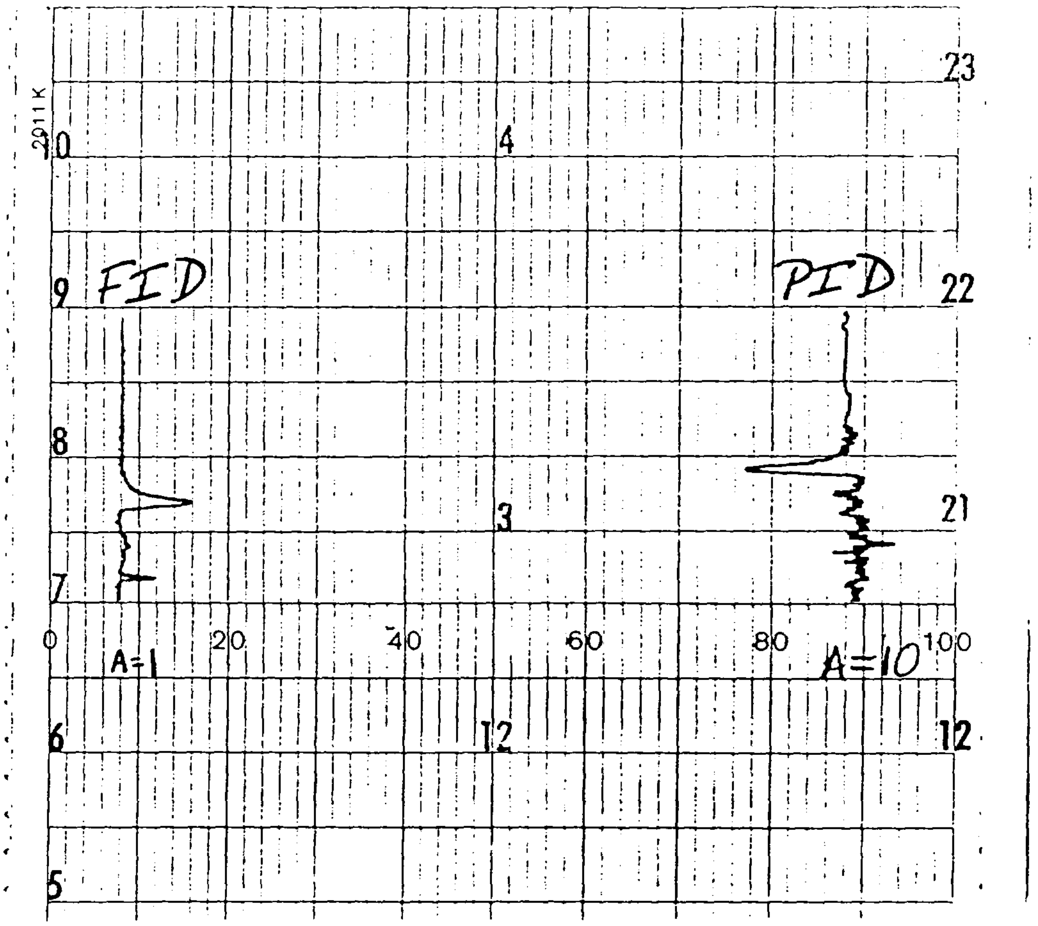
FIGURE 3-2



100 ul injection Method Blank

80/100 Carbopack B/3% SP2100, 6'x¼" OD Stainless Steel, injector/detector temperature 180°, oven/column temperature 60°, backpressure 10 psi, chart speed 1 cm/min.

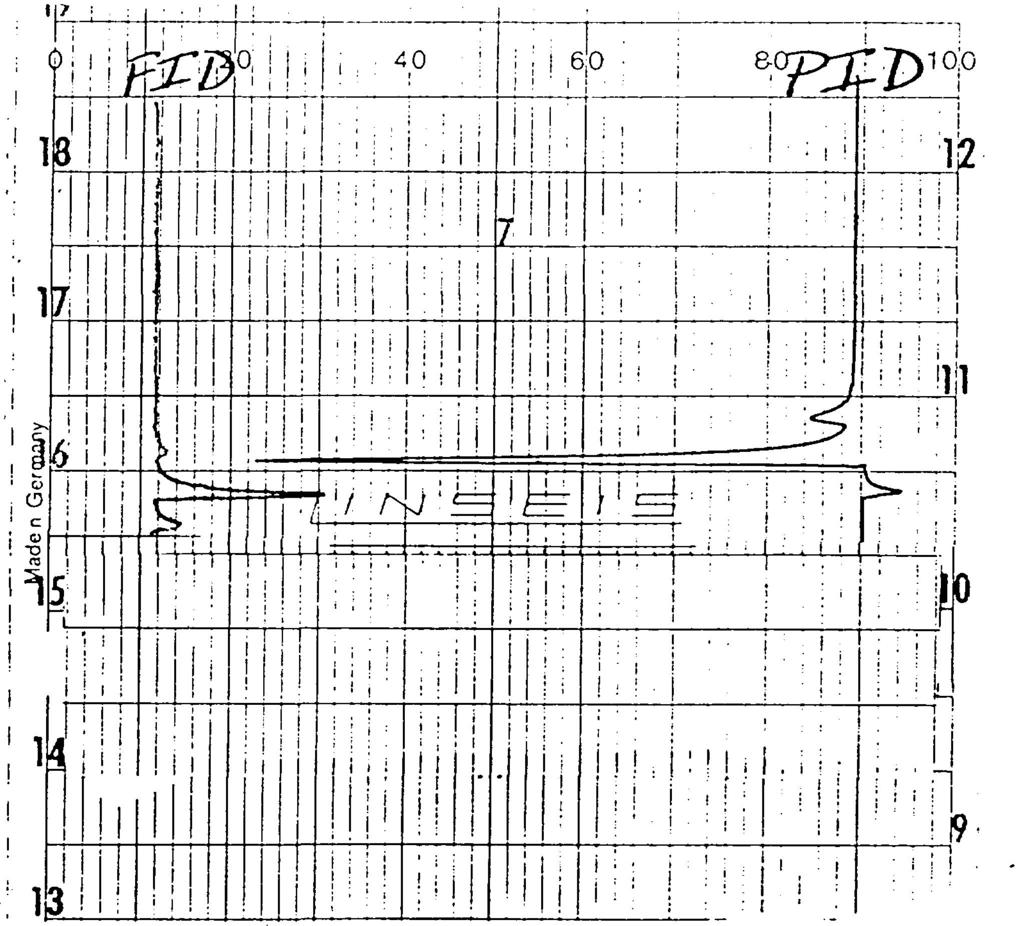
FIGURE 3-3



5 ml injection through 1 ml gas sample loop Toluene 0.1 ppm

80/100 Carbopack B/3% SP2100, 6"x¼" OD Stainless Steel, injector/detector temperature 180°, oven/column temperature 60°, backpressure 10 psi, chart speed 1 cm/min.

FIGURE 3-4



5 ml injection through 1 ml gas sample loop Benzene 10.1 ppm

80/100 Carbopack B/3% SP2100, 6'x¼" OD Stainless Steel, injector/detector temperature 180°, oven/column temperature 60°, backpressure 10 psi, chart speed 1 cm/min.

FIGURE 3-5

3.3 Sample Preparation:

3.3.1 Water Samples

Water samples are collected in 40 ml Volatile Organic Analysis (VOA) vials with no air in the vial, labeled as to sample location and time collection and shuttled to the field lab where all information is recorded on chain of custody forms and samples are signed over to the analyst. The analyst places the samples into a refrigerator to cool to less than 10°C.

Once cool, samples are opened and approximately 10 ml is poured off to form a headspace over the sample. The vial is then resealed and allowed to reach room temperature. The sample is agitated at room temperature to ensure that equilibria is reached between the liquid and vapor phases. 100 ul of the headspace is withdrawn from the vial and injected into the gas chromatograph.

Quantification is performed by External Standard-Peak Area and/or External Standard-Peak Height methods using the following equation:

$$R \times \frac{A\ Sx}{A\ std} \times RF = \text{concentration (mg/l)}$$

where:

R = Area units of the peak(s) of interest

A Sx = Attenuation of integration of sample

A std = Attenuation of integration of standard

RF = Response factor in ppm/R or ppb/R

Calculation RF

$$\frac{\text{Concentration of Standard}}{\text{Area Units of Peak(s)}} \text{ (ppm or ppb)}$$

3.3.2 Soil/Sediment Samples

Preweighted VOA vials are sent into the field for sample collection. Samples are collected by filling approximately one-third (1/3) of the vial with sample, and sealing. Chain of Custody information is noted and samples signed over to the analyst. Upon receipt of samples, the gross weight of the vial and sample are recorded and the sample weight calculated by subtracting the tare weight from the gross weight. The sample is allowed to reach room temperature and agitated to ensure equilibria between the sample and headspace. 100 ul of the headspace is then analyzed at typical GC conditions.

Quantification is performed by External Standard-Peak Area and/or External Standard-Peak Height methods using the following equation:

$$\frac{R}{Sx\ W} \times \frac{A\ Sx}{A\ Std} \times RF = \text{Concentration}$$

Where:

R = Instrument response of the peak(s) of interest (area units or peak heights)

A Sx = Instrument attenuation for sample run.

A Std = Instrument attenuation for standard run.

Sx W = Sample weight in grams.

Rf = Response factor = $\frac{\text{ug of standard added to empty vial}}{R}$

The above computation assumes that 100 percent of the analyte partitions into the headspace. In reality, the headspace partitioning is much lower. Therefore, the calculated value is actually the lowest concentration possible in the sample matrix.

3.3.3 Air/Gaseous Samples

Samples are collected in 5 ml gas tight syringes and the needle plugged with a piece of septum to avoid sample loss during transport to the field laboratory. Chain of custody procedures are followed and the sample syringes signed over to the analyst. Upon receipt of a sample, the analyst removes the piece of septum and loads the sample into a 1 ml sample loop. The loop is allowed to equilibrate and is then flushed onto the GC column at typical conditions.

Quantification is performed by External Standard-Peak Area and/or External Standard-Peak Height methods using the following equation:

$$R \times \frac{A\ Sx}{A\ Std} \times RF = \text{Concentration}$$

Where R = Instrument response for the peak(s) of interest (area units or peak height).

A Sx = Instrument attenuation for sample run.
A std = Instrument attenuation for standard run.
RF = Response factor in ppm/R or ppb/R

Note that for air samples the terms ppm and mg/m^3 are not equivalent. A compound specific conversion factor must be applied to translate ppm (a volume to volume measurement) to mg/m^3 (a weight to volume measurement). The following formula can be used to make the conversion between the two sets of units:

$$\text{ppm} = \frac{\text{mg/m3} \times 24.45}{\text{molecular weight of compound}} \quad \text{at } 25^{o}\text{C}$$

4.0 DOCUMENTATION AND QUALITY CONTROL

All samples are handled using proper chain of custody procedures. Once received by the analyst, each sample is recorded in the field laboratory log and assigned a unique identification number. This number is then used as the identifier on all analysis sheets, chromatograms, and report sheets. Operating conditions, attenuations, injection volumes, observations and comments are recorded on sample run sheets. (See Figure 3-6.)

The proper operation of the system is documented through the use of an initial calibration and continuing calibration standards. Prior to the analysis of any samples, a standard is run. A check standard is then reanalyzed after each ten (10) samples and following the final sample.

Air blanks are analyzed at the beginning and end of a sample batch as well as immediately following a sample which shows a positive response on either detector.

Replicate injections are made on ten (10) percent of all samples submitted for analysis.

5.0 INSTRUMENT SENSITIVITY

The sensitivity of the field screening procedure is a function of the physical and chemical properties of the compound being analyzed. For the chlorinated alkenes which are the target compounds for this investigation (i.e., dichloroethylene, trichloroethylene and tetrachloroethylene) the expected range of sensitivities for each sample media is listed below.

Media	Sensitivity
Water	1 - 5 ug/l
Soil	10 - 50 ug/kg
Air/Soil gas	10 - 50 ppb

Stamina Mills Remedial Investigation
Pump Test
Field GC Precalibration Evaluation

Comparison of EPA Method 601 and Static Headspace Analysis Using HNU Model 321 Equipped with an ELCD and PID

		Low-Level Standard Results in ug/l (ppb)[2]		
	TRUE[1] VALUE	EPA 601	321/ELCD	321/PID
Trans 1,2 Dichloroethene	4.8	4.2	3.4	3.6
Trichloroethene	5.8	5.8	6.7	5.5
Tetrachloroethene	6.0	5.8	6.6	6.2

		Mid-Level Standard Results in ug/l (ppb)[2]		
	TRUE[1] VALUE	EPA 601	321/ELCD	321/PID
Trans 1,2 Dichloroethene	31.6	36.2	27	26
Trichloroethene	45.2	48.3	39	42
Tetrachloroethene	47.2	46.9	42	42

1. True Value of Standards - Prepared by dilution of a laboratory stock solution prepared on June 6, 1988.

2. Calibration Evaluation conducted on June 8, 1988.

Stamina Mills Remedial Investigation
Pump Test
Field GC Precalibration Evaluation

Reproducibility of a Low Level Standard by Static Headspace Method Using HNU Model 321 Equipped with an ELCD

	TRUE[1] VALUE	Results in ug/l (ppb)[2] 1	2	3	4	MEAN
Trans 1,2 Dichloroethene	3.2	2.3	2.5	2.6	2.3	2.4
Trichloroethene	4.6	5.2	5.7	5.6	6.0	5.6
Tetrachloroethene	4.8	5.1	5.2	5.3	5.5	5.3

Reproducibility of a Low Level Standard by Static Headspace Method Using HNU Model 321 Equipped with a PID

	TRUE[1] VALUE	Results in ug/l (ppb)[2] 1	2	3	4	MEAN
Trans 1,2 Dichloroethene	3.2	2.3	2.4	2.4	2.6	2.4
Trichloroethene	4.6	4.0	4.0	4.0	4.5	4.1
Tetrachloroethene	4.8	3.7	5.0	5.0	3.7	4.4

---

1. True Value of Standards - Prepared by dilution of a laboratory stock solution prepared on June 6, 1988.

2. Calibration Evaluation conducted on June 8, 1988.

APPENDIX D

MONITORING WELL LOGS FROM SELECTED ON-SITE BEDROCK WELLS

BORING / MONITORING WELL LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, N. Smithfield RI
CLIENT ARMY CORPS OF ENGINEERS
GHR FIELD GEOLOGIST MIKE SHERRILL (GZA)
BORING CONTRACTOR GUILD DRILLING
FOREMAN A. WHITAKER

BORING No. MW- 2
LOCATION Refer to Site Plan
SHEET No. 1 OF 6
JOB No. 3108019
DATE (S) 6-9-86 to 6-10-86

GROUND ELEV. = 202.09'
TOP OF CASING ELEV. = 204.4'

CASING		SAMPLER	
SIZE:	HW to 9.0'; NW to 14.5 ft	TYPE:	2' x 1 3/8" ID Split Spoon
HAMMER:	300#	HAMMER:	140#
FALL:	24-inch	FALL:	30-inch

GROUNDWATER LEVEL READINGS

DATE	DEPTH
7-1-86	14.25' PVC
6-16-86	12.2' Ground
6-18-86	14.1' PVC
9-15-86	14.61' PVC

DEPTH	CAS. BL. /FT.	SM-19S- SAMPLE No.	PEN./REC.	DEPTH	BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		014	12/8	0-1.0	11-102		Gravelly SAND: medium dense to very dense, consisting of 60 to 70% fine sands, 25 to 35% coarse and fine gravels, less than 5% non-plastic fines; dry, brown and light grey; granular and rock rubble FILL (SP)	HNu Units SOILS: 20 ppm	Steel Guard Casing	1.
1						GRANULAR AND ROCK RUBBLE FILL				
	46									
2										
	27									
3		015	18/7	3-4.5	14-9-6		Gravelly SAND: medium dense, consisting of 80% medium to fine sands, 10 to 15% fine gravels, less than 5% non-plastic fines; brown, dry to moist; granular FILL (SP)	11 ppm		
4	18									
	11	016	24/9	4.5-6.5	4-7-			42 ppm		
5					4-3	5.0±			Bento-nite and Cement Grout 0 ft. to 13.9 ft.	
	10					Silty SAND FILL or RACEWAY WASHOUT				
6							Silty SAND: medium dense, becoming loose, consisting of 70% fine sands, 20% non-plastic fines, 10% fine gravels, moist, brown granular FILL, possibly washout from raceway (SP-SM)			
	8	017	24/5	6.8-8.8	3-3-7-5			100 ppm		
7										
	4									
8										
	15						Silty SAND, gravelly: loose, consisting of 60% fine sand, 25 to 30% non-plastic fines, less than 10% fine gravel, brown, moist: raceway FILL or Washout (SP-SM)			
9						9.0				
		018	24/14	9-11	9-30-	Silty SAND TILL		45 ppm	Solid PVC Riser Pipe	2.
					63-98					
10						9.7'				
					Core Time Min/Ft	SAPROLITE DECOMPOSED QUARTZ-MICA SCHIST	Silty SAND, gravelly: dense, 70% fine sands, 20% non-plastic fines, 10% platy gravels; changing to very dense SAPROLITE: soft guartz-mica schist friable to fine sand to finer particles.			
11		C-1	3.4'/0.7'	11-14.4				Breathing Zone: 0.2 to 0.4 ppm Throughout		
			0% RQD		1.8					4.
12										
					1.2					
13										
					1.2	13.7'±			13.9'	
14		C-2	2.6/2.5	14.4-17		BEDROCK	Refer to Rock Core Log, pages 3 to 6, for Bedrock lithology, discontinuities, etc.	BEDROCK PERMEABILITY TESTING	Bento-nite Seal	3.
			23% RQD		13.0					
15									15.8'	
					4				Ottawa SAND Filter	6.
16										
					4					
17		C-3	3.0/2.8	17-20				18.4' to 23.2' COULD NOT SEAL PACKERS FLOW BY.	17.4'	
			45% RQD		5				1.5-in. ID PVC Well Screen	
18										
					4					
19										
20					4					

NOTES:
1. An HNu Model PI-101 photoionization detector was used to monitor levels of volatile organic compounds in headspace over soil samples and in breathing zone.
2. Drive and wash drilling of HW casing to 9.0 ft, Rotary drilled roller bit and NW casing to 11.0 ft.
3. Drilled NW casing to 14.5 feet after recovery of core run No. C-1.
4. Cored bedrock from 11.0 ft to 37.0 ft. using NV-2 size double-wall core barrel with diamond impregnated bit. Used approximately 700 gallons, non-recirculating, with high volume of wash water return throughout.
5. Evacuated 13 gallons ± at 0.8 to 0.9 GPM.

BORING / MONITORING WELL LOG

BORING No. MW-2

SHEET No. 2 OF 6

JOB No. 3108019

DEPTH	CAS. BL. /FT.	SAMPLE SM-19S- No.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		C-4	5.0/5.0	20-25	Min/Ft	BEDROCK	Refer to Rock Core Log, pages 3 to 6, for Bedrock lithology, discontinuities, etc.	BEDROCK PERMEA-BILITY TESTING:		5.
21			24% RQD		3.3					
22					3.0			19.9' to 24.7' K < 0.5 Ft/ Day		
23					3.0					
24					2.0					
25					2.0					
		C-5	5.0/5.0	25-30.0				24.7' to 29.5' K < 0.05 Ft/ Day No Flow		
26			72% RQD		3.8					
27					1.6				1.5-in. ID PVC Well Screen in Ottawa SAND Filter	
28					1.6					
29					1.6			29.5' to 34.3' K < 0.05 Ft/ Day No Flow		
30					2.0					
		C-6	5.0/4.8	30-35						
31			70% RQD		2.0					
32					3.7					
33					2.5					
34					1.8					
35					2.0					
		C-7	2.0/2.0	35-37						
36			100% RQD		2.0					
37					2.2					7.
							End of Exploration 37.0 Ft.			

NOTES:

6. Bedrock zone from 19.9 ft. to 34.3 ft. was pressure tested using double level inflatable Packer assembly across three test intervals. Unable to seal Packers across test interval from 18.4 ft. to 23.2 ft.
7. Observation well installed consisting of 1.5-inch ID PVC pipe, screened from 17.4' to 37 ft, with Ottawa Sand to 15.8 ft; Bentonite pellet seal 13.9' to 15.8', and bentonite and cement grout from surface to 13.9 ft. Installation completed with placement of 5 ft. length of 3-inch ID steel guard casing with screw-on cap and lock to 3 ft, concreted at ground surface.
8. Drilling and sampling tools steam-cleaned after installation.

BORING / MONITORING WELL LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, N. Smithfield RI
CLIENT ARMY CORPS OF ENGINEERS
GHR FIELD GEOLOGIST MIKE SHERRILL (GZA)
BORING CONTRACTOR GUILD DRILLING
FOREMAN A. WHITAKER

BORING No. MW- 2A
LOCATION 3' north of MW-2
SHEET No. 1 OF 1
JOB No. 3108019
DATE (S) 6-16-86

GROUND ELEV. = 202.21'
TOP OF CASING ELEV. = 204.47'

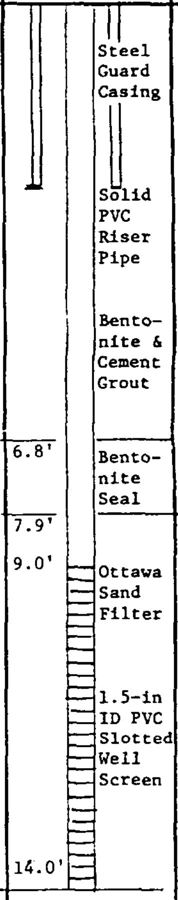
CASING
SIZE: Rotary drilled NW
HAMMER: Casing to 14.0 ft
FALL:

SAMPLER
TYPE:
HAMMER:
FALL:

GROUNDWATER LEVEL READINGS

DATE	DEPTH
7-1-86	14.06' PVC
6-18-86	13.3' PVC
6-20-86	13.5' PVC
9-15-86	14.48' PVC

DEPTH	CAS. BL. /FT.	SAMPLE No.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
1							No sampling attempted Refer to log MW-2 for description of stratography	HNu: Breathing Zone: ND-0.1 ppm		1.
2										
3										
4										
5								1 ppm		
6										
7										
8								2-3 ppm		
9										
10										
12										
13						14.0'				
14							End of exploration 14.0'			
15										
16										
17										
18										
19										
20										



NOTES:
1. An HNu Model PI-101 photoionization detector was used to monitor volatile organic compound levels in the breathing zone.
2. NW casing was rotary drilled to a depth of 14.0 ft with high volume of wash water return throughout.
3. Observation well installed consisting of 1.5-inch ID PVC, screened from 9.0' to 14.0', Ottawa Sand to 7.9 ft, bentonite seal from 6.8' to 7.9', bentonite and cement grout from 6.8' to surface. A 5' x 3" steel guard casing with screw-on cap and lock was placed to 2.8 ft, and a concrete seal set at ground surface.

BORING / MONITORING WELL LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, N. Smithfield RI
CLIENT ARMY CORPS OF ENGINEERS
GHR FIELD GEOLOGIST MIKE SHERRILL (GZA)
BORING CONTRACTOR GUILD DRILLING
FOREMAN A. WHITAKER

BORING No. MW- 3
LOCATION NE of Leach Field
SHEET No. 1 OF 6
JOB No. 3108019
DATE (S) 6-16-86 to 6-17-86

GROUND ELEV. = 210.56'
TOP OF CASING ELEV. = 212.35'

CASING
SIZE: HW to NW
HAMMER: 300#
FALL: 24±

SAMPLER
TYPE: 2' x 1 3/8" ID Split Spoon
HAMMER: 140#
FALL: 30-in

GROUNDWATER LEVEL READINGS
DATE 6-17-86 DEPTH 10.5' Ground

DEPTH	CAS. BL. /FT.	SAMPLE SM-19S- No.	PEN./REC.	DEPTH	BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		032	24/14	0-2	17-28-18-		Gravelly SAND; dense, approximately 40 to 50% fine sands, 30 to 40% coarse and fine angular gravel, less than 10% non-plastic fines, brown and grey, dry; FILL. (SP-SM)	HNu Units		1.
1	15				14	GRANULAR AND BLAST ROCK		15.8 ppm	Well Integrity lost. Installation Abandoned.	
2	26									
		033	24/19	2-4	26-30-12-					
3	40				31		Gravelly SAND; dense, 60% to 65% fine sands, 25% to 30% fine rounded to angular gravel, 10-15% non-plastic fines; brown, dry (SP-SM)	17.5 ppm		
						—3.5'—				
4	37									
		034	30/17	4-6.5	15-16-11-	REWORKED TILL: Silty to GRAVELLY SANDS				
5	31				9-9		Silty SAND, gravelly; medium dense; approximately 40% fine sand, 30-35% non-plastic fines, 25-30% coarse and fine angular schistose gravels; grey to light brown, dry. (SM)	2.7 ppm		
6	25									
7	27	035	24/13	6.5-8.5	9-10-9-		Gravelly SAND; medium dense to very dense, approximately 50% fine sand, 35-40% fine schistose gravel, 10-15% non-plastic fines, moist, grey to brown; decomposed rock/residual Till. (SM)	5.2 ppm		
					85					
8	71					—8.0'—				
						SAPROLITE Decomposed BEDROCK				
9	282							16 ppm Breathing Zone 0.2 ppm Throughout		
		036	23/14	9-10.9	20-23-		Silty SAND; dense, approximately 60% very fine sands, 25% platy friable gravel, 20% non-plastic fines, moist, weathered, decomposed rock (SM)			
10					27-114					2.
11		C-1	4.3'/3.85'	10.9-15.2	Core Time Min/Ft	—10.8'—				
			58% RQD				Refer to Rock Core Log, page 3 to 6, for description of bedrock lithology, fracture and structural discontinuities, etc.	BEDROCK PERMEABILITY:		3.
12					2	FIRM BEDROCK				4,
13					2					
14					1.3					
15					2.3					
		C-2	5.0/5.0	15.2-20.2				15.1'- 19.9' K = 5.1 Ft/ Day		5.
16			20% ROD		1.7					
17					1.5					
								17.1'- 21.9' K = 7.12 Ft/ Day		
18					1.5					
19					2.25					
20					2.2					

NOTES:

1. An HNu model PI-101 photoionization detector was used to monitor volatile organic levels in breathing zone and headspace air over soil samples.
2. Drive and wash HW casing to 9.0 ft, rotary drilled NW casing to 10.9 ft.
3. Cored from 10.9 ft. to 35.7 ft, with no return of wash water. Used approximately 1400 gallons during coring.
4. Pumped completed borehole at a yield of 7 GPM ± for 15 minutes.

GHR

BORING / MONITORING WELL LOG

BORING No. MW-3

SHEET No. 2 OF 6

JOB No. 3108019

DEPTH	CAS. BL. /FT.	SM-19S- SAMPLE				GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		No.	PEN./REC.	DEPTH	BLOWS/6"					
20		C-3	4.6-4.7	20.2-24.8	Core Time Min/Ft		Refer to Rock Core Log, pages 3 to 6, for description of bedrock lithology, fracture and structure discontinuities.	BEDROCK PERMEA- BILITY: 21.2' to 26 ft. K = 0.07 Ft/ Day		5.
			85% RQD							
21					1.6					
22					1.9					
23					2.3					
24					3.2					
25		C-4	3.3-3.3	24.8-28.1	2.0/0.6'					
			85% RQD							
26					3.7			26.1' to 30.9' K = 0.1 Ft/ Day		
27					3.3					
28					4.3					
		C-5	4.1-4.1	28.1-32.2						
29			75% RQD		3.5					
30					4.0					
31					3.3					
32		C-6	0.1/Frag's	32.2-32.3	JAMB					
33		C-7	3.4/3.4	32.3-35.7						
			40% RQD		4.2					
34					5.2					
35					4.5					
36					5.7		End of Exploration 35.7 Ft.			
37										
38										
39										
40										
41										
42										
43										
44										

NOTES:

5. Rock zone was pressure tested from 15.1 ft to 30.9 ft using double-level inflatable Packer assembly across four test intervals.
6. Observation well originally screened from 30.8 to 35.8 ft across sand filled vertical fracture zone was displaced after introduction of 70 + gallons of grout. Well integrity lost and installation abandoned.
7. Drilling and sampling tools were steam-cleaned at completion of installation.

BORING / MONITORING WELL LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, N. Smithfield RI
CLIENT ARMY CORPS OF ENGINEERS
GHR FIELD GEOLOGIST MIKE SHERRILL (GZA)
BORING CONTRACTOR GUILD DRILLING
FOREMAN A. WHITAKER

BORING No. MW- 3A
LOCATION 15' East of MW-3
SHEET No. 1 OF 6
JOB No. 3108019
DATE (S) 6-26-86 to 6-30-86

GROUND ELEV. = 210.56'
TOP OF CASING ELEV. = 212.35'

CASING
SIZE: HW to 9.0 Ft; NW Spun to 10.8 Ft.
HAMMER: 300#
FALL: 24-inch

SAMPLER
TYPE:
HAMMER:
FALL:

GROUNDWATER LEVEL READINGS

DATE	DEPTH
7-1-86	11.55' PVC
8-11-86	11.72' PVC
9-15-86	10.79' PVC

DEPTH	CAS. BL. /FT.	SM-19S- SAMPLE No.	PEN./REC.	DEPTH	BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
1							No soil samples attempted. Refer to log of borehole MW-3.	HNu: Breathing Zone: N.D. to 0.2 ppm Throughout	Steel Guard Casing 1.5'	1.
2										
3										
4									Bento-nite and Cement Grout	
5										
6									1.5-in ID PVC Solid Riser Pipe	
7										
8										
9										
		C-1	4.4/3.7	9.6-14.0	Core Time Min/Ft	-9.6'-			10.0	2.
10			57% RQD		4.8	BEDROCK	Refer to Rock Core Log for detailed description of bedrock lithology, discontinuities and coring/pressure testing details.	BEDROCK PERMEA-BILITY TESTING:	Bento-nite Seal	
11					3.1					
12					4.1			13.5' to 34.2'	11.9'	3.
13					2.0			13.5' to 18.7' K = 5.4 F/D		
14		C-2	1.0/0.9	14-15					13.9'	4.
			90% RQD		1.8					
15		C-3	5.0/3.5	15-20						
			54% RQD		2.0			15.9' to 20.7' K = 5.9 F/D		
16										
					1.3				1.5-in. ID PVC Well Screen in Ottawa SAND Filter	
17										
					1.7					
18										
					1.5					
19										
20					1.5					

NOTES:
1. Exploration MW-3A replaces lost well installation MW-3. No overburden sampling performed.
2. Rotary drilled to 9.0 ft, followed by HW casing driven to 9.0 and NW casing drilled to 9.6 ft. NW casing drilled to 10.8 ft after recovery of core run C-1.
3. Cored from 9.6 ft to 38.4 ft with continuous loss of drilling water. Used approximately 1.0 tank volume (2300 gallons) to complete hole, estimated 25 Gal/Min during coring.
4. See next page.

GHR

BORING / MONITORING WELL LOG

BORING No. MW-3A
SHEET No. 2 OF 6
JOB No. 3108019

DEPTH	CAS. BL. /FT.	SAMPLE SM-19S-				GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		No.	PEN./REC.	DEPTH	BLOWS/6"					
		C-4	4.9/5.1	20-24.9		BEDROCK	Refer to Rock Core Logs, pages 3 to 6, for description of bedrock lithology, discontinuities, etc.	20.4 ' to 25.2': K= 6.4 F/D		
21			52% RQD		2.0					
22					1.5					
23					2.2					
24					2.0					
25		C-5	4.2/4.2	24.9-29.1	5.2			24.9' to 29.7': No Flow K= 0.03 F/D	1.5-in. ID PVC Well Screen in Ottawa SAND Filter	
			22% RQD							
26					2.2					
27					4.5					
28					4.2					
29					7.0					
		C-6	5.0/5.0	29.1-34.1				29.4' to 34.2': K= 4.7 F/D		
30			42% RQD		1.6					
31					2.8					
32					3.2					
33					2.2					
34					2.2					
		C-7	4.3/4.2	34.1-38.4						
35			9% RQD		4.2					
36					3.2					
37					2.5				36.9'	
38					2.5					
					1.5/0.3'					
39							End of Exploration 38.4 Ft.			
40										

NOTES:
4. Rock zone was pressure tested from 13.5 ft to 34.2 ft using double-level inflatable Packer assembly across five test intervals.
5. Observation well installed consisting of 1.5-inch ID PVC pipe, screened from 13.9 ft to 36.9', Ottawa Sand filter to 11.9 ft, Bentonite seal from 10.0 ft. Installation completed with placement of 5 ft length of 3-inch ID steel guard casing with screw-on cap and lock to 3 ft, concreted in place.
6. Drilling and sampling tools were steam-cleaned subsequent to installation.

BORING / MONITORING WELL LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, N. Smithfield RI
CLIENT ARMY CORPS OF ENGINEERS
GHR FIELD GEOLOGIST MIKE SHERRILL (GZA)
BORING CONTRACTOR GUILD DRILLING
FOREMAN A. WHITAKER

BORING No. MW-5
LOCATION West Perimeter, 10 Ft east of Stake
SHEET No. 1 OF 6
JOB No. 3108019
DATE (S) 6-3-86 to 6-5-86

GROUND ELEV. = 214.29'
TOP OF CASING ELEV. = 216.20'

CASING		SAMPLER	
SIZE:	HW to 9 ft, NW to 14 Ft	TYPE:	Split Spoon 2' x 1 3/8 in
HAMMER:	300#	HAMMER:	140#
FALL:	20 in ±	FALL:	30 inch

GROUNDWATER LEVEL READINGS

DATE	DEPTH
6-5-86	14.3' Ground
6-18-86	15.0' PVC
7-1-86	15.49' PVC
9-15-86	15.59' PVC

DEPTH	CAS. BL. /FT.	SAMPLE SM-19S- No.	PEN./REC.	DEPTH	BLOWS/6"	GEN. STRATA DESC.	NOTES
		001	24/13	0-2	15-18-20-		1.
1	8				12	MIXED GRANULAR FILL and TOPSOIL	
2	26						
		002	24/11	2-4	13-9-12-19		
3	32						
4	71					—4.0'—	
		003	24/15	4-6	29-49-	GRAVELLY SANDS : OUTWASH/ ALLUVIUM	
5	39				74-124		
6	67						
	230/	3 inches				—6.3'—	
7						BOULDER —7.0'—	
		004	24/12	7.2-9.2	41-39-41-		
8	N.O.				91	SILTY SAND : TILL	2.
9	N.O.						
		005	16/11	9.2-10.5	33-43-		
					118	—9.8'—	
10							
11						SAPROLITE	
						SEVERELY	
		006	9/8	11.5-12.3	54-89/3	WEATHERED	
12					in.	QUARTZ- MICA	
						SCHIST	
13							
					Core Time		
					Min/Ft		3.
14						—14.0'—	
		C-1	24/15	14-16		BEDROCK	
			0% RQD		1.5		
15							
					3.0		4.
16		C-2	54/52	16-20.5			5.
			31% RQD		2.0		
17							
					2.5		
18							
					2.0		
19							6.
20					2.0		

SAMPLE DESCRIPTION

Gravelly SAND; consisting of 60 to 65% fine sand, 25 to 30% fine to coarse, angular gravel, less than 10% non-plastic fines, less than 1% roots; dark brown, moist, gap-graded, sandy FILL, mixed with Topsoil (SP-SM).

Silty SAND, gravelly: consisting of 60%± fine sands, 20 to 25% non-plastic fines, 15% fine schistose gravel, less than 5% wood fragments; brown, dry to moist gap-graded sandy FILL. (SM).

Gravelly SAND; very dense, consisting of 50 to 60% medium to fine sands, 30 to 35% medium to fine, hard gravels, less than 10% non-plastic fines; brown, moist, gap-graded; kame or river terrace deposits (SP-SM).

Silty SAND, gravelly: very dense, 50 to 60% fine + to medium sands, 20 to 30% non-plastic fines, 10 to 20% medium to fine, angular to subrounded gravels; grey and brown, moist; TILL (SM).

Silty SAND: very dense, consisting of 50 to 60% fine sand, 20 to 30% non-plastic fines, 10 to 15% hard, fine gravel, 10% decomposed schistose rock fragments; brown (sands) to light grey, dry to moist; TILL to SAPROLITE (SM).

SAPROLITE: very dense, relict micaceous schist, friable to fine sand and finer particles, light grey, moist; decomposed/ weathered rock.

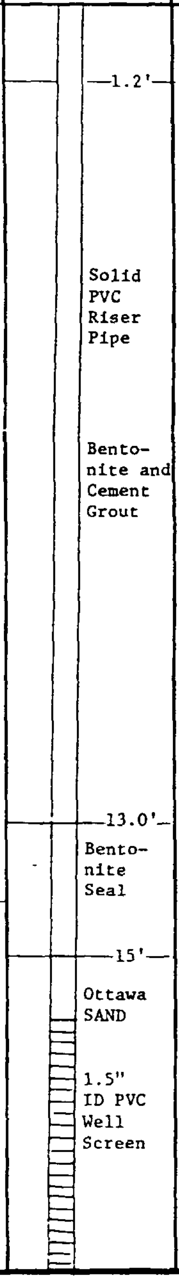
Refer to Rock Core Logs, pages 3 to 6 for bedrock lithology, discontinuities, etc.

FIELD TESTING

HNu ppm
SOILS
N.D.
0.3
3.4
3.5
2.0
0.4
Breathing Zone: 0.2 to 0.4 ppm Throughout

BEDROCK PRESSURE TESTING
19.9 ft to 33.5 ft.

INSTALLATION LOG



NOTES:
1. An HNu Model PI-101 photoionization detector was used to screen soil samples for volatile organic compounds.
2. Drive and wash drilling of HW casing to 9 ft, then rotary drilling of roller bit and NW casing with Econo shoe to 14 ft. Approximately 500 gallons of non-recirculated water used, with high wash water return volume.
3. Cored bedrock from 14.0 to 40.0 feet: using NV-2 size, double core barrel with diamond impregnated bit.
4. No wash water return during rock coring from 16 to 40 ft. Used approximately 1300 gallons.

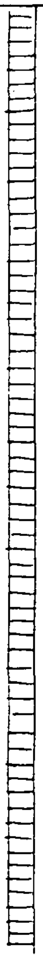
GHR

BORING / MONITORING WELL LOG

BORING No. MW-5

SHEET No. 2 OF 6

JOB No. 3108019

DEPTH	CAS. BL. /FT.	SAMPLE				GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		SM-19S- No.	PEN./REC.	DEPTH	BLOWS/6"					
20					Min/Ft	BEDROCK	Refer to Rock Core Log, page 3 to 6, for Bedrock lithology, discontinuities, etc.	PRESSURE TESTING: 19.9'-24.7' Could not hold pressure K 17.5 ft/day	 1.5 in ID PVC Well Screen in Ottawa Sand Filter Pack	6.
		C-3	60/59	20.5-25.5						
			25% RQD		2.0					
					2.5					
					2.0					
					1.3			23.9'-28.7' K= 7.6 ft/day		
25										
					2.4					
		C-4	58/58	25.5-30.3	1.5					
			52% RQD							
					2.5					
					2.0					
					2.7			28.7'-33.5' K=1.25 ft/day		
30					2.0					
		C-5	56/56	30.3-35.0						
			21% RQD		3.0					
					3.7					
					3.3					
					3.0					7.
35					3.0				35.1	
		C-6	60/56	35.0-40.0						
			50% RQD		3.5					
					3.0					
					3.0					
					4.7					8.
40					4.3					
							End of Exploration 40 Ft.			

NOTES:

5. Pumped approximately 5 gallons before lift capacity of pump exceeded.
6. Attempted Packer test. Packer obstructed at 15.5 ft. Drilled NW casing from 14 to 17.0 ft. Borehole was clear to 36 ft depth. Rock zone (19.9 ft to 33.5 ft) pressure tested across three intervals.
6. Observation well installed consisting of 1.5-in ID PVC: screened from 16.1 to 35.1 ft, Ottawa Sand filter to 15.0 ft, Bentonite pellet seal from 13 to 15 ft, Bentonite and cement grout to 1.2 ft. Installation completed with a 5 ft length of 3-inch ID steel guard pipe with screw-on cap and lock set to 3 ft depth, backfilled and concreted at ground surface.
8. Drilling and sampling tools were steam-cleaned subsequent to well completion.

BORING / MONITORING WELL LOG

PROJECT STAMINA MILLS SUPERFUND SITE
ADDRESS Forestdale, N. Smithfield RI
CLIENT ARMY CORPS OF ENGINEERS
GHR FIELD GEOLOGIST MIKE SHERRILL (GZA)
BORING CONTRACTOR GUILD DRILLING
FOREMAN A. WHITAKER

BORING No. MW- 9
LOCATION North of Landfill East of Blacksmitn Shop
SHEET No. 1 OF 5
JOB No. 3108019
DATE (S) 6-30-86 to 7-2-86

GROUND ELEV. = 215.47'
TOP OF CASING ELEV. = 217.87'

CASING		SAMPLER	
SIZE:	Drilled HW to 9.0 ft.	TYPE:	2' x 1 3/8" Split Spoon
HAMMER:	and NW to 11.2 ft.	HAMMER:	140#
FALL:		FALL:	30-inch

GROUNDWATER LEVEL READINGS

DATE	DEPTH
7-1-86	8.1' Ground
7-2-86	7.3' Ground
8-12-86	8.52' PVC
9-15-86	8.23' PVC

DEPTH	CAS. BL. /FT.	SM-19S- SAMPLE No.	PEN./REC.	DEPTH	BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
1		055	24/2'	0-2	3-5-3-7	TOPSOIL GRANULAR FILL	Silty SAND, loose, approximately 60 to 70% fine Sand, 25 to 30% non-plastic fines, 10% coarse gravel, less than 10% roots; Fill and Topsoil (SM).	HNu Soils 0.3 ppm	Steel Guard Casing	1.
2 3		056	24/7'	2-4	82-31- 22-17	2' BOULDER (WALL)	Silty SAND, dense, approximately 60 to 70% fine sands, 30% non-plastic fines (Silt); moist, light brown natural outwash sediments (SM).	0.2 ppm		
4 5 6		057	30/8'	4-6.5	17-15-10 9-5	3.5' OUTWASH AND ICE CONTACT DEPOSITS Silty to Gravelly SAND	Silty SAND, medium dense, consisting of 55 to 60% uniform fine sand, 35 to 40% non-plastic fines (Silt), less than 5% fine rounded Gravel, wet, grey. (SM).	0.4 ppm	Bento-nite and Cement Grout	
7 8		058	30/15'	6.5-9.0	3-14-44- 54-69	7.5'-8.0' SANDY TILL	Gravelly SAND, silty, stratified with SAND, very dense consisting of 45 to 50% uniform brown fine Sand, 35 to 40% coarse and fine hard angular Gravels, 5 to 10% non-plastic fines, grey, moist. (SP-SM) to (SP)	0.9 ppm	1.5-in ID Solid PVC Riser Pipe	2.
9		059	3.5/0'	9-9.3	120/3.5"		No recovery - very dense: Wash recovery of angular coarse to fine Sands.	Breathing Zone: 0.2 ppm Throughout		
10		060	10/8'	10- 10.8	23-47/4" 50/0		SAND, dense, consisting of 90% uniform fine Sand, 5 to 10% non-plastic fines, 5% coarse Gravel (1 piece); moist to wet; outwash, (SP-SM): change at 11 ft. to very dense soil, not represented in recovery.			
11 12 13 14		C-1	4.0'/3.9' RQD=100%	11.3-15.3	Core Time Min/Ft 3.3 4.1 4.2	10.8' BEDROCK	Refer to Rock Core Log pages 3 to 5, for description of bedrock lithology, structure and fracture discontinuities.	BEDROCK PERMEA-BILITY 14' to 32.3': 14' to 18.8': No Flow K = 0.03 F/D	11.4' 12.9'	3.
15 16 17 18 19 20		C-2	4.8/5.0 RQD=100%	15.3-20.1	4.1 4.3 4.8 4.8 4.4				Ottawa Sand Filter 1.5-in ID PVC Well Screen	

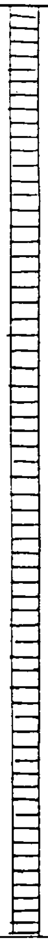
NOTES:
1. An HNu Model PI-101 photoionization detector was used to monitor volatile organic levels in the breathing zone and headspace air over soil samples.
2. Rotary drilled HW and NW casing to 11.3 ft through dense Till from 8.0 ft + to firm bedrock at 10.8 ft.
3. Cored bedrock from 11.3 ft to 35.1 ft with double tube core barrel, diamond impregnated bit, with high volume of wash water return throughout.

GHR

BORING / MONITORING WELL LOG

BORING No. MW-9
SHEET No. 2 OF 5
JOB No. 3108019

DEPTH	CAS. BL. /FT.	SAMPLE SM-19S- No.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
20		C-3	5.0/5.0	20.1-25.1	4.8 min/ft	BEDROCK	Refer to Rock Core Log, pages 3 to 5, for description of bedrock lithology, structure, and fracture discontinuities			
21			96% RQD					18.5' to 23.3': No Flow K = 0.03 F/D		
					4.1					
22										
					4.5					
23										
					4.3			23' to 27.8': No Flow K = 0.03 F/D		
24										
					5.8				Ottawa Sand Filter	
25										
		C-4	5.0/4.8	25.1-30.1	5.2					
26			26% RQD							
					3.1					
27								27.5' to 32.3 ft. No Flow K = 0.03 F/D		
					2.8					
28										
					3.7					
29										
					3.8					
30									1.5-in. ID PVC Well Screen	
		C-5	5.0/5.0	30.1-35.1	3.5					
31			70% RQD							
					4.8					
32										
					3.3					
33										
34										
									34.9'	
35										
							End of Exploration at 35.1 ft.			
36										
37										
38										
39										
40										
41										
42										
43										
44										



NOTES:
4. Borehole was pumped at 1 to 2 GPM yield before lift capacity of pump was exceeded. Slow recharge in rock zone (casing set into rock).
5. Rock zone was pressure tested from 14.0 to 32.3 ft. depths across four test intervals.
6. Observation well installed consisting of 1.5-inch ID PVC pipe, screened from 12.9 ft to 34.9 ft, Ottawa sand to 11.4 ft, bentonite and cement grout from 11.4 ft to ground surface. Well was completed with placement of a 5 ft x 3 inch steel guard casing with screw-on cap and lock to 3 ft, and placement of a concrete surface seal.

BORING / MONITORING WELL LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE - PHASE II
ADDRESS FORESTDALE, N. SMITHFIELD, RI
CLIENT ARMY CORP OF ENGINEERS
GHR FIELD GEOLOGIST GERARD MARTIN
BORING CONTRACTOR GUILD DRILLING COMPANY
FOREMAN AL WHITAKER

BORING No. MW - 13
LOCATION REFER TO SITE PLAN
SHEET No. 1 OF 2
JOB No. 3108018.A
DATE (S) 5/31/88 to 6/1/88

GROUND ELEV. = 207.6
TOP OF CASING ELEV. = 209.86

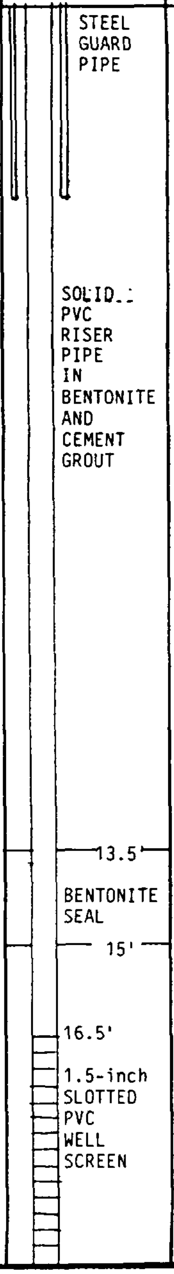
CASING
SIZE: HW (3")
HAMMER: 300 lbs.
FALL: 24 inches

SAMPLER
TYPE: Split Spoon, 2'X1 3/8" ID
HAMMER: 140 lbs.
FALL: 30 - inches

GROUNDWATER LEVEL READINGS
DATE 6/28/88 DEPTH 156.5

DEPTH	CAS. BL. /FT.	SAMPLE No.	PEN./REC.	DEPTH	BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING
		S-1	24"/3"	0 - 2	3/5/5/4	GRANULAR	SAND,gravelly: dense,consisting of 65% fine to very fine sand, 15% rounded to subrounded,fine to medium gravel,10% medium to coarse sand,10% non-plastic fines(silt), light brown,dry,non-stratified,FILL.	ND
1								
2		S-2	24"/12"	2 - 4'	10/4/4/4		SAND,gravelly: loose, consisting of 60% fine sand,15% subangular to subrounded medium gravel,15% medium to coarse sand, 10% non-plastic fines, light brown, dry, FILL.	ND
3								
4		S-3	24"/5"	4 - 6'	28/14/6/9		SAND: dense consisting of 65% fine sand, 15% coarse sand, 10% fine gravel, 10% non-plastic fines(silt), brown,moist,non-stratified,FILL.	0.2
5								
6		S-4	24"/14"	6 - 8'	6/7/5/7		GRAVELLY SAND: dense consisting of 50% coarse sand,20% angular to subrounded fine to medium gravel,15% fine to medium sand,15% non-plastic fines(silt),dark brown,moist to wet, stratified, FILL.	0.1
7								
8		S-5	24"/10"	8 - 10'	13/8/5/5		SILTY SAND: medium dense,consisting of 55% fine sand,25% non-plastic fines(silt),15% angular to subrounded fine to medium gravel,5% medium to coarse sand,dark brown,black and orange-brown,wet,semi-stratified, FILL.	ND
9								
10		S-6	24"/8"	10 - 12'	9/8/3/3			
11								
12		S-7	24"/9"	12 - 14'	3/4/3/3		GRAVELLY SAND: loose,consisting of 50% fine to coarse sand,30% angular to subangular fine to medium gravel, 20% non-plastic fines(silt),dark brown to light grey,wet, non-stratified, FILL.	0.2
13								
14		S-8	24"/5"	14 - 16'	8/11/13/12		GRAVELLY SAND: very loose,consisting of 50% very fine to fine sand,30% angular to subrounded fine to medium gravel,10% medium to coarse sand,10% non-plastic fines(silt),dark brown to red-brown,wet,non-stratified,FILL	0.1
15								
16		S-9	24"/16"	6 - 18'	9/7/10/14		SAND: dense, consisting of 60% fine sand, 20% medium to coarse sand, 20% angular fine to coarse gravel (weathered bedrock), brown, wet, non stratified, FILL.	0.4
17								
18		S-10	24"/18"	18 - 20'	30/63/44/35		SAND, gravelly: dense, consisting of 65% fine to coarse sand, 20% subangular to subrounded fine gravel, 15% non-plastic fines (silt), brown, wet, FILL.	0.8
19								
20								

INSTALLATION LOG



NOTES

NOTES:
1. Refer to Note 1, Monitoring Well Log MW-1.

BORING /MONITORING WELL LOG

BORING No. MW-13

SHEET No. 2 OF 2

JOB No. 3018 018.A

DEPTH	CAS. BL. /FT.	SAMPLE No.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
20		S-11	24"/11"	20'-22'	19/11/13/1	BOULDERS	SAPROLITE (weathered building stone)		1.5-inch SLOTTED PVC WELL SCREEN IN OTTAWA SAND BACKFILL	
21										
22		S-12	24"/11"	22'-24'	5/7/9/16	REWORKED SANDY TILL	SAND: loose to dense, consisting of 65% fine sand, 20% medium to coarse sand, 15% andular fine gravel (weathered bedrock), brown wet, FILL (3"), overlying Gravelly SAND: loose, consisting of 70% fine to coarse sand, 30% angular fine to medium gravel (weathered bedrock), brown, wet, FILL, (5") overlying GRAVEL, loose consisting of 80% subangular fine to medium gravel, 20% medium to coarse sand, blue-gray, wet, GRAVEL-PACK AND SAPROLITE.	0.8		
23										
24										
		S-13	3"/3"	24'-24.25'	75 for 3"					
		C-1	24"/19"	24.3-26.3	MIN/FT 3.0	BEDROCK	Soft, fine to medium-grained, light gray to blue-gray, Quartz-Bionite Schist, many low to subhorizontal fractures. RQD (C-1) = 0"/24" = 0%			
25										
					4.0					
26							Bottom of exploration at 26.5'			
27										

NOTES:

BORING / MONITORING WELL LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE-PHASE II
ADDRESS FORESTDALE, N. SMITHFIELD, R.I.
CLIENT ARMY CORPS OF ENGINEERS
GHR FIELD GEOLOGIST GERARD MARTIN
BORING CONTRACTOR GUILD DRILLING CO.
FOREMAN AL WHITAKER

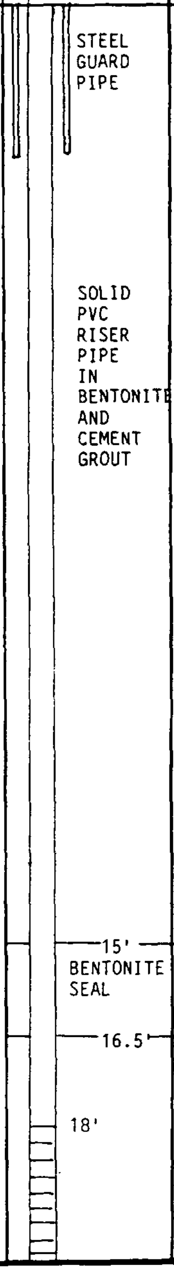
BORING No. MW-14
LOCATION REFER TO SITE PLAN
SHEET No. 1 OF 2
JOB No. 3108 018.A
DATE (S) 5/25/88 to 5/25/88

GROUND ELEV. = 212.5
TOP OF CASING ELEV. = 214.72

CASING
SIZE: HW (3")
HAMMER: 300 lbs
FALL: 24 inches

SAMPLER
TYPE: SPLIT SPOON, 2'x1 3/8" ID
HAMMER: 140 lbs
FALL: 30 inches

GROUNDWATER LEVEL READINGS
DATE 6/28/88 DEPTH 14.09

DEPTH	CAS. BL. /FT.	SAMPLE				GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		No.	PEN./REC.	DEPTH	BLOWS/6"					
1		S-1	24"/9"	0-2'	3/6/7/10	SANDY FILL	SAND loose, consisting of 65% very fine to fine sand, 20% medium to coarse sand, 15% subabgular fine to medium gravel, brown, dry, FILL.	ND		
2 3		S-2	24"/11"	2-4'	5/9/10/7		SAND medium dense, consisting of 55% very fine to fine sand, 25% coarse sand, 15% non-plastic fines (silt), 5% angular fine gravel, brown, dry, non-stratified, FILL.	ND		
4 5		S-3	24"/9"	4-6'	5/5/7/11		SAND: dense, consisting of 55% very fine to fine sand, 25% coarse sand, 10% angular fine gravel, 10% non-plastic fines (silt), brown, dry, non-stratified, FILL.	0.2		
6 7		S-4	24"/8"	6-8'	7/9/21/30		SAND: loose, consisting of 60% fine sand, 20% medium to coarse sand, 10% non-plastic fines, 10% angular coarse gravel (bedrock pieces), dark to light brown, dry, non-stratified, FILL.	0.2		
8 9		S-5	24"/7"	8-10'	12/5/8/5	GRANULAR FILL	Gravelly SAND: loose, consisting of 50% very fine ti fine sand, 25% angular medium to coarse gravel, 15% non-piastic fines, (silt), 10% coarse sand, light-gray to brown, wet, non-stratified, FILL.	0.4		
10 11		S-6	24"/4"	10-12'	7/2/1/-	SANDY SILTY FILL	Silty SAND: loose, consisting of 45% very fine to fine sand, 30% non-plastic fines (silt) 15% angular fine to medium gravel, 10% medium to coarse sand, light gray to brown, wet, non-stratified, FILL.	ND		
12 13		S-7	24"/11"	12-14'	1/-/-/-		SAND, silty: very loose, consisting of 55% fine sand, 25% non-plastic fines (silt), 10% subrounded to angular fine gravel, 10% medium to coarse sand, dark, brown, wet, non-stratified, FILL	0.2		
14 15		S-8	24"/9"	14-16'	1/2/3/1		Silty SAND: loose, consisting of 45% very fine to fine sand, 40% non-plastic fines (silt) 10% rounded to angular fine to medium gravel, 5% medium to coarse sand, dark brown, wet, slight sewage odor), stratified, FILL.	0.4		
16 17		S-9	24"/4"	16-18'	1/-/-/-		SAND, gravelly: loose, consisting of 55% fine to coarse sand, 25% sub-angular to rounded fine to medium gravel, 20% non-plastic fines (silt), brown, wet, non-stratified, FILL.	0.4		
18 19 20		S-10	24"/2"	18-20'	7/1/1/2		Silty, SAND: loose, consisting of 50% fine sand, 30% non-plastic fines (silt), 15% rounded coarse gravel, 5% medium to coarse sand, Gray, wet, non-stratified, FILL	0.2		

NOTES:

1. Refer to Note 1, Monitoring Well Log MW-1.

GHR

BORING/MONITORING WELL LOG

BORING No. MW-14
SHEET No. 2 OF 2
JOB No. 3108 018.A

DEPTH	CAS. BL. /FT.	SAMPLE No.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
20		S-11	24"/2"	20-22'	3/1/-/2	GRANULAR FILL	SAND, gravelly: loose, consisting o 65% medium to coarse sand, 20% subrounded fine to medium gravel, 15% non-plastic fines, (silt) gray, wet, non-straitified, FILL.	ND		
21										
22		S-12	24"/10"	22-24'	2/1/4/4		Silty SAND: loose, consisting of 50% fine to coarse sand, 30% non-plastic fines (silt) 20% rounded fine to coarse gravel, Gray to brown gray, wet, straitified, FILL.	0.4	1.5-inch SLOTTED PVC WELL SCREEN IN OTTAWA SAND BACKFILL	
23										
24		S-13	24"/2"	24-26'	6/7/5/3		SAND, gravelly: loose, consisting of 45% fine sand, 25% medium to coarse sand, 20% subangular fine to medium gravel, Gray-brown, wet, non-stratified, FILL	0.6		
25										
26		S-14	24"/19"	26-28'	15/20/48/50		SAND: loose, consisting of 75% fine to medium sand, 20% coarse sand, 5% angular fine gravel, brown, wet, FILL, (4") overlying Gravelly SAND: loose, 50% fine to medium sand, 40% angular fine to coarse sand, 10% non-plastic fines (silt), brown, wet, FILL (2") overlying FINE SAND: loose, 100% fine sand, light brown, wet, FILL (2") overlying weathered bedrock (11")	0.2		
27						REWORKED TILL				
					MIN/FT					
28		C-1	24"/23"	28-30'	3.0	BEDROCK	Soft, fine to medium-grained, Quartz-Bionite Schist with trace amount of altered garmet. Few low angle fractures with no staining. RQD (C-1) = 11"/24" = 46%		28'	
29					4.0				29' BENTONITE SEAL	
30							Bottom of the exploration at 30'.			

NOTES: 1. Refer to Note 1, Monitoring Well Log MW-1.

BORING / MONITORING WELL LOG

GHR

PROJECT STAMINA MILLS SUPERFUND SITE - PHASE II
ADDRESS FORESTDALE N. SMITHFIELD, RI
CLIENT ARMY CORPS OF ENGINEERS
GHR FIELD GEOLOGIST GERARD MARTIN
BORING CONTRACTOR GUILD DRILLING CO.
FOREMAN A. WHITAKER

BORING No. MW - 15
LOCATION Refer to Site Plan
SHEET No. 1 OF 4
JOB No. 3108018.A
DATE (S) 5/26/88 to 5/27/88

GROUND ELEV = 211.6
TOP OF CASING ELEV. = 213.96

CASING
SIZE: HW (3")
HAMMER: 300 lbs.
FALL: 24 inches

SAMPLER
TYPE: Split Spoon, 2'X1-3/8" ID
HAMMER: 140 lbs.
FALL: 30 inches

GROUNDWATER LEVEL READINGS
DATE 6/28/88 DEPTH 12.95

DEPTH	CAS. BL. /FT.	SAMPLE				GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		No.	PEN./REC.	DEPTH	BLOWS/6"					
		S-1	12"/10"	0-1'	12/40	GRANULAR FILL	Gravelly SAND : Dense, consisting of 50% fine sand, 30% fine to medium gravel, 10% coarse sand, 10% non-plastic fines(silt); brown, dry, non-stratified,FILL.	ND	Steel Guard Casing	1.
1										
2		S-2	24"/24"	2-4'	12/21/10/19		Gravelly SAND: Dense, consisting of 60% fine sand,25% rounded to sub-angular gravel, 10% medium to coarse sand, 50% non-plastic fines,(silt), brown dry, stratified, FILL.	ND		
3										
4		S-3	24"/16"	4-6'	22/25/38/36	SANDY SILTY TILL TO SAPROLITE	SAND, Silty: Medium dense,consisting of 80% fine to very fine sand, 15% non-plastic fines, (silt) 5% sub-rounded gravel, light brown to dark brown, dry FILL, overlying weathered bedrock.	2.0	BENTONITE AND CEMENT GROUT TO 14' FT.	
5										
6		S-4	6"/6"	6-6.5'	55 for 6"		Weathered Bedrock: Roller bitted to 9'.			
7										
8										
9							Refer to Rock Core Log MW-15 (pages 3 to 4) for Bedrock lithology and fracture description.			
10									SOLID PVC RISER PIPE	
11										
12										
13										
14									14.0'	
15									BENTONITE SEAL	
16									16.0'	
17										
18									18.0'	
19									WELL SCREEN	

NOTES:

1. Refer to Note 1, Monitoring Well Log MW-1.

GHR

BORING/MONITORING WELL LOG

BORING No. MW - 15

SHEET No. 2 OF 4

JOB No. 3108018.A

DEPTH	CAS. BL. /FT.	SAMPLE				GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		No.	PEN./REC.	DEPTH	BLOWS/6"					
21									 1.5-inch PVC WELL SCREEN IN OTTAWA SAND FILTER PACK 28'	
22										
23										
24										
25										
26										
27										
28										
29							Bottom of exploration at 29'.			

NOTES:

BORING / MONITORING WELL LOG

PROJECT Stamina Mills Superfund Site-Phase II
ADDRESS Forestdale, N. Smithfield, R.I.
CLIENT Army Corps of Engineers
GHR FIELD GEOLOGIST Gerard Martin
BORING CONTRACTOR Guild Drilling Co.
FOREMAN Al Whitaker

BORING No. MW- 16
LOCATION Refer to Site Plan
SHEET No. 1 OF 4
JOB No. 3108018.A
DATE (S) 6/1/88 to 6/2/88

GHR

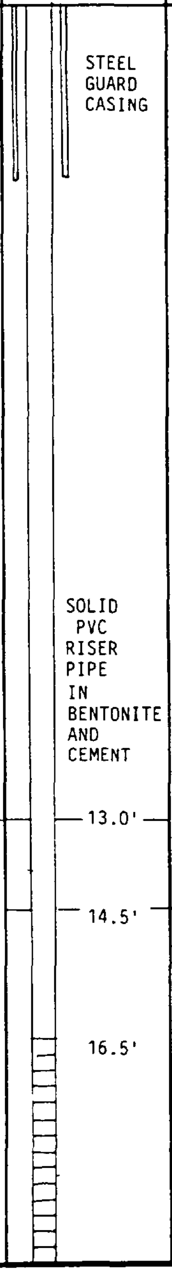
GROUND ELEV.
= 207.6
TOP OF CASING ELE
= 209.89

CASING
SIZE: HW (3")
HAMMER: 300 lbs.
FALL: 24 inches

SAMPLER
TYPE: Split Spoon, 2"x1 3/8" ID
HAMMER: 140 lbs.
FALL: 30 inches

GROUNDWATER LEVEL READINGS
DATE 6/28/88 DEPTH 11.12

DEPTH	CAS. BL. /FT.	SAMPLE No.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		S-1	24"/16"	0-2'	3/4/3/3	GRANULAR FILL AND BOULDERS	SAND, gravelly: Loose, consisting of 70% fine sand, 20% sub-angular to rounded gravel, 5% non-plastic fines (silt), brown, dry, non-stratified, FILL.	ND		1.
1										
2		S-2	24"/12"	4-6'	8/5/10/8		Gravelly SAND: loose to dense, consisting of 60% fine sand, 25% subangular to angular fine to coarse gravel, 10% non-plastic fines (silt), 5% medium to coarse sand, brown-gray, dry, non-stratified, FILL.	1.0		
3										
4										
5										
6							Boulders			
7										
8										
9		S-3	24"/7"	9-11'	11/6/6/6		SAND, gravelly: loose, consisting of 65% fine sand, 20% angular to subrounded fine to coarse gravel, 10% non-plastic fines, (silt), 5% medium to coarse sand, light brown to gray brown, wet, non-stratified FILL.	3.0		
10										
11										
12										
13							Refer to Rock Core Log MW-16 (page 3 of 4) for bedrock lithology and fractures description.			
14										
15										
16										
17										
18										
19										



NOTES:
1. Refer to Note 1, Monitoring Well Log MW-1.

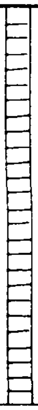
GHR

BORING/MONITORING WELL LOG

BORING No. MW-16

SHEET No. 2 OF 4

JOB No. 3108018.A

DEPTH	CAS. BL. /FT.	SAMPLE				GEN. STRATA DESC.	SAMPLE DESCRIPTION	FIELD TESTING	INSTALLATION LOG	NOTES
		No.	PEN./REC.	DEPTH	BLOWS/6"					
20										
21										
22									1.5-inch PVC WELL SCREEN IN OTTAWA SAND FILTER PACK	
23										
24										
25										
26									26.5'	
27							Bottom of Exploration at 26.5'			

NOTES:

BORING LOCATION STAMINA HILLS
FORESTDALE, RHODE ISLAND
DRILLED BY GUILD DRILLING COMPANY
LOGGED BY SRH REVIEWED CAL
CASING ID 3"
GROUND EL (MSL)
DATE START/FINISH 3/19/82 / 3/22/82
CORE SIZE NX
INCLINATION Vertical
DEPTH to WATER TABLE DATE
CORE TYPE
BEARING
TOTAL DEPTH 58 ft.

EL MSL ft	SAMPLE DEPTH ft	SAMPLE TYPE and No	SAMPLE N or REC	RATE OF ADV min/ft	WATER or ROD CONTENT %	PRESSURE TEST gpm / psi	STRIKE/DIP F-FOLIATION J-JOINT C-CONTACT B-BEDDING S-SLICKENSIDE	CORE BREAKS	- SOIL AND ROCK DESCRIPTIONS - (WEATHERING, DEFECTS, etc.)	(TYPE, TEXTURE, MINERALOGY, COLOR, HARDNESS, etc.)
									Top of Rock @ 8 ft.	
	8	Run 1		avg ±2				8 J	Zone of small fragments broken by joints and by drilling	Light gray, medium grained Schist. Occasional darker layers. Bedding foliation commonly dips 20°, but ranges from nearly horizontal to approximately 45°. Occasional pegmatite veins. Zones of minor deformation (folding, especially around pegmatite intrustions, and small scale faulting (<1/8"). Some small solution cavities present in some layers (<5%).
	9				35			9 J D D		
	10		60" Rec			10-15ft 9.2gpm / 5psi		10 D D J	Zone of small fragments broken by joints and drilling	
	11							11 D D		Apparently 2 predominant joint orientations: 1) Subparallel to bedding foliation (approximate)
	12							12	Zone of small fragments	
	13	Run 2		avg ±2		13-18ft 17.6gpm / 5spi	J 85°	D 13 D D D D J		2) Nearly vertical. Mostly joints appear relatively tight. Orange (rust) staining common on joint surfaces. Some surfaces silty
	14		60" Rec					14	Fragments broken by joints and by drilling	
	15				20			15 J		
	16							J 16 J J		
	17							J 17		

LEGEND
N - STANDARD PENETRATION RESISTANCE, BLOWS/FT
REC - LENGTH RECOVERED/LENGTH CORED, %
RQD - LENGTH OF SOUND CORE 4" AND LONGER/LENGTH CORED, %
S - SPLIT SPOON SAMPLE
U - UNDISTURBED SAMPLES
F - FIXED PISTON
S - SHELBY TUBE
D - DENISON
P - PITCHER
O - OSTERBERG
D - DRILLING BREAK
WZ - WEATHERED
k - COEFFICIENT OF PERMEABILITY
Ω - GROUNDWATER

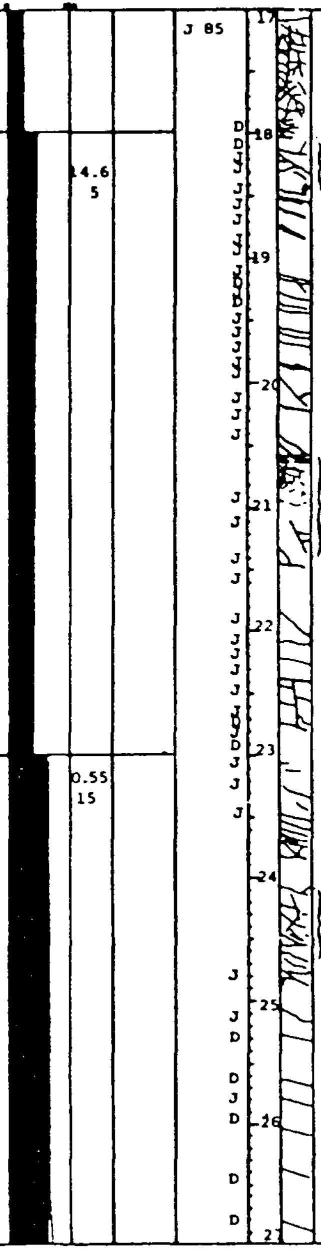
NOTES
1) Most drilling breaks were along bedding foliation.

PAGE 1 OF 6
LOG OF BORING FORM

GOLDBERG-ZOINO & ASSOCIATES, INC.
GEOTECHNICAL-GEOHYDROLOGICAL CONSULTANTS

BORING LOCATION STAMINA MILLS
FORESTDALE, RHODE ISLAND
DRILLED BY GUILD DRILLING COMPANY
LOGGED BY SRH REVIEWED CAL
CASING ID 3"
GROUND EL (MSL)
DATE START/FINISH 3/19/82 / 3/22/82
CORE SIZE NX
INCLINATION Vertical
DEPTH to WATER TABLE DATE
CORE TYPE
BEARING
TOTAL DEPTH 58 ft.

EL MSL ft	SAMPLE DEPTH ft	SAMPLE TYPE and No	SAMPLE N or REC	RATE OF ADV min/ft	WATER or RQD CONTENT %	WATER or RQD CONTENT GRAPHIC	PRESSURE TEST gpm / psi	PRESSURE TEST COMPUTED k 10^{-4} cm/sec	STRIKE/DIP F-FOLIATION J-JOINT C-CONTACT B-BEDDING S-SLICKENSIDE	CORE BREAKS	SOIL AND ROCK DESCRIPTIONS (WEATHERING, DEFECTS, etc.) (TYPE, TEXTURE, MINERALOGY, COLOR, HARDNESS, etc.)
	17				20				J 85	17	Zone of fragments broken by joints and drilling
	18	Run 3					14.6 5		D D J J J J J J J J	18	Weathered, shattered zone-weathered, rusty joints.
	19		60" Rec	+2	40				J D D J J J J J J	19	Silty material and rust straining on joint surface. Very weathered zones.
	20								J J J	20	
	21								J J J J	21	Zone of fragments: extremely weathered, rusty joints
	22								J J J J J J J D	22	
	23	Run4					0.55 15		D J J J	23	Weathered, rusty, fractured
	24		60" Rec		60				J	24	Rusty Zone of rusty, weathered crumbly fragments Rusty
	25								J D D J D	25	
	26								D D	26	
	27									27	



LEGEND
N - STANDARD PENETRATION RESISTANCE, BLOWS/FT
REC - LENGTH RECOVERED/LENGTH CORED, %
RQD - LENGTH OF SOUND CORE 4" AND LONGER/LENGTH CORED, %
S - SPLIT SPOON SAMPLE
D - DRILLING BREAK
WX - WEATHERED
k - COEFFICIENT OF PERMEABILITY
∇ - GROUNDWATER
U - UNDISTURBED SAMPLES
F - FIXED PISTON
S - SHELBY TUBE
D - DENISON
P - PITCHER
O - OSTERBERG

NOTES

PAGE 2 OF 6 LOG OF BORING

FORM

GOLDBERG-ZOINO & ASSOCIATES, INC.
GEOTECHNICAL-GEOHYDROLOGICAL CONSULTANTS

BORING LOCATION STAMINA MILLS
FORESTDALE, RHODE ISLAND
DRILLED BY GUILD DRILLING COMPANY
LOGGED BY SRH REVEIWED CAL
CASING ID 3"
GROUND EL (MSL)
DATE START/FINISH 3/19/82 / 3/22/82
CORE SIZE NX
INCLINATION Vertical
DEPTH to WATER TABLE
DATE
CORE TYPE
BEARING
TOTAL DEPTH 58 ft.

EL MSL ft	SAMPLE DEPTH ft	SAMPLE TYPE and No.	N or REC	RATE OF ADV min/ft	WATER or RQD CONTENT %	PRESSURE TEST	STRUCTURE	SOIL AND ROCK DESCRIPTIONS	
	27				60		D D J		
	28	Run 5	60" Rec	1.5	95	<0.1 14	D D D		Piece broke at 28.5' when re-turned to core box
	29			3.45			D D D D	Pegmatite vein Pegmatite vein (breaks approximately follow contacts)	
	30			3.0			J J J J	Zone of distinct orange weathered tight joints at 15°± to bedding foliation	
	31			2.5			J D J D		Piece broke when re-turned to box
	32			2.5			D D D		
	33	Run6		2.5		<0.1 16	J D D	Weathered joint surface orange zone ~1/2" thick in top of section	
	34			3	100		D D D D		
	35		60" Rec	3			D B D		
	36			3.5			J D		
	37								

LEGEND
N - STANDARD PENETRATION RESISTANCE, BLOWS/FT
REC - LENGTH RECOVERED/LENGTH CORED, %
RQD - LENGTH OF SOUND CORE 4" AND LONGER/LENGTH CORED, %
S - SPLIT SPOON SAMPLE
U - UNDISTURBED SAMPLES
B - DRILLING BREAK
F - FIXED PISTON
WS - WEATHERED
S - SHELBY TUBE
k - COEFFICIENT OF PERMEABILITY
D - DENISON
P - PITCHER
∇ - GROUNDWATER
O - OSTERBERG

NOTES.

Some of the breaks reported, especially for Run 5, may have occurred during handlings transport of core boxes. RQD was calculated in the field on the day of drilling

PAGE 3 OF 6

LOG OF BORING FORM

GOLDBERG-ZOINO & ASSOCIATES, INC.
GEOTECHNICAL-GEOHYDROLOGICAL CONSULTANTS

BORING LOCATION STAMINA MILLS
FORESTDALE, RHODE ISLAND
DRILLED BY GUILD DRILLING COMPANY
LOGGED BY SRH REVEIWED CAL
CASING ID 3"
GROUND EL (MSL)
DATE START/FINISH 3/19/82 / 3/22/82
CORE SIZE NX
INCLINATION Vertical
DEPTH to WATER TABLE DATE
CORE TYPE
BEARING
TOTAL DEPTH 58 ft.

EL MSL ft	SAMPLE DEPTH ft	SAMPLE TYPE and No.	N or REC	RATE OF ADV min/ft	WATER or RQD CONTENT %	PRESSURE TEST gpm/psi	STRIKE, DIP	- SOIL AND ROCK DESCRIPTIONS -
	37			3.5	100		D D J D	Rusty silty joint
	38	Run7				<0.1 19		Zone of orange weathered fragments
				3.0			J J	Zone of distinct orange-weathered tight joints
	39		60" Rec	3.25	60		D D	
	40						J J	Fragments; near-horizontal fractured appear to be drilling breaks.
				3.0			J J	
	41						J	Weathered, silty
				3.5			D J	Weathered
	42						J	
				3.0			B J	Pegmatite vein, inclusion
	43	Run8				<0.1 22	D J J J	Bedding foliation dipping @45°
				3.0				
	44		43" Rec	3.25			J J J	Rough, graphite on joint surface pyrolusite?
	45			3.25			J J J J J J J	Rock weathered (solution) Pegmatite veins, zone of small fragments, weathered
	46			3.5			J J D	
	47							

LEGEND
- N = STANDARD PENETRATION RESISTANCE, BLOWS/FT
- REC = LENGTH RECOVERED/LENGTH CORED, %
- RQD = LENGTH OF SOUND CORE 4" AND LONGER/LENGTH CORED, %
- S = SPLIT SPOON SAMPLE   U = UNDISTURBED SAMPLES
- D = DRILLING BREAK   F = FIXED PISTON
- WS = WEATHERED   S = SHELBY TUBE
- k = COEFFICIENT OF PERMEABILITY   D = DENISON
- P = PITCHER
- ▽ = GROUNDWATER   O = OSTERBERG

NOTES

PAGE 4 OF 6 LOG OF BORING

FORM

GOLDBERG-ZOINO & ASSOCIATES, INC.
GEOTECHNICAL-GEOHYDROLOGICAL CONSULTANTS

BORING LOCATION STAMINA MILLS
FORESTDALE, RHODE ISLAND
DRILLED BY GUILD DRILLING COMPANY
LOGGED BY SRH REVEIWED CAL
CASING ID 3"
GROUND EL (MSL)
DATE START/FINISH 3/19/82 / 3/22/82
CORE SIZE NX
INCLINATION Vertical
DEPTH to WATER TABLE
DATE
CORE TYPE
BEARING
TOTAL DEPTH 58 ft.

EL MSL ft	SAMPLE DEPTH ft	SAMPLE TYPE and No	SAMPLE N or REC	RATE OF ADV min/ft	WATER or RQD CONTENT %	GRAPHIC	PRESSURE TEST gpm/psi	COMPUTED k	STRIKE/DIP	- SOIL AND ROCK DESCRIPTIONS - (WEATHERING, DEFECTS, etc.) (TYPE, TEXTURE, MINERALOGY, COLOR, HARDNESS, etc.)
	47								D	
				3.5					J J J	Shattered zone
									D,J	
	48	Run9					<0.1 24			
				4.0					J	
									J J	
	49									
				4.0					J J	
	50		Rec 60"						J J J	
				4.5					J	
	51								J D J	Rough, orange. Appears to have been solution along joint surface (hole ½")
				5.0						Silty
									D	
	52									
				5.0						
	53	Run10					<0.1 26		D	
				5.0						
	54								D D	
			Rec 60"	5.0					D	
	55								D	
				4.5					D D	
	56								D	
				4.0					D	
									D,J	

LEGEND
N = STANDARD PENETRATION RESISTANCE, BLOWS/FT
REC = LENGTH RECOVERED/LENGTH CORED, %
RQD = LENGTH OF SOUND CORE 4" AND LONGER/LENGTH CORED, %
S = SPLIT SPOON SAMPLE
U = UNDISTURBED SAMPLES
B = DRILLING BREAK
F = FIXED PISTON
WE = WEATHERED
S = SHELBY TUBE
k = COEFFICIENT OF PERMEABILITY
D = DENISON
P = PITCHER
▽ = GROUNDWATER
O = OSTERBERG

NOTES

PAGE 5 OF 6
LOG OF BORING FORM

GOLDBERG-ZOINO & ASSOCIATES, INC.
GEOTECHNICAL-GEOHYDROLOGICAL CONSULTANTS

BORING LOCATION STAMINA MILLS
FORESTDALE, RHODE ISLAND

DRILLED BY GUILD DRILLING COMPANY
LOGGED BY SRH REVIEWED CAL

CASING ID 3"
GROUND EL (MSL)
DATE START/FINISH 3/19/82 / 3/22/82

CORE SIZE NX
INCLINATION Vertical
DEPTH to WATER TABLE
DATE

CORE TYPE
BEARING
TOTAL DEPTH 58 ft.

EL MSL ft	SAMPLE DEPTH ft	SAMPLE TYPE and No.	SAMPLE N or REC	RATE OF ADV min/ft	WATER or RQD CONTENT %	WATER or RQD CONTENT GRAPHIC	PRESSURE TEST GPM / psi	PRESSURE TEST COMPUTED K ×10⁻ cm/sec	STRIKE/DIP F: FOLIATION J: JOINT C: CONTACT B: BEDDING S: SLICKENSIDE	CORE BREAKS	- SOIL AND ROCK DESCRIPTIONS - (WEATHERING, DEFECTS, etc.) (TYPE, TEXTURE, MINERALOGY, COLOR, HARDNESS, etc.)
	57									57	
				4.0							
									D D		
	58									58	Bottom of Boring at 58.0 ft.

LEGEND
N= STANDARD PENETRATION RESISTANCE, BLOWS/FT
REC=LENGTH RECOVERED/LENGTH CORED, %
RQD=LENGTH OF SOUND CORE 4" AND LONGER/LENGTH CORED, %
S= SPLIT SPOON SAMPLE U= UNDISTURBED SAMPLES
D= DRILLING BREAK F= FIXED PISTON
WX= WEATHERED S= SHELBY TUBE
K= COEFFICIENT OF PERMEABILITY D= DENISON
P= PITCHER
∇= GROUNDWATER O= OSTERBERG

NOTES

PAGE 6 OF 6

LOG OF BORING FORM

GOLDBERG-ZOINO & ASSOCIATES, INC.
GEOTECHNICAL-GEOHYDROLOGICAL CONSULTANTS

APPENDIX E

BAROMETRIC EFFICIENCY AND WATER LEVEL CORRECTION CALCULATIONS

BAROMETRIC CORRECTION CALCULATIONS

Source of barometric information was Warwick Airport, RI

Only day of no pumping at the Forestdale Water Association well was Sunday, June 12, 1988.

VILLAGE WELL

Date/time:	6-12-88/0400	6-13-88/0400
Water level (ft):	150.82	149.61
Barometric (inches Hg):	29.810	29.920

$$29.810 \text{ inches Hg} \times \frac{1.13 \text{ ft } H_2O}{1 \text{ in. Hg}} = 33.685 \text{ ft } H_2O$$

$$29.920 \text{ inches Hg} \times \frac{1.13 \text{ ft } H_2O}{1 \text{ in. Hg}} = 33.810 \text{ ft } H_2O$$

BE = ΔWΔB (100)
BE - Barometric Efficiency
ΔW - Change in water level (ft)
ΔB - Change in barometric pressure (ft of H_2O)

BE = (150.82 - 149.61) (33.685 - 33.810) (100) = 15%

$$\Delta WL \text{ (ft)} = 0.15 \underset{(\text{ft } H_2O)}{(\Delta B)}$$

if ΔB → 0.01 in. Hg
= 0.0113 ft H_2O
then ΔW = 0.0113 x 0.15 = 0.002 ft

Time:	6/15/88		6/16/88		6/17/88		6/18/88		6/19/88
Date:	2350		2350		2350		2350		2350
Barom:	29.970		29.945		29.960		30.120		30.090
ΔB:		0.025		0.015		0.16		0.03	
W_C:		0.004 ft		0.0025 ft		0.027 ft		0.005 ft	

The greatest change in barometric pressure occurred between the 17th and 18th (ΔB = 0.16 ft H_2O) with a correction of 0.027 ft which is considered insignificant with respect to the drawdowns observed due to pumping; this includes the Stamina Mills well where Δs = 0.25 ft; with correction the drawdown in the Stamina Mills well would be 0.22 ft and reversal would still occur.

POST OFFICE

Date/time:	6-12-88/0400	6-13-88/0400
Water level (ft):	39.651	39.354
Barometric (inches Hg):	29.810	29.920
(ft H_2O):	33.685	33.810

$$BE = \frac{39.651 - 39.354}{1/(33.685 - 33.810)} = \frac{0.297}{8} (100) = 3.712\%$$

if BΔ = 0.01 ing Hg
= 0.0113
ΔW = 0.0004 ft —— insignificant

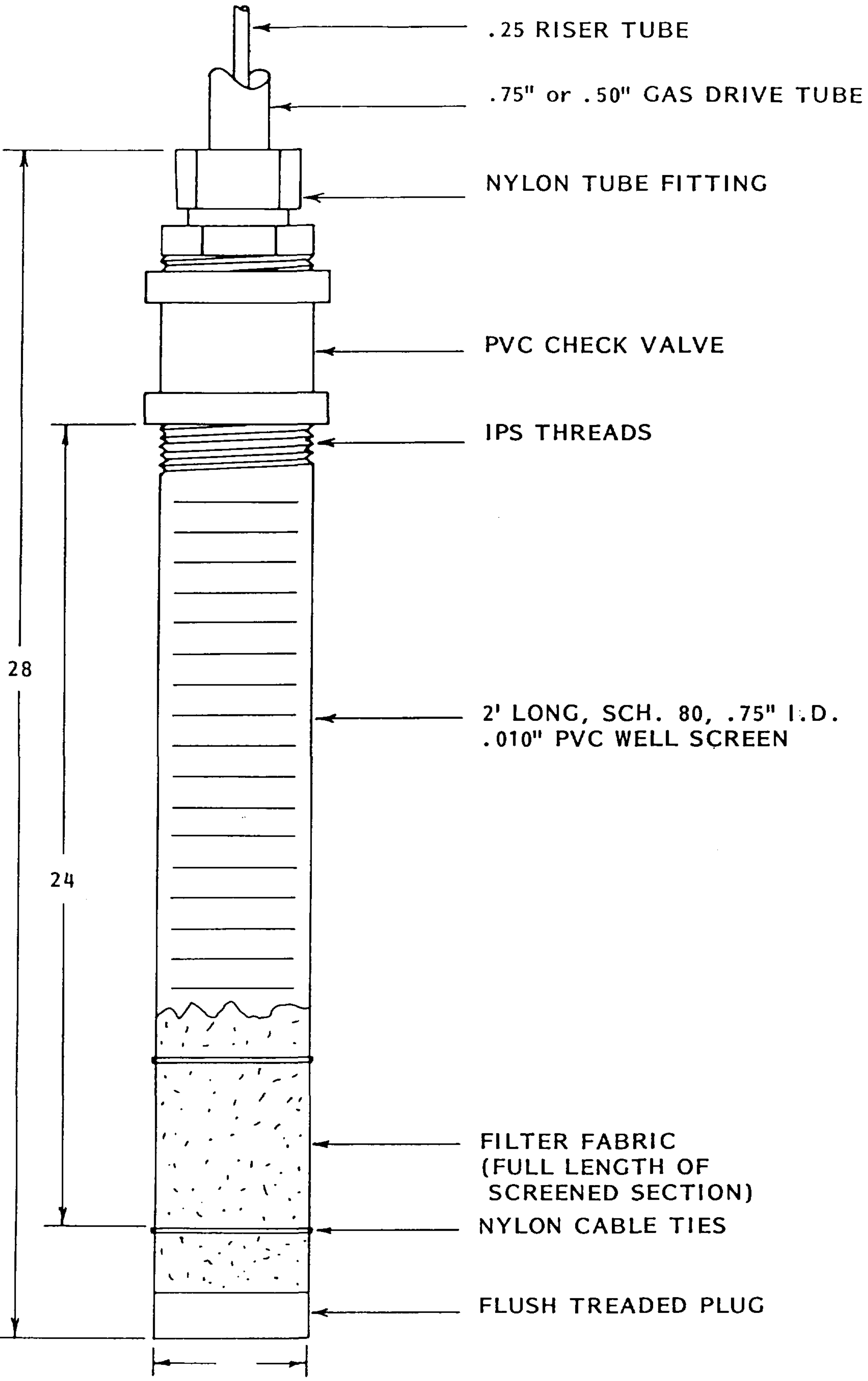
APPENDIX F

GAS-DRIVE SAMPLER CONSTRUCTION AND OPERATION

F.1 Gas-Drive Sampler Construction and Operation

The gas-drive samplers were constructed of Schedule 80, .75-inch diameter, .010-inch slotted 2-foot long PVC well screens. One end of the screen was fitted with a male flush threaded plug, the other end was threaded with standard male IPS (pipe) threads. A PVC check valve was attached to the threaded section of the screen. A nylon tube fitting was threaded to the top of the check valve. A .25-inch O.D. section of polyethylene tubing was fitted into the nylon tube fitting. A .25-inch O.D. length of polyethylene tubing was inserted inside the .50-inch polyethylene and allowed to reach approximately 1.5 feet above the top of the .75-inch PVC well screen. Glue, tape or other materials that could potentially contain volatile organic compounds were not used to assemble the sampler.

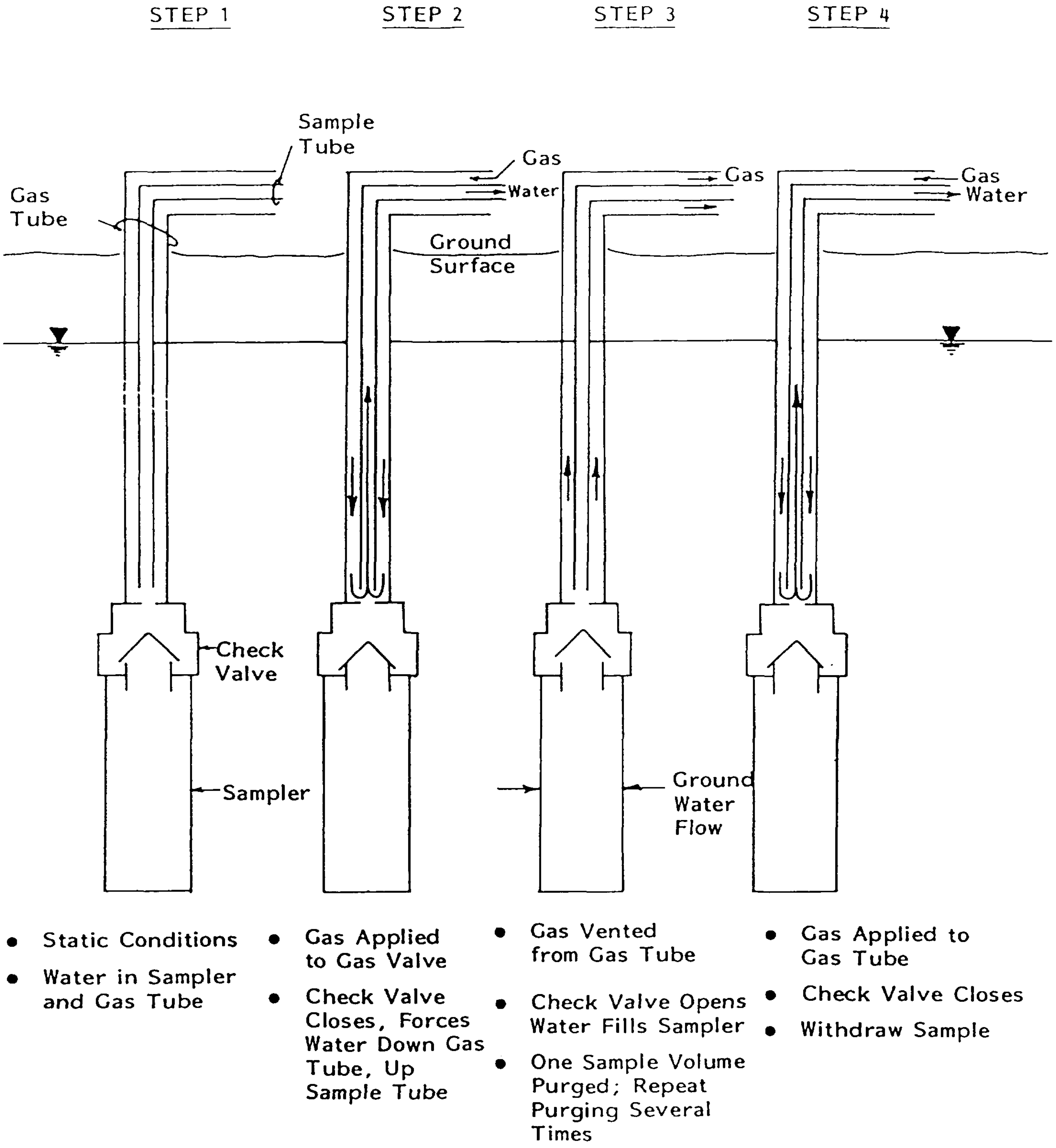
The gas-drive samplers were activated by applying pressure from a cylinder of compressed high-purity nitrogen gas to the top of the outer riser tube. The check valve within the sampler closes when pressurized, and all standing water within the riser tubes was forced out through the inner tubing. The system was then vented, and the procedure repeated to remove stagnant water from the sampler body. After flushing was completed, a sample of fresh formation water was withdrawn and collected.



NOTES:

1) Figure not to scale.
2) Sampler Design can be modified to accomodate hydrogeologic and water quality conditions.

BASIC GAS-DRIVE SAMPLER DESIGN



SAMPLER OPERATION

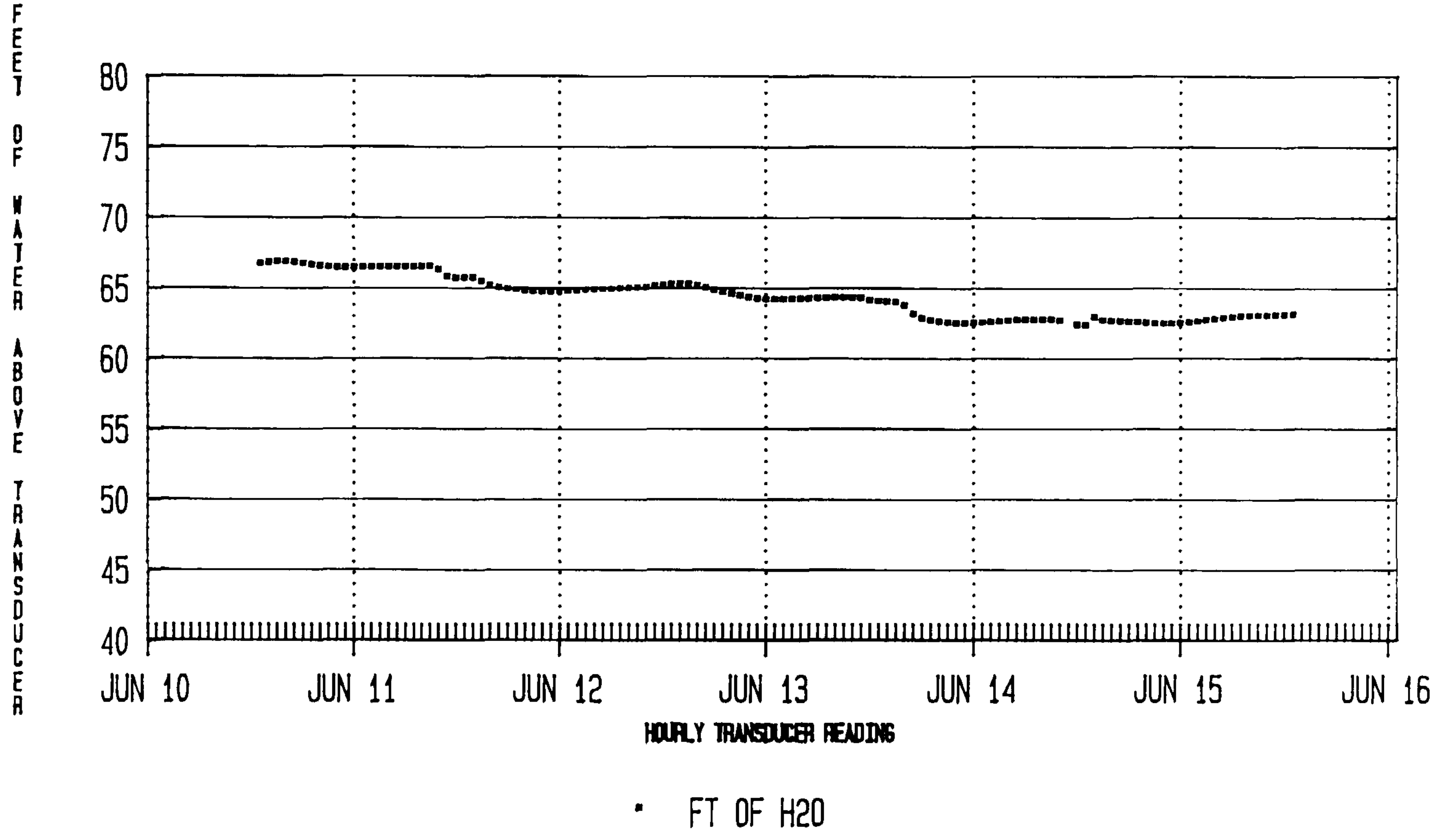
APPENDIX G

PRE-PUMP AMBIENT READINGS

STAMINA MILLS PUMPING TEST

BACKGROUND DATA - WHEATON (I-34)

ELEV. OF TRANSDUCER = 163.7 FT (MSL)

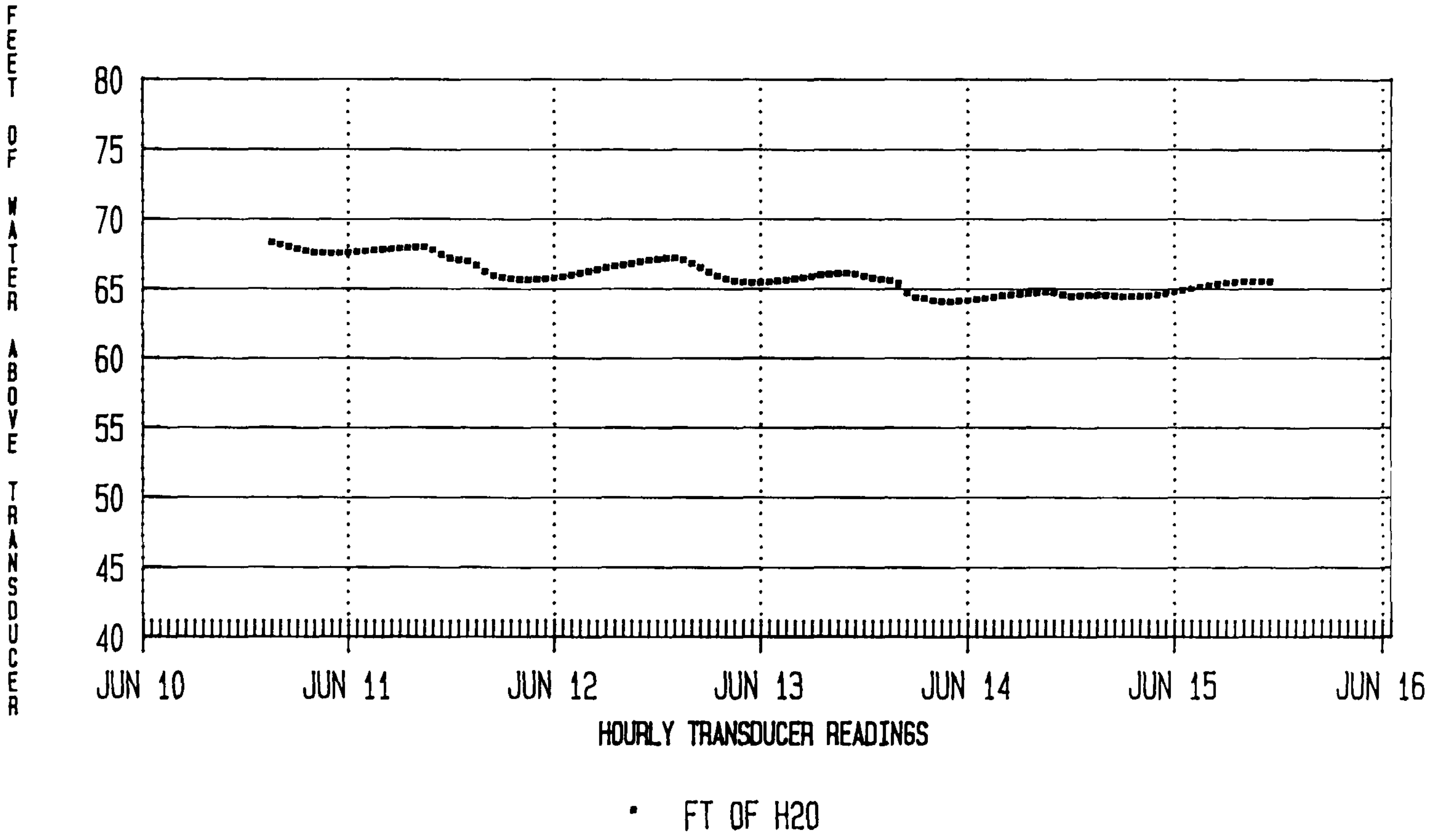


FWAM PUMPED ON: 6/11/88 AT 1457-1600 HRS
6/13/88 AT 1630 - 1800 HRS, AND ON
6/14/88 AT 1030 - 1230 HRS

STAMINA MILLS PUMPING TEST

BACKGROUND DATA - POST OFFICE (I-31)

ELEV. OF TRANS. = 142.7 FT (MSL)

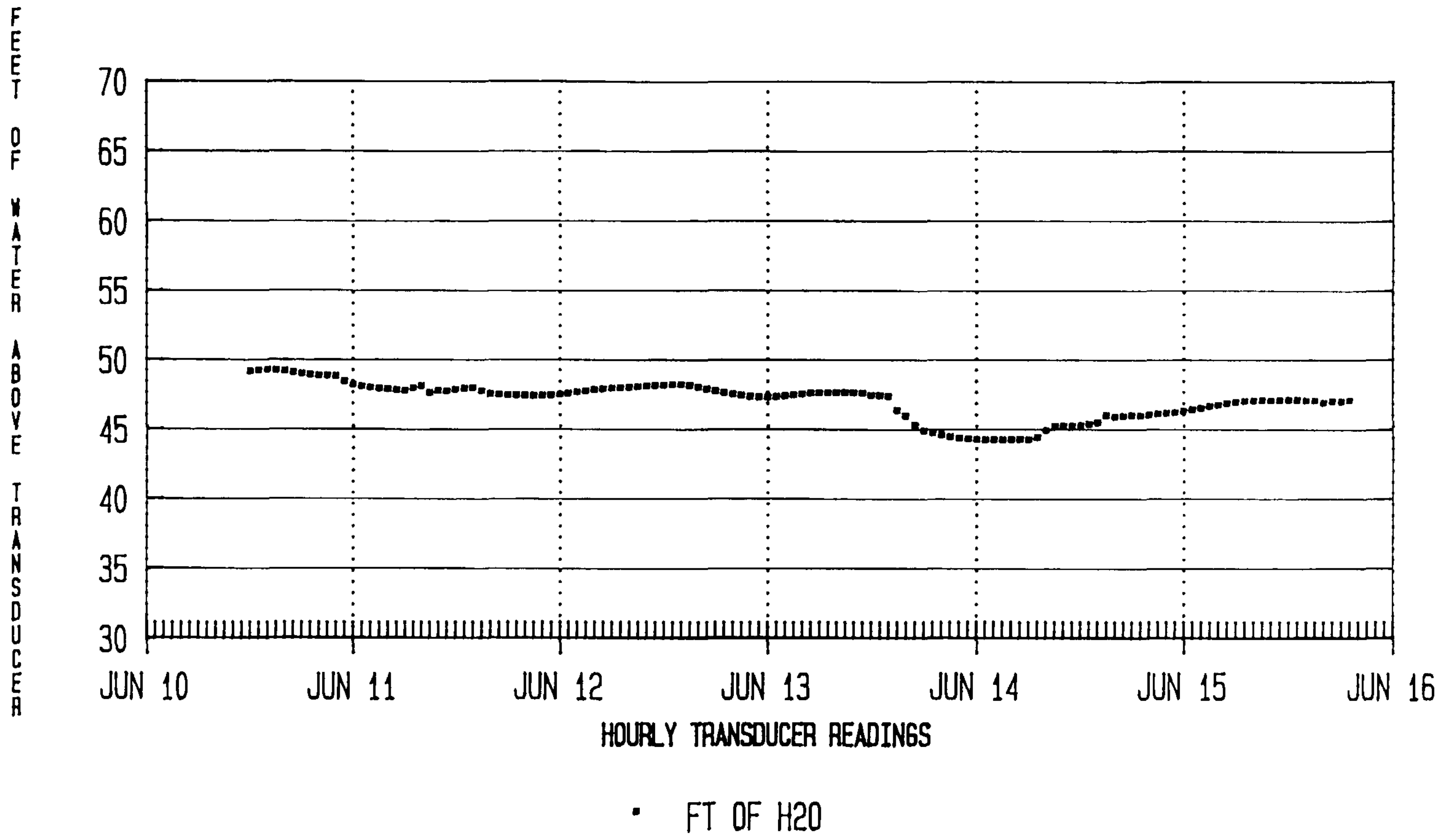


FWAW PUMPED ON: 6/11/88 AT 1457-1600 HRS
6/13/88 AT 1630 - 1800 HRS, AND ON
6/14/88 AT 1030 - 1230 HRS

STAMINA MILLS PUMPING TEST

BACKGROUND DATA - M. FREITAS (I-12)

ELEV. OF TRANS. = 161.5 FT (MSL)

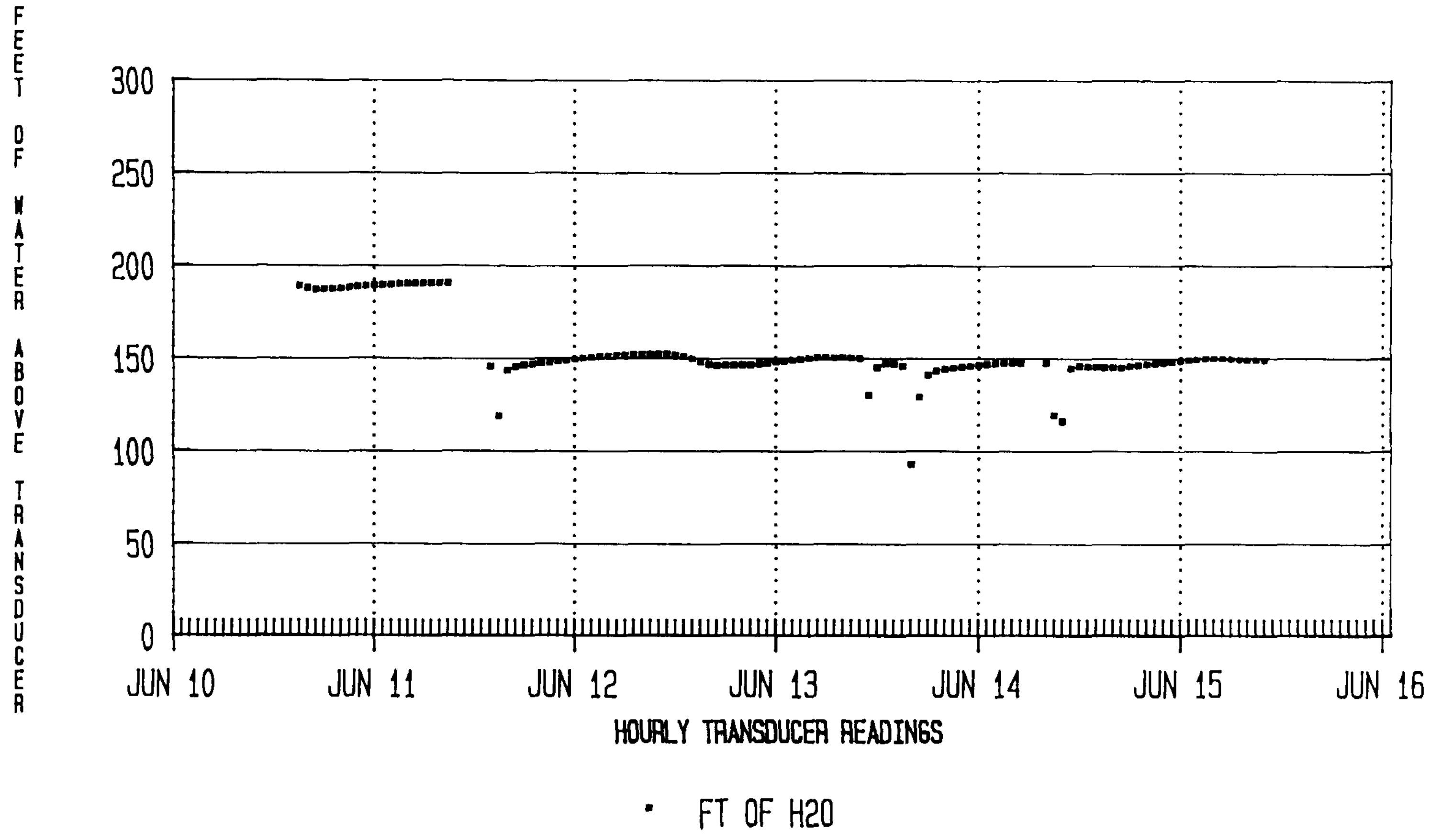


FWAW PUMPED ON: 6/11/88 AT 1457-1600 HRS
6/13/88 AT 1630 - 1800 HRS, AND ON
6/14/88 AT 1030 - 1230 HRS

STAMINA MILLS PUMPING TEST

BACKGROUND DATA - FWAW

ELEV. OF TRANS. = 61.6 FT (MSL)

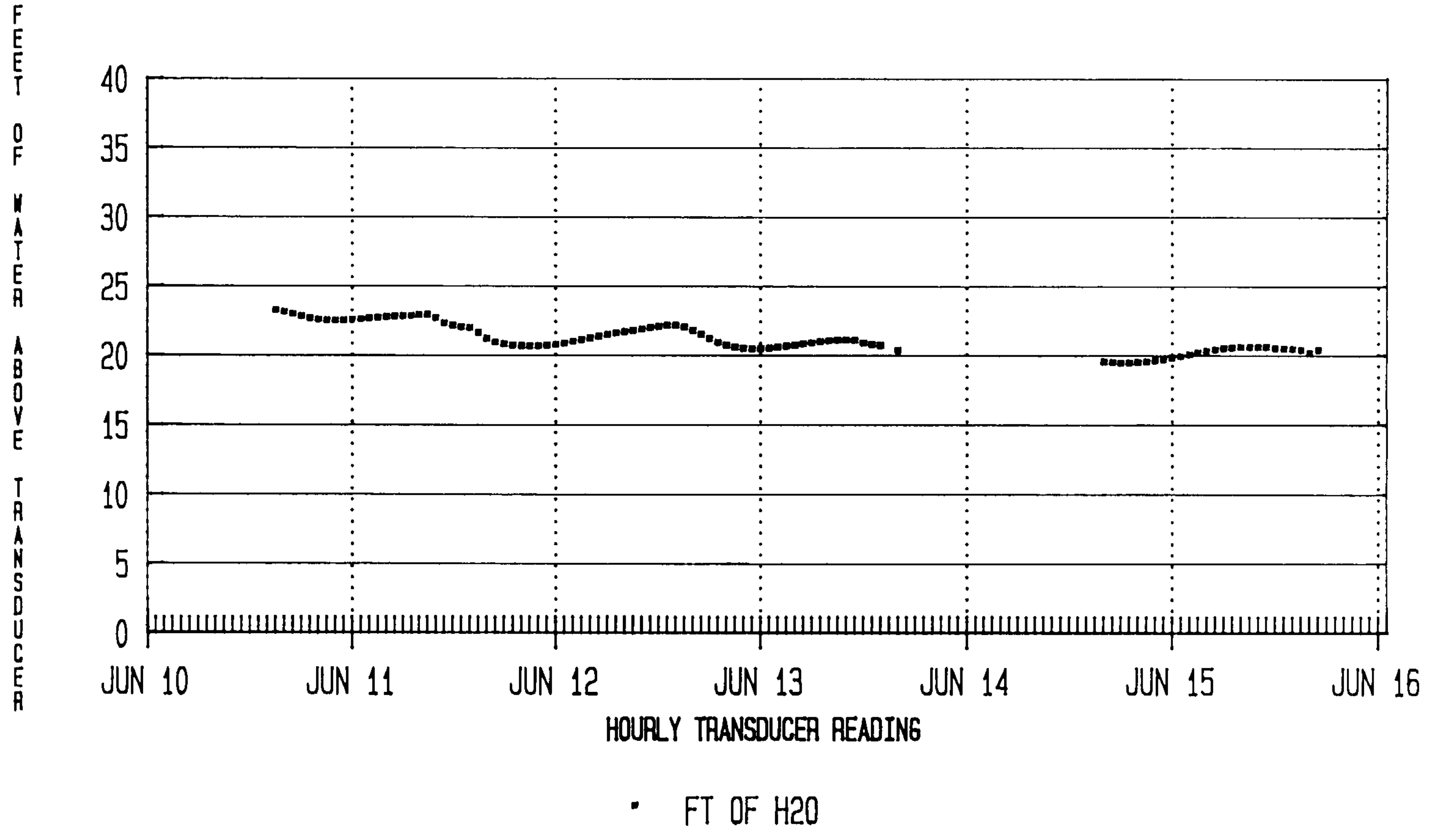


FWAW PUMPED ON: 6/11/88 AT 1457-1600 HRS
6/13/88 AT 1630 - 1800 HRS, AND ON
6/14/88 AT 1030 - 1230 HRS

STAMINA MILLS PUMPING TEST

BACKGROUND DATA - BOSCO (I-7)

ELEV. OF TRANS. = 190.5 FT (MSL)

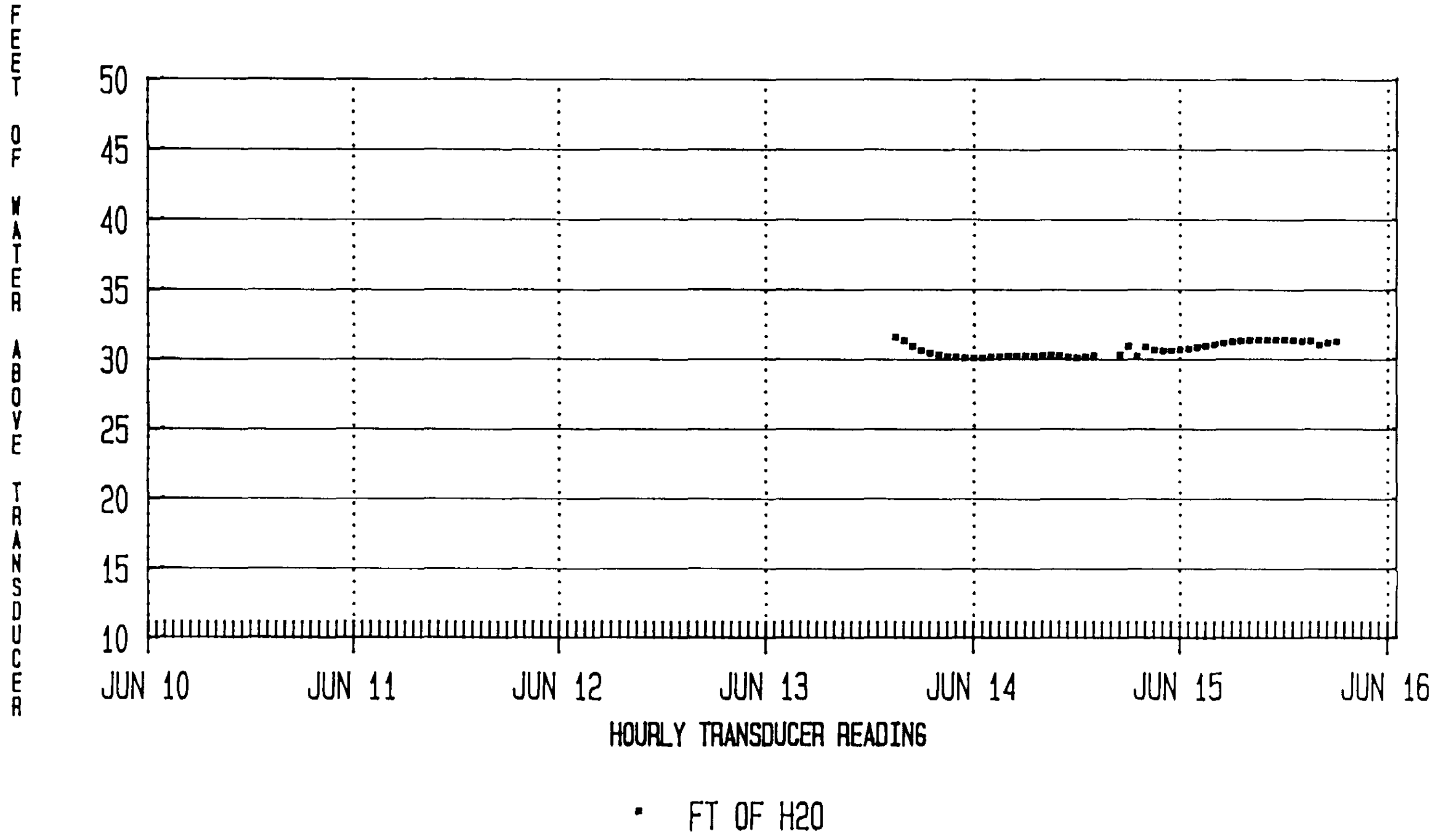


FWAW PUMPED ON: 6/11/88 AT 1457-1600 HRS
6/13/88 AT 1630 - 1800 HRS, AND ON
6/14/88 AT 1030 - 1230 HRS

STAMINA MILLS PUMPING TEST

BACKGROUND DATA - LOVETTE (I-37)

ELEV. OF TRANSDUCER = 177.2 FT (MSL)

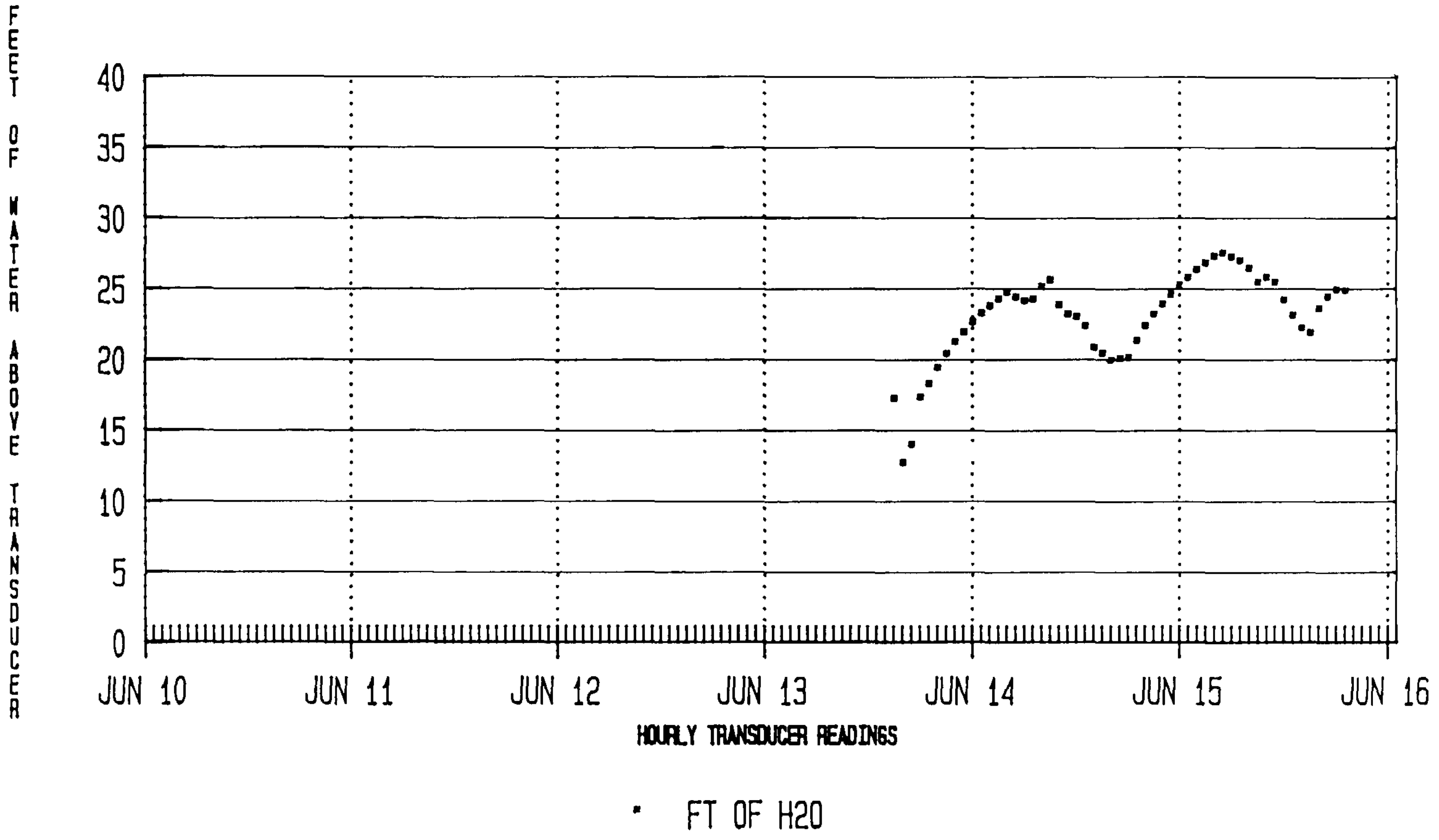


FWAW PUMPED ON: 6/11/88 AT 1457-1600 HRS
6/13/88 AT 1630 - 1800 HRS, AND ON
6/14/88 AT 1030 - 1230 HRS.

STAMINA MILLS PUMPING TEST

BACKGROUND DATA - KENOIAN (I-2)

ELEV. OF TRANS. = 181.3 FT (MSL)

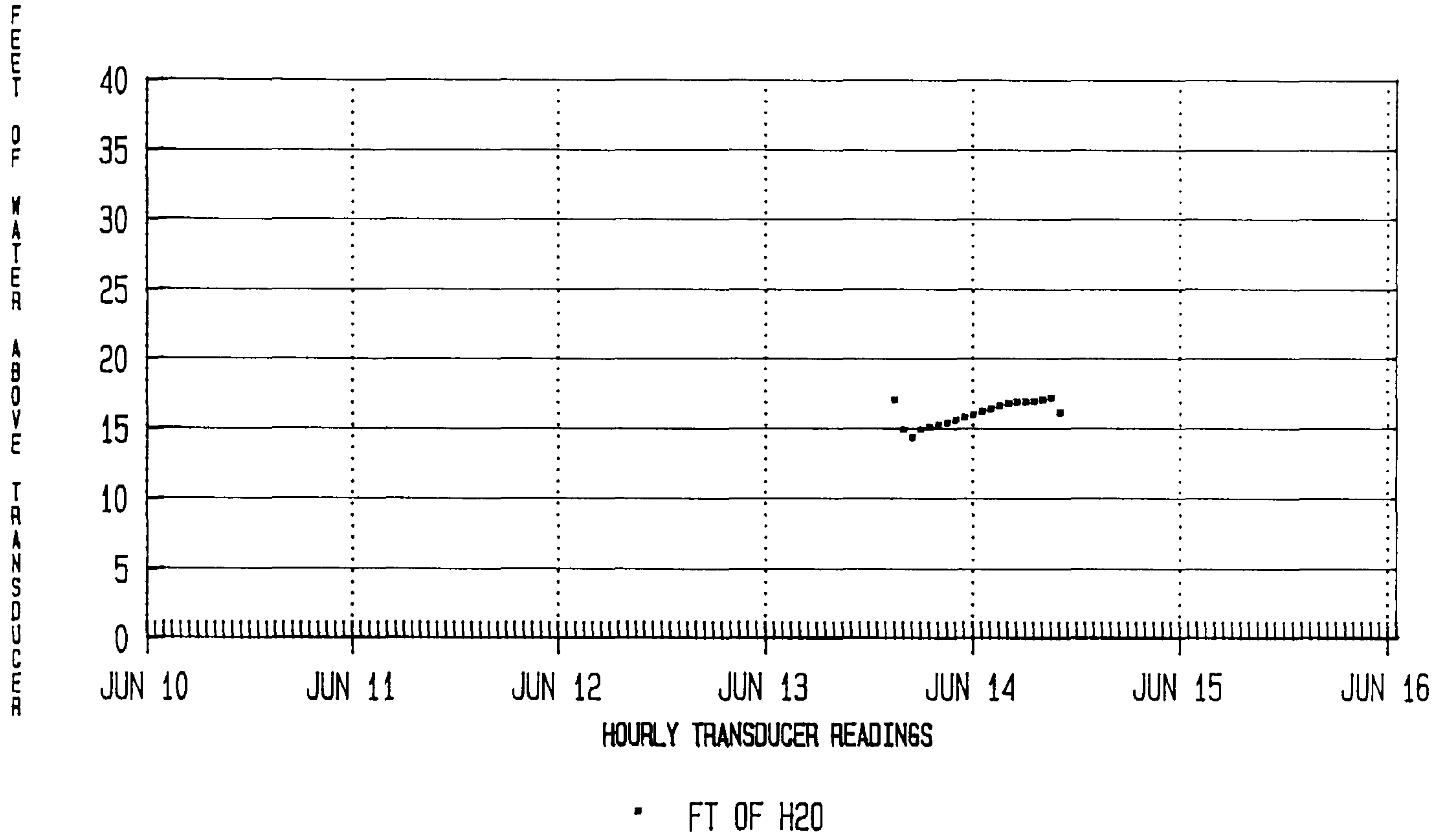


FVAW PUMPED ON: 6/11/88 AT 1457-1600 HRS
6/13/88 AT 1630 - 1800 HRS, AND ON
6/14/88 AT 1030 - 1230 HRS

STAMINA MILLS PUMPING TEST

BACKGROUND DATA - J. FREITAS (I-13)

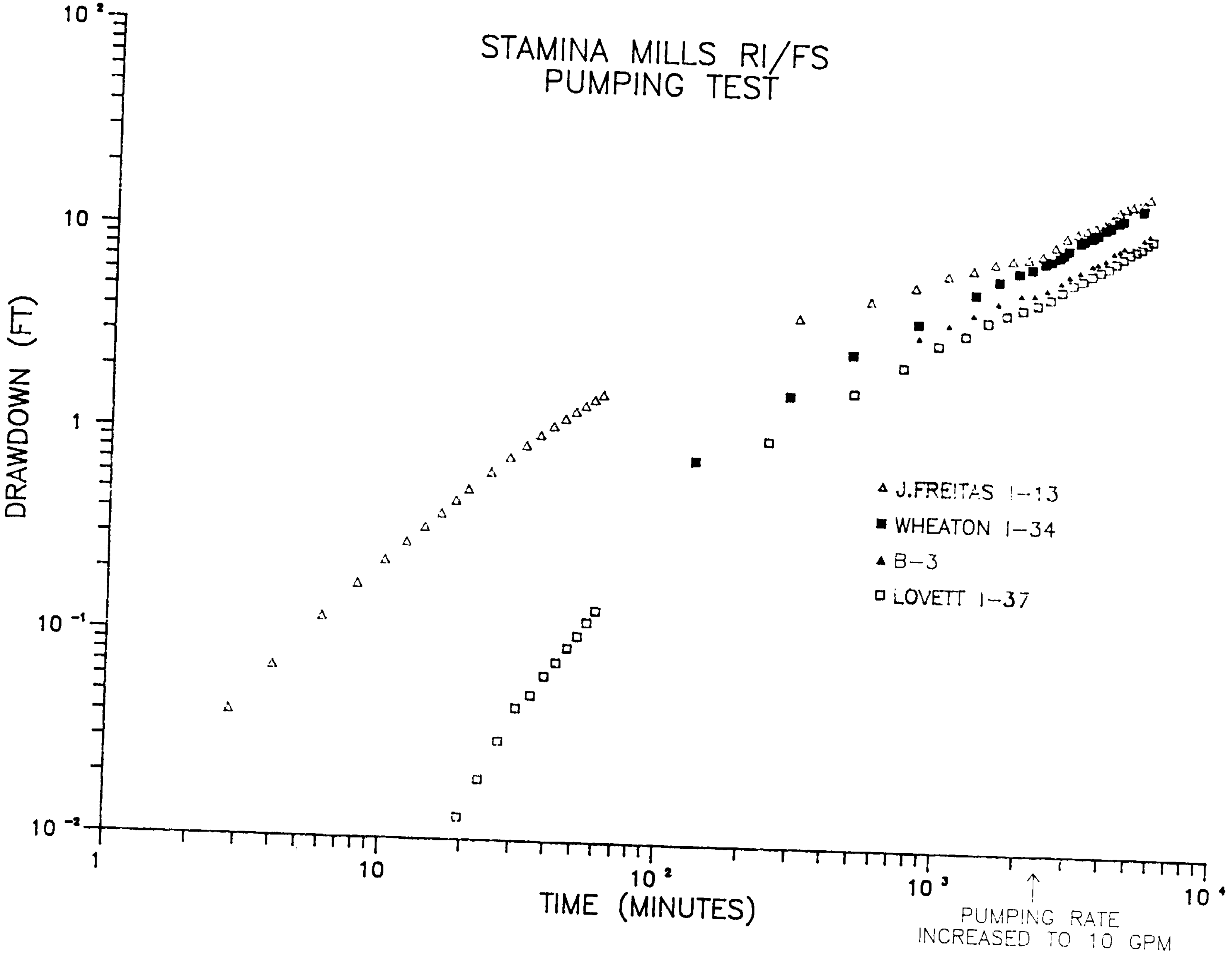
ELEV. OF TRANS. = 190.3 FT (MSL)

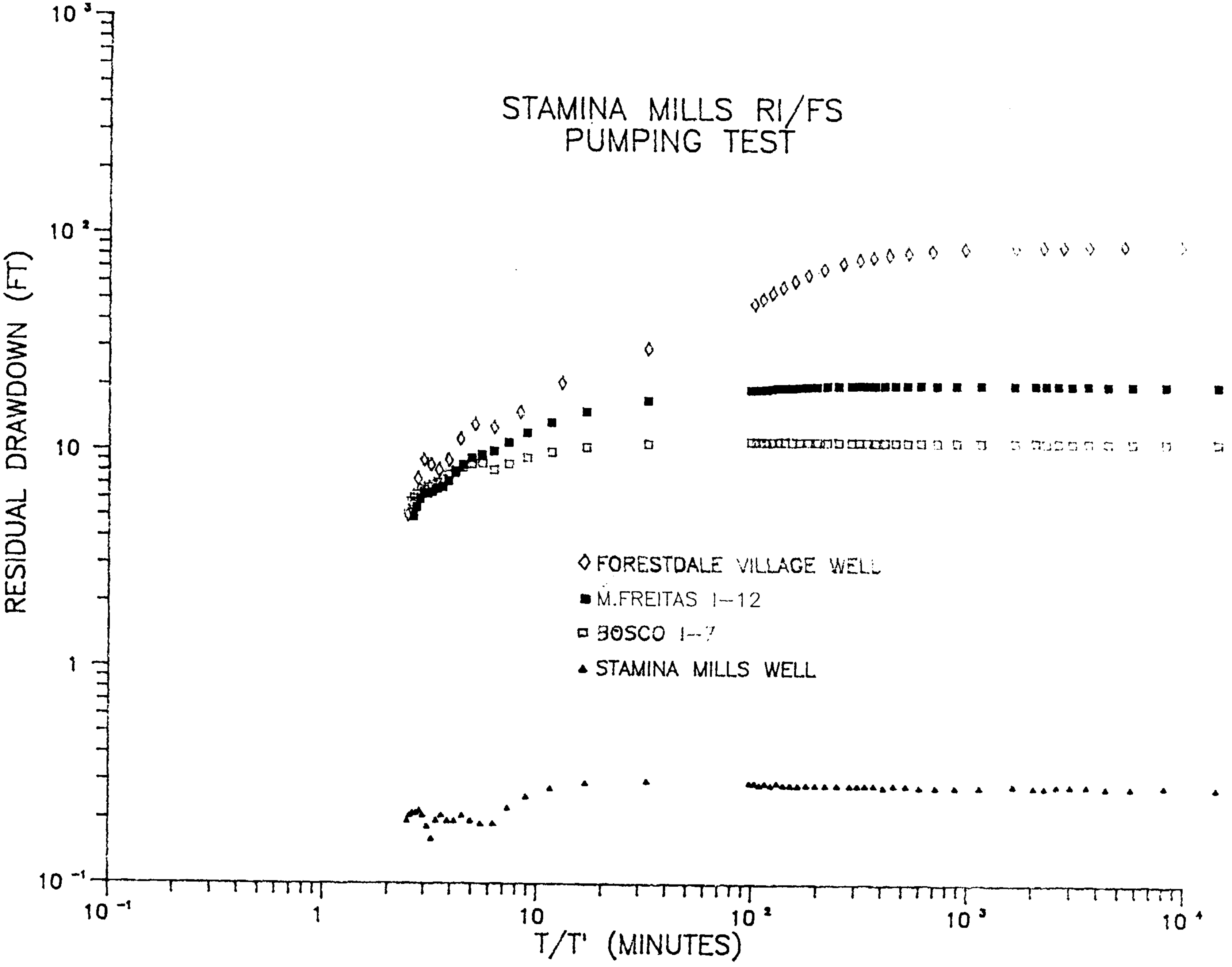


FWAW PUMPED ON: 6/11/88 AT 1457-1600
6/13/88 AT 1630 - 1800 HRS, AND ON
6/14/88 AT 1030 - 1230 HRS

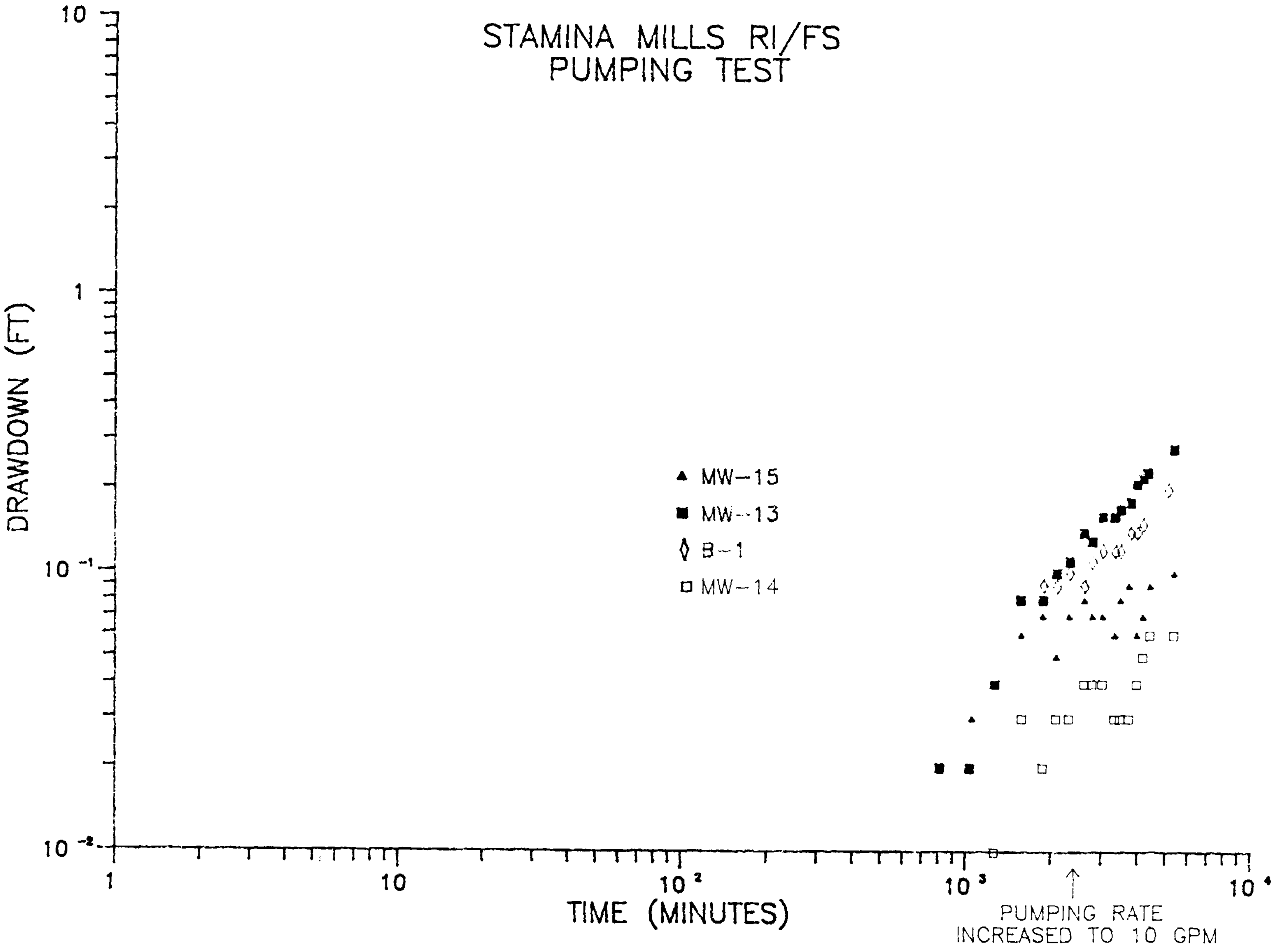
APPENDIX H

DRAWDOWN VERSUS TIME PLOTS AND WATER LEVEL MEASUREMENTS

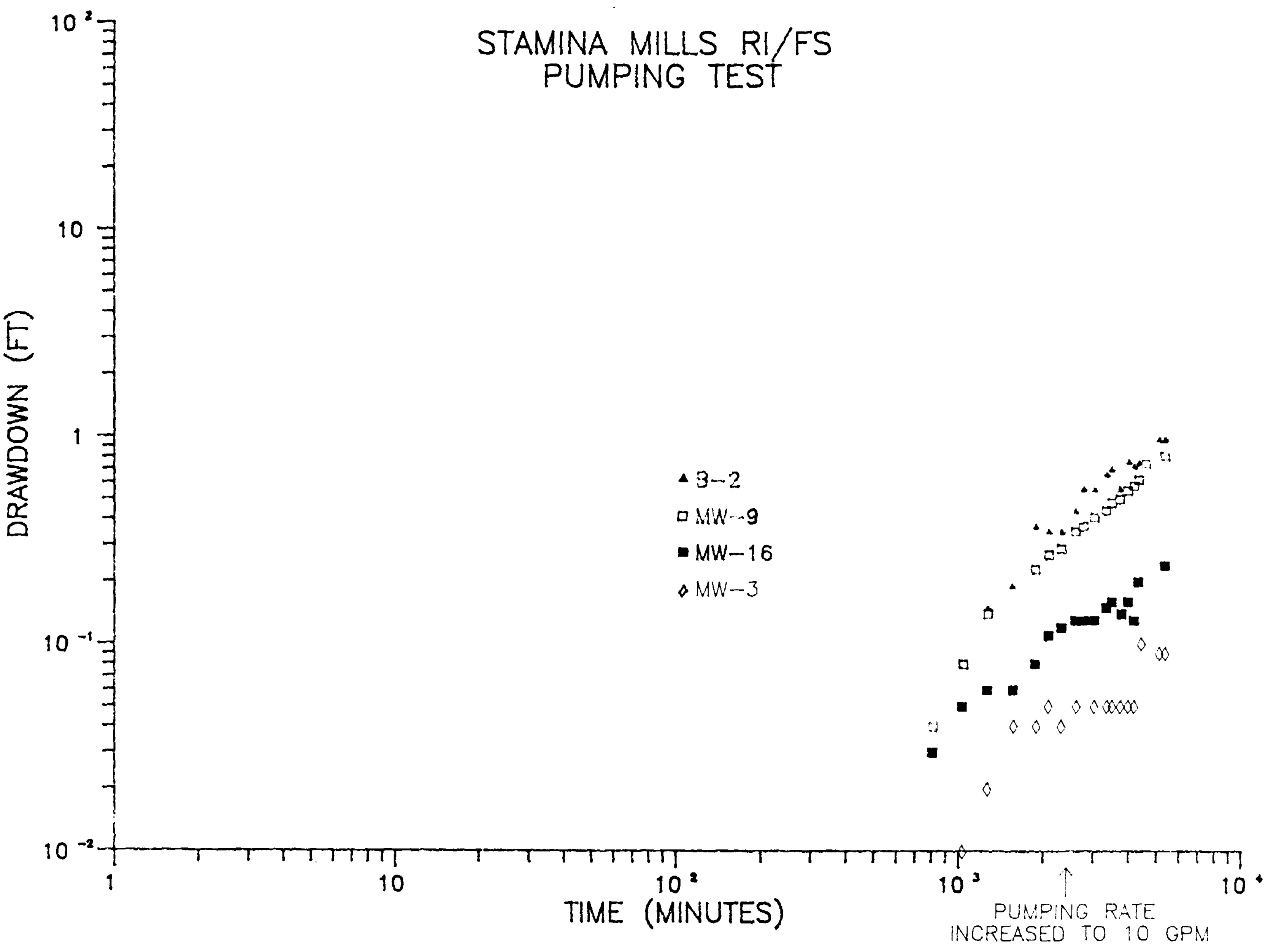

STAMINA MILLS RI/FS
PUMPING TEST

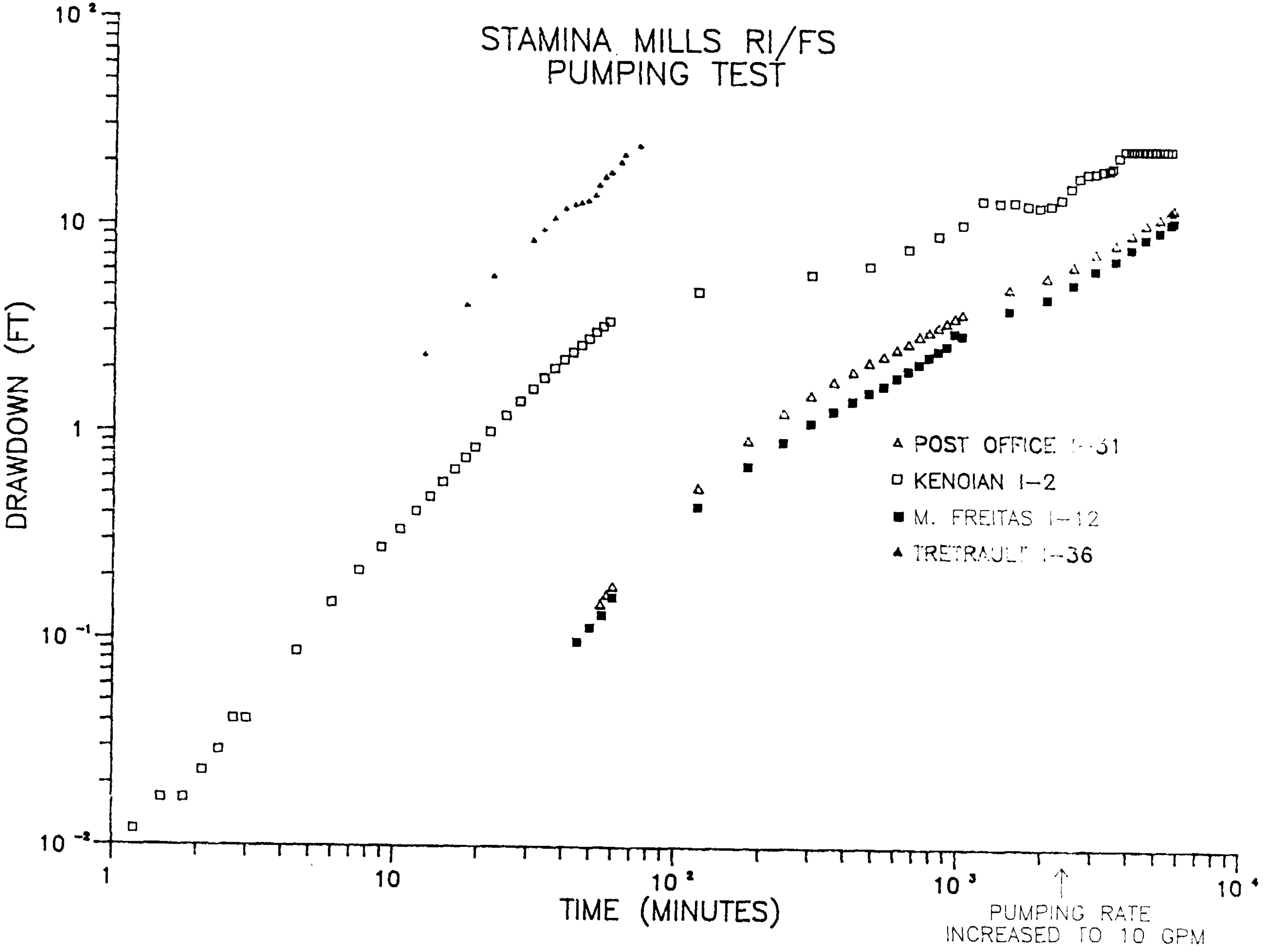


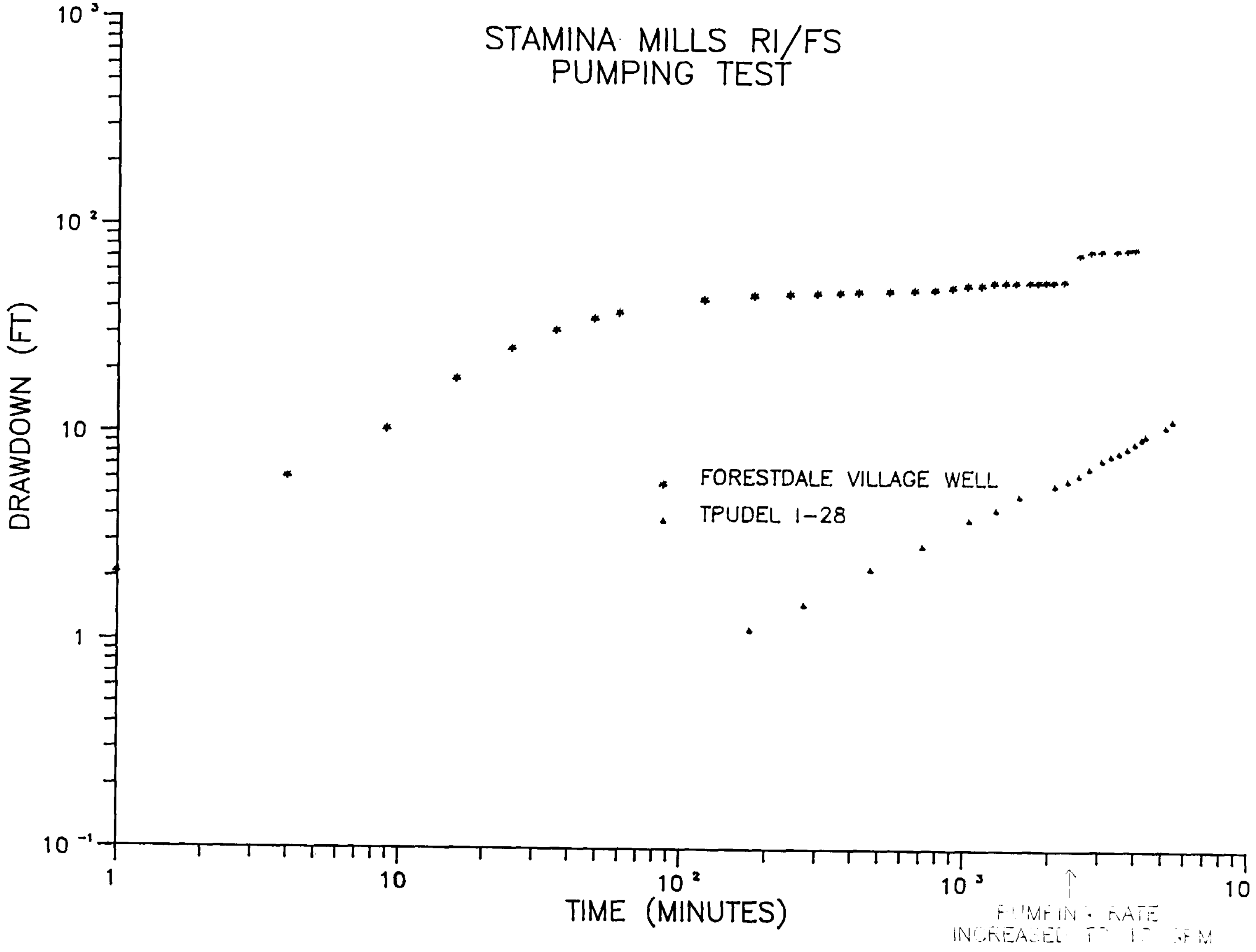
RECOVERY DATA



STAMINA MILLS RI/FS
PUMPING TEST


STAMINA MILLS RI/FS
PUMPING TEST
▲ 3-2
□ MW-9
■ MW-16
◇ MW-3
DRAWDOWN (FT)
10^2
10
1
10^{-1}
10^{-2}
1
10
10^2
10^3
10^4
TIME (MINUTES)
PUMPING RATE
INCREASED TO 10 GPM


STAMINA MILLS RI/FS
PUMPING TEST
DRAWDOWN (FT)
10²
10
1
10⁻¹
10⁻²
TIME (MINUTES)
1
10
10²
10³
10⁴
△ POST OFFICE I-31
□ KENOIAN I-2
■ M. FREITAS I-12
▲ TRETRAULT I-36
PUMPING RATE
INCREASED TO 10 GPM


STAMINA MILLS RI/FS
PUMPING TEST
DRAWDOWN (FT)
10^3
10^2
10
1
10^{-1}
1
10
10^2
10^3
10^4
TIME (MINUTES)
FORESTDALE VILLAGE WELL
TPUDEL I-28
PUMPING RATE
INCREASED TO 1[illegible] GPM

```
STAMINA MILLS PUMPING TEST - JUNE 1989

BACKGROUND DATA
FWAW (I-32)
Elev. of Transducer = 61.5 ft (msl)

Model SDEE-01B
S/N 0290    Block 1
--------------------
Program:     INTERVAL
Readings:    21
Start Time: 16:00:00
Start date: 06/10
Range:       0050 PSI
Units:       Ft-H20
--------------------
Interval:  01:00:00
   Time      Chnl 1
15:00:00   +189.00
17:00:00   +187.83
18:00:00   +187.00
19:00:00   +187.20
20:00:00   +187.37
21:00:00   +187.73
22:00:00   +188.20
23:00:00   +188.65
--  6/11
00:00:00   +188.96
01:00:00   +189.20
02:00:00   +189.52
03:00:00   +189.75
04:00:00   +190.03
05:00:00   +190.24
06:00:00   +190.31
07:00:00   +190.45
08:00:00   +190.50
09:00:00   +190.65
10:00:00   +190.51
---------------


NEW TEST


Step 1
Interval 00:00:06
Model SDEE-01B
S/N 0290    Block 2
--------------------
Program:     STEP TEST
Readings:    8
Start Time: 14:54:12
Start date: 06/11
Range:       0050 PSI
Units:       Ft-H20
--------------------

Readings 31
---------------
   Time      Chnl 1
14:54:12   +148.66
14:54:18   +148.65
14:54:24   +148.65
14:54:30   +148.65
14:54:36   +148.65
14:54:42   +148.65
14:54:48   +148.63
14:54:54   +148.65
Test 2 aborted at Step 1


NEW TEST

Model SDEE-01B
S/N 0290    Block 3
--------------------
Program:     STEP TEST
Readings:    36
Start Time: 14:57:00
Start date: 06/11
Range:       0050 PSI
Units:       Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time      Chnl 1
14:57:00   +148.59
14:57:06   +148.60
14:57:12   +148.59
14:57:18   +148.20
14:57:24   +147.14
14:57:30   +145.17
14:57:36   +145.29
14:57:42   +144.43
14:57:48   +144.33
14:57:54   +144.38
14:58:00   +144.46
14:58:06   +144.52
14:58:12   +144.59
14:58:18   +144.63
14:58:24   +144.70

14:58:30   +144.75
14:58:36   +144.81
14:58:42   +144.87
14:58:48   +144.89
14:58:54   +144.97
14:59:00   +145.00
14:59:06   +145.05
14:59:12   +145.11
14:59:18   +145.13
14:59:24   +145.15
14:59:30   +145.25
14:59:36   +145.19
14:59:42   +145.32
14:59:48   +145.33
14:59:54   +145.37
15:00:00   +145.44
---------------
Step 2
Interval 00:00:30
Readings 34
---------------
   Time      Chnl 1
15:00:30   +145.58
15:01:00   +146.22
15:01:30   +146.78
15:02:00   +147.17
15:02:30   +142.03
Test 3 aborted at Step 2



NEW TEST


Model SDEE-01B
S/N 0290    Block 4
--------------------
Program:     STEP TEST
Readings:    95
Start Time: 15:03:56
Start date: 06/11
Range:       0050 PSI
Units:       Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time      Chnl 1
15:03:56   +144.35

15:04:02   +143.25
15:04:08   +142.24
15:04:14   +141.21
15:04:20   +140.33
15:04:26   +139.26
15:04:32   +138.33
15:04:38   +137.35
15:04:44   +136.41
15:04:50   +135.38
15:04:56   +134.47
15:05:02   +133.52
15:05:08   +132.69
15:05:14   +131.75
15:05:20   +130.83
15:05:26   +129.91
15:05:32   +128.97
15:05:38   +128.14
15:05:44   +127.15
15:05:50   +126.29
15:05:56   +125.30
15:06:02   +124.42
15:06:08   +123.51
15:06:14   +122.64
15:06:20   +121.76
15:06:26   +120.84
15:06:32   +119.92
15:06:38   +119.11
15:06:44   +118.17
15:06:50   +117.38
15:06:56   +116.65
---------------
Step 2
Interval 00:00:30
Readings 34
---------------
   Time      Chnl 1
15:07:26   +114.41
15:07:56   +112.46
15:08:26   +110.45
15:08:56   +108.49
15:09:26   +105.75
15:09:56   +105.85
15:10:26   +104.86
15:10:56   +103.96
15:11:26   +103.37
15:11:56   +102.86
15:12:26   +102.35
15:12:56   +101.81
15:13:26   +101.32
15:13:56   +100.81
```

I-32 cont.

```
15:14:26   +100.31
15:14:56   +99.821
15:15:26   +99.348
15:15:56   +98.852
15:16:26   +98.402
15:16:56   +97.918
15:17:26   +97.445
15:17:56   +96.972
15:18:26   +96.522
15:18:56   +96.061
15:19:26   +95.622
15:19:56   +95.161
15:20:26   +94.700
15:20:56   +94.250
15:21:26   +93.812
15:21:56   +93.385
15:22:26   +92.958
15:22:56   +92.555
15:23:26   +92.128
15:23:56   +91.713
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time     Chnl 1
15:24:56   +90.940
15:25:56   +90.190
15:26:56   +89.429
15:27:56   +88.725
15:28:56   +87.999
15:29:56   +87.295
15:30:56   +86.615
15:31:56   +85.934
15:32:56   +85.277
15:33:56   +84.620
15:34:56   +84.008
15:35:56   +83.351
15:36:56   +82.774
15:37:56   +82.636
15:38:56   +83.029
15:39:56   +82.763
15:40:56   +82.474
15:41:56   +82.209
15:42:56   +81.921
15:43:56   +81.679
Test 4 aborted at Step 3

NEW TEST


Model SDEE-01B
S/N 0290    Block 5
--------------------
Program:    INTERVAL
Readings:   49
Start Time: 16:00:00
Start date: 06/11
Range:      0050 PSI
Units:      Ft-H20
--------------------
Interval:  01:00:00
   Time     Chnl 1
16:00:00   +118.78
17:00:00   +143.38
18:00:00   +145.42
19:00:00   +146.28
20:00:00   +146.85
21:00:00   +147.31
22:00:00   +147.79
23:00:00   +148.35
--  6/12
00:00:00   +148.81
01:00:00   +149.41
02:00:00   +149.93
03:00:00   +150.30
04:00:00   +150.76
05:00:00   +151.13
06:00:00   +151.50
07:00:00   +151.70
08:00:00   +151.81
09:00:00   +152.03
10:00:00   +152.27
11:00:00   +152.30
12:00:00   +152.32
13:00:00   +151.58
14:00:00   +150.70
15:00:00   +149.54
16:00:00   +148.25
17:00:00   +146.62
18:00:00   +146.24
19:00:00   +146.20
20:00:00   +146.17
21:00:00   +146.31
22:00:00   +146.35
23:00:00   +146.91
--  6/13
00:00:00   +147.45
01:00:00   +148.05
02:00:00   +148.58
03:00:00   +149.07
04:00:00   +149.55
05:00:00   +149.93
06:00:00   +150.29
07:00:00   +150.41
08:00:00   +150.27
09:00:00   +150.38
10:00:00   +150.15
11:00:00   +149.94
12:00:00   +139.96
13:00:00   +144.87
14:00:00   +147.19
15:00:00   +147.05
16:00:00   +145.64
---------------


NEW TEST


Model SDEE-01B
S/N 0290    Block 6
--------------------
Program:    STEP TEST
Readings:   119
Start Time: 16:30:00
Start date: 06/13
Range:      0050 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time     Chnl 1
16:30:00   +143.34
16:30:06   +142.42
16:30:12   +141.72
16:30:18   +141.08
16:30:24   +140.59
16:30:30   +140.19
16:30:36   +139.99
16:30:42   +139.78
16:30:48   +139.55
16:30:54   +139.35
16:31:00   +139.12
16:31:06   +138.91
16:31:12   +138.71
16:31:18   +138.52
16:31:24   +138.27
16:31:30   +137.99
16:31:36   +137.74
16:31:42   +137.45
16:31:48   +137.20
16:31:54   +136.91
16:32:00   +136.64
16:32:06   +136.40
16:32:12   +136.12
16:32:18   +135.86
16:32:24   +135.58
16:32:30   +135.29
16:32:36   +135.05
16:32:42   +134.79
16:32:48   +134.54
16:32:54   +134.32
16:33:00   +134.08
---------------
Step 2
Interval 00:00:30
Readings 34
---------------
   Time     Chnl 1
16:33:30   +132.29
16:34:00   +130.15
16:34:30   +128.54
16:35:00   +127.43
16:35:30   +126.24
16:36:00   +125.09
16:36:30   +123.93
16:37:00   +122.87
16:37:30   +121.79
16:38:00   +120.78
16:38:30   +119.83
16:39:00   +118.79
16:39:30   +117.84
16:40:00   +116.89
16:40:30   +115.99
16:41:00   +115.12
16:41:30   +114.24
16:42:00   +113.41
16:42:30   +112.63
16:43:00   +111.82
16:43:30   +111.05
16:44:00   +110.29
16:44:30   +109.49
16:45:00   +108.75
16:45:30   +108.04
16:46:00   +107.36
16:46:30   +106.68
16:47:00   +106.01
16:47:30   +105.39
16:48:00   +104.69
16:48:30   +104.07
16:49:00   +103.46
```

```
16:49:30   +102.05
16:50:00   +102.26
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time     Chnl 1
16:51:00   +101.20
16:52:00   +100.14
16:53:00   +99.163
16:54:00   +98.160
16:55:00   +97.202
16:56:00   +96.280
16:57:00   +95.323
16:58:00   +94.469
16:59:00   +93.581
17:00:00   +92.774
17:01:00   +91.989
17:02:00   +91.217
17:03:00   +90.479
17:04:00   +89.763
17:05:00   +89.060
17:06:00   +88.379
17:07:00   +87.745
17:08:00   +87.065
17:09:00   +86.442
17:10:00   +85.808
17:11:00   +85.219
17:12:00   +84.654
17:13:00   +84.101
17:14:00   +83.535
17:15:00   +82.982
17:16:00   +82.451
17:17:00   +81.932
17:18:00   +81.436
17:19:00   +80.940
17:20:00   +80.502
17:21:00   +80.054
17:22:00   +79.626
17:23:00   +79.199
17:24:00   +78.518
17:25:00   +77.803
17:26:00   +77.068
17:27:00   +76.385
17:28:00   +75.750
17:29:00   +75.139
17:30:00   +74.493
---------------

Step 4
Interval 01:00:00
Readings 14
---------------
   Time     Chnl 1
18:30:00   +128.95
19:30:00   +140.82
20:30:00   +142.36
21:30:00   +143.20
22:30:00   +144.00
23:30:00   +144.66
--  6/14
00:30:00   +145.26
01:30:00   +145.75
02:30:00   +146.26
03:30:00   +146.72
04:30:00   +147.13
05:30:00   +147.48
06:30:00   +147.59
07:30:00   +147.45
---------------
STAMINA MILLS PUMPING TEST

Model SDEE-018
S/N 0290    Block 1
--------------------
Program:    STEP TEST
Readings:   130
Start Time: 10:30:00
Start date: 06/14
Range:      0050 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time     Chnl 1
10:30:00   +147.17
10:30:06   +146.35
10:30:12   +145.53
10:30:18   +145.23
10:30:24   +144.37
10:30:30   +143.39
10:30:36   +142.40
10:30:42   +141.43
10:30:48   +140.47
10:30:54   +139.50
10:31:00   +138.51
10:31:06   +137.69
10:31:12   +136.75
10:31:18   +135.75

10:31:24   +134.77
10:31:30   +133.90
10:31:36   +133.03
10:31:42   +132.18
10:31:48   +131.26
10:31:54   +130.33
10:32:00   +129.51
10:32:06   +128.63
10:32:12   +127.73
10:32:18   +126.78
10:32:24   +125.86
10:32:30   +125.09
10:32:36   +124.41
10:32:42   +124.01
10:32:48   +123.75
10:32:54   +123.68
10:33:00   +123.64
---------------
Step 2
Interval 00:00:30
Readings 34
---------------
   Time     Chnl 1
10:33:30   +123.46
10:34:00   +123.25
10:34:30   +123.14
10:35:00   +123.00
10:35:30   +122.94
10:36:00   +123.14
10:36:30   +123.36
10:37:00   +123.46
10:37:30   +123.62
10:38:00   +123.72
10:38:30   +123.87
10:39:00   +123.94
10:39:30   +124.04
10:40:00   +124.09
10:40:30   +124.16
10:41:00   +124.25
10:41:30   +124.31
10:42:00   +124.35
10:42:30   +124.37
10:43:00   +124.43
10:43:30   +124.45
10:44:00   +124.39
10:44:30   +124.16
10:45:00   +124.01
10:45:30   +123.91
10:46:00   +123.77
10:46:30   +123.64
10:47:00   +123.56
10:47:30   +123.42

10:48:00   +123.32
10:48:30   +123.19
10:49:00   +123.08
10:49:30   +123.00
10:50:00   +122.87
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time     Chnl 1
10:51:00   +122.62
10:52:00   +122.56
10:53:00   +122.44
10:54:00   +122.35
10:55:00   +122.26
10:56:00   +122.18
10:57:00   +122.09
10:58:00   +121.99
10:59:00   +121.90
11:00:00   +121.81
11:01:00   +121.71
11:02:00   +121.59
11:03:00   +121.48
11:04:00   +121.41
11:05:00   +121.29
11:06:00   +121.20
11:07:00   +121.10
11:08:00   +121.01
11:09:00   +120.90
11:10:00   +120.80
11:11:00   +120.71
11:12:00   +120.63
11:13:00   +120.54
11:14:00   +120.45
11:15:00   +120.36
11:16:00   +120.29
11:17:00   +120.20
11:18:00   +120.13
11:19:00   +120.03
11:20:00   +119.95
11:21:00   +119.86
11:22:00   +119.79
11:23:00   +119.71
11:24:00   +119.63
11:25:00   +119.54
11:26:00   +119.49
11:27:00   +119.40
11:28:00   +119.33
11:29:00   +119.27
11:30:00   +119.22
---------------
```

```
I-32 cont.

Step 4
Interval 01:00:00
Readings 25
---------------
   Time     Chnl 1
12:30:00   +115.67
13:30:00   +144.30
14:30:00   +145.73
15:30:00   +145.42
16:30:00   +145.13
17:30:00   +144.87
18:30:00   +144.54
19:30:00   +144.82
20:30:00   +145.52
21:30:00   +146.12
22:30:00   +146.60
23:30:00   +147.09
--  6/15
00:30:00   +147.53
01:30:00   +148.03
02:30:00   +148.46
03:30:00   +148.84
04:30:00   +149.27
05:30:00   +149.61
06:30:00   +149.84
07:30:00   +149.73
08:30:00   +149.58
09:30:00   +149.22
10:30:00   +148.94
11:30:00   +149.04
12:30:00   +148.72
---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 1989

DRAWDOWN DATA
FORESTDALE VILLAGE WELL
Elev. of Transducer = 61.6 ft (msl)

Model SDEE-01B
S/N 0290    Block 1
--------------------
Program:     STEP TEST
Readings:    131
Start Time: 21:00:00
Start date: 06/15
Range:       0050 PSI
Units:       Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time      Chnl 1
21:00:00   +145.55
21:00:06   +146.01
21:00:12   +145.81
21:00:18   +145.60
21:00:24   +145.44
21:00:30   +145.26
21:00:36   +145.07
21:00:42   +144.89
21:00:48   +144.74
21:00:54   +144.58
21:01:00   +144.43
21:01:06   +144.25
21:01:12   +144.07
21:01:18   +143.91
21:01:24   +143.75
21:01:30   +143.57
21:01:36   +143.41
21:01:42   +143.27
21:01:48   +143.14
21:01:54   +142.94
21:02:00   +142.79
21:02:06   +142.66
21:02:12   +142.49
21:02:18   +142.36
21:02:24   +142.22
21:02:30   +142.10
21:02:36   +141.95
21:02:42   +141.83
21:02:48   +141.68
21:02:54   +141.54
21:03:00   +141.43
---------------

Step 2
Interval 00:00:30
Readings 34
---------------
   Time      Chnl 1
21:03:30   +140.34
21:04:00   +140.29
21:04:30   +139.74
21:05:00   +139.35
21:05:30   +138.75
21:06:00   +138.31
21:06:30   +137.88
21:07:00   +137.45
21:07:30   +137.02
21:08:00   +136.58
21:08:30   +135.19
21:09:00   +135.81
21:09:30   +135.42
21:10:00   +135.04
21:10:30   +134.51
21:11:00   +134.04
21:11:30   +133.52
21:12:00   +132.79
21:12:30   +131.94
21:13:00   +131.08
21:13:30   +130.30
21:14:00   +129.68
21:14:30   +129.08
21:15:00   +128.48
21:15:30   +127.90
21:16:00   +127.30
21:16:30   +126.73
21:17:00   +126.16
21:17:30   +125.63
21:18:00   +125.11
21:18:30   +124.59
21:19:00   +124.05
21:19:30   +123.57
21:20:00   +123.08
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time      Chnl 1
21:21:00   +122.14
21:22:00   +121.28
21:23:00   +120.39
21:24:00   +119.57

21:25:00   +118.79
21:26:00   +118.24
21:27:00   +117.29
21:28:00   +116.60
21:29:00   +115.88
21:30:00   +115.27
21:31:00   +114.65
21:32:00   +114.03
21:33:00   +113.45
21:34:00   +112.93
21:35:00   +112.36
21:36:00   +111.85
21:37:00   +111.37
21:38:00   +110.88
21:39:00   +110.40
21:40:00   +109.92
21:41:00   +109.48
21:42:00   +109.01
21:43:00   +108.60
21:44:00   +108.14
21:45:00   +107.76
21:46:00   +107.39
21:47:00   +107.00
21:48:00   +106.66
21:49:00   +106.32
21:50:00   +105.97
21:51:00   +105.64
21:52:00   +105.34
21:53:00   +105.01
21:54:00   +104.69
21:55:00   +104.39
21:56:00   +104.11
21:57:00   +103.81
21:58:00   +103.55
21:59:00   +103.29
22:00:00   +103.05
---------------
Step 4
Interval 01:00:00
Readings 26
---------------
   Time      Chnl 1
23:00:00   +94.919
--  6/16
00:00:00   +92.093
01:00:00   +90.813
02:00:00   +89.925
03:00:00   +89.212
04:00:00   +88.656

05:00:00   +88.299
06:00:00   +87.932
07:00:00   +87.375
08:00:00   +86.857
09:00:00   +86.583
10:00:00   +86.315
11:00:00   +85.715
12:00:00   +84.470
13:00:00   +83.074
14:00:00   +82.762
15:00:00   +82.544
16:00:00   +82.278
17:00:00   +81.044
18:00:00   +79.937
19:00:00   +79.545
20:00:00   +79.493
21:00:00   +79.372
22:00:00   +79.257
23:00:00   +79.295
--  6/17
00:00:00   +79.049
---------------


NEW TEST


Model SDEE-01B
S/N 0290    Block 2
--------------------
Program:     INTERVAL
Readings:    37
Start Time: 01:00:00
Start date: 06/17
Range:       0050 PSI
Units:       Ft-H20
--------------------
Interval:  01:00:00
   Time      Chnl 1
01:00:00   +79.199
02:00:00   +79.352
03:00:00   +79.326
04:00:00   +79.014
05:00:00   +78.807
06:00:00   +78.725
07:00:00   +78.680
08:00:00   +78.507
09:00:00   +78.436
10:00:00   +78.196
```

```
I-32P cont

11:00:00   +56.339
12:00:00   +60.469
13:00:00   +58.300
14:00:00   +49.916
15:00:00   +41.050
16:00:00   +37.310
17:00:00   +35.110
18:00:00   +34.615
19:00:00   +34.091
20:00:00   +33.515
21:00:00   +33.077
22:00:00   +32.777
23:00:00   +32.304
--   6/18
00:00:00   +31.947
01:00:00   +31.647
02:00:00   +31.313
03:00:00   +31.070
04:00:00   +30.590
05:00:00   +30.528
06:00:00   +30.171
07:00:00   +29.963
08:00:00   +29.721
09:00:00   +29.675
10:00:00   +29.306
11:00:00   +28.856
12:00:00   +27.622
13:00:00   +26.699
---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 1988

RECOVERY DATA
FORESTDALE VILLAGE WELL
Elev. of Transducer = 32.2 ft (msl)

Model SDEE-018
S/N 0290    Block 1
---------------------
Program:    STEP TEST
Readings:   167
Start Time: 20:00:00
Start date: 06/19
Range:      0250 PSI
Units:      Ft-H20
---------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time     Chnl 1
20:00:00   +2.7564
20:00:06   +3.6791
20:00:12   +4.5594
20:00:18   +5.6157
20:00:24   +6.5740
20:00:30   +7.4505
20:00:36   +8.3270
20:00:42   +9.1805
20:00:48   +10.010
20:00:54   +10.852
20:01:00   +11.660
20:01:06   +12.353
20:01:12   +13.055
20:01:18   +13.713
20:01:24   +14.347
20:01:30   +15.004
20:01:36   +15.650
20:01:42   +16.250
20:01:48   +16.827
20:01:54   +17.461
20:02:00   +18.015
20:02:06   +18.545
20:02:12   +19.006
20:02:18   +19.537
20:02:24   +20.021
20:02:30   +20.483
20:02:36   +20.967
20:02:42   +21.428
20:02:48   +21.867
20:02:54   +22.317
20:03:00   +22.766
---------------

Step 2
Interval 00:00:30
Readings 34
---------------
   Time     Chnl 1
20:03:30   +24.427
20:04:00   +26.075
20:04:30   +27.726
20:05:00   +29.336
20:05:30   +31.024
20:06:00   +32.697
20:06:30   +34.286
20:07:00   +35.995
20:07:30   +37.598
20:08:00   +39.224
20:08:30   +40.816
20:09:00   +42.361
20:09:30   +43.965
20:10:00   +45.459
20:10:30   +46.744
20:11:00   +48.117
20:11:30   +49.420
20:12:00   +50.508
20:12:30   +51.727
20:13:00   +52.972
20:13:30   +54.241
20:14:00   +55.452
20:14:30   +56.594
20:15:00   +57.758
20:15:30   +58.958
20:16:00   +60.111
20:16:30   +61.265
20:17:00   +62.441
20:17:30   +63.548
20:18:00   +64.598
20:18:30   +65.740
20:19:00   +66.801
20:19:30   +67.996
20:20:00   +69.003
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time     Chnl 1
20:21:00   +71.126
20:22:00   +73.213
20:23:00   +75.301
20:24:00   +77.342

20:25:00   +79.176
20:26:00   +81.125
20:27:00   +82.947
20:28:00   +84.723
20:29:00   +86.453
20:30:00   +88.172
20:31:00   +89.857
20:32:00   +91.643
20:33:00   +93.247
20:34:00   +94.873
20:35:00   +96.591
20:36:00   +98.033
20:37:00   +99.405
20:38:00   +100.83
20:39:00   +102.23
20:40:00   +103.55
20:41:00   +104.86
20:42:00   +106.03
20:43:00   +107.23
20:44:00   +108.37
20:45:00   +109.54
20:46:00   +110.60
20:47:00   +111.65
20:48:00   +112.66
20:49:00   +113.68
20:50:00   +114.62
20:51:00   +115.51
20:52:00   +116.47
20:53:00   +117.37
20:54:00   +118.21
20:55:00   +119.03
20:56:00   +119.80
20:57:00   +120.62
20:58:00   +121.39
20:59:00   +122.20
21:00:00   +123.10
---------------
Step 4
Interval 01:00:00
Readings 62
---------------
   Time     Chnl 1
22:00:00   +140.35
23:00:00   +144.88
--  6/20
00:00:00   +147.65
01:00:00   +150.34
02:00:00   +152.06
03:00:00   +153.95

04:00:00   +155.49
05:00:00   +156.98
06:00:00   +158.60
07:00:00   +159.80
08:00:00   +160.93
09:00:00   +161.74
10:00:00   +162.25
11:00:00   +162.73
12:00:00   +163.28
13:00:00   +163.77
14:00:00   +164.18
15:00:00   +164.03
16:00:00   +163.79
17:00:00   +163.43
18:00:00   +163.41
19:00:00   +163.69
20:00:00   +163.78
21:00:00   +164.16
22:00:00   +164.82
23:00:00   +165.21
--  6/21
00:00:00   +165.76
01:00:00   +166.32
02:00:00   +166.60
03:00:00   +167.27
04:00:00   +167.74
05:00:00   +168.15
06:00:00   +168.49
07:00:00   +168.74
08:00:00   +168.88
09:00:00   +169.00
10:00:00   +169.13
11:00:00   +168.95
12:00:00   +167.90
13:00:00   +168.08
14:00:00   +168.45
15:00:00   +168.65
16:00:00   +168.62
17:00:00   +168.75
18:00:00   +168.49
19:00:00   +168.35
20:00:00   +168.17
21:00:00   +168.24
22:00:00   +168.68
23:00:00   +169.00
--  6/22
00:00:00   +169.42
01:00:00   +169.86
02:00:00   +170.37
```

```
I-32R cont

03:00:00   +170.77
04:00:00   +171.17
05:00:00   +171.54
06:00:00   +171.76
07:00:00   +171.73
08:00:00   +171.96
09:00:00   +172.27
10:00:00   +172.35
11:00:00   +172.33
---------------
```

```
STAMINA MILLS PUMPING - JUNE 1988

BACKGROUND DATA
Post Office (I-31)
Elev. of Transducer = 142.7 ft (msl)

Model SDEE-01B
S/N 0295     Block 1
--------------------
Program:     INTERVAL
Readings:    73
Start Time: 16:00:00
Start date: 06/10
Range:       0015 PSI
Units:       Ft-H20
--------------------
Interval:  01:00:00
  Time      Chnl 1
16:00:00   +68.293
17:00:00   +68.143
18:00:00   +67.988
19:00:00   +67.822
20:00:00   +67.577
21:00:00   +67.573
22:00:00   +57.515
23:00:00   +67.510
--  6/11
00:00:00   +67.533
01:00:00   +57.562
02:00:00   +67.625
03:00:00   +57.577
04:00:00   +67.735
05:00:00   +67.787
06:00:00   +67.832
07:00:00   +57.857
08:00:00   +57.897
09:00:00   +67.942
10:00:00   +57.977
11:00:00   +67.752
12:00:00   +67.348
13:00:00   +67.140
14:00:00   +67.032
15:00:00   +56.533
16:00:00   +66.615
17:00:00   +56.133
18:00:00   +65.895
19:00:00   +56.750
20:00:00   +65.578
21:00:00   +55.612
22:00:00   +65.595
23:00:00   +55.612
--  6/12
00:00:00   +65.553
01:00:00   +65.717
02:00:00   +65.820
03:00:00   +65.947
```

```
24:00:00   +65.085
05:00:00   +66.218
25:00:00   +66.350
07:00:00   +66.472
08:00:00   +65.582
09:00:00   +65.685
10:00:00   +66.777
11:00:00   +66.893
12:00:00   +66.997
13:00:00   +67.083
14:00:00   +67.158
15:00:00   +67.158
16:00:00   +67.020
17:00:00   +66.777
18:00:00   +66.472
19:00:00   +66.155
20:00:00   +65.872
21:00:00   +65.670
22:00:00   +65.532
23:00:00   +65.445
--  6/13
00:00:00   +65.405
01:00:00   +55.417
02:00:00   +65.457
03:00:00   +65.515
04:00:00   +65.590
05:00:00   +65.670
06:00:00   +65.768
07:00:00   +55.867
08:00:00   +65.958
09:00:00   +66.022
10:00:00   +66.057
11:00:00   +66.073
12:00:00   +65.038
13:00:00   +65.867
14:00:00   +65.733
15:00:00   +55.642
16:00:00   +65.548
---------------
```

```
NEW TEST


Model SDEE-01B
S/N 0295     Block 2
--------------------
Program:     STEP TEST
Readings:    130
Start Time: 16:30:00
Start date: 06/13
Range:       0015 PSI
Units:       Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
  Time      Chnl 1
16:30:00   +65.480
16:30:06   +65.480
15:30:12   +65.399
16:30:18   +65.399
16:30:24   +55.480
16:30:30   +65.399
16:30:36   +65.399
16:30:42   +65.399
15:30:48   +55.399
16:30:54   +65.399
16:31:00   +65.462
16:31:06   +65.462
16:31:12   +65.399
16:31:18   +65.462
16:31:24   +65.462
16:31:30   +65.462
16:31:36   +65.462
16:31:42   +65.462
15:31:48   +65.399
16:31:54   +65.462
15:32:00   +65.462
16:32:06   +65.462
16:32:12   +55.462
16:32:18   +65.462
16:32:24   +65.462
16:32:30   +65.462
15:32:36   +65.462
16:32:42   +65.462
16:32:48   +55.462
16:32:54   +65.462
16:33:00   +55.462
---------------
```

```
Step 2
Interval 00:00:30
Readings 34
---------------
  Time      Chnl 1
16:33:30   +65.399
16:34:00   +65.462
16:34:30   +65.462
16:35:00   +55.462
16:35:30   +65.462
16:36:00   +55.457
16:36:30   +65.457
16:37:00   +65.457
16:37:30   +65.457
15:38:00   +55.457
16:38:30   +65.452
16:39:00   +65.445
16:39:30   +65.452
16:40:00   +65.433
16:40:30   +65.445
16:41:00   +65.445
16:41:30   +65.445
16:42:00   +65.433
16:42:30   +65.428
16:43:00   +65.428
16:43:30   +65.428
15:44:00   +65.428
16:44:30   +65.428
15:45:00   +55.422
16:45:30   +65.422
16:46:00   +65.422
16:46:30   +65.422
16:47:00   +55.422
16:47:30   +65.417
15:48:00   +65.417
16:48:30   +65.405
15:49:00   +55.417
16:49:30   +65.405
16:50:00   +65.398
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
  Time      Chnl 1
16:51:00   +65.393
15:52:00   +65.393
16:53:00   +65.393
16:54:00   +55.397
16:55:00   +65.382
```

I-31 cont.

```
16:56:00   +65.382
16:57:00   +65.270
16:58:00   +65.365
16:59:00   +65.358
17:00:00   +65.342
17:01:00   +65.342
17:02:00   +65.342
17:03:00   +65.342
17:04:00   +65.323
17:05:00   +65.323
17:06:00   +65.318
17:07:00   +65.318
17:08:00   +65.301
17:09:00   +65.295
17:10:00   +65.290
17:11:00   +65.278
17:12:00   +65.278
17:13:00   +65.267
17:14:00   +65.267
17:15:00   +65.255
17:16:00   +65.255
17:17:00   +65.255
17:18:00   +65.237
17:19:00   +65.227
17:20:00   +65.227
17:21:00   +65.220
17:22:00   +65.203
17:23:00   +65.197
17:24:00   +65.197
17:25:00   +65.192
17:26:00   +65.180
17:27:00   +65.168
17:28:00   +65.163
17:29:00   +65.163
17:30:00   +65.157
---------------
Step 4
Interval 01:00:00
Readings 25
---------------
   Time     Chnl 1
18:30:00   +64.650
19:30:00   +64.327
20:30:00   +64.363
21:30:00   +64.107
22:30:00   +64.043
23:30:00   +64.038
-- '6/14
00:30:00   +64.055
01:30:00   +64.113
02:30:00   +64.198
03:30:00   +64.275
04:30:00   +64.372
05:30:00   +64.458
06:30:00   +64.533
07:30:00   +64.592
08:30:00   +64.627
09:30:00   +64.555
10:30:00   +64.713
11:30:00   +64.660
12:30:00   +64.505
13:30:00   +64.395
14:30:00   +64.453
15:30:00   +64.488
16:30:00   +64.488
17:30:00   +64.465
18:30:00   +64.437
---------------
NEW TEST


Model SDEE-01B
S/N 0295    Block 3
--------------------
Program:    INTERVAL
Readings:   24
Start Time: 20:00:00
Start date: 06/14
Range:      0015 PSI
Units:      Ft-H20
--------------------
Interval:  01:00:00
   Time     Chnl 1
20:00:00   +64.372
21:00:00   +64.413
22:00:00   +64.425
23:00:00   +64.455
--  6/15
00:00:00   +64.528
01:00:00   +64.620
02:00:00   +64.725
03:00:00   +64.845
04:00:00   +64.972
05:00:00   +65.098
06:00:00   +65.220
07:00:00   +65.323
08:00:00   +65.405
09:00:00   +65.457
10:00:00   +65.585
11:00:00   +65.485
12:00:00   +65.492
13:00:00   +65.485
```

STAMINA MILLS PUMPING - JUNE 1988

DRAWDOWN DATA
POST OFFICE WELL
Elev. of Transducer = 142.7 ft (msl)

```
Model SDEE-013
S/N 0295    Block 1
--------------------
Program:    STEP TEST
Readings:   138
Start Time: 21:00:00
Start date: 06/15
Range:      0015 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time    Chnl 1
21:00:00   +
21:00:06   +65.382
21:00:12   +65.382
21:00:18   +65.382
21:00:24   +65.382
21:00:30   +65.382
21:00:36   +65.382
21:00:42   +65.382
21:00:48   +65.382
21:00:54   +65.370
21:01:00   +65.370
21:01:06   +65.370
21:01:12   +65.382
21:01:18   +65.382
21:01:24   +65.382
21:01:30   +65.370
21:01:36   +65.382
21:01:42   +65.382
21:01:48   +65.382
21:01:54   +65.382
21:02:00   +65.382
21:02:06   +65.382
21:02:12   +65.382
21:02:18   +55.382
21:02:24   +65.382
21:02:30   +55.370
21:02:36   +65.382
21:02:42   +65.370
21:02:48   +65.382
21:02:54   +65.382
21:03:00   +65.382
---------------
```

```
Step 2
Interval 00:00:30
Readings 34
---------------
   Time    Chnl 1
21:03:30   +65.382
21:04:00   +55.372
21:04:30   +65.370
21:05:00   +55.370
21:05:30   +65.370
21:06:00   +65.370
21:06:30   +65.370
21:07:00   +65.370
21:07:30   +65.370
21:08:00   +65.370
21:08:30   +65.370
21:09:00   +65.370
21:09:30   +65.370
21:10:00   +65.355
21:10:30   +65.370
21:11:00   +65.365
21:11:30   +65.365
21:12:00   +65.355
21:12:30   +65.370
21:13:00   +65.365
21:13:30   +65.365
21:14:00   +65.355
21:14:30   +65.365
21:15:00   +55.355
21:15:30   +65.365
21:16:00   +65.365
21:16:30   +65.365
21:17:00   +55.358
21:17:30   +65.358
21:18:00   +55.358
21:18:30   +65.358
21:19:00   +55.358
21:19:30   +65.358
21:20:00   +55.358
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time    Chnl 1
21:21:00   +65.353
21:22:00   +65.353
21:23:00   +65.342
21:24:00   +55.342
```

```
21:25:00   +55.342
21:26:00   +65.335
21:27:00   +55.335
21:28:00   +65.335
21:29:00   +65.330
21:30:00   +65.323
21:31:00   +55.323
21:32:00   +65.323
21:33:00   +65.319
21:34:00   +65.318
21:35:00   +65.307
21:36:00   +65.302
21:37:00   +65.302
21:38:00   +65.295
21:39:00   +65.295
21:40:00   +65.295
21:41:00   +55.290
21:42:00   +65.278
21:43:00   +65.272
21:44:00   +65.272
21:45:00   +65.267
21:46:00   +65.260
21:47:00   +55.250
21:48:00   +65.255
21:49:00   +65.243
21:50:00   +65.243
21:51:00   +55.237
21:52:00   +65.237
21:53:00   +65.227
21:54:00   +65.227
21:55:00   +55.220
21:56:00   +65.208
21:57:00   +55.208
21:58:00   +65.203
21:59:00   +65.197
22:00:00   +65.197
---------------
Step 4
Interval 01:00:00
Readings 33
---------------
   Time    Chnl 1
23:00:00   +64.829
--  6/16
00:00:00   +54.453
01:00:00   +54.118
02:00:00   +63.835
03:00:00   +63.577
04:00:00   +63.358
```

```
05:00:00   +63.155
06:00:00   +62.983
07:00:00   +52.798
08:00:00   +62.608
09:00:00   +62.383
10:00:00   +62.222
11:00:00   +62.065
12:00:00   +61.899
13:00:00   +61.703
14:00:00   +61.530
15:00:00   +61.391
16:00:00   +61.270
17:00:00   +51.150
18:00:00   +61.017
19:00:00   +60.780
20:00:00   +60.583
21:00:00   +60.405
22:00:00   +60.278
23:00:00   +60.158
--  6/17
00:00:00   +60.053
01:00:00   +59.950
02:00:00   +59.863
03:00:00   +59.765
04:00:00   +59.718
05:00:00   +59.662
06:00:00   +59.503
07:00:00   +59.563
---------------


NEW TEST


Model SDEE-018
S/N 0295    Block 2
--------------------
Program:    INTERVAL
Readings:   50
Start Time: 08:00:00
Start date: 06/17
Range:      0015 PSI
Units:      Ft-H20
--------------------
Interval:  01:00:00
   Time    Chnl 1
08:00:00   +59.505
09:00:00   +59.402
10:00:00   +59.315
```

```
I-31P cont

11:00:00   +59.223          13:00:00   +53.698
12:00:00   +59.113          14:00:00   +53.528
13:00:00   +59.003          15:00:00   +53.353
14:00:00   +58.893          16:00:00   +53.162
15:00:00   +58.727          17:00:00   +52.995
16:00:00   +58.612          18:00:00   +52.828
17:00:00   +58.485          19:00:00   +52.707
18:00:00   +58.358          ---------------
19:00:00   +58.223
20:00:00   +58.047
21:00:00   +57.943
22:00:00   +57.815
23:00:00   +57.707
--  6/18
00:00:00   +57.597
01:00:00   +57.487
02:00:00   +57.372
03:00:00   +57.292
04:00:00   +57.163
05:00:00   +57.083
06:00:00   +57.008
07:00:00   +56.950
08:00:00   +56.875
09:00:00   +56.755
10:00:00   +56.685
11:00:00   +56.593
12:00:00   +56.478
13:00:00   +56.333
14:00:00   +56.190
15:00:00   +56.063
16:00:00   +55.890
17:00:00   +55.700
18:00:00   +55.550
19:00:00   +55.382
20:00:00   +55.215
21:00:00   +55.082
22:00:00   +54.910
23:00:00   +54.812
--  5/19
00:00:00   +54.702
01:00:00   +54.603
02:00:00   +54.512
03:00:00   +54.425
04:00:00   +54.355
05:00:00   +54.292
06:00:00   +54.235
07:00:00   +54.172
08:00:00   +54.113
09:00:00   +54.050
10:00:00   +54.003
11:00:00   +53.918
12:00:00   +53.778
```

```
STAMINA MILLS PUMPING - JUNE 1989

RECOVERY DATA
POST OFFICE WELL
Elev. of Transducer = 142.7 ft (msl)

Model SDEE-015              Step 2                      20:25:00   +52.470
S/N 0295    Block 1         Interval 00:00:30           20:26:00   +52.470
--------------------        Readings 34                 20:27:00   +52.455
Program:    STEP TEST       ---------------             20:28:00   +52.465
Readings:   157               Time     Chnl 1           20:29:00   +52.455
Start Time: 20:00:00        20:03:30   +52.493          20:30:00   +52.465
Start date: 06/19           20:04:00   +52.493          20:31:00   +52.4554
Range:      0015 PSI        20:04:30   +52.493          20:32:00   +52.458
Units:      Ft-H20          20:05:00   +52.493          20:33:00   +52.458
--------------------        20:05:30   +52.493          20:34:00   +52.458
Step 1                      20:06:00   +52.493          20:35:00   +52.458
Interval 00:00:06           20:06:30   +52.493          20:36:00   +52.458
Readings 31                 20:07:00   +52.493          20:37:00   +52.458
---------------             20:07:30   +52.493          20:38:00   +52.447
  Time     Chnl 1           20:08:00   +52.493          20:39:00   +52.458
20:00:00   +52.430          20:08:30   +52.493          20:40:00   +52.447
20:00:06   +52.435          20:09:00   +52.493          20:41:00   +52.458
20:00:12   +52.442          20:09:30   +52.493          20:42:00   +0.0000
20:00:18   +52.447          20:10:00   +52.493
20:00:24   +52.458          20:10:30   +52.493
20:00:30   +52.458          20:11:00   +52.482
20:00:36   +52.465          20:11:30   +52.493
20:00:42   +52.465          20:12:00   +52.493
20:00:48   +52.470          20:12:30   +52.493
20:00:54   +52.470          20:13:00   +52.482
20:01:00   +52.470          20:13:30   +52.482
20:01:06   +52.470          20:14:00   +52.482
20:01:12   +52.477          20:14:30   +52.482
20:01:18   +52.470          20:15:00   +52.482
20:01:24   +52.482          20:15:30   +52.482
20:01:30   +52.482          20:16:00   +52.482
20:01:36   +52.482          20:16:30   +52.482
20:01:42   +52.477          20:17:00   +52.477
20:01:48   +52.482          20:17:30   +52.477
20:01:54   +52.482          20:18:00   +52.477
20:02:00   +52.482          20:18:30   +52.482
20:02:06   +52.482          20:19:00   +52.477
20:02:12   +52.482          20:19:30   +52.477
20:02:18   +52.493          20:20:00   +52.477
20:02:24   +52.482          ---------------
20:02:30   +52.493          Step 3
20:02:36   +52.493          Interval 00:01:00
20:02:42   +52.493          Readings 40
20:02:48   +52.493          ---------------
20:02:54   +52.493            Time     Chnl 1
20:03:00   +52.493          20:21:00   +52.477
---------------             20:22:00   +52.470
                            20:23:00   +52.470
                            20:24:00   +52.470
```

```
STAMINA MILLS PUMPING TEST - JUNE 1988

BACKGROUND DATA
Menoian (I-2)
Elev. of transducer = 180.22 ft (msl)

Model SDEE-012            ---------------           Step 3                    Step 4
S/N 0252   Block 1        Step 2                    Interval 00:01:00         Interval 01:00:00
--------------------      Interval 00:00:30         Readings 40               Readings 25
Program:    STEP TEST     Readings 34               ---------------           ---------------
Readings:   130           ---------------             Time      Chnl 1          Time      Chnl 1
Start Time: 16:30:00        Time      Chnl 1        16:51:00  +15.252         18:30:00  +14.013
Start date: 06/13         16:33:30  +17.017         16:52:00  +15.154         19:30:00  +17.334
Range:      0025 PSI      16:34:00  +16.971         16:53:00  +15.056         20:30:00  +18.297
Units:      Ft-H2O        16:34:30  +16.925         16:54:00  +14.976         21:30:00  +19.410
--------------------      16:35:00  +16.867         16:55:00  +14.878         22:30:00  +20.419
Step 1                    16:35:30  +16.804         16:56:00  +14.797         23:30:00  +21.261
Interval 00:00:06         16:36:00  +16.746         16:57:00  +14.705         --  6/14
Readings 31               16:36:30  +16.688         16:58:00  +14.635         00:30:00  +21.959
---------------           16:37:00  +16.631         16:59:00  +14.549         01:30:00  +22.657
  Time      Chnl 1        16:37:30  +16.561         17:00:00  +14.480         02:30:00  +23.280
16:30:00  +17.265         16:38:00  +16.504         17:01:00  +14.410         03:30:00  +23.816
16:30:06  +17.265         16:38:30  +16.440         17:02:00  +14.335         04:30:00  +24.306
16:30:12  +17.242         16:39:00  +16.388         17:03:00  +14.266         05:30:00  +24.773
16:30:18  +17.248         16:39:30  +16.325         17:04:00  +14.197         06:30:00  +24.439
16:30:24  +17.242         16:40:00  +16.262         17:05:00  +14.139         07:30:00  +24.168
16:30:30  +17.236         16:40:30  +16.221         17:06:00  +14.076         08:30:00  +24.283
16:30:36  +17.230         16:41:00  +16.163         17:07:00  +14.007         09:30:00  +25.142
16:30:42  +17.230         16:41:30  +16.112         17:08:00  +13.938         10:30:00  +25.638
16:30:48  +17.225         16:42:00  +16.077         17:09:00  +13.863         11:30:00  +23.856
16:30:54  +17.213         16:42:30  +16.019         17:10:00  +13.770         12:30:00  +23.193
16:31:00  +17.207         16:43:00  +15.979         17:11:00  +13.678         13:30:00  +22.997
16:31:06  +17.207         16:43:30  +15.939         17:12:00  +13.597         14:30:00  +22.363
16:31:12  +17.201         16:44:00  +15.887         17:13:00  +13.528         15:30:00  +20.834
16:31:18  +17.201         16:44:30  +15.846         17:14:00  +13.470         16:30:00  +20.431
16:31:24  +17.184         16:45:00  +15.806         17:15:00  +13.413         17:30:00  +19.935
16:31:30  +17.178         16:45:30  +15.766         17:16:00  +13.344         18:30:00  +20.056
16:31:36  +17.178         16:46:00  +15.725         17:17:00  +13.286         ---------------
16:31:42  +17.173         16:46:30  +15.685         17:18:00  +13.222
16:31:48  +17.155         16:47:00  +15.644         17:19:00  +13.171
16:31:54  +17.155         16:47:30  +15.593         17:20:00  +13.119
16:32:00  +17.150         16:48:00  +15.558         17:21:00  +13.073
16:32:06  +17.144         16:48:30  +15.512         17:22:00  +13.038
16:32:12  +17.138         16:49:00  +15.460         17:23:00  +12.986
16:32:18  +17.132         16:49:30  +15.408         17:24:00  +12.957
16:32:24  +17.121         16:50:00  +15.362         17:25:00  +12.923
16:32:30  +17.115         ---------------           17:26:00  +12.888
16:32:36  +17.103                                   17:27:00  +12.846
16:32:42  +17.092                                   17:28:00  +12.813
16:32:48  +17.086                                   17:29:00  +12.755
16:32:54  +17.075                                   17:30:00  +12.709
16:33:00  +17.063                                   ---------------
```

```
i-2 cont.

NEW TEST


Model SDEE-01B
S/N 0292    Block 2
--------------------
Program:    INTERVAL
Readings:   25
Start Time: 19:00:00
Start date: 06/14
Range:      0025 PSI
Units:      Ft-H20
--------------------
Interval:  01:00:00
   Time     Chnl 1
19:00:00   +20.125
20:00:00   +21.348
21:00:00   +22.385
22:00:00   +23.205
23:00:00   +23.914
--  6/15
00:00:00   +24.594
01:00:00   +25.258
02:00:00   +25.823
03:00:00   +26.359
04:00:00   +26.838
05:00:00   +27.299
06:00:00   +27.530
07:00:00   +27.259
08:00:00   +25.988
09:00:00   +26.451
10:00:00   +25.471
11:00:00   +25.823
12:00:00   +25.454
13:00:00   +24.220
14:00:00   +23.118
15:00:00   +22.213
16:00:00   +21.990
17:00:00   +23.508
18:00:00   +24.473
19:00:00   +24.958
20:00:00   +24.900
---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 1988

DRAWDOWN DATA
KENDIAN (I-2)
Elev. of Transducer = 181.1 ft (msl)

Model SDEE-01B          ---------------         ---------------         ---------------
S/N 0292    Block 1     Step 2                  Step 3                  Step 4
--------------------    Interval 00:00:30       Interval 00:01:00       Interval 01:00:00
Program:    STEP TEST   Readings 34             Readings 40             Readings 32
Readings:   137         ---------------         ---------------         ---------------
Start Time: 21:00:00      Time     Chnl 1         Time     Chnl 1         Time     Chnl 1
Start date: 06/15       21:03:30   +24.525      21:21:00   +23.537      23:00:00   +19.739
Range:      0025 PSI    21:04:00   +24.519      21:22:00   +23.574      --  6/16
Units:      Ft-H20      21:04:30   +24.496      21:23:00   +23.499      00:00:00   +19.249
--------------------    21:05:00   +24.467      21:24:00   +23.435      01:00:00   +18.862
Step 1                  21:05:30   +24.452      21:25:00   +23.372      02:00:00   +18.678
Interval 00:00:06       21:06:00   +24.433      21:26:00   +23.297      03:00:00   +18.482
Readings 31             21:06:30   +24.410      21:27:00   +23.233      04:00:00   +18.216
---------------         21:07:00   +24.398      21:28:00   +23.170      05:00:00   +18.061
  Time     Chnl 1       21:07:30   +24.369      21:29:00   +23.089      06:00:00   +17.761
21:00:00   +24.583      21:08:00   +24.346      21:30:00   +23.032      07:00:00   +16.798
21:00:06   +24.583      21:08:30   +24.335      21:31:00   +22.952      08:00:00   +15.659
21:00:12   +24.571      21:09:00   +24.306      21:32:00   +22.882      09:00:00   +16.458
21:00:18   +24.571      21:09:30   +24.289      21:33:00   +22.818      10:00:00   +16.071
21:00:24   +24.571      21:10:00   +24.260      21:34:00   +22.749      11:00:00   +15.397
21:00:30   +24.583      21:10:30   +24.243      21:35:00   +22.686      12:00:00   +12.986
21:00:36   +24.571      21:11:00   +24.220      21:36:00   +22.605      13:00:00   +13.926
21:00:42   +24.583      21:11:30   +24.196      21:37:00   +22.541      14:00:00   +14.139
21:00:48   +24.583      21:12:00   +24.168      21:38:00   +22.472      15:00:00   +14.197
21:00:54   +24.571      21:12:30   +24.139      21:39:00   +22.409      16:00:00   +13.874
21:01:00   +24.571      21:13:00   +24.121      21:40:00   +22.334      17:00:00   +10.927
21:01:06   +24.583      21:13:30   +24.093      21:41:00   +22.265      18:00:00   +10.610
21:01:12   +24.571      21:14:00   +24.070      21:42:00   +22.195      19:00:00   +10.922
21:01:18   +24.571      21:14:30   +24.041      21:43:00   +22.138      20:00:00   +11.233
21:01:24   +24.571      21:15:00   +24.006      21:44:00   +22.057      21:00:00   +11.129
21:01:30   +24.566      21:15:30   +23.977      21:45:00   +22.005      22:00:00   +11.296
21:01:36   +24.571      21:16:00   +23.948      21:46:00   +21.930      23:00:00   +11.175
21:01:42   +24.566      21:16:30   +23.920      21:47:00   +21.861      --  6/17
21:01:48   +24.566      21:17:00   +23.885      21:48:00   +21.803      00:00:00   +11.302
21:01:54   +24.565      21:17:30   +23.856      21:49:00   +21.734      01:00:00   +11.504
21:02:00   +24.571      21:18:00   +23.827      21:50:00   +21.659      02:00:00   +11.637
21:02:06   +24.560      21:18:30   +23.799      21:51:00   +21.584      03:00:00   +11.665
21:02:12   +24.560      21:19:00   +23.764      21:52:00   +21.515      04:00:00   +11.759
21:02:18   +24.560      21:19:30   +23.735      21:53:00   +21.440      05:00:00   +11.852
21:02:24   +24.554      21:20:00   +23.701      21:54:00   +21.377      06:00:00   +11.637
21:02:30   +24.560                              21:55:00   +21.313      ---------------
21:02:36   +24.554                              21:56:00   +21.244
21:02:42   +24.542                              21:57:00   +21.186
21:02:48   +24.542                              21:58:00   +21.123
21:02:54   +24.542                              21:59:00   +21.071
21:03:00   +24.542                              22:00:00   +21.007
```

I-2 cont.

```
NEW TEST


Model SDEE-01B
S/N 0292    Block 2
--------------------
Program:     INTERVAL
Readings:    61
Start Time: 07:00:00
Start date: 06/17
Range:       0025 PSI
Units:       Ft-H20
--------------------
Interval:  01:00:00
   Time     Chnl 1
07:00:00   +11.608
08:00:00   +11.591
09:00:00   +11.567
10:00:00   +11.262
11:00:00   +10.622
12:00:00   +9.7341
13:00:00   +9.5496
14:00:00   +8.7192
15:00:00   +8.1079
16:00:00   +7.1852
17:00:00   +6.8162
18:00:00   +6.1472
19:00:00   +6.0261
20:00:00   +5.9858
21:00:00   +6.0088
22:00:00   +5.9339
23:00:00   +5.8243
--  5/18
00:00:00   +5.6513
01:00:00   +5.4956
02:00:00   +5.3168
03:00:00   +5.2765
04:00:00   +5.1900
05:00:00   +5.1208
06:00:00   +5.0285
07:00:00   +4.9420
08:00:00   +4.6479
09:00:00   +3.9732
10:00:00   +3.3216
11:00:00   +2.0933
12:00:00   +0.3921
13:00:00   +0.3921
14:00:00   +0.3921
15:00:00   +0.3921
16:00:00   +0.3921
17:00:00   +0.3863
18:00:00   +0.3806
19:00:00   +0.3748
20:00:00   +0.3690
21:00:00   +0.3690
22:00:00   +0.3517
23:00:00   +0.3460
--  5/19
00:00:00   +0.3460
01:00:00   +0.3460
02:00:00   +0.3402
03:00:00   +0.3450
04:00:00   +0.3402
05:00:00   +0.3460
06:00:00   +0.3460
07:00:00   +0.3450
08:00:00   +0.3460
09:00:00   +0.3402
10:00:00   +0.3460
11:00:00   +0.3460
12:00:00   +0.3460
13:00:00   +0.3690
14:00:00   +0.3575
15:00:00   +0.3517
16:00:00   +0.3575
17:00:00   +0.3517
18:00:00   +0.3517
19:00:00   +0.3517
---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 1988

RECOVERY DATA
KENDIAN (I-2)
Elev. of Transducer =191.3 ft (msl)

Model SDEE-01B            Step 2                    20:25:00  +0.3517         04:00:00  +5.3111
S/N 0232    Block 1       Interval 00:00:30         20:26:00  +0.3517         05:00:00  +6.4875
--------------------      Readings 34               20:27:00  +0.3517         06:00:00  +7.3352
Program:    STEP TEST     ---------------           20:28:00  +0.3517         07:00:00  +8.0733
Readings:   165              Time    Chnl 1         20:29:00  +0.3517         08:00:00  +9.2785
Start Time: 20:00:00      20:03:30  +0.3517         20:30:00  +0.3517         09:00:00  +10.097
Start date: 06/19         20:04:00  +0.3575         20:31:00  +0.3517         10:00:00  +10.501
Range:      0025 PSI      20:04:30  +0.3690         20:32:00  +0.3575         11:00:00  +10.950
Units:      Ft-H20        20:05:00  +0.3575         20:33:00  +0.3517         12:00:00  +11.977
--------------------      20:05:30  +0.3575         20:34:00  +0.3460         13:00:00  +12.571
Step 1                    20:06:00  +0.3517         20:35:00  +0.3460         14:00:00  +12.634
Interval 00:00:06         20:06:30  +0.3575         20:36:00  +0.3460         15:00:00  +11.591
Readings 31               20:07:00  +0.3575         20:37:00  +0.3517         16:00:00  +11.227
---------------           20:07:30  +0.3575         20:38:00  +0.3460         17:00:00  +10.391
   Time    Chnl 1         20:08:00  +0.3575         20:39:00  +0.3517         18:00:00  +10.512
20:00:00  +0.3517         20:08:30  +0.3575         20:40:00  +0.3517         19:00:00  +10.899
20:00:06  +0.3517         20:09:00  +0.3575         20:41:00  +0.3460         20:00:00  +11.256
20:00:12  +0.3517         20:09:30  +0.3575         20:42:00  +0.3460         21:00:00  +12.115
20:00:18  +0.3460         20:10:00  +0.3575         20:43:00  +0.3517         22:00:00  +13.090
20:00:24  +0.3517         20:10:30  +0.3575         20:44:00  +0.3517         23:00:00  +13.315
20:00:30  +0.3517         20:11:00  +0.3575         20:45:00  +0.3575         --  6/21
20:00:36  +0.3575         20:11:30  +0.3575         20:46:00  +0.3517         00:00:00  +14.295
20:00:42  +0.3517         20:12:00  +0.3517         20:47:00  +0.3517         01:00:00  +15.033
20:00:48  +0.3517         20:12:30  +0.3575         20:48:00  +0.3460         02:00:00  +15.668
20:00:54  +0.3517         20:13:00  +0.3575         20:49:00  +0.3517         03:00:00  +16.285
20:01:00  +0.3575         20:13:30  +0.3575         20:50:00  +0.3517         04:00:00  +16.798
20:01:06  +0.3575         20:14:00  +0.3575         20:51:00  +0.3460         05:00:00  +17.334
20:01:12  +0.3575         20:14:30  +0.3575         20:52:00  +0.3517         06:00:00  +17.669
20:01:18  +0.3517         20:15:00  +0.3517         20:53:00  +0.3517         07:00:00  +17.842
20:01:24  +0.3575         20:15:30  +0.3575         20:54:00  +0.3517         08:00:00  +17.755
20:01:30  +0.3517         20:16:00  +0.3575         20:55:00  +0.3575         09:00:00  +18.026
20:01:36  +0.3517         20:16:30  +0.3575         20:56:00  +0.3575         10:00:00  +17.974
20:01:42  +0.3575         20:17:00  +0.3517         20:57:00  +0.3575         11:00:00  +16.313
20:01:48  +0.3517         20:17:30  +0.3575         20:58:00  +0.3575         12:00:00  +14.664
20:01:54  +0.3575         20:18:00  +0.3575         20:59:00  +0.3517         13:00:00  +15.869
20:02:00  +0.3517         20:18:30  +0.3517         21:00:00  +0.3460         14:00:00  +16.469
20:02:06  +0.3517         20:19:00  +0.3575         ---------------           15:00:00  +16.631
20:02:12  +0.3575         20:19:30  +0.3575         Step 4                    16:00:00  +16.734
20:02:18  +0.3575         20:20:00  +0.3575         Interval 01:00:00         17:00:00  +16.481
20:02:24  +0.3517         ---------------           Readings 60               18:00:00  +16.106
20:02:30  +0.3517         Step 3                    ---------------           19:00:00  +15.714
20:02:36  +0.3690         Interval 00:01:00            Time    Chnl 1         20:00:00  +16.048
20:02:42  +0.3575         Readings 40               22:00:00  +0.3575         21:00:00  +16.257
20:02:48  +0.3575         ---------------           23:00:00  +0.3575         22:00:00  +16.925
20:02:54  +0.3690            Time    Chnl 1         --  6/20                  23:00:00  +17.385
20:03:00  +0.3517         20:21:00  +0.3517         00:00:00  +0.3690         --  6/22
---------------           20:22:00  +0.3575         01:00:00  +0.6574         00:00:00  +18.009
                          20:23:00  +0.3575         02:00:00  +2.2547         01:00:00  +18.672
                          20:24:00  +0.3517         03:00:00  +3.9098         02:00:00  +19.239
```

```
I-2R cont

03:00:00   +19.745
04:00:02   +20.375
05:00:00   +20.633
06:00:00   +20.829
07:00:00   +20.702
08:00:00   +21.129
09:00:00   +21.221
---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 1989

BACKGROUND DATA
J. Freitas (I-13)
Elev. of Transducer = 190.3 ft (msl)

Model SDEE-01B
S/N 0234    Block 11
--------------------
Program:     STEP TEST
Readings:    123
Start Time: 16:30:00
Start date: 06/13
Range:       0015 PSI
Units:       Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
  Time     Chnl 1
16:30:00  +17.016
16:30:06  +17.009
16:30:12  +17.009
16:30:18  +17.009
16:30:24  +17.009
16:30:30  +17.005
16:30:36  +17.005
16:30:42  +17.005
16:30:48  +17.005
16:30:54  +17.002
16:31:00  +16.998
16:31:06  +16.998
16:31:12  +16.998
16:31:18  +16.998
16:31:24  +16.992
16:31:30  +16.988
16:31:36  +16.985
16:31:42  +16.988
16:31:48  +16.981
16:31:54  +16.985
16:32:00  +16.974
16:32:06  +16.971
16:32:12  +16.971
16:32:18  +16.971
16:32:24  +16.971
16:32:30  +16.967
16:32:36  +16.967
16:32:42  +16.964
16:32:48  +16.960
16:32:54  +16.960
16:33:00  +16.954
---------------

Step 2
Interval 00:00:30
Readings 34
---------------
  Time     Chnl 1
16:33:30  +16.936
16:34:00  +16.925
16:34:30  +16.909
16:35:00  +16.895
16:35:30  +16.877
16:36:00  +16.857
16:36:30  +16.836
16:37:00  +16.815
16:37:30  +16.798
16:38:00  +16.777
16:38:30  +16.760
16:39:00  +16.739
16:39:30  +16.718
16:40:00  +16.701
16:40:30  +16.680
16:41:00  +16.652
16:41:30  +16.632
16:42:00  +16.611
16:42:30  +16.590
16:43:00  +16.569
16:43:30  +16.552
16:44:00  +16.535
16:44:30  +16.511
16:45:00  +16.483
16:45:30  +16.466
16:46:00  +16.445
16:46:30  +16.424
16:47:00  +16.403
16:47:30  +16.383
16:48:00  +16.362
16:48:30  +16.341
16:49:00  +16.324
16:49:30  +16.306
16:50:00  +16.279
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
  Time     Chnl 1
16:51:00  +16.241
16:52:00  +16.199
16:53:00  +16.161
16:54:00  +16.123
16:55:00  +16.082
16:56:00  +16.044
16:57:00  +16.005
16:58:00  +15.967
16:59:00  +15.929
17:00:00  +15.891
17:01:00  +15.857
17:02:00  +15.819
17:03:00  +15.781
17:04:00  +15.746
17:05:00  +15.711
17:06:00  +15.673
17:07:00  +15.639
17:08:00  +15.608
17:09:00  +15.573
17:10:00  +15.538
17:11:00  +15.507
17:12:00  +15.469
17:13:00  +15.441
17:14:00  +15.407
17:15:00  +15.376
17:16:00  +15.345
17:17:00  +15.313
17:18:00  +15.279
17:19:00  +15.251
17:20:00  +15.217
17:21:00  +15.185
17:22:00  +15.161
17:23:00  +15.130
17:24:00  +15.099
17:25:00  +15.068
17:26:00  +15.037
17:27:00  +15.009
17:28:00  +14.978
17:29:00  +14.950
17:30:00  +14.919
---------------
Step 4
Interval 01:00:00
Readings 18
---------------
  Time     Chnl 1
18:30:00  +14.881
19:30:00  +14.929
20:30:00  +15.102
21:30:00  +15.241
22:30:00  +15.421
23:30:00  +15.594
--  6/14
00:30:00  +15.791
01:30:00  +15.978
02:30:00  +16.182
03:30:00  +16.386
04:30:00  +16.593
05:30:00  +16.756
06:30:00  +16.857
07:30:00  +16.874
08:30:00  +16.909
09:30:00  +17.026
10:30:00  +17.175
11:30:00  +16.095
---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 1988

DRAWDOWN DATA
J. FREITAS (I-13)
Elev. of Transducer = 190.3 ft. (msl)

Model SDEE-01B
S/N 0294    Block 1
--------------------
Program:     STEP TEST
Readings:    138
Start Time: 21:00:00
Start date: 06/15
Range:       0015 PSI
Units:       Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time     Chnl 1
21:00:00   +18.327
21:00:06   +18.327
21:00:12   +18.324
21:00:18   +18.324
21:00:24   +18.324
21:00:30   +18.324
21:00:36   +18.320
21:00:42   +18.320
21:00:48   +18.320
21:00:54   +18.320
21:01:00   +18.317
21:01:05   +18.317
21:01:12   +18.317
21:01:18   +18.317
21:01:24   +18.313
21:01:30   +18.313
21:01:36   +18.306
21:01:42   +18.306
21:01:48   +18.303
21:01:54   +18.303
21:02:00   +18.303
21:02:05   +18.299
21:02:12   +18.299
21:02:18   +18.296
21:02:24   +18.296
21:02:30   +18.289
21:02:36   +18.289
21:02:42   +18.285
21:02:48   +18.285
21:02:54   +18.282
21:03:00   +18.282
---------------

Step 2
Interval 00:00:30
Readings 34
---------------
   Time     Chnl 1
21:03:30   +18.266
21:04:00   +18.258
21:04:30   +18.244
21:05:00   +18.234
21:05:30   +18.220
21:06:00   +18.206
21:06:30   +18.192
21:07:00   +18.182
21:07:30   +18.165
21:08:00   +18.151
21:08:30   +18.137
21:09:00   +18.126
21:09:30   +18.113
21:10:00   +18.095
21:10:30   +18.081
21:11:00   +18.071
21:11:30   +18.057
21:12:00   +18.040
21:12:30   +18.026
21:13:00   +18.016
21:13:30   +17.998
21:14:00   +17.985
21:14:30   +17.971
21:15:00   +17.957
21:15:30   +17.940
21:16:00   +17.926
21:16:30   +17.908
21:17:00   +17.891
21:17:30   +17.881
21:18:00   +17.853
21:18:30   +17.846
21:19:00   +17.832
21:19:30   +17.815
21:20:00   +17.798
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time     Chnl 1
21:21:00   +17.770
21:22:00   +17.739
21:23:00   +17.708
21:24:00   +17.680
21:25:00   +17.646
21:26:00   +17.618
21:27:00   +17.587
21:28:00   +17.556
21:29:00   +17.525
21:30:00   +17.497
21:31:00   +17.459
21:32:00   +17.441
21:33:00   +17.414
21:34:00   +17.383
21:35:00   +17.358
21:36:00   +17.327
21:37:00   +17.300
21:38:00   +17.272
21:39:00   +17.248
21:40:00   +17.216
21:41:00   +17.192
21:42:00   +17.168
21:43:00   +17.140
21:44:00   +17.113
21:45:00   +17.085
21:46:00   +17.061
21:47:00   +17.030
21:48:00   +17.009
21:49:00   +16.985
21:50:00   +16.960
21:51:00   +16.933
21:52:00   +16.909
21:53:00   +16.884
21:54:00   +16.857
21:55:00   +16.832
21:56:00   +16.812
21:57:00   +16.791
21:58:00   +16.763
21:59:00   +16.742
22:00:00   +16.718
---------------
Step 4
Interval 01:00:00
Readings 23
---------------
   Time     Chnl 1
23:00:00   +15.566
--  6/16
00:00:00   +15.047
01:00:00   +14.594
02:00:00   +14.237
03:00:00   +13.943
04:00:00   +13.598
05:00:00   +13.483
06:00:00   +13.276
07:00:00   +13.016
08:00:00   +12.770
09:00:00   +12.542
10:00:00   +12.331
11:00:00   +12.092
12:00:00   +11.653
13:00:00   +11.584
14:00:00   +11.424
15:00:00   +11.431
16:00:00   +11.532
17:00:00   +11.227
18:00:00   +10.895
19:00:00   +10.646
20:00:00   +10.539
21:00:00   +10.380
22:00:00   +10.269
23:00:00   +10.141
--  6/17
00:00:00   +10.040
01:00:00   +9.9578
02:00:00   +9.9025
03:00:00   +9.8402
04:00:00   +9.7918
05:00:00   +9.7537
06:00:00   +9.7053
07:00:00   +9.6534
---------------


NEW TEST


Model SDEE-01B
S/N 0294    Block 2
--------------------
Program:     INTERVAL
Readings:    59
Start Time: 08:00:00
Start date: 06/17
Range:       0015 PSI
Units:       Ft-H20
--------------------
Interval:  01:00:00
   Time     Chnl 1
08:00:00   +9.5807
09:00:00   +9.5011
10:00:00   +9.3143
```

I-13P cont

```
11:00:00   +9.1136            13:00:00   +0.9159
12:00:00   +8.7384            14:00:00   +0.5535
13:00:00   +8.5565            15:00:00   +0.1626
14:00:00   +8.3143            16:00:00   -0.0449
15:00:00   +7.9545            17:00:00   -0.0415
16:00:00   +7.6639            18:00:00   -0.0415
17:00:00   +7.4493            ---------------
18:00:00   +7.2141
19:00:00   +7.0376
20:00:00   +6.8858
21:00:00   +6.7331
22:00:00   +6.5829
23:00:00   +6.4805
--  6/18
00:00:00   +6.3560
01:00:00   +6.2245
02:00:00   +6.0930
03:00:00   +5.9858
04:00:00   +5.8795
05:00:00   +5.7816
06:00:00   +5.7020
07:00:00   +5.6259
08:00:00   +5.5394
09:00:00   +5.1969
10:00:00   +5.2349
11:00:00   +5.0585
12:00:00   +3.9790
13:00:00   +4.4253
14:00:00   +4.2973
15:00:00   +3.9444
16:00:00   +3.5984
17:00:00   +3.3769
18:00:00   +3.1174
19:00:00   +2.8787
20:00:00   +2.7254
21:00:00   +2.5880
22:00:00   +2.4877
23:00:00   +2.3424
--  6/19
00:00:00   +2.2974
01:00:00   +2.2074
02:00:00   +2.1209
03:00:00   +2.0587
04:00:00   +2.0033
05:00:00   +1.9583
06:00:00   +1.9203
07:00:00   +1.8718
08:00:00   +1.8130
09:00:00   +1.7230
10:00:00   +1.6054
11:00:00   +1.4429
12:00:00   +1.0864
```

```
STAMINA MILLS PUMPING TEST - JUNE 1999

RECOVERY DATA
J. FREITAS (I-13)
Elev. of Transducer = 184.1 ft (msl)

Model SDEE-019
S/N 0294    Block 1
--------------------
Program:    STEP TEST
Readings:   143
Start Time: 20:00:00
Start date: 06/19
Range:      2015 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time     Chnl 1
20:00:00   +6.7089
20:00:06   +6.7054
20:00:12   +6.7089
20:00:18   +6.7020
20:00:24   +6.7020
20:00:30   +6.7020
20:00:36   +6.6985
20:00:42   +6.7020
20:00:48   +6.6985
20:00:54   +6.6951
20:01:00   +6.6985
20:01:06   +6.6951
20:01:12   +6.6951
20:01:18   +6.6951
20:01:24   +6.6951
20:01:30   +6.6881
20:01:36   +6.6881
20:01:42   +6.6881
20:01:48   +6.6881
20:01:54   +6.6847
20:02:00   +6.6847
20:02:06   +6.6847
20:02:12   +6.6812
20:02:18   +6.6812
20:02:24   +6.6812
20:02:30   +6.6812
20:02:36   +6.6812
20:02:42   +6.6812
20:02:48   +6.6778
20:02:54   +6.6778
20:03:00   +6.6778
---------------

Step 2
Interval 00:00:30
Readings 34
---------------
   Time     Chnl 1
20:03:30   +6.6778
20:04:00   +6.6708
20:04:30   +6.6708
20:05:00   +6.6674
20:05:30   +6.6674
20:06:00   +6.6639
20:06:30   +6.6639
20:07:00   +6.6605
20:07:30   +6.6605
20:08:00   +6.6605
20:08:30   +6.6570
20:09:00   +6.6570
20:09:30   +6.6570
20:10:00   +6.6501
20:10:30   +6.6570
20:11:00   +6.6501
20:11:30   +6.6466
20:12:00   +6.6466
20:12:30   +6.6466
20:13:00   +6.6501
20:13:30   +6.6466
20:14:00   +6.6432
20:14:30   +6.6432
20:15:00   +6.6466
20:15:30   +6.6432
20:16:00   +6.6432
20:16:30   +6.6432
20:17:00   +6.6432
20:17:30   +6.6432
20:18:00   +6.6397
20:18:30   +6.6432
20:19:00   +6.6397
20:19:30   +6.6397
20:20:00   +6.6328
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time     Chnl 1
20:21:00   +6.6328
20:22:00   +6.6328
20:23:00   +6.6328
20:24:00   +12.469

20:25:00   +12.473
20:26:00   +12.473
20:27:00   +12.469
20:28:00   +12.473
20:29:00   +12.473
20:30:00   +12.473
20:31:00   +12.476
20:32:00   +12.476
20:33:00   +12.476
20:34:00   +12.476
20:35:00   +12.480
20:36:00   +12.480
20:37:00   +12.480
20:38:00   +12.487
20:39:00   +12.487
20:40:00   +12.487
20:41:00   +12.487
20:42:00   +12.490
20:43:00   +12.494
20:44:00   +12.490
20:45:00   +12.490
20:46:00   +12.494
20:47:00   +12.494
20:48:00   +12.497
20:49:00   +12.497
20:50:00   +12.497
20:51:00   +12.504
20:52:00   +12.504
20:53:00   +12.504
20:54:00   +12.504
20:55:00   +12.507
20:56:00   +12.507
20:57:00   +12.507
20:58:00   +12.511
20:59:00   +12.511
21:00:00   +12.514
---------------
Step 4
Interval 01:00:00
Readings 38
---------------
   Time     Chnl 1
22:00:00   +12.611
23:00:00   +12.732
--  6/20
00:00:00   +12.867
01:00:00   +13.006
02:00:00   +13.151
03:00:00   +13.303

04:00:00   +13.452
05:00:00   +13.604
06:00:00   +13.755
07:00:00   +13.903
08:00:00   +14.257
09:00:00   +14.133
10:00:00   +14.272
11:00:00   +14.372
12:00:00   +14.445
13:00:00   +14.497
14:00:00   +14.542
15:00:00   +14.597
16:00:00   +14.656
17:00:00   +14.711
18:00:00   +14.767
19:00:00   +14.805
20:00:00   +14.812
21:00:00   +14.822
22:00:00   +14.846
23:00:00   +14.895
--  6/21
00:00:00   +14.961
01:00:00   +15.033
02:00:00   +15.120
03:00:00   +15.213
04:00:00   +15.310
05:00:00   +15.421
06:00:00   +15.525
07:00:00   +15.635
08:00:00   +15.743
09:00:00   +15.839
10:00:00   +15.947
11:00:00   +15.247
---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 15, 1988

DRAWDOWN DATA
STAMINA MILLS WELL
Elev. of Transducer = 162.2 ft (msl)

Model SDEE-01B
S/N 0289    Block 1
--------------------
Program:    STEP TEST
Readings:   133
Start Time: 21:00:00
Start date: 06/15
Range:      0025 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time     Chnl 1
21:00:00   +34.911
21:00:06   +34.911
21:00:12   +34.911
21:00:18   +34.911
21:00:24   +34.911
21:00:30   +34.911
21:00:36   +34.911
21:00:42   +34.911
21:00:48   +34.911
21:00:54   +34.911
21:01:00   +34.911
21:01:06   +34.911
21:01:12   +34.911
21:01:18   +34.911
21:01:24   +34.911
21:01:30   +34.911
21:01:36   +34.899
21:01:42   +34.911
21:01:48   +34.911
21:01:54   +34.911
21:02:00   +34.911
21:02:06   +34.899
21:02:12   +34.911
21:02:18   +34.917
21:02:24   +34.911
21:02:30   +34.911
21:02:36   +34.911
21:02:42   +34.911
21:02:48   +34.911
21:02:54   +34.911
21:03:00   +34.911
---------------

Step 2
Interval 00:00:30
Readings 34
---------------
   Time     Chnl 1
21:03:30   +34.911
21:04:00   +34.917
21:04:30   +34.911
21:05:00   +34.917
21:05:30   +34.917
21:06:00   +34.917
21:06:30   +34.911
21:07:00   +34.911
21:07:30   +34.911
21:08:00   +34.911
21:08:30   +34.911
21:09:00   +34.911
21:09:30   +34.911
21:10:00   +34.911
21:10:30   +34.911
21:11:00   +34.911
21:11:30   +34.911
21:12:00   +34.911
21:12:30   +34.911
21:13:00   +34.911
21:13:30   +34.911
21:14:00   +34.911
21:14:30   +34.911
21:15:00   +34.911
21:15:30   +34.911
21:16:00   +34.911
21:16:30   +34.911
21:17:00   +34.911
21:17:30   +34.911
21:18:00   +34.911
21:18:30   +34.911
21:19:00   +34.911
21:19:30   +34.911
21:20:00   +34.911
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time     Chnl 1
21:21:00   +34.911
21:22:00   +34.911
21:23:00   +34.911
21:24:00   +34.911

21:25:00   +34.911
21:26:00   +34.911
21:27:00   +34.911
21:28:00   +34.911
21:29:00   +34.911
21:30:00   +34.911
21:31:00   +34.911
21:32:00   +34.911
21:33:00   +34.911
21:34:00   +34.911
21:35:00   +34.911
21:36:00   +34.911
21:37:00   +34.911
21:38:00   +34.911
21:39:00   +34.911
21:40:00   +34.911
21:41:00   +34.911
21:42:00   +34.911
21:43:00   +34.911
21:44:00   +34.911
21:45:00   +34.911
21:46:00   +34.911
21:47:00   +34.899
21:48:00   +34.911
21:49:00   +34.899
21:50:00   +34.911
21:51:00   +34.899
21:52:00   +34.911
21:53:00   +34.911
21:54:00   +34.899
21:55:00   +34.911
21:56:00   +34.899
21:57:00   +34.899
21:58:00   +34.899
21:59:00   +34.911
22:00:00   +34.899
---------------
Step 4
Interval 01:00:00
Readings 33
---------------
   Time     Chnl 1
23:00:00   +34.899
--  6/16
00:00:00   +34.899
01:00:00   +34.899
02:00:00   +34.894
03:00:00   +34.917
04:00:00   +34.911

05:00:00   +34.911
06:00:00   +34.899
07:00:00   +34.899
08:00:00   +34.894
09:00:00   +34.894
10:00:00   +34.888
11:00:00   +34.899
12:00:00   +34.917
13:00:00   +34.922
14:00:00   +34.922
15:00:00   +34.928
16:00:00   +34.928
17:00:00   +34.922
18:00:00   +34.911
19:00:00   +34.888
20:00:00   +34.888
21:00:00   +34.882
22:00:00   +34.894
23:00:00   +34.882
--  6/17
00:00:00   +34.882
01:00:00   +34.882
02:00:00   +34.871
03:00:00   +34.865
04:00:00   +34.865
05:00:00   +34.859
06:00:00   +34.859
07:00:00   +34.859
---------------


NEW TEST


Model SDEE-01B
S/N 0289    Block 2
--------------------
Program:    INTERVAL
Readings:   59
Start Time: 08:00:00
Start date: 06/17
Range:      0025 PSI
Units:      Ft-H20
--------------------
Interval:  01:00:00
   Time     Chnl 1
08:00:00   +34.859
09:00:00   +34.859
10:00:00   +34.847
```

SM WELL cont.

```
11:00:00   +34.847
12:00:00   +34.853
13:00:00   +34.847
14:00:00   +34.847
15:00:00   +34.830
16:00:00   +34.830
17:00:00   +34.824
18:00:00   +34.824
19:00:00   +34.813
20:00:00   +34.813
21:00:00   +34.801
22:00:00   +34.796
23:00:00   +34.784
--  6/18
00:00:00   +34.790
01:00:00   +34.790
02:00:00   +34.784
03:00:00   +34.784
04:00:00   +34.778
05:00:00   +34.767
06:00:00   +34.767
07:00:00   +34.767
08:00:00   +34.761
09:00:00   +34.761
10:00:00   +34.749
11:00:00   +34.761
12:00:00   +34.778
13:00:00   +34.778
14:00:00   +34.778
15:00:00   +34.778
16:00:00   +34.778
17:00:00   +34.755
18:00:00   +34.744
19:00:00   +34.744
20:00:00   +34.732
21:00:00   +34.721
22:00:00   +34.715
23:00:00   +34.715
--  6/19
00:00:00   +34.692
01:00:00   +34.692
02:00:00   +34.686
03:00:00   +34.686
04:00:00   +34.680
05:00:00   +34.685
06:00:00   +34.669
07:00:00   +34.663
08:00:00   +34.657
09:00:00   +34.657
10:00:00   +34.663
11:00:00   +34.657
12:00:00   +34.665
13:00:00   +34.686
14:00:00   +34.680
15:00:00   +34.685
16:00:00   +34.680
17:00:00   +34.651
```

```
STAMINA MILLS PUMPING TEST - JUNE 15, 1988

RECOVERY DATA
STAMINA MILLS WELL
Elev. of Transducer = 162.2 ft (msl)

Model SDEE-01B              Step 2                    20:25:00   +34.623        04:00:00   +34.628
S/N 0283    Block 1         Interval 00:00:30         20:26:00   +34.623        05:00:00   +34.634
--------------------        Readings 34               20:27:00   +34.623        06:00:00   +34.634
Program:    STEP TEST       ---------------           20:28:00   +34.623        07:00:00   +34.651
Readings:   169                Time     Chnl 1        20:29:00   +34.623        08:00:00   +34.657
Start Time: 20:00:00        20:03:30   +34.623        20:30:00   +34.623        09:00:00   +34.663
Start date: 06/19           20:04:00   +34.628        20:31:00   +34.623        10:00:00   +34.680
Range:      0025 PSI        20:04:30   +34.628        20:32:00   +34.623        11:00:00   +34.686
Units:      Ft-H20          20:05:00   +34.628        20:33:00   +34.623        12:00:00   +34.698
--------------------        20:05:30   +34.623        20:34:00   +34.623        13:00:00   +34.715
Step 1                      20:06:00   +34.628        20:35:00   +34.623        14:00:00   +34.721
Interval 00:00:06           20:06:30   +34.628        20:36:00   +34.623        15:00:00   +34.726
Readings 31                 20:07:00   +34.623        20:37:00   +34.623        16:00:00   +34.732
---------------             20:07:30   +34.628        20:38:00   +34.623        17:00:00   +34.721
   Time     Chnl 1          20:08:00   +34.628        20:39:00   +34.623        18:00:00   +34.721
20:00:00   +34.623          20:08:30   +34.628        20:40:00   +34.623        19:00:00   +34.715
20:00:06   +34.623          20:09:00   +34.628        20:41:00   +34.623        20:00:00   +34.715
20:00:12   +34.628          20:09:30   +34.628        20:42:00   +34.623        21:00:00   +34.703
20:00:18   +34.628          20:10:00   +34.628        20:43:00   +34.623        22:00:00   +34.698
20:00:24   +34.628          20:10:30   +34.628        20:44:00   +34.617        23:00:00   +34.703
20:00:30   +34.628          20:11:00   +34.623        20:45:00   +34.617        --  6/21
20:00:36   +34.623          20:11:30   +34.628        20:46:00   +34.623        00:00:00   +34.703
20:00:42   +34.623          20:12:00   +34.623        20:47:00   +34.623        01:00:00   +34.703
20:00:48   +34.628          20:12:30   +34.623        20:48:00   +34.617        02:00:00   +34.715
20:00:54   +34.628          20:13:00   +34.623        20:49:00   +34.623        03:00:00   +34.715
20:01:00   +34.628          20:13:30   +34.623        20:50:00   +34.617        04:00:00   +34.715
20:01:06   +34.628          20:14:00   +34.628        20:51:00   +34.623        05:00:00   +34.715
20:01:12   +34.628          20:14:30   +34.623        20:52:00   +34.617        06:00:00   +34.703
20:01:18   +34.628          20:15:00   +34.623        20:53:00   +34.623        07:00:00   +34.703
20:01:24   +34.628          20:15:30   +34.623        20:54:00   +34.617        08:00:00   +34.703
20:01:30   +34.628          20:16:00   +34.623        20:55:00   +34.617        09:00:00   +34.703
20:01:36   +34.623          20:16:30   +34.623        20:56:00   +34.617        10:00:00   +34.715
20:01:42   +34.623          20:17:00   +34.623        20:57:00   +34.617        11:00:00   +34.715
20:01:48   +34.623          20:17:30   +34.623        20:58:00   +34.617        12:00:00   +34.726
20:01:54   +34.623          20:18:00   +34.623        20:59:00   +34.617        13:00:00   +34.732
20:02:00   +34.628          20:18:30   +34.623        21:00:00   +34.617        14:00:00   +34.749
20:02:06   +34.623          20:19:00   +34.623        ---------------           15:00:00   +34.755
20:02:12   +34.623          20:19:30   +34.623        Step 4                    16:00:00   +34.749
20:02:18   +34.628          20:20:00   +34.623        Interval 01:00:00         17:00:00   +34.726
20:02:24   +34.623          ---------------           Readings 64               18:00:00   +34.721
20:02:30   +34.628          Step 3                    ---------------           19:00:00   +34.703
20:02:36   +34.623          Interval 00:01:00            Time     Chnl 1        20:00:00   +34.703
20:02:42   +34.628          Readings 40               22:00:00   +34.617        21:00:00   +34.698
20:02:48   +34.623          ---------------           23:00:00   +34.611        22:00:00   +34.698
20:02:54   +34.623             Time     Chnl 1        --  6/20                  23:00:00   +34.692
20:03:00   +34.623          20:21:00   +34.623        00:00:00   +34.611        --  6/22
---------------             20:22:00   +34.623        01:00:00   +34.617        00:00:00   +34.698
                            20:23:00   +34.623        02:00:00   +34.617        01:00:00   +34.698
                            20:24:00   +34.623        03:00:00   +34.623        02:00:00   +34.698
```

```
SM WELL cont

03:00:00   +34.698
04:00:00   +34.698
05:00:00   +34.698
06:00:00   +34.698
07:00:00   +34.703
08:00:00   +34.703
09:00:00   +34.703
10:00:00   +34.715
11:00:00   +34.715
12:00:00   +34.721
13:00:00   +34.732
---------------
```

STAMINA MILLS PUMPING TEST - JUNE 1988

BACKGROUND DATA
Bosco (I-7)
Elev. of transducer = 190.75 (msl)

```
Model SDEE-01B
S/N 0262    Block 1
--------------------
Program:    INTERVAL
Readings:   72
Start Time: 16:00:00
Start date: 06/10
Range:      0015 PSI
Units:      Ft-H20
--------------------
Interval:  01:00:00
  Time       Chnl 1
16:00:00   +23.233
17:00:00   +23.098
18:00:00   +22.946
19:00:00   +22.787
20:00:00   +22.645
21:00:00   +22.545
22:00:00   +22.486
23:00:00   +22.479
--  6/11
00:00:00   +22.490
01:00:00   +22.531
02:00:00   +22.579
03:00:00   +22.635
04:00:00   +22.690
05:00:00   +22.739
06:00:00   +22.777
07:00:00   +22.815
08:00:00   +22.846
09:00:00   +22.887
10:00:00   +22.922
11:00:00   +22.676
12:00:00   +22.292
13:00:00   +22.119
14:00:00   +22.022
15:00:00   +21.939
16:00:00   +21.600
17:00:00   +21.182
18:00:00   +20.912
19:00:00   +20.777
20:00:00   +20.697
21:00:00   +20.652
22:00:00   +20.635
23:00:00   +20.652
--  6/12
00:00:00   +20.594
01:00:00   +20.766
02:00:00   +20.953
03:00:00   +20.988
```

```
04:00:00   +21.119
05:00:00   +21.240
06:00:00   +21.365
07:00:00   +21.486
08:00:00   +21.597
09:00:00   +21.694
10:00:00   +21.794
11:00:00   +21.894
12:00:00   +21.998
13:00:00   +22.081
14:00:00   +22.157
15:00:00   +22.154
16:00:00   +22.019
17:00:00   +21.791
18:00:00   +21.486
19:00:00   +21.192
20:00:00   +20.912
21:00:00   +20.711
22:00:00   +20.575
23:00:00   +20.486
--  6/13
00:00:00   +20.449
01:00:00   +20.458
02:00:00   +20.507
03:00:00   +20.573
04:00:00   +20.649
05:00:00   +20.725
06:00:00   +20.811
07:00:00   +20.905
08:00:00   +20.988
09:00:00   +21.047
10:00:00   +21.085
11:00:00   +21.102
12:00:00   +21.071
13:00:00   +20.888
14:00:00   +20.770
15:00:00   +20.687
---------------
```

```
NEW TEST


Model SDEE-01B
S/N 0262    Block 2
--------------------
Program:    STEP TEST
Readings:   96
Start Time: 16:30:00
Start date: 06/13
Range:      0015 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
  Time       Chnl 1
16:30:00   +20.524
16:30:06   +20.531
16:30:12   +20.521
16:30:18   +20.521
16:30:24   +20.521
16:30:30   +20.521
16:30:36   +20.521
16:30:42   +20.521
16:30:48   +20.521
16:30:54   +20.521
16:31:00   +20.521
16:31:06   +20.521
16:31:12   +20.517
16:31:18   +20.521
16:31:24   +20.517
16:31:30   +20.521
16:31:36   +20.521
16:31:42   +20.517
16:31:48   +20.517
16:31:54   +20.521
16:32:00   +20.521
16:32:06   +20.517
16:32:12   +20.521
16:32:18   +20.517
16:32:24   +20.521
16:32:30   +20.517
16:32:36   +20.521
16:32:42   +20.517
16:32:48   +20.517
16:32:54   +20.517
16:33:00   +20.517
---------------
```

```
Step 2
Interval 00:00:30
Readings 34
---------------
  Time       Chnl 1
16:33:30   +20.517
16:34:00   +20.517
16:34:30   +20.514
16:35:00   +20.507
16:35:30   +20.514
16:36:00   +20.507
16:36:30   +20.507
16:37:00   +20.503
16:37:30   +20.503
16:38:00   +20.500
16:38:30   +20.497
16:39:00   +20.497
16:39:30   +20.493
16:40:00   +20.493
16:40:30   +20.486
16:41:00   +20.486
16:41:30   +20.493
16:42:00   +20.483
16:42:30   +20.483
16:43:00   +20.479
16:43:30   +20.479
16:44:00   +20.479
16:44:30   +20.469
16:45:00   +20.476
16:45:30   +20.465
16:46:00   +20.465
16:46:30   +20.462
16:47:00   +20.462
16:47:30   +20.462
16:48:00   +20.462
16:48:30   +20.455
16:49:00   +20.455
16:49:30   +20.455
16:50:00   +20.448
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
  Time       Chnl 1
16:51:00   +20.438
16:52:00   +20.427
16:53:00   +20.420
16:54:00   +20.407
16:55:00   +20.400
```

```
I-7B cont

16:56:00   +20.385          00:00:00   +19.590
16:57:00   +20.379          01:00:00   +19.677
16:58:00   +20.365          02:00:00   +19.784
16:59:00   +20.358          03:00:00   +19.905
17:00:00   +20.341          04:00:00   +20.036
17:01:00   +20.330          05:00:00   +20.168
17:02:00   +20.313          06:00:00   +20.285
17:03:00   +20.303          07:00:00   +20.396
17:04:00   +20.289          08:00:00   +20.479
17:05:00   +20.275          09:00:00   +20.538
17:06:00   +20.265          10:00:00   +20.573
17:07:00   +20.251          11:00:00   +20.573
17:08:00   +20.234          12:00:00   +20.576
17:09:00   +20.223          13:00:00   +20.576
17:10:00   +20.206          14:00:00   +20.476
17:11:00   +20.192          15:00:00   +20.462
17:12:00   +20.175          16:00:00   +20.431
17:13:00   +20.161          17:00:00   +20.362
17:14:00   +20.151          18:00:00   +20.151
17:15:00   +19.510          19:00:00   +20.372
17:16:00   +19.510          ---------------
17:17:00   +19.504
17:18:00   +19.504
17:19:00   +19.504
17:20:00   +19.504
17:21:00   +19.500
Test 2 aborted at Step 3


NEW TEST


Model SDEE-01B
S/N 0262    Block 3
--------------------
Program:    INTERVAL
Readings:   26
Start Time: 18:00:00
Start date: 05/14
Range:      0015 PSI
Units:      Ft-H20
--------------------
Interval:  01:00:00
   Time     Chnl 1
18:00:00   +19.497
19:00:00   +19.465
20:00:00   +19.420
21:00:00   +19.452
22:00:00   +19.476
23:00:00   +19.517
--  5/15
```

STAMINA MILLS PUMPING TEST - JUNE 1988

DRAWDOWN DATA
BOSCO (I-7)
Elev. of Transducer = 190.7 ft (msl)

```
Model SDEE-01P
S/N 0262    Block 1
--------------------
Program:    STEP TEST
Readings:   113
Start Time: 21:00:00
Start date: 06/15
Range:      0015 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
  Time      Chnl 1
21:00:00   +20.424
21:00:06   +20.424
21:00:12   +20.420
21:00:18   +20.420
21:00:24   +20.420
21:00:30   +20.420
21:00:36   +20.424
21:00:42   +20.420
21:00:48   +20.424
21:00:54   +20.420
21:01:00   +20.424
21:01:06   +20.420
21:01:12   +20.424
21:01:18   +20.420
21:01:24   +20.420
21:01:30   +20.424
21:01:36   +20.424
21:01:42   +20.420
21:01:48   +20.420
21:01:54   +20.420
21:02:00   +20.420
21:02:06   +20.420
21:02:12   +20.424
21:02:18   +20.420
21:02:24   +20.420
21:02:30   +20.420
21:02:36   +20.420
21:02:42   +20.420
21:02:48   +20.424
21:02:54   +20.420
21:03:00   +20.420
---------------
```

```
Step 2
Interval 00:00:30
Readings 34
---------------
  Time      Chnl 1
21:03:30   +20.420
21:04:00   +20.424
21:04:30   +20.424
21:05:00   +20.424
21:05:30   +20.424
21:06:00   +20.424
21:06:30   +20.424
21:07:00   +20.420
21:07:30   +20.420
21:08:00   +20.417
21:08:30   +20.417
21:09:00   +20.417
21:09:30   +20.417
21:10:00   +20.417
21:10:30   +20.417
21:11:00   +20.410
21:11:30   +20.410
21:12:00   +20.410
21:12:30   +20.410
21:13:00   +20.410
21:13:30   +20.407
21:14:00   +20.407
21:14:30   +20.407
21:15:00   +20.407
21:15:30   +20.403
21:16:00   +20.403
21:16:30   +20.407
21:17:00   +20.403
21:17:30   +20.403
21:18:00   +20.403
21:18:30   +20.403
21:19:00   +20.400
21:19:30   +20.396
21:20:00   +20.396
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
  Time      Chnl 1
21:21:00   +20.396
21:22:00   +20.386
21:23:00   +20.379
21:24:00   +20.372
```

```
21:25:00   +20.355
21:26:00   +20.362
21:27:00   +20.351
21:28:00   +20.349
21:29:00   +20.341
21:30:00   +20.330
21:31:00   +20.324
21:32:00   +20.313
21:33:00   +20.306
21:34:00   +20.296
21:35:00   +20.289
21:36:00   +20.282
21:37:00   +20.272
21:38:00   +20.261
21:39:00   +20.251
21:40:00   +20.244
21:41:00   +20.234
21:42:00   +20.223
21:43:00   +20.213
21:44:00   +20.199
21:45:00   +15.359
21:46:00   +15.365
21:47:00   +15.358
21:48:00   +15.358
21:49:00   +15.352
21:50:00   +15.352
21:51:00   +15.348
21:52:00   +15.341
21:53:00   +15.341
21:54:00   +15.338
21:55:00   +15.334
21:56:00   +15.334
21:57:00   +15.331
21:58:00   +15.327
21:59:00   +15.320
22:00:00   +15.317
---------------
Step 4
Interval 01:00:00
Readings 8
---------------
  Time      Chnl 1
23:00:00   +15.199
-- 6/16
00:00:00   +15.032
01:00:00   +14.985
02:00:00   +14.850
03:00:00   +14.808
04:00:00   +14.753
```

```
05:00:00   +14.701
06:00:00   +14.646
---------------


NEW TEST


Model SDEE-01P
S/N 0262    Block
------------------
Program:     INTERV
Readings:    60
Start Time: 08:00:
Start date: 05/17
Range:       0015 P
Units:       Ft-H20
------------------
Interval:  01:00:0
  Time      Chnl 1
08:00:00   +14.570
09:00:00   +14.462
10:00:00   +14.376
11:00:00   +14.286
12:00:00   +14.172
13:00:00   +14.047
14:00:00   +13.929
15:00:00   +13.750
16:00:00   +13.635
17:00:00   +13.504
18:00:00   +13.369
19:00:00   +13.234
20:00:00   +13.054
21:00:00   +12.947
22:00:00   +12.822
23:00:00   +12.708
-- 6/18
00:00:00   +12.594
01:00:00   +12.480
02:00:00   +12.372
03:00:00   +12.272
04:00:00   +12.151
05:00:00   +12.075
06:00:00   +11.999
07:00:00   +11.933
08:00:00   +11.850
09:00:00   +11.736
10:00:00   +11.649
11:00:00   +11.539
```

I-7P cont.

```
12:00:00   +11.421
13:00:00   +11.269
14:00:00   +11.130
15:00:00   +10.995
16:00:00   +10.829
17:00:00   +10.632
18:00:00   +10.490
19:00:00   +10.317
20:00:00   +10.141
21:00:00   +10.009
22:00:00   +9.8402
23:00:00   +9.7399
--  6/19
00:00:00   +9.6257
01:00:00   +9.5323
02:00:00   +9.4388
03:00:00   +9.3558
04:00:00   +9.2797
05:00:00   +9.2174
06:00:00   +9.1517
07:00:00   +9.0928
08:00:00   +9.0340
09:00:00   +8.9683
10:00:00   +8.9025
11:00:00   +8.8230
12:00:00   +8.6811
13:00:00   +8.5738
14:00:00   +8.4006
15:00:00   +8.2521
16:00:00   +8.0514
17:00:00   +7.8888
18:00:00   +7.7123
19:00:00   +0.0865
---------------
```

STAMINA MILLS PUMPING TEST - JUNE 1988

RECOVERY DATA
BOSCO (I-7)
Elev. of Transducer = 162.4 ft (msl)

```
Model SDEE-018
S/N 0293    Block 1
--------------------
Program:    STEP TEST
Readings:   157
Start Time: 20:00:00
Start date: 06/19
Range:      0025 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
  Time     Chnl 1
20:00:00  +36.093
20:00:06  +36.093
20:00:12  +36.093
20:00:18  +36.093
20:00:24  +36.093
20:00:30  +36.093
20:00:36  +36.093
20:00:42  +36.093
20:00:48  +36.093
20:00:54  +36.093
20:01:00  +36.093
20:01:06  +36.093
20:01:12  +36.093
20:01:18  +36.093
20:01:24  +36.093
20:01:30  +36.093
20:01:36  +36.093
20:01:42  +36.093
20:01:48  +36.093
20:01:54  +36.093
20:02:00  +36.105
20:02:06  +36.093
20:02:12  +36.093
20:02:18  +36.093
20:02:24  +36.093
20:02:30  +36.093
20:02:36  +36.093
20:02:42  +36.105
20:02:48  +36.093
20:02:54  +36.093
20:03:00  +36.093
---------------

Step 2
Interval 00:00:30
Readings 34
---------------
  Time     Chnl 1
20:03:30  +36.093
20:04:00  +36.093
20:04:30  +36.087
20:05:00  +36.087
20:05:30  +36.087
20:06:00  +36.087
20:06:30  +36.093
20:07:00  +36.087
20:07:30  +36.093
20:08:00  +36.093
20:08:30  +36.093
20:09:00  +36.082
20:09:30  +36.087
20:10:00  +36.087
20:10:30  +36.082
20:11:00  +36.082
20:11:30  +36.082
20:12:00  +36.082
20:12:30  +36.082
20:13:00  +36.087
20:13:30  +36.082
20:14:00  +36.082
20:14:30  +36.082
20:15:00  +36.082
20:15:30  +36.082
20:16:00  +36.082
20:16:30  +36.076
20:17:00  +36.082
20:17:30  +36.082
20:18:00  +36.076
20:18:30  +36.082
20:19:00  +36.082
20:19:30  +36.076
20:20:00  +36.076
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
  Time     Chnl 1
20:21:00  +36.064
20:22:00  +36.064
20:23:00  +36.064
20:24:00  +36.076

20:25:00  +36.076
20:26:00  +36.076
20:27:00  +36.064
20:28:00  +36.064
20:29:00  +36.058
20:30:00  +36.064
20:31:00  +36.064
20:32:00  +36.058
20:33:00  +36.058
20:34:00  +36.058
20:35:00  +36.058
20:36:00  +36.058
20:37:00  +36.058
20:38:00  +36.064
20:39:00  +36.058
20:40:00  +36.058
20:41:00  +36.053
20:42:00  +36.058
20:43:00  +36.053
20:44:00  +36.058
20:45:00  +36.058
20:46:00  +36.053
20:47:00  +36.058
20:48:00  +36.053
20:49:00  +36.053
20:50:00  +36.053
20:51:00  +36.053
20:52:00  +36.053
20:53:00  +36.053
20:54:00  +36.053
20:55:00  +36.053
20:56:00  +36.053
20:57:00  +36.053
20:58:00  +36.053
20:59:00  +36.058
21:00:00  +36.058
---------------
Step 4
Interval 01:00:00
Readings 62
---------------
  Time     Chnl 1
22:00:00  +36.151
23:00:00  +36.255
--  6/20
00:00:00  +36.428
01:00:00  +36.572
02:00:00  +36.727
03:00:00  +36.877

04:00:00  +37.050
05:00:00  +37.246
06:00:00  +37.454
07:00:00  +37.644
08:00:00  +37.829
09:00:00  +38.019
10:00:00  +38.221
11:00:00  +38.406
12:00:00  +38.594
13:00:00  +38.763
14:00:00  +38.953
15:00:00  +38.838
16:00:00  +38.521
17:00:00  +38.359
18:00:00  +38.273
19:00:00  +38.261
20:00:00  +38.434
21:00:00  +38.561
22:00:00  +38.653
23:00:00  +38.752
--  6/21
00:00:00  +38.861
01:00:00  +38.959
02:00:00  +39.063
03:00:00  +39.172
04:00:00  +39.265
05:00:00  +39.374
06:00:00  +39.490
07:00:00  +39.605
08:00:00  +39.715
09:00:00  +39.813
10:00:00  +39.922
11:00:00  +40.014
12:00:00  +40.072
13:00:00  +40.118
14:00:00  +40.159
15:00:00  +40.210
16:00:00  +40.291
17:00:00  +40.332
18:00:00  +40.378
19:00:00  +40.430
20:00:00  +40.487
21:00:00  +40.522
22:00:00  +40.574
23:00:00  +40.637
--  6/22
00:00:00  +40.706
01:00:00  +40.770
02:00:00  +40.833
```

I-70 cont

```
03:00:00   +42.308
04:00:00   +40.983
05:00:00   +41.075
06:00:00   +41.150
07:00:00   +41.243
08:00:00   +41.312
09:00:00   +41.455
10:00:00   +41.767
11:00:00   +41.992
---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 1988

BACKGROUND DATA
M. Freitas (I-12)
Elev. of Transducer = 161.5 ft (msl)

Model SDEE-01B
S/N 0293    Block 1
--------------------
Program:    INTERVAL
Readings:   75
Start Time: 13:00:00
Start date: 06/10
Range:      0025 PSI
Units:      Ft-H20
--------------------
Interval:  01:00:00
   Time      Chnl 1
13:00:00   +49.108
14:00:00   +49.201
15:00:00   +49.241
16:00:00   +49.218
17:00:00   +49.149
18:00:00   +49.051
19:00:00   +48.959
20:00:00   +48.878
21:00:00   +48.814
22:00:00   +48.809
23:00:00   +48.785
--  6/11
00:00:00   +48.405
01:00:00   +48.168
02:00:00   +48.047
03:00:00   +47.967
04:00:00   +47.903
05:00:00   +47.846
06:00:00   +47.794
07:00:00   +47.730
08:00:00   +47.932
09:00:00   +48.094
10:00:00   +47.575
11:00:00   +47.730
12:00:00   +47.707
13:00:00   +47.828
14:00:00   +47.921
15:00:00   +47.961
16:00:00   +47.713
17:00:00   +47.500
18:00:00   +47.453
19:00:00   +47.436
20:00:00   +47.425
21:00:00   +47.390
22:00:00   +47.373
23:00:00   +47.390
--  6/12
00:00:00   +47.419
01:00:00   +47.471
02:00:00   +47.551
03:00:00   +47.644
04:00:00   +47.730
05:00:00   +47.805
06:00:00   +47.880
07:00:00   +47.926
08:00:00   +47.961
09:00:00   +48.001
10:00:00   +48.036
11:00:00   +48.088
12:00:00   +48.128
13:00:00   +48.174
14:00:00   +48.192
15:00:00   +48.192
16:00:00   +48.122
17:00:00   +48.001
18:00:00   +47.863
19:00:00   +47.713
20:00:00   +47.598
21:00:00   +47.500
22:00:00   +47.402
23:00:00   +47.309
--  6/13
00:00:00   +47.285
01:00:00   +47.280
02:00:00   +47.309
03:00:00   +47.378
04:00:00   +47.442
05:00:00   +47.511
06:00:00   +47.575
07:00:00   +47.592
08:00:00   +47.598
09:00:00   +47.598
10:00:00   +47.598
11:00:00   +47.586
12:00:00   +47.580
13:00:00   +47.419
14:00:00   +47.402
15:00:00   +47.332
---------------

NEW TEST


Model SDEE-01B
S/N 0293    Block 2
--------------------
Program:    STEP TEST
Readings:   125
Start Time: 16:30:00
Start date: 06/13
Range:      0025 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time      Chnl 1
16:30:00   +46.340
16:30:06   +46.340
16:30:12   +46.340
16:30:18   +46.340
16:30:24   +46.340
16:30:30   +46.340
16:30:36   +46.340
16:30:42   +46.340
16:30:48   +46.340
16:30:54   +46.340
16:31:00   +46.340
16:31:06   +46.340
16:31:12   +46.340
16:31:18   +46.340
16:31:24   +46.340
16:31:30   +46.340
16:31:36   +46.340
16:31:42   +46.340
16:31:48   +46.335
16:31:54   +46.335
16:32:00   +46.335
16:32:06   +46.335
16:32:12   +46.335
16:32:18   +46.335
16:32:24   +46.335
16:32:30   +46.335
16:32:36   +46.335
16:32:42   +46.335
16:32:48   +46.335
16:32:54   +46.335
16:33:00   +46.335
---------------
Step 2
Interval 00:00:30
Readings 34
---------------
   Time      Chnl 1
16:33:30   +46.335
16:34:00   +46.329
16:34:30   +46.329
16:35:00   +46.329
16:35:30   +46.317
16:36:00   +46.317
16:36:30   +46.317
16:37:00   +46.312
16:37:30   +46.312
16:38:00   +46.312
16:38:30   +46.306
16:39:00   +46.306
16:39:30   +46.305
16:40:00   +46.306
16:40:30   +46.300
16:41:00   +46.300
16:41:30   +46.300
16:42:00   +46.294
16:42:30   +46.294
16:43:00   +46.294
16:43:30   +46.293
16:44:00   +46.283
16:44:30   +46.283
16:45:00   +46.277
16:45:30   +46.277
16:46:00   +46.277
16:46:30   +46.271
16:47:00   +46.271
16:47:30   +46.265
16:48:00   +46.265
16:48:30   +46.255
16:49:00   +46.265
16:49:30   +46.254
16:50:00   +46.254
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time      Chnl 1
16:51:00   +46.248
16:52:00   +46.242
16:53:00   +46.237
```

I-12 cont.

```
16:55:00   +46.219      ---------------      Model SDEE-01B           --  5/15
16:56:00   +46.214      Step 4               S/N 0293    Block 1      00:00:00   +46.202
16:57:00   +46.208      Interval 01:00:00    --------------------     01:00:00   +46.293
16:58:00   +46.202      Readings 20          Program:    INTERVAL     02:00:00   +46.287
16:59:00   +46.202      ---------------      Readings:   31           03:00:00   +46.496
17:00:00   +46.191        Time     Chnl 1    Start Time: 14:00:00     04:00:00   +46.617
17:01:00   +46.185      18:30:00   +45.253   Start date: 06/14        05:00:00   +46.721
17:02:00   +46.173      19:30:00   +44.876   Range:      0025 PSI     06:00:00   +46.931
17:03:00   +46.173      20:30:00   +44.703   Units:      Ft-H20       07:00:00   +46.923
17:04:00   +46.156      21:30:00   +44.559   --------------------     08:00:00   +46.992
17:05:00   +46.150      22:30:00   +44.432   Interval:  01:00:00      09:00:00   +47.021
17:06:00   +46.144      23:30:00   +44.339     Time      Chnl 1       10:00:00   +47.044
17:07:00   +46.139      --  5/14             14:00:00   +45.366       11:00:00   +47.027
17:08:00   +46.127      00:30:00   +44.299   15:00:00   +45.481       12:00:00   +47.050
17:09:00   +46.121      01:30:00   +44.241   16:00:00   +45.983       13:00:00   +47.067
17:10:00   +46.116      02:30:00   +44.218   17:00:00   +45.879       14:00:00   +47.056
17:11:00   +46.110      03:30:00   +44.230   18:00:00   +45.931       15:00:00   +47.027
17:12:00   +46.092      04:30:00   +44.236   19:00:00   +45.983       16:00:00   +47.032
17:13:00   +46.087      05:30:00   +44.247   20:00:00   +45.950       17:00:00   +46.871
17:14:00   +46.081      06:30:00   +44.253   21:00:00   +46.029       18:00:00   +46.998
17:15:00   +46.075      07:30:00   +44.230   22:00:00   +46.092       19:00:00   +46.953
17:16:00   +46.064      08:30:00   +44.409   23:00:00   +46.144       20:00:00   +47.050
17:17:00   +46.058      09:30:00   +44.910                            ---------------
17:18:00   +46.052      10:30:00   +45.204
17:19:00   +46.035      11:30:00   +45.251
17:20:00   +46.029      12:30:00   +45.245
17:21:00   +46.023      13:30:00   +45.279
17:22:00   +46.018      ---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 1998

DRAWDOWN DATA
M. FREITAS (I-12)
Elev. of Transducer = 151.5 ft (msl)

Model SDEE-01B
S/N 0293     Block 1
--------------------
Program:      STEP TEST
Readings:     138
Start Time: 21:00:00
Start date: 06/15
Range:        2025 PSI
Units:        Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
  Time       Chnl 1
21:00:00    +47.084
21:00:06    +47.079
21:00:12    +47.084
21:00:18    +47.084
21:00:24    +47.084
21:00:30    +47.084
21:00:36    +47.084
21:00:42    +47.084
21:00:48    +47.084
21:00:54    +47.084
21:01:00    +47.084
21:01:06    +47.084
21:01:12    +47.084
21:01:18    +47.084
21:01:24    +47.084
21:01:30    +47.084
21:01:35    +47.084
21:01:42    +47.084
21:01:48    +47.084
21:01:54    +47.084
21:02:00    +47.084
21:02:06    +47.084
21:02:12    +47.084
21:02:18    +47.084
21:02:24    +47.084
21:02:30    +47.084
21:02:36    +47.084
21:02:42    +47.084
21:02:48    +47.090
21:02:54    +47.084
21:03:00    +47.084

---------------
Step 2
Interval 00:00:30
Readings 34
---------------
  Time       Chnl 1
21:03:30    +47.084
21:04:00    +47.090
21:04:30    +47.090
21:05:00    +47.090
21:05:30    +47.090
21:06:00    +47.084
21:06:30    +47.090
21:07:00    +47.084
21:07:30    +47.084
21:08:00    +47.084
21:08:30    +47.079
21:09:00    +47.084
21:09:30    +47.084
21:10:00    +47.084
21:10:30    +47.084
21:11:00    +47.079
21:11:30    +47.079
21:12:00    +47.079
21:12:30    +47.079
21:13:00    +47.079
21:13:30    +47.084
21:14:00    +47.079
21:14:30    +47.079
21:15:00    +47.079
21:15:30    +47.079
21:16:00    +47.079
21:16:30    +47.079
21:17:00    +47.067
21:17:30    +47.067
21:18:00    +47.079
21:18:30    +47.067
21:19:00    +47.067
21:19:30    +47.067
21:20:00    +47.067

---------------
Step 3
Interval 00:01:00
Readings 40
---------------
  Time       Chnl 1
21:21:00    +47.057
21:22:00    +47.061
21:23:00    +47.061
21:24:00    +47.056
21:25:00    +47.056
21:26:00    +47.056
21:27:00    +47.050
21:28:00    +47.056
21:29:00    +47.044
21:30:00    +47.050
21:31:00    +47.044
21:32:00    +47.032
21:33:00    +47.032
21:34:00    +47.027
21:35:00    +47.027
21:36:00    +47.021
21:37:00    +47.021
21:38:00    +47.015
21:39:00    +47.015
21:40:00    +47.004
21:41:00    +47.004
21:42:00    +46.998
21:43:00    +46.998
21:44:00    +46.992
21:45:00    +46.986
21:46:00    +46.986
21:47:00    +46.981
21:48:00    +46.969
21:49:00    +46.969
21:50:00    +46.959
21:51:00    +46.953
21:52:00    +46.963
21:53:00    +46.957
21:54:00    +46.952
21:55:00    +46.952
21:56:00    +46.934
21:57:00    +46.940
21:58:00    +46.934
21:59:00    +46.923
22:00:00    +46.923
---------------
Step 4
Interval 01:00:00
Readings 33
---------------
  Time       Chnl 1
23:00:00    +45.640
-- 6/16
00:00:00    +45.387
01:00:00    +45.167
02:00:00    +45.954
03:00:00    +45.793
04:00:00    +45.637
05:00:00    +45.493
06:00:00    +45.372
07:00:00    +45.216
08:00:00    +45.060
09:00:00    +44.899
10:00:00    +44.720
11:00:00    +44.559
12:00:00    +44.409
13:00:00    +43.993
14:00:00    +44.063
15:00:00    +43.965
16:00:00    +43.890
17:00:00    +43.760
18:00:00    +43.653
19:00:00    +43.544
20:00:00    +43.434
21:00:00    +43.334
22:00:00    +43.094
23:00:00    +43.077
```

```
I-12 cont.                   08:00:00   +40.020
                             09:00:00   +39.916
--  6/17                     10:00:00   +39.766
00:00:00   +42.984           11:00:00   +39.697
01:00:00   +42.904           12:00:00   +39.588
02:00:00   +42.823           13:00:00   +39.449
03:00:00   +42.754           14:00:00   +39.311
04:00:00   +42.684           15:00:00   +39.190
05:00:00   +42.644           16:00:00   +39.034
06:00:00   +42.596           17:00:00   +38.895
07:00:00   +42.529           18:00:00   +38.792
---------------              19:00:00   +38.553
                             20:00:00   +38.532
                             21:00:00   +38.429
NEW TEST                     22:00:00   +38.325
                             23:00:00   +37.771
                             --  6/19
Model SDEE-01B               00:00:00   +38.042
S/N 0293    Block 2          01:00:00   +37.956
--------------------         02:00:00   +37.863
Program:    INTERVAL         03:00:00   +37.771
Readings:   60               04:00:00   +37.696
Start Time: 08:00:00         05:00:00   +37.615
Start date: 06/17            06:00:00   +37.552
Range:      0025 PSI         07:00:00   +37.489
Units:      Ft-H20           08:00:00   +37.419
--------------------         09:00:00   +37.344
Interval:  01:00:00          10:00:00   +37.275
   Time     Chnl 1           11:00:00   +37.189
08:00:00   +42.459           12:00:00   +37.085
09:00:00   +42.379           13:00:00   +36.958
10:00:00   +42.183           14:00:00   +36.831
11:00:00   +42.171           15:00:00   +36.704
12:00:00   +42.056           16:00:00   +36.335
13:00:00   +41.935           17:00:00   +36.364
14:00:00   +41.837           18:00:00   +36.306
15:00:00   +41.698           19:00:00   +36.203
16:00:00   +41.566           ---------------
```

```
STAMINA MILLS PUMPING TEST - JUNE 1988

RECOVERY DATA
M. FREITAS (I-12)
Elev. of Transducer = 179.6 ft (msl)

Model SDEE-019
S/N 0262    Block 1
--------------------
Program:    STEP TEST
Readings:   163
Start Time: 20:00:00
Start date: 06/19
Range:      0015 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time     Chnl 1
20:00:00  +10.646
20:00:06  +10.645
20:00:12  +10.646
20:00:18  +10.642
20:00:24  +10.642
20:00:30  +10.645
20:00:36  +10.642
20:00:42  +10.642
20:00:48  +10.642
20:00:54  +10.645
20:01:00  +10.642
20:01:06  +10.542
20:01:12  +10.646
20:01:18  +10.542
20:01:24  +10.646
20:01:30  +10.642
20:01:36  +10.646
20:01:42  +10.645
20:01:48  +10.546
20:01:54  +10.646
20:02:00  +10.646
20:02:06  +10.545
20:02:12  +10.642
20:02:18  +10.542
20:02:24  +10.646
20:02:30  +10.546
20:02:36  +10.646
20:02:42  +10.645
20:02:48  +10.646
20:02:54  +10.646
20:03:00  +10.646
---------------

Step 2
Interval 00:00:30
Readings 34
---------------
   Time     Chnl 1
20:03:30  +10.646
20:04:00  +10.546
20:04:30  +10.649
20:05:00  +10.549
20:05:30  +10.649
20:06:00  +10.553
20:06:30  +10.653
20:07:00  +10.556
20:07:30  +10.656
20:09:00  +10.663
20:08:30  +10.667
20:09:00  +10.670
20:09:30  +10.674
20:10:00  +10.681
20:10:30  +10.684
20:11:00  +10.587
20:11:30  +10.691
20:12:00  +10.694
20:12:30  +10.701
20:13:00  +10.708
20:13:30  +10.708
20:14:00  +10.719
20:14:30  +10.722
20:15:00  +10.725
20:15:30  +10.732
20:15:00  +10.739
20:16:30  +10.746
20:17:00  +10.750
20:17:30  +10.760
20:18:00  +10.754
20:18:30  +10.770
20:19:00  +10.781
20:19:30  +10.784
20:20:00  +10.791
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time     Chnl 1
20:21:00  +10.815
20:22:00  +10.836
20:23:00  +10.857
20:24:00  +10.878
20:25:00  +10.899
20:25:00  +10.923
20:27:00  +10.943
20:28:00  +10.975
20:29:00  +10.999
20:30:00  +11.023
20:31:00  +11.051
20:32:00  +11.078
20:33:00  +11.106
20:34:00  +11.134
20:35:00  +11.158
20:36:00  +11.189
20:37:00  +11.220
20:38:00  +11.248
20:39:00  +11.279
20:40:00  +11.307
20:41:00  +11.338
20:42:00  +11.366
20:43:00  +11.397
20:44:00  +11.424
20:45:00  +11.459
20:46:00  +11.490
20:47:00  +11.518
20:48:00  +11.549
20:49:00  +11.577
20:50:00  +11.611
20:51:00  +11.646
20:52:00  +11.674
20:53:00  +11.705
20:54:00  +11.732
20:55:00  +11.754
20:56:00  +11.791
20:57:00  +11.822
20:58:00  +11.850
20:59:00  +11.881
21:00:00  +11.909
---------------
Step 4
Interval 01:00:00
Readings 58
---------------
   Time     Chnl 1
22:00:00  +13.219
23:00:00  +13.874
--  6/20
00:00:00  +14.601
01:00:00  +15.251
02:00:00  +15.853
03:00:00  +16.435
04:00:00  +16.932
05:00:00  +17.524
06:00:00  +18.012
07:00:00  +18.472
08:00:00  +18.926
09:00:00  +19.344
10:00:00  +19.725
11:00:00  +20.078
12:00:00  +20.458
13:00:00  +20.811
14:00:00  +21.057
15:00:00  +21.213
16:00:00  +21.317
17:00:00  +21.400
18:00:00  +21.548
19:00:00  +21.625
20:00:00  +21.770
21:00:00  +21.967
22:00:00  +22.178
23:00:00  +22.389
--  6/21
00:00:00  +22.618
01:00:00  +22.853
02:00:00  +23.088
03:00:00  +23.313
04:00:00  +23.534
05:00:00  +23.759
06:00:00  +23.963
07:00:00  +24.136
08:00:00  +24.233
09:00:00  +24.351
10:00:00  +24.434
11:00:00  +24.334
12:00:00  +24.389
13:00:00  +24.486
14:00:00  +24.572
15:00:00  +24.531
16:00:00  +24.687
17:00:00  +24.575
18:00:00  +24.631
19:00:00  +24.604
20:00:00  +24.642
21:00:00  +24.749
22:00:00  +24.691
23:00:00  +25.029
--  6/22
00:00:00  +25.152
01:00:00  +25.372
02:00:00  +25.538
```

```
I-12R cort

03:00:00   +25.721
04:00:00   +25.931
05:00:00   +26.046
06:00:00   +26.174
07:00:00   +26.323
---------------
```

STAMINA MILLS PUMPING TEST - JUNE 1988

BACKGROUND DATA
Lovett (I-37)
Elev.of Transducer = 177.2 ft (msl)

```
Model SDEE-015
S/N 0297    Block 1
--------------------
Program:    STEP TEST
Readings:   127
Start Time: 16:30:00
Start date: 06/13
Range:      0015 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
   Time     Chnl 1
16:30:00  +31.544
16:30:06  +31.544
16:30:12  +31.551
16:30:18  +31.544
16:30:24  +31.544
16:30:30  +31.541
16:30:36  +31.544
16:30:42  +31.544
16:30:48  +31.544
16:30:54  +31.544
16:31:00  +31.544
16:31:06  +31.541
16:31:12  +31.544
16:31:18  +31.544
16:31:24  +31.544
16:31:30  +31.541
16:31:36  +31.541
16:31:42  +31.544
16:31:48  +31.544
16:31:54  +31.541
16:32:00  +31.541
16:32:06  +31.541
16:32:12  +31.541
16:32:18  +31.541
16:32:24  +31.541
16:32:30  +31.541
16:32:36  +31.541
16:32:42  +31.541
16:32:48  +31.541
16:32:54  +31.541
16:33:00  +31.541
---------------
```

```
Step 2
Interval 00:00:30
Readings 34
---------------
   Time     Chnl 1
16:33:30  +31.541
16:34:00  +31.537
16:34:30  +31.537
16:35:00  +31.537
16:35:30  +31.534
16:36:00  +31.534
16:36:30  +31.534
16:37:00  +31.530
16:37:30  +31.530
16:38:00  +31.530
16:38:30  +31.530
16:39:00  +31.520
16:39:30  +31.520
16:40:00  +31.520
16:40:30  +31.517
16:41:00  +31.520
16:41:30  +31.517
16:42:00  +31.513
16:42:30  +31.517
16:43:00  +31.513
16:43:30  +31.506
16:44:00  +31.506
16:44:30  +31.503
16:45:00  +31.503
16:45:30  +31.503
16:46:00  +31.499
16:46:30  +31.496
16:47:00  +31.499
16:47:30  +31.496
16:48:00  +31.492
16:48:30  +31.492
16:49:00  +31.486
16:49:30  +31.486
16:50:00  +31.485
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
   Time     Chnl 1
16:51:00  +31.482
16:52:00  +31.479
16:53:00  +31.475
16:54:00  +31.468
16:55:00  +31.465
```

```
16:56:00  +31.461
16:57:00  +31.458
16:58:00  +31.451
16:59:00  +31.447
17:00:00  +31.444
17:01:00  +31.441
17:02:00  +31.437
17:03:00  +31.430
17:04:00  +31.427
17:05:00  +31.423
17:06:00  +31.413
17:07:00  +31.409
17:08:00  +31.406
17:09:00  +31.402
17:10:00  +31.399
17:11:00  +31.392
17:12:00  +31.389
17:13:00  +31.382
17:14:00  +31.375
17:15:00  +31.371
17:16:00  +31.364
17:17:00  +31.364
17:18:00  +31.354
17:19:00  +31.351
17:20:00  +31.347
17:21:00  +31.337
17:22:00  +31.333
17:23:00  +31.330
17:24:00  +31.325
17:25:00  +31.316
17:26:00  +31.313
17:27:00  +31.309
17:28:00  +31.295
17:29:00  +31.295
17:30:00  +31.288
---------------
Step 4
Interval 01:00:00
Readings 22
---------------
   Time     Chnl 1
18:30:00  +30.897
19:30:00  +30.580
20:30:00  +30.434
21:30:00  +30.281
22:30:00  +30.174
23:30:00  +30.102
--  6/14
00:30:00  +30.074
01:30:00  +30.057
```

```
02:30:00  +30.074
03:30:00  +30.105
04:30:00  +30.143
05:30:00  +30.181
06:30:00  +30.212
07:30:00  +30.223
08:30:00  +30.209
09:30:00  +30.216
10:30:00  +30.254
11:30:00  +30.226
12:30:00  +30.129
13:30:00  +30.063
14:30:00  +30.140
15:30:00  +30.205
---------------


NEW TEST


Model SDEE-018
S/N 0297    Block 2
--------------------
Program:    INTERVAL
Readings:   26
Start Time: 18:00:00
Start date: 06/14
Range:      0015 PSI
Units:      Ft-H20
--------------------
Interval:  01:00:00
   Time     Chnl 1
18:00:00  +30.309
19:00:00  +30.915
20:00:00  +30.178
21:00:00  +30.852
22:00:00  +30.624
23:00:00  +30.586
--  6/15
00:00:00  +30.600
01:00:00  +30.548
02:00:00  +30.728
03:00:00  +30.825
04:00:00  +30.932
05:00:00  +31.039
06:00:00  +31.140
07:00:00  +31.226
08:00:00  +31.292
09:00:00  +31.316
10:00:00  +31.364
```

I-37 cont.

```
11:00:00   +31.344
12:00:00   +31.344
13:00:00   +31.357
14:00:00   +31.330
15:00:00   +31.264
16:00:00   +31.292
17:00:00   +30.984
18:00:00   +31.146
19:00:00   +31.240
---------------
```

STAMINA MILLS PUMPING TEST - JUNE 1988

DRAWDOWN DATA
LOVETTE (I-37)
Elev. of Transducer = 177.2 ft (msl)

```
Model SDEE-01B
S/N 0297    Block 1
--------------------
Program:    STEP TEST
Readings:   138
Start Time: 21:00:00
Start date: 06/15
Range:      0015 PSI
Units:      Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
  Time     Chnl 1
21:00:00  +31.326
21:00:06  +31.326
21:00:12  +31.326
21:00:18  +31.326
21:00:24  +31.326
21:00:30  +31.326
21:00:36  +31.326
21:00:42  +31.325
21:00:48  +31.326
21:00:54  +31.325
21:01:00  +31.326
21:01:06  -31.326
21:01:12  +31.326
21:01:18  +31.326
21:01:24  +31.326
21:01:30  +31.326
21:01:36  +31.326
21:01:42  +31.325
21:01:48  +31.326
21:01:54  +31.326
21:02:00  +31.326
21:02:06  +31.326
21:02:12  +31.326
21:02:18  +31.326
21:02:24  +31.326
21:02:30  +31.325
21:02:36  +31.326
21:02:42  +31.325
21:02:48  +31.326
21:02:54  +31.325
21:03:00  +31.326

---------------
Step 2
Interval 00:00:30
Readings 34
---------------
  Time     Chnl 1
21:03:30  +31.326
21:04:00  +31.326
21:04:30  +31.325
21:05:00  +31.326
21:05:30  +31.330
21:06:00  +31.326
21:06:30  +31.325
21:07:00  +31.326
21:07:30  +31.325
21:08:00  +31.326
21:08:30  +31.325
21:09:00  +31.326
21:09:30  +31.325
21:10:00  +31.326
21:10:30  +31.319
21:11:00  +31.319
21:11:30  +31.319
21:12:00  +31.319
21:12:30  +31.319
21:13:00  +31.316
21:13:30  +31.319
21:14:00  +31.319
21:14:30  +31.319
21:15:00  +31.319
21:15:30  +31.319
21:16:00  +31.316
21:16:30  +31.313
21:17:00  +31.316
21:17:30  +31.316
21:18:00  +31.313
21:18:30  +31.315
21:19:00  -31.313
21:19:30  +31.313
21:20:00  +31.313
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
  Time     Chnl 1
21:21:00  +31.309
21:22:00  +31.309

21:23:00  +31.306
21:24:00  +31.306
21:25:00  +31.299
21:26:00  +31.295
21:27:00  +31.295
21:28:00  +31.292
21:29:00  +31.292
21:30:00  +31.285
21:31:00  +31.281
21:32:00  +31.281
21:33:00  +31.278
21:34:00  +31.278
21:35:00  +31.274
21:36:00  +31.274
21:37:00  +31.264
21:38:00  +31.264
21:39:00  +31.261
21:40:00  +31.261
21:41:00  +31.257
21:42:00  +31.254
21:43:00  +31.250
21:44:00  +31.243
21:45:00  +31.240
21:46:00  +31.236
21:47:00  +31.236
21:48:00  +31.233
21:49:00  +31.226
21:50:00  +31.223
21:51:00  +31.223
21:52:00  +31.216
21:53:00  +31.212
21:54:00  +31.216
21:55:00  +31.205
21:56:00  +31.202
21:57:00  +31.198
21:58:00  +31.188
21:59:00  +31.188
22:00:00  +31.181
---------------
Step 4
Interval 01:00:00
Readings 33
---------------
  Time     Chnl 1
23:00:00  +30.832
--  6/16
00:00:00  +30.595
01:00:00  +30.330

02:00:00  +30.088
03:00:00  +29.894
04:00:00  +29.714
05:00:00  +29.562
06:00:00  +29.420
07:00:00  +29.257
08:00:00  +29.102
09:00:00  +28.922
10:00:00  +28.628
11:00:00  +28.493
12:00:00  +28.347
13:00:00  +28.195
14:00:00  +28.064
15:00:00  +27.963
16:00:00  +27.891
17:00:00  +27.790
18:00:00  +27.583
19:00:00  +27.510
20:00:00  +27.427
21:00:00  +27.152
22:00:00  +27.109
23:00:00  +27.015
--  6/17
00:00:00  +26.908
01:00:00  +26.815
02:00:00  +26.725
03:00:00  +26.545
04:00:00  +26.517
05:00:00  +26.510
06:00:00  +26.469
07:00:00  +26.417
---------------
```

I-37 cont.

NEW TEST

```
Model SDEE-01B                -- 6/19
S/N 0297    Block 2           00:00:00   +21.953
--------------------          01:00:00   +21.856
Program:     INTERVAL         02:00:00   +21.753
Readings:    59               03:00:00   +21.669
Start Time: 08:00:00          04:00:00   +21.586
Start date: 06/17             05:00:00   +21.512
Range:       0015 PSI         06:00:00   +21.448
Units:       Ft-H20           07:00:00   +21.389
--------------------          08:00:00   +21.320
Interval:  01:00:00           09:00:00   +21.234
   Time      Chnl 1           10:00:00   +21.169
08:00:00   +26.340            11:00:00   +21.081
09:00:00   +26.188            12:00:00   +20.977
10:00:00   +26.133            13:00:00   +20.559
11:00:00   +26.029            14:00:00   +20.628
12:00:00   +25.922            15:00:00   +20.545
13:00:00   +25.815            16:00:00   +20.355
14:00:00   +25.707            17:00:00   +20.261
15:00:00   +25.585            18:00:00   +20.064
16:00:00   +25.361            ---------------
17:00:00   +25.306
18:00:00   +25.219
19:00:00   +25.126
20:00:00   +25.033
21:00:00   +24.780
22:00:00   +24.725
23:00:00   +24.628
--  6/18
00:00:00   +24.534
01:00:00   +24.437
02:00:00   +24.344
03:00:00   +24.254
04:00:00   +24.053
05:00:00   +24.022
06:00:00   +23.964
07:00:00   +23.939
08:00:00   +23.874
09:00:00   +23.666
10:00:00   +23.617
11:00:00   +23.531
12:00:00   +23.424
13:00:00   +23.305
14:00:00   +23.158
15:00:00   +23.081
16:00:00   +22.957
17:00:00   +22.822
18:00:00   +22.607
19:00:00   +22.548
20:00:00   +22.458
21:00:00   +22.351
22:00:00   +22.119
23:00:00   +22.043
```

```
STAMINA MILLS PUMPING TEST - JUNE 1989

RECOVERY DATA
LOVETTE(I-37)
Elev. of Transducer = 177.2 ft (msl)

Model SDEE-018
S/N 0297    Block 1
--------------------
Program:     STEP TEST
Readings:    165
Start Time:  20:00:00
Start date:  06/19
Range:       0015 PSI
Units:       Ft-H20
--------------------
Step 1
Interval 00:00:06
Readings 31
---------------
  Time      Chnl 1
20:00:00   +19.950
20:00:06   +19.950
20:00:12   +19.950
20:00:18   +19.950
20:00:24   +19.943
20:00:30   +19.943
20:00:36   +19.943
20:00:42   +19.943
20:00:48   +19.943
20:00:54   +19.943
20:01:00   +19.950
20:01:06   +19.943
20:01:12   +19.943
20:01:18   +19.950
20:01:24   +19.943
20:01:30   +19.943
20:01:36   +19.952
20:01:42   +19.950
20:01:48   +19.943
20:01:54   +19.950
20:02:00   +19.950
20:02:06   +19.950
20:02:12   +19.950
20:02:18   +19.950
20:02:24   +19.950
20:02:30   +19.950
20:02:36   +19.950
20:02:42   +19.950
20:02:48   +19.950
20:02:54   +19.950
20:03:00   +19.950
---------------

Step 2
Interval 00:00:30
Readings 34
---------------
  Time      Chnl 1
20:03:30   +19.950
20:04:00   +19.950
20:04:30   +19.950
20:05:00   +19.950
20:05:30   +19.950
20:06:00   +19.943
20:06:30   +19.939
20:07:00   +19.939
20:07:30   +19.939
20:08:00   +19.936
20:08:30   +19.936
20:09:00   +19.935
20:09:30   +19.936
20:10:00   +19.933
20:10:30   +19.933
20:11:00   +19.953
20:11:30   +19.953
20:12:00   +19.915
20:12:30   +19.822
20:13:00   +19.794
20:13:30   +19.818
20:14:00   +19.787
20:14:30   +19.787
20:15:00   +19.791
20:15:30   +19.801
20:16:00   +19.791
20:16:30   +19.794
20:17:00   +19.805
20:17:30   +19.801
20:18:00   +19.808
20:18:30   +19.805
20:19:00   +19.808
20:19:30   +19.808
20:20:00   +19.808
---------------
Step 3
Interval 00:01:00
Readings 40
---------------
  Time      Chnl 1
20:21:00   +19.811
20:22:00   +19.819
20:23:00   +19.811
20:24:00   +19.822

20:25:00   +19.818
20:26:00   +19.818
20:27:00   +19.818
20:28:00   +19.818
20:29:00   +19.818
20:30:00   +19.818
20:31:00   +19.818
20:32:00   +19.818
20:33:00   +19.818
20:34:00   +19.818
20:35:00   +19.818
20:36:00   +19.818
20:37:00   +19.818
20:38:00   +19.818
20:39:00   +19.811
20:40:00   +19.818
20:41:00   +19.811
20:42:00   +19.811
20:43:00   +19.811
20:44:00   +19.811
20:45:00   +19.811
20:46:00   +19.811
20:47:00   +15.811
20:48:00   +19.808
20:49:00   +19.908
20:50:00   +19.808
20:51:00   +19.808
20:52:00   +19.811
20:53:00   +19.908
20:54:00   +19.808
20:55:00   +19.808
20:56:00   +19.808
20:57:00   +19.808
20:58:00   +19.808
20:59:00   +19.808
21:00:00   +19.808
---------------
Step 4
Interval 01:00:00
Readings 60
---------------
  Time      Chnl 1
22:00:00   +19.856
23:00:00   +19.994
--  6/20
00:00:00   +20.099
01:00:00   +20.251
02:00:00   +20.417
03:00:00   +20.607

04:00:00   +20.799
05:00:00   +21.009
06:00:00   +21.240
07:00:00   +21.455
08:00:00   +21.676
09:00:00   +21.884
10:00:00   +22.100
11:00:00   +22.310
12:00:00   +22.496
13:00:00   +22.683
14:00:00   +22.829
15:00:00   +22.998
16:00:00   +23.171
17:00:00   +23.299
18:00:00   +23.417
19:00:00   +23.507
20:00:00   +23.611
21:00:00   +23.714
22:00:00   +23.804
23:00:00   +23.905
--  6/21
00:00:00   +24.012
01:00:00   +24.116
02:00:00   +24.230
03:00:00   +24.341
04:00:00   +24.455
05:00:00   +24.572
06:00:00   +24.700
07:00:00   +24.832
08:00:00   +24.967
09:00:00   +25.078
10:00:00   +25.185
11:00:00   +25.278
12:00:00   +25.354
13:00:00   +25.413
14:00:00   +25.455
15:00:00   +25.523
16:00:00   +25.565
17:00:00   +25.610
18:00:00   +25.659
19:00:00   +25.714
20:00:00   +25.766
21:00:00   +25.797
22:00:00   +25.835
23:00:00   +25.880
--  6/22
00:00:00   +25.946
01:00:00   +26.021
02:00:00   +26.050
```

```
I-378 cont

03:00:00   +26.125
04:00:00   +26.222
05:00:00   +26.285
06:00:00   +26.375
07:00:00   +26.475
08:00:00   +26.565
09:00:00   +26.645
---------------
```

```
[illegible] MILLS PUMPING TEST   JUNE 1988

BACKGROUND DATA
[illegible]eaton (1-34)
Elev. of Transducer = 153.7 ft (msl)

Model [illegible]-01B         02:00:00   +64.771      NEW TEST                     Step 2
S/N [illegible]   Block 1     03:00:00   +64.825                                   Interval 00:00:30
---------------------         04:00:00   +64.843                                   Readings 34
Program:    INTERVAL          05:00:00   +64.880      Model [illegible]-01B        ---------------
Readings:   74                06:00:00   +64.903      S/N [illegible]   Block 2      Time       Chnl 1
Start Time: 14:00:00          07:00:00   +64.944      ---------------------        15:33:30   +63.980
Start date: 05/10             08:00:00   +64.973      Program:    STEP TEST        15:34:00   +63.975
Range:      0025 PSI          09:00:00   +65.001      Readings:   105              15:34:30   +63.975
Units:      Ft-H2O            10:00:00   +65.032      Start Time: 15:30:00         15:35:00   +63.975
---------------------         11:00:00   +65.076      Start date: 05/13            15:35:30   +63.975
Interval:  01:00:00           12:00:00   +65.142      Range:      0025 PSI         15:36:00   +63.975
   Time      Chnl 1           13:00:00   +65.215      Units:      Ft-H2O           15:36:30   +63.975
14:00:00   +66.754            14:00:00   +65.257      ---------------------        15:37:00   +63.975
15:00:00   +66.812            15:00:00   +65.295      Step 1                       15:37:30   +63.969
16:00:00   +66.875            16:00:00   +65.273      Interval 00:00:06            15:38:00   +63.975
17:00:00   +66.876            17:00:00   +65.192      Readings 31                  15:38:30   +63.969
18:00:00   +66.819            18:00:00   +65.036      ---------------              15:39:00   +63.969
19:00:00   +66.726            19:00:00   +64.857        Time      Chnl 1           15:39:30   +63.969
20:00:00   +66.622            20:00:00   +64.713      15:30:00   +63.985           15:40:00   +63.969
21:00:00   +66.547            21:00:00   +64.575      15:30:06   +63.975           15:40:30   +63.969
22:00:00   +66.473            22:00:00   +64.454      15:30:12   +63.975           15:41:00   +63.969
23:00:00   +66.437            23:00:00   +64.332      15:30:18   +63.975           15:41:30   +63.969
--  5/11                      --  5/13                15:30:24   +63.975           15:42:00   +63.969
00:00:00   +66.432            00:00:00   +64.257      15:30:30   +63.975           15:42:30   +63.969
01:00:00   +66.432            01:00:00   +64.228      15:30:36   +63.975           15:43:00   +63.963
02:00:00   +66.449            02:00:00   +64.200      15:30:42   +63.975           15:43:30   +63.963
03:00:00   +66.472            03:00:00   +64.208      15:30:48   +63.975           15:44:00   +63.963
04:00:00   +66.459            04:00:00    64.223      15:30:54   +63.975           15:44:30   +63.963
05:00:00   +66.501            05:00:00   +64.251      15:31:00   +63.975           15:45:00   +63.[illegible]
06:00:00   +66.506            06:00:00   +64.263      15:31:06   +63.980           15:45:30   +63.963
07:00:00   +66.525            07:00:00   +64.292      15:31:12   +63.975           15:46:00   +63.963
08:00:00   +66.526            08:00:00   +64.304      15:31:18   +63.975           15:46:30   +63.963
09:00:00   +66.510            09:00:00   +64.327      15:31:24   +63.975           15:47:00   +63.963
10:00:00   +66.535            10:00:00   +64.327      15:31:30   +63.975           15:47:30   +63.963
11:00:00   +66.379            11:00:00   +64.221      15:31:36   +63.975           15:48:00   +63.958
12:00:00   +65.903            12:00:00   +64.204      15:31:42   +63.986           15:48:30   +63.958
13:00:00   +65.833            13:00:00   +64.131      15:31:48   +63.975           15:49:00   +63.958
14:00:00   +65.705            14:00:00   +64.055      15:31:54   +63.986           15:49:30   +63.958
15:00:00   +65.704            15:00:00   +64.021      15:32:00   +63.975           15:50:00   +63.958
16:00:00   +65.474            ---------------         15:32:06   +63.986           ---------------
17:00:00   +65.174                                    15:32:12   +63.975           Step 3
18:00:00   +65.[illegible]                            15:32:18   +63.969           Interval 00:01:00
19:00:00   +64.[illegible]                            15:32:24   +63.975           Readings 40
20:00:00   +64.[illegible]                            15:32:30   +63.980           ---------------
21:00:00   +64.802                                    15:32:36   +63.975             Time      Chnl 1
22:00:00   +64.733                                    15:32:42   +63.975           15:51:00   +63.952
23:00:00   +64.711                                    15:32:48   +63.975           15:52:00   +63.952
--  5/12                                              15:32:54   +63.975           15:53:00   +63.952
00:00:00   +64.713                                    15:33:00   +63.980           15:54:00   +63.946
01:00:00   +64.722                                    ---------------              15:55:00   +63.946
```

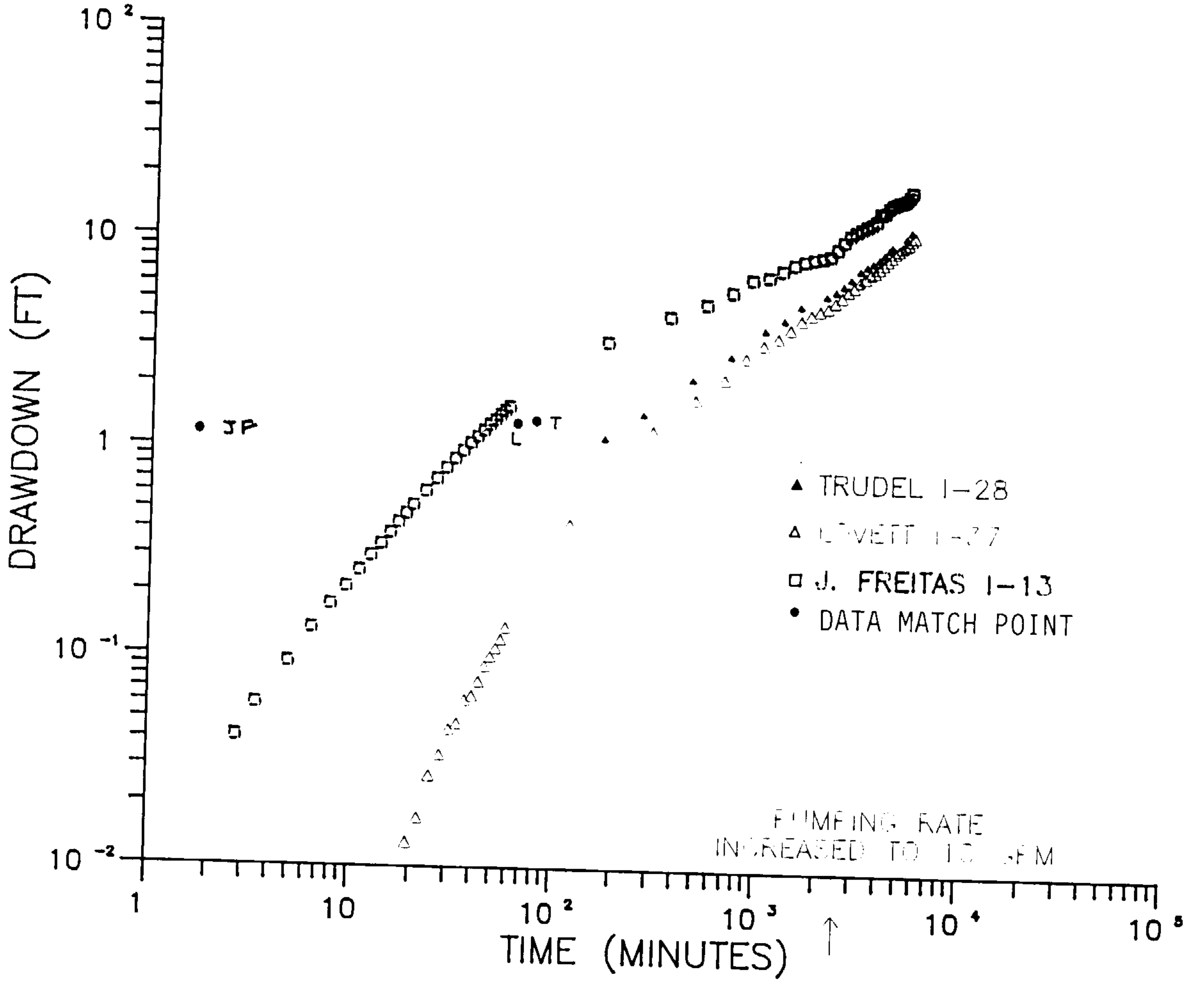
```
1 In cont.

16:56:00   +63.[illegible]          04:30:00   +62.[illegible]
16:57:00   +63.935          05:30:00   +62.660
16:58:00   +63.929          06:30:00   +62.724
16:59:00   +63.929          07:30:00   +62.71[illegible]
17:00:00   +63.923          08:30:00   +62.747
17:01:00   +63.917          09:30:00   +62.751
17:02:00   +63.917          10:30:00   +62.724
17:03:00   +63.9[illegible]          11:30:00   +62.[illegible]
17:04:00   +63.908          13:00:00   +62.678
17:05:00   +63.900          14:00:00   +62.640
17:06:00   +63.902          15:00:00   +62.560
17:07:00   +63.894          16:00:00   +62.718
17:08:00   +63.889          17:00:00   +62.572
17:09:00   +63.883          18:00:00   +62.562
17:10:00   +63.871          19:00:00   +62.522
17:11:00   +63.871          20:00:00   +62.574
17:12:00   +63.865          21:00:00   +62.522
17:13:00   +63.860          22:00:00   +62.487
17:14:00   +63.854          23:00:00   +62.475
17:15:00   +63.840          --  6/15
17:16:00   +63.837          00:00:00   +62.481
17:17:00   +63.831          01:00:00   +62.510
17:18:00   +63.831          02:00:00   +62.552
17:19:00   +63.823          03:00:00   +62.621
17:20:00   +63.813          04:00:00   +62.713
17:21:00   +63.813          05:00:00   +62.792
17:22:00   +63.793          06:00:00   +62.872
17:23:00   +63.796          07:00:00   +62.943
17:24:00   +63.792          08:00:00   +62.995
17:25:00   +63.785          09:00:00   +63.025
17:26:00   +63.773          10:00:00   +63.050
17:27:00   +63.752          11:00:00   +63.075
17:28:00   +63.752          12:00:00   +63.098
17:29:00   +63.752          13:00:00   +63.127
17:30:00   +63.728          14:00:00   +63.151
--------------              --------------
Step 6
Interval 01:00:00
Readings 13
--------------
   Time     Chnl 1
18:30:00   +63.156
19:30:00   +63.045
20:30:00   +62.725
21:30:00   +62.[illegible]
22:30:00   +62.528
23:30:00   +62.5[illegible]
--  6/14
00:30:00   +62.487
01:30:00   +62.524
02:30:00   +62.545
03:30:00   +62.585
```

APPENDIX I

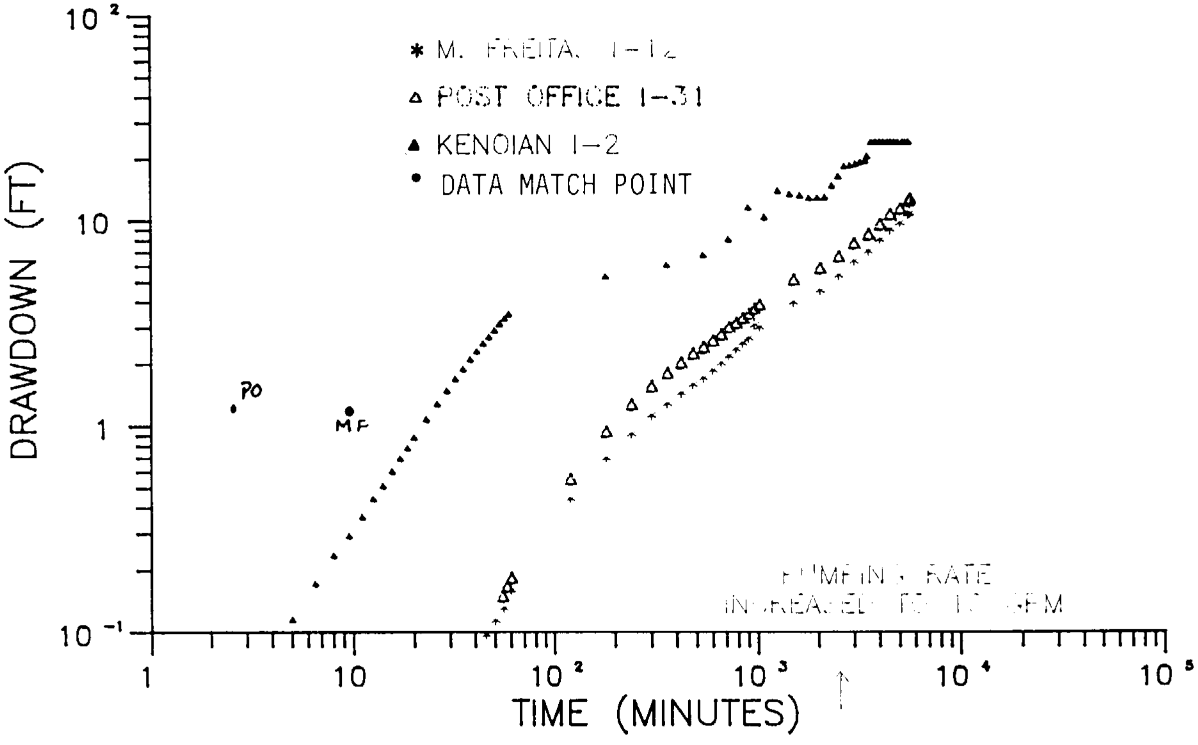
BARRENBLATT MODEL CALCULATIONS

STAMINA MILLS RI/FS
PUMPING TEST



BARENBLATT MODEL (LOG PLOT)

STAMINA MILLS RI/FS
PUMPING TEST



BARENBLATT MODEL (LOG PLOT)

BARENBLATT MODEL

M. Freitas I-12

$$T_F = \frac{Q}{4\pi\Delta s} = W_F = \frac{1347.6\ ft^3/d}{4\pi(1.2\ ft)} = 89.4\ ft^2/d = 669\ gpd/ft$$

$$S_B = \frac{4T_F t\ \theta}{r^2} = \frac{4(89.4\ ft^2/d)\ (9.3\ min)}{1440(245\ ft)^2} = 3.8\ E\text{-}5$$

Post Office I-31

$$T_F = \frac{1347.6\ ft^3/d}{4\pi(1.2\ ft)} = 89.4\ ft^2/d = 669\ gpd/ft$$

$$S_B = \frac{4(89.4\ ft^2/d)\ (2.6\ min)}{1440(790\ ft)^2} = 1.1\ E\text{-}6$$

Trudel I-28

$$T_F = \frac{1347.6\ ft^3/d}{4\pi\ (1.4\ ft)} = 76.6\ ft^2/d = 573\ gpd/ft$$

$$S_B = \frac{4(76.6\ ft^2/d)\ (78\ min)}{1440(675\ ft)^2} = 3.6\ E\text{-}5$$

J. Freitas I-13

$$T_F = \frac{1347.6\ ft^3/d}{4\pi\ (1.2\ ft)} = 89.4\ ft^2/d = 669\ gpd/ft$$

$$S_B = \frac{4(89.4\ ft^2/d)\ (1.7\ min)}{1440\ (190\ ft)^2} = 1.2\ E\text{-}5$$

Kenoian I-2 - No match point

Lovett I-37

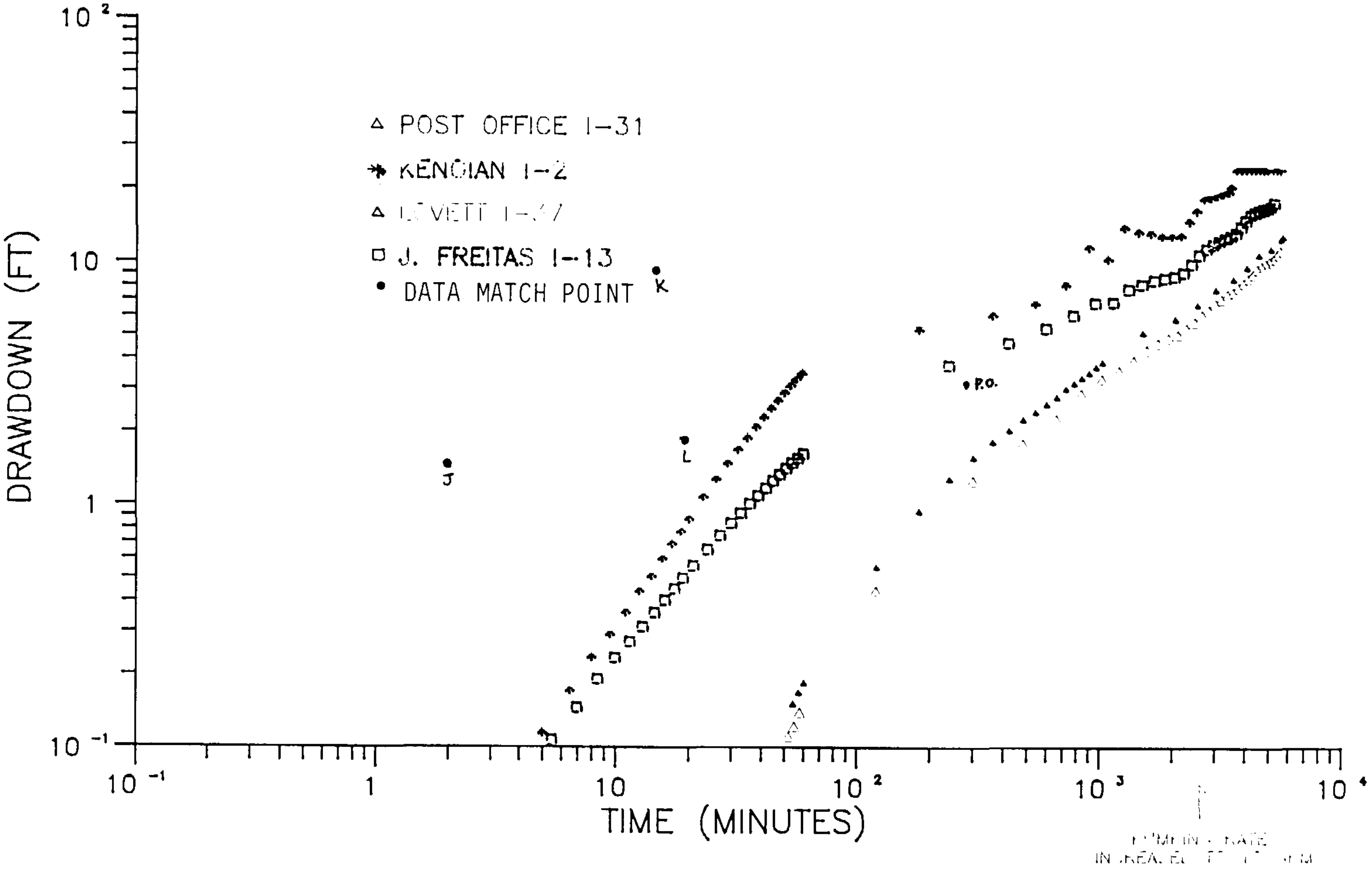
$$T_F = \frac{1347.6\ ft^3/d = 71.5\ ft^2/d}{4\pi(1.5\ ft)} = 535\ gpd/ft$$

$$S_B = \frac{4(71.5\ ft^2/d)\ (63\ min)}{1440\ (570\ ft)^2} = 3.8\ E\text{-}5$$

APPENDIX J

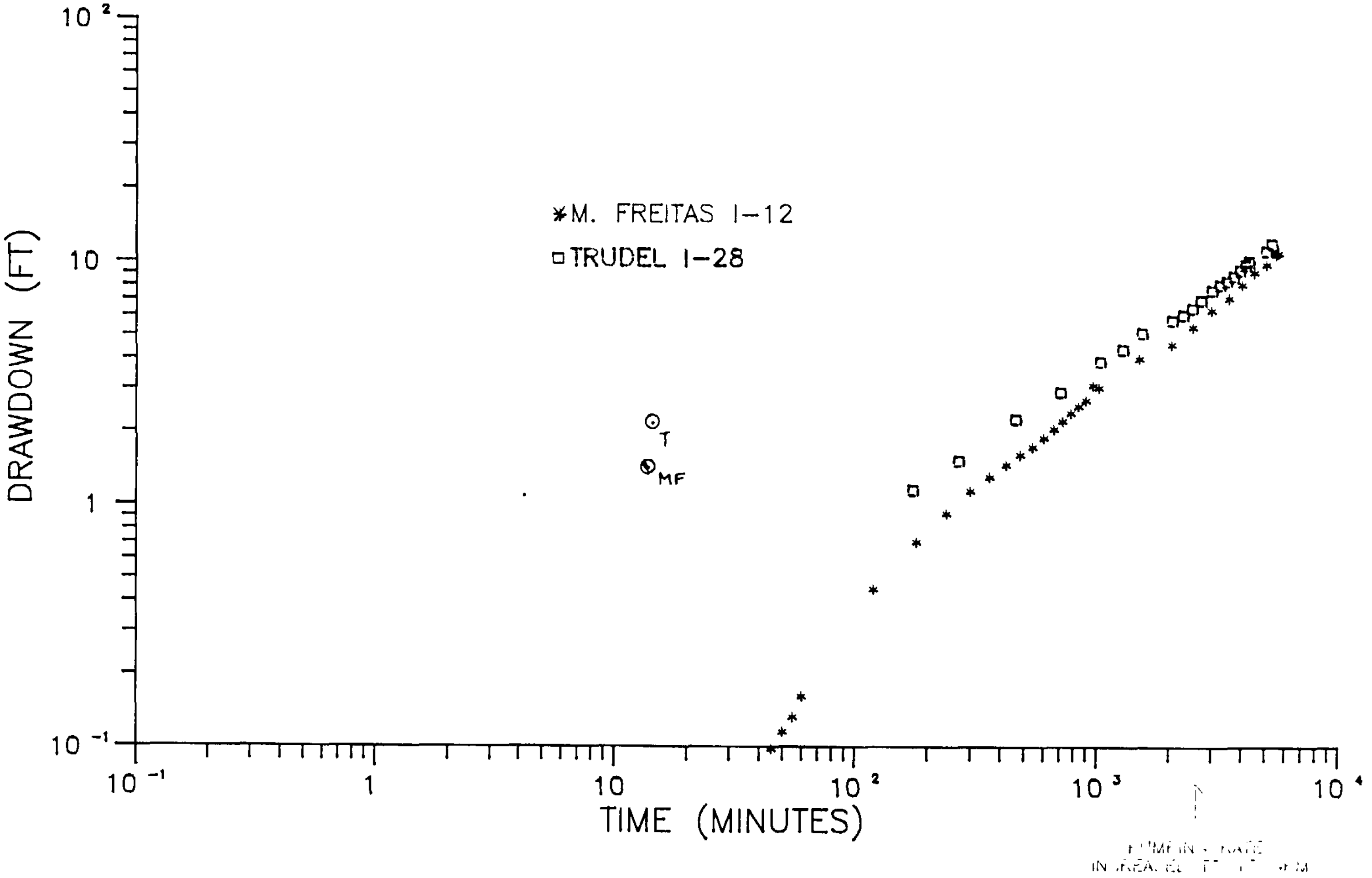
RANDOM BLOCK AND FISSURE MODEL CALCULATIONS

STAMINA MILLS RI/FS
PUMPING TEST



RANDOM BLOCK AND FISSURE MODEL

STAMINA MILLS RI/FS
PUMPING TEST



RANDOM BLOCK AND FISSURE MODEL

RANDOM BLOCK AND FISSURE

Kenoian I-2

$$T_F = \frac{1347.6\ ft^3/d\ (1)}{4\pi(9ft)}$$

$$S_F = \frac{4(11.9\ ft^2/d)(15\ min)}{1440\ (265ft)^2} = 7.1\ E\text{-}6$$

Lovett I-37

$$T_F = \frac{1347.6(1)}{4\pi(1.7)} = 63.1\ ft^2/d$$

$$S_F = \frac{4(63.1)(19)}{1440\ (570)^2} = 1.0\ E\text{-}5$$

J. Freitas I-13

$$T_F = \frac{1347.6(1)}{4\pi(1.5)} = 71.5\ ft^2/d$$

$$S_F = \frac{4(71.5)(1.9)}{1440\ (190)^2} = 1.1\ E\text{-}5$$

M. Freitas I-12

$$T_F = \frac{1347.6(1)}{4\pi(1.3)} = 82.5\ ft^2/d$$

$$S_F = \frac{4(82.5)(14)}{4\pi(245)^2} = 6.1\ E\text{-}3$$

Post Office I-31

$$T_F = \frac{1347.6(1)}{4\pi(2.8)} = 38.3\ ft^2/d$$

$$S_F = \frac{4(38.3)(270)}{1440\ (790)^2} = 4.6\ E\text{-}5$$

Trudel I-28

$$T_F = \frac{1347.6(1)}{4\pi(2.1)} = 51.1\ ft^2/d$$

$$S_F = \frac{4(51.1)(15)}{1440\ (675)^2} = 4.7\ E\text{-}6$$

The heat-pulse flowmeter system (Hess, 1982, 1985) was used to provide accurate measurements of flow distributions in the boreholes at the Mirror Lake and Oracle sites. The heat-pulse flowmeter consists of a resistance-wire heating grid, vertically centered between two temperature-sensitive resistors (thermistors) within a hollow, vertically oriented tube. To measure the velocity of the water through the tube, the heat grid is heated momentarily with a short pulse of electric current. The sheet of water heated by the current pulse then moves past one of the thermistors, producing an unbalanced condition in the thermal-electric bridge. This signal is amplified electronically and is recorded on a clock-driven strip chart. The direction of the deflection in the curve on the chart indicates whether flow is up or down the borehole; the velocity of flow is determined from the time between trigger pulse and the local maximum of the thermal bridge response.

At higher flow rates, the flowmeter response is calibrated in liters per minute. At lower flow rates, most flow can bypass the flowmeter measurement section by means of the annular space between centralized flowmeter and the borehole wall. In such low flow cases, the flowmeter was used with a flow concentration skirt composed of several layers

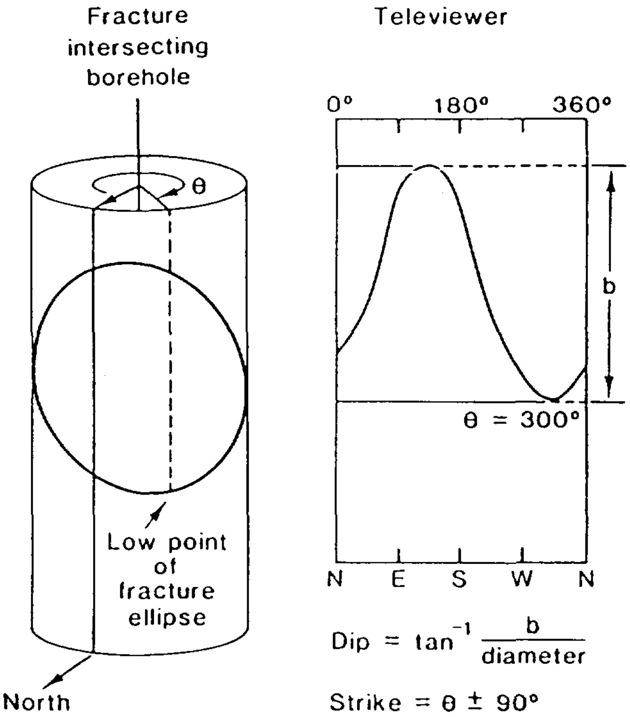


Fig. 3. Illustration of fracture strike and dip determination from televiewer logs.

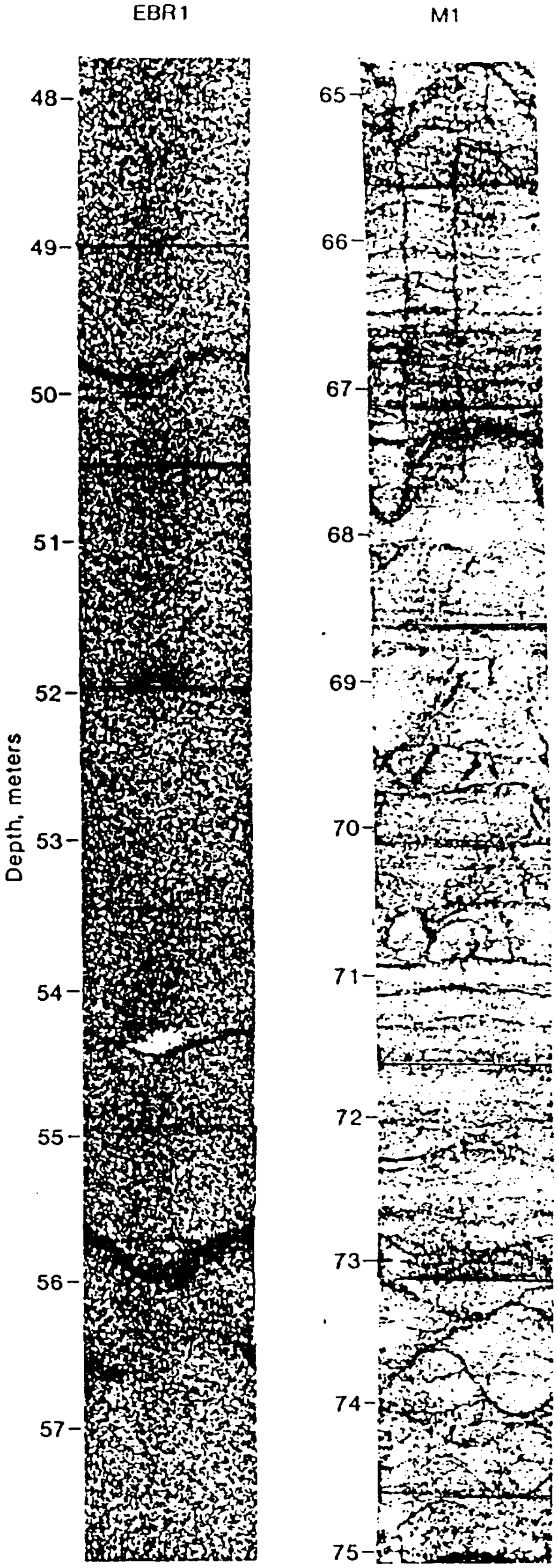
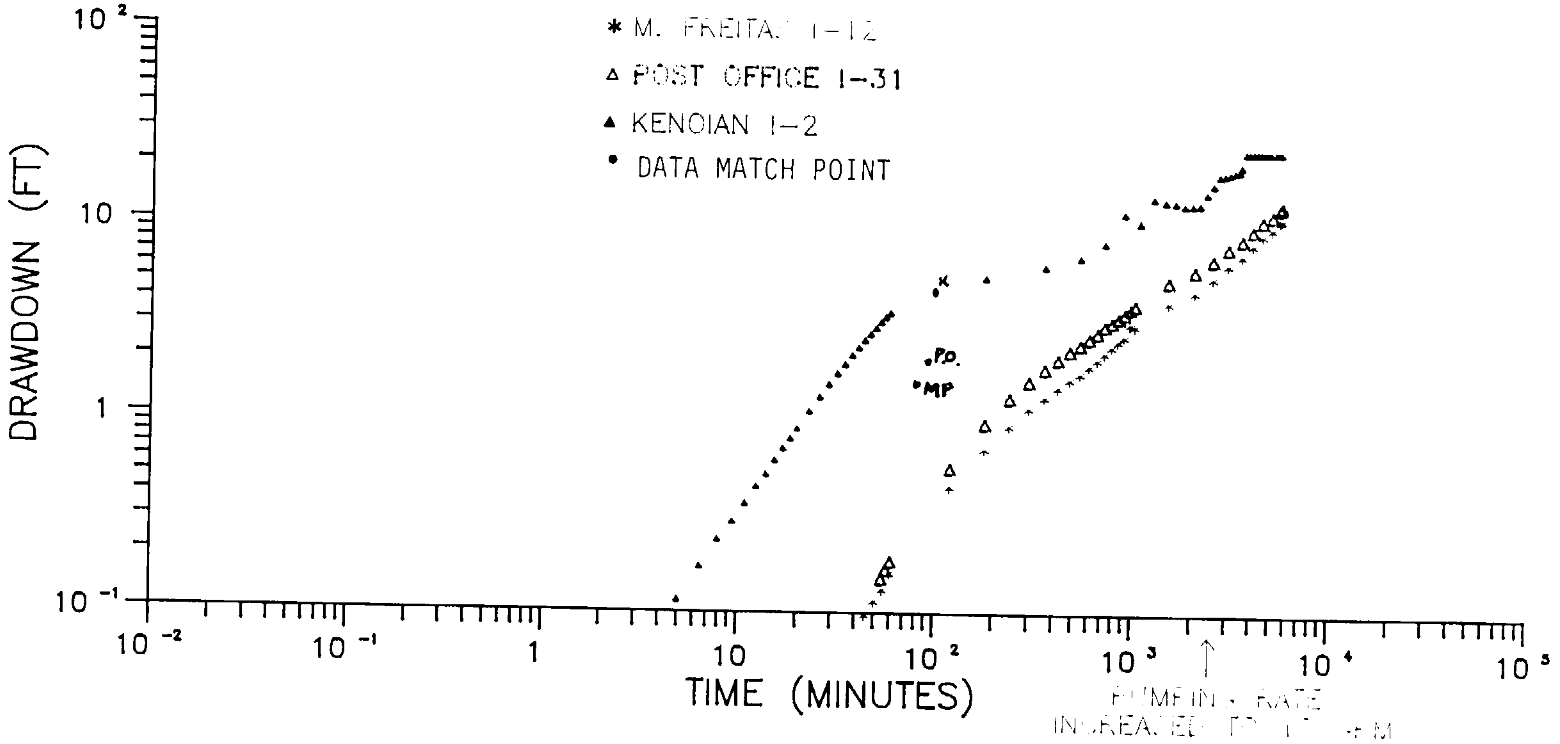


Fig. 4. Representative examples of borehole acoustic-televiewer logs, showing degree of fracturing in boreholes at (A) Mirror Lake site, and (B) Oracle site.

APPENDIX K

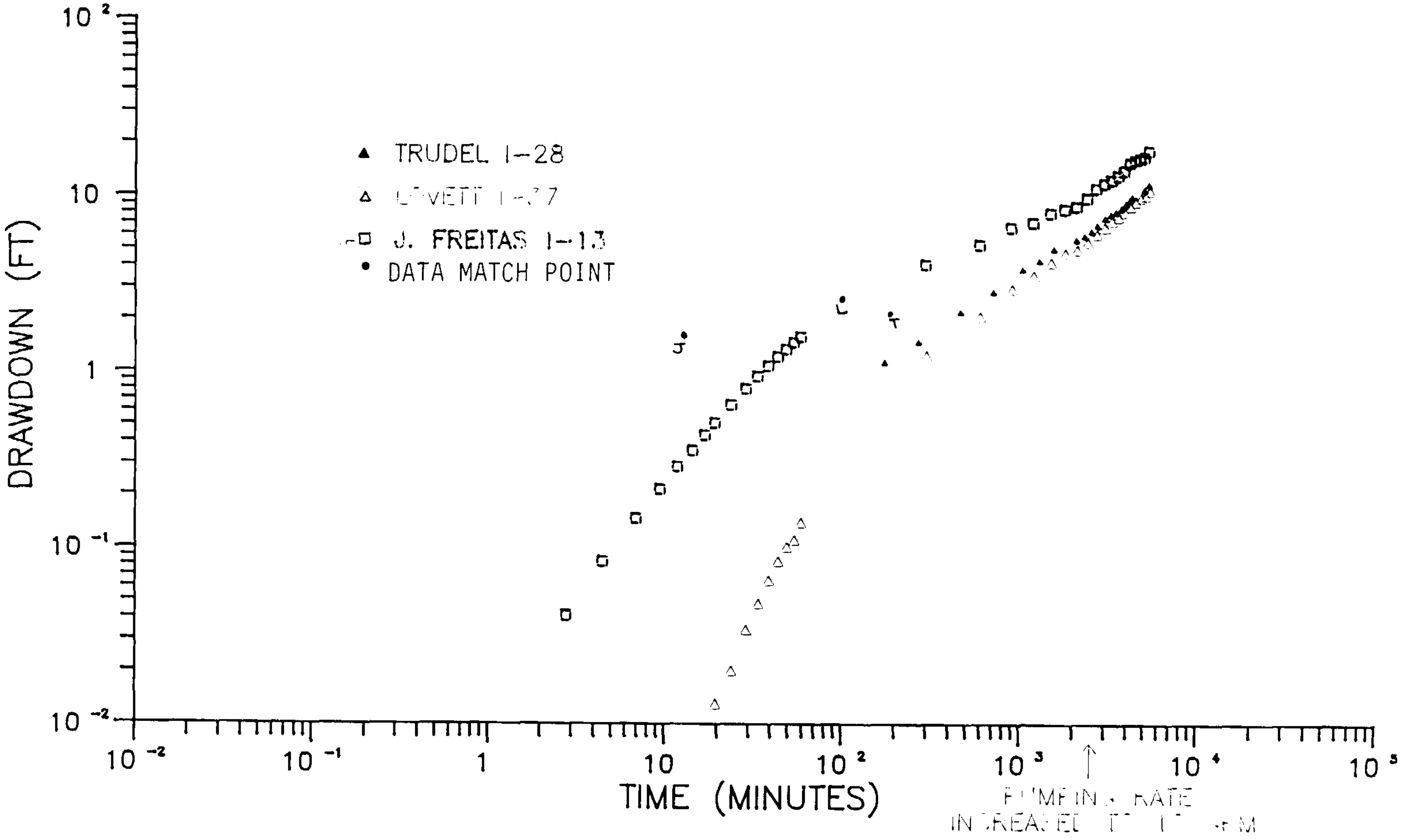
TWO-LAYER BLOCK AND FISSURE MODEL CALCULATIONS

STAMINA MILLS RI/FS
PUMPING TEST



TWO LAYER BLOCK AND FISSUE MODEL
(WATER TABLE CONDITIONS)

STAMINA MILLS RI/FS
PUMPING TEST



TWO LAYER BLOCK AND FISSURE MODEL
(WATER TABLE CONDITIONS)

TWO LAYER BLOCK AND FISSURE - WATER TABLE AQUIFER

$$T_F = (Q/4\pi\Delta s)\ \ W(u)$$

$$S_F = (4T_F t/r^2)(u)$$

KENOIAN I-2

$$T_F = \frac{1347.6\ \text{ft}^3/\text{d}\ (1)}{4\ \pi(4.5)\ \text{ft}} = 23.8\ \text{ft}^2/\text{d}$$

$$S_F = \frac{4(23.8\ \text{ft}^2/\text{d})\ (91\ \text{min})}{1440\ (265\ \text{ft})^2} = 8.6\ \text{E-5}$$

LOVETT I-37

$$T_F = \frac{1347.6\ \text{ft}^3/\text{d}\ (1)}{4\,\pi\ 2.7\ \text{ft}} = 39.7\ \text{ft}^2/\text{d}$$

$$S_F = \frac{4(39.7\ \text{ft}^2/\text{d})(98\ \text{min})}{1440\ (570\ \text{ft})^2} = 3.3\ \text{E-5}$$

J. FREITAS I-13

$$T_F = \frac{1347.6\ \text{ft}^3/\text{d}\ (1)}{4\,\pi\ 1.7\ \text{ft}} = 63.1\ \text{ft}^2/\text{d}$$

$$S_F = \frac{4(63.1\ \text{ft}^2/\text{d})(12\ \text{min})}{1440\ (190\ \text{ft})^2} = 5.8\ \text{E-5}$$

M. FREITAS I-12

$$T_F = \frac{1347.6\ \text{ft}^3/\text{d}\ (1)}{4\pi\ 1.5\ \text{ft}} = 71.5\ \text{ft}^2/\text{d}$$

$$S_F = \frac{4(71.5\ \text{ft}^2/\text{d})\ (80\ \text{min})}{1440\ (245\ \text{ft})^2} = 2.6\ \text{E-4}$$

POST OFFICE I-31

$$T_F = \frac{1347.6\ \text{ft}^3/\text{d}\ (1)}{4\pi\ \ 2\ \text{ft}} = 53.6\ \text{ft}^2/\text{d}$$

$$S_F = \frac{4(53.6\ \text{ft}^2/\text{d})(90\ \text{min})}{1440\ (790\ \text{ft})^2} = 2.1\ \text{E-5}$$

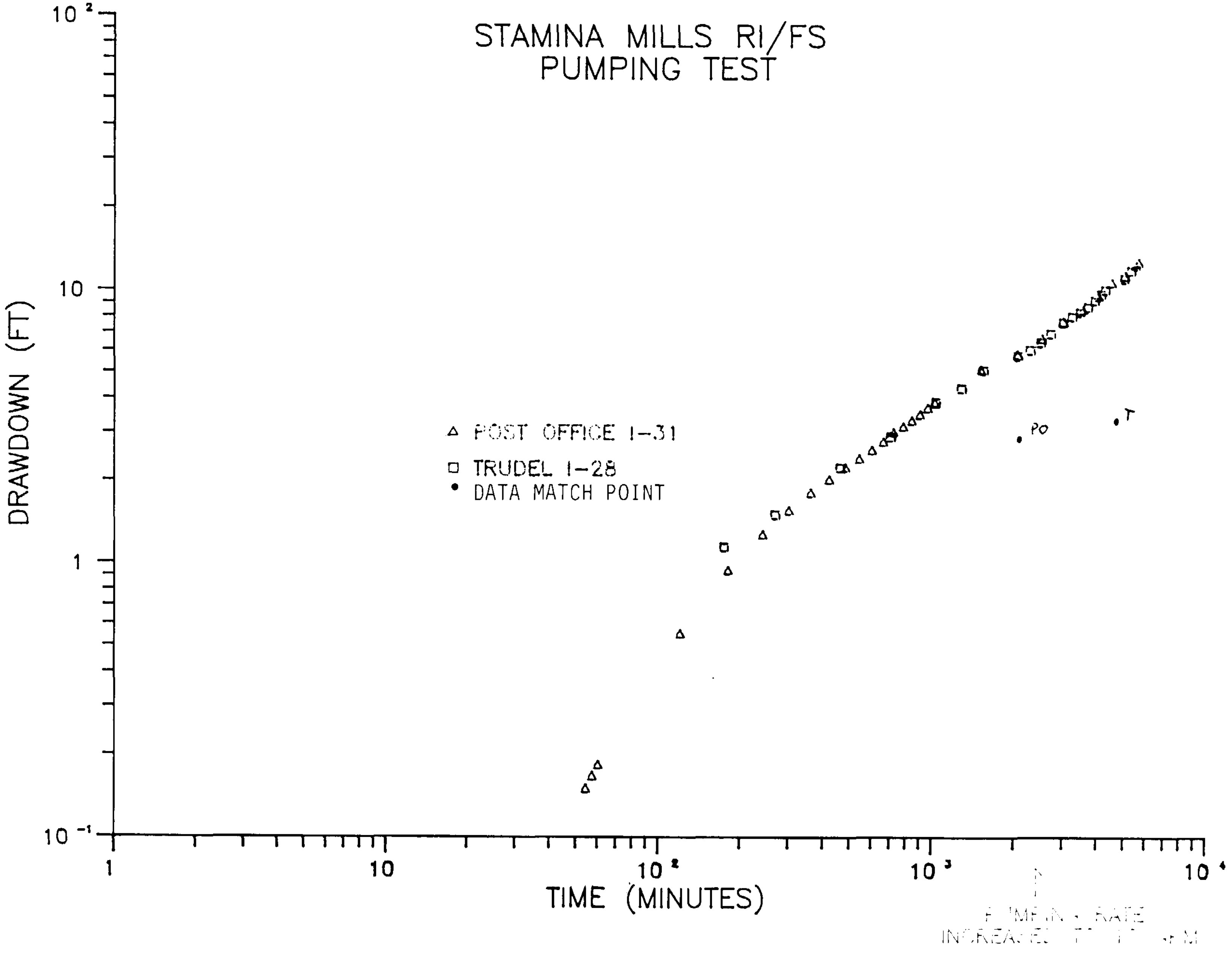
TRUDEL I-28

$$T_F = \frac{1347.6\ \text{ft}^3/\text{d}}{4\pi\ 2\ \text{ft}} = 53.6\ \text{ft}^2/\text{d}$$

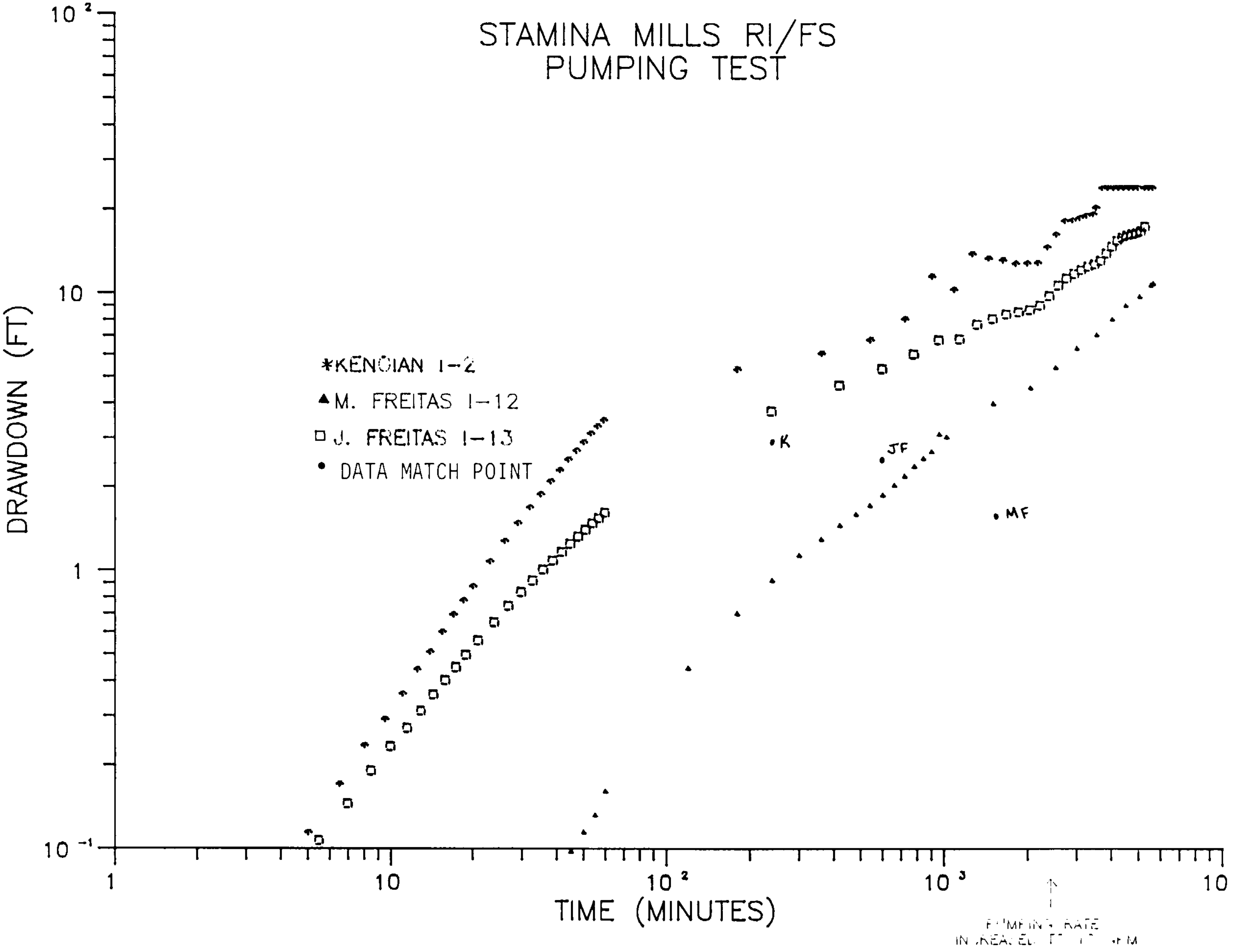
$$S_F = \frac{4(53.6\ \text{ft}^2/\text{d})\ (180\ \text{min})}{1440\ (675\ \text{ft})^2} = 1\ \text{E-6}$$

APPENDIX L

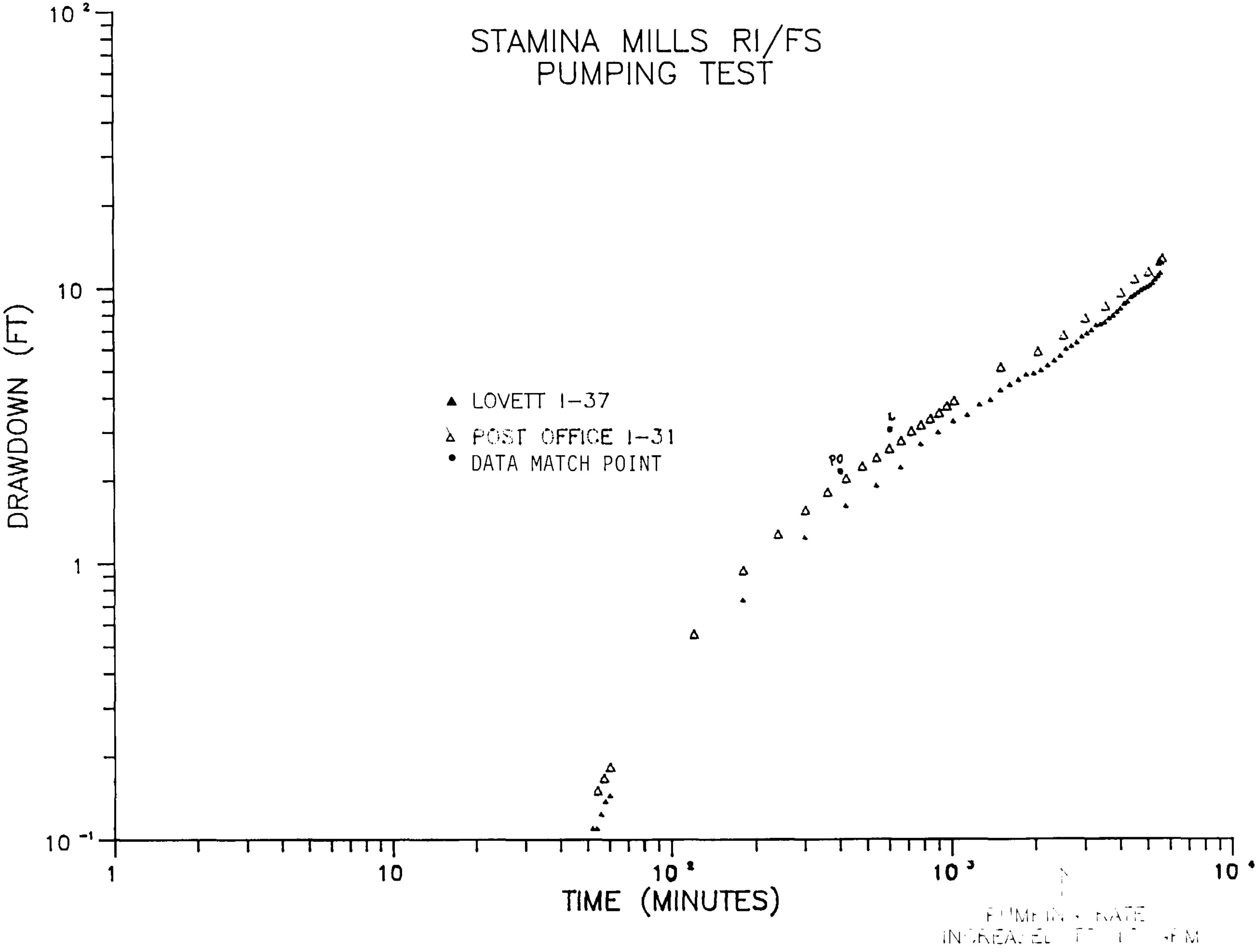
GRINGARTEN AND WHITHERSPOON MODEL CALCULATIONS



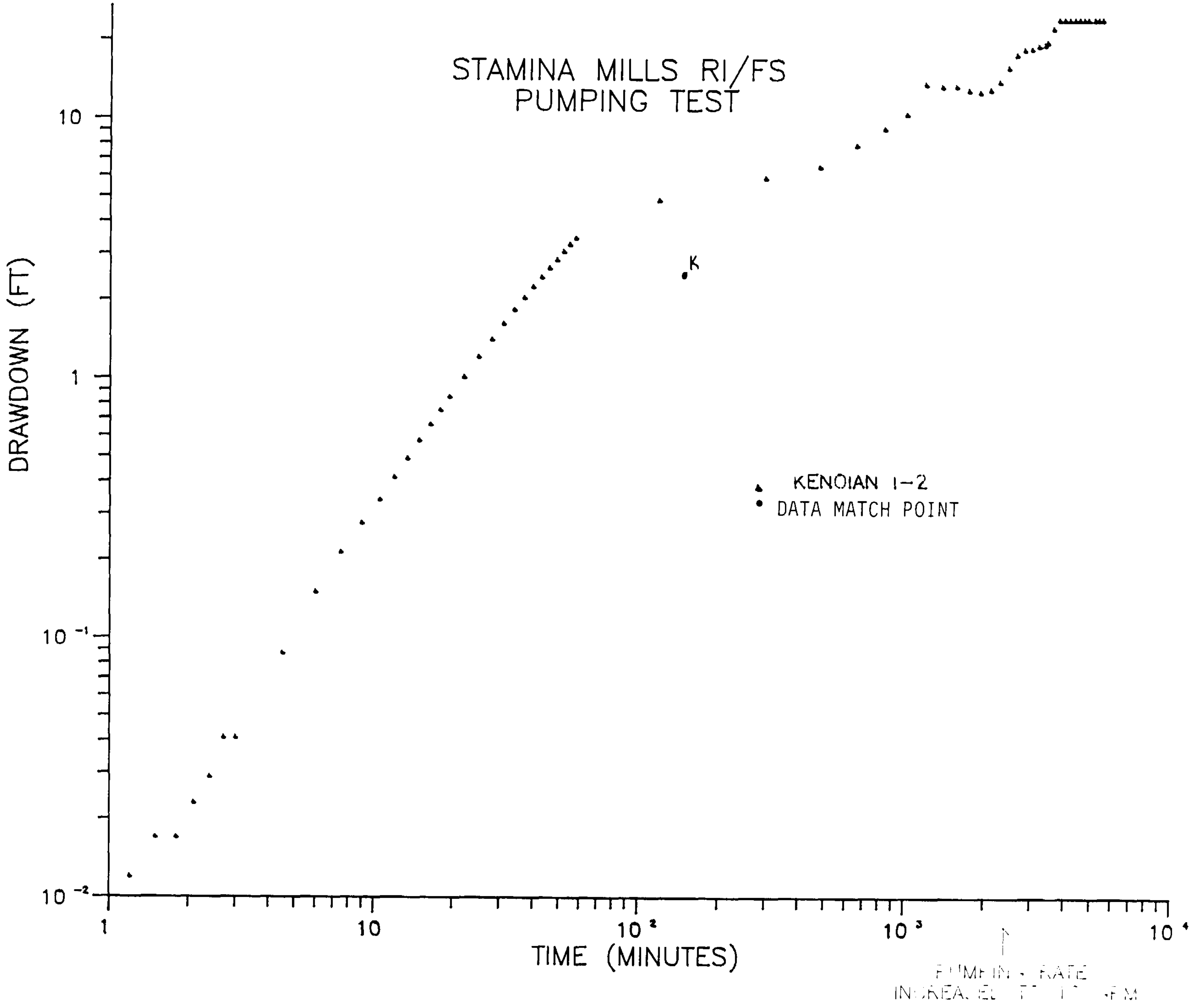
GRINGARTEN AND WITHERSPOON MODEL (45°)



GRINGARTEN AND WITHERSPOON MODEL (45°)



GRINGARTEN AND WITHERSPOON MODEL (0°)



GRINGARTEN AND WITHERSPOON (90°)

GRINGARTEN & WITHERSPOON

$\boxed{45^\circ}$

POST OFFICE I-31

$$Tm = \frac{1347.6\ ft^3/d\ (1)}{4\pi(2.7\ ft)} = 39.7\ ft^2/d$$

TRUDEL I-28

$$Tm = \frac{1347.6(1)}{4\pi(3.2)} = 33.5\ ft^2/d$$

J. FREITAS I-13

$$Tm = \frac{1347.6(1)}{4\pi(2.5)} = 42.9\ ft^2/d$$

M. FREITAS I-12

$$Tm = \frac{1347.6(1)}{4\pi(1.5)} = 71.5\ ft^2/d$$

KENOIAN I-2

$$Tm = \frac{1347.6(1)}{4\pi(2.8)} = 38.3\ ft^2/d$$

$\boxed{0^\circ\text{ - Parallel}}$

POST OFFICE I-31

$$Tm = \frac{1347.6(1)}{4\pi(2.1)} = 51.1\ ft^2/d$$

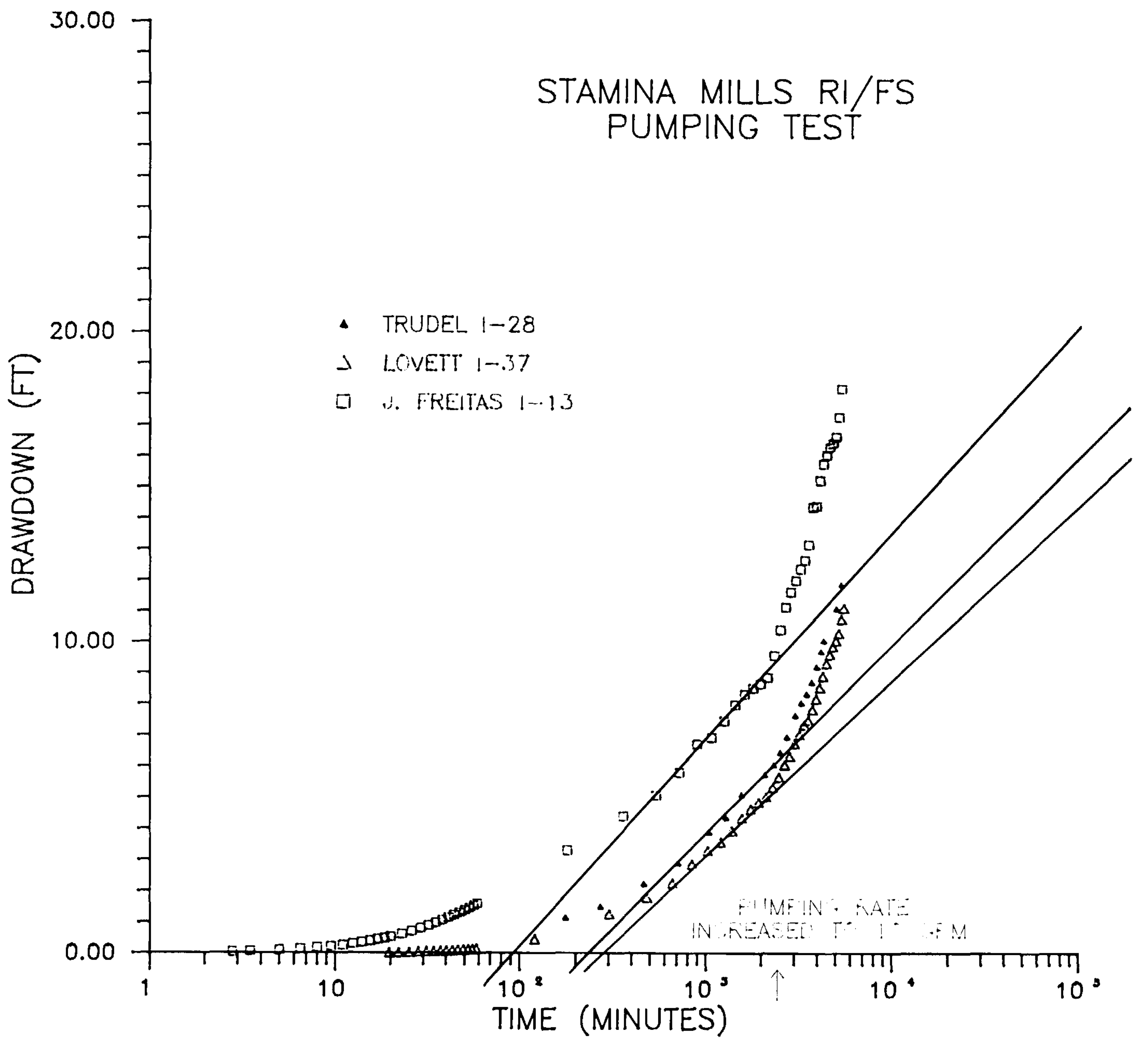
LOVETT I-37

$$Tm = \frac{1347.6(1)}{4\pi(3.0)} = 35.8\ ft^2/d$$

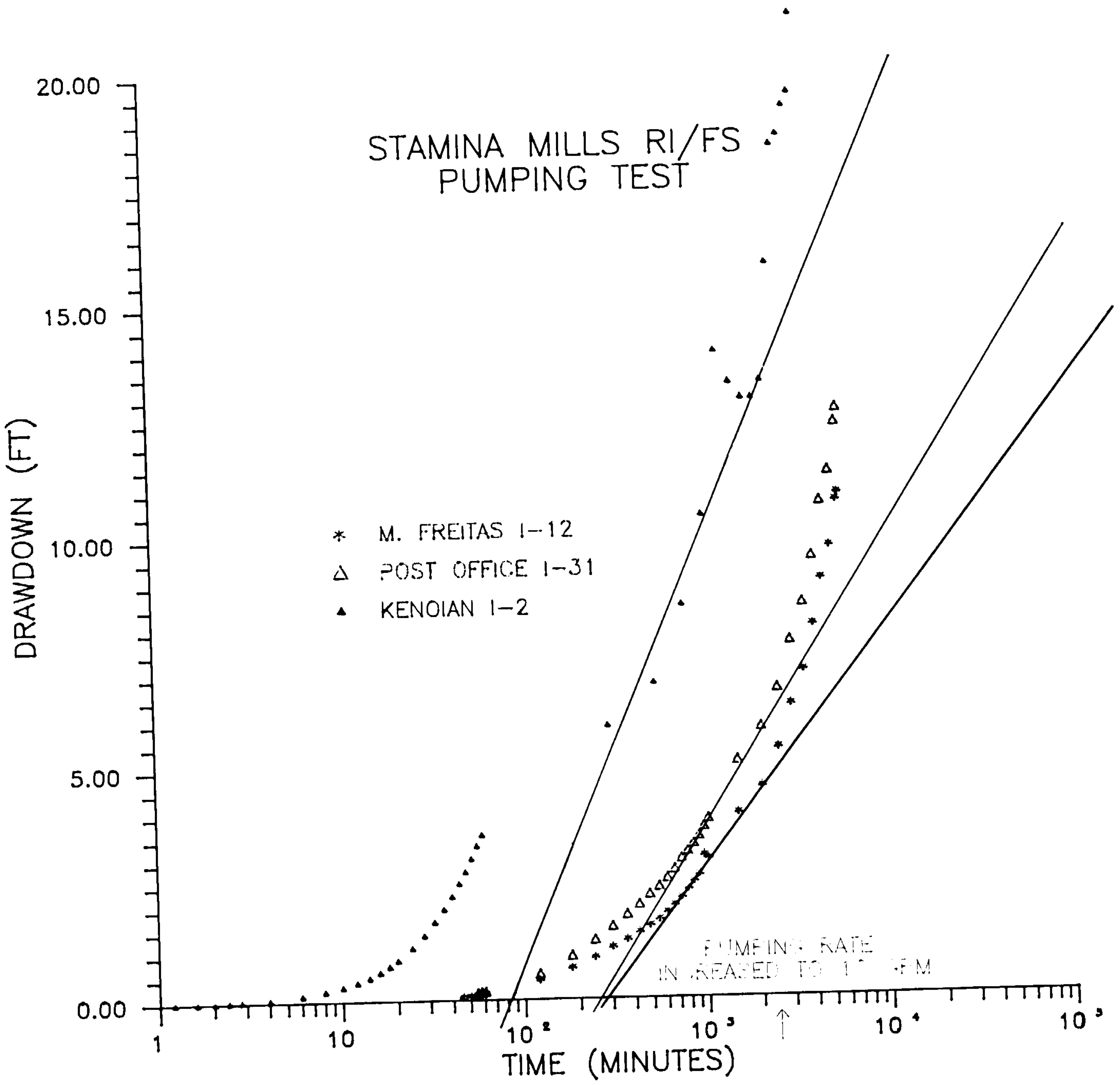
$\boxed{90^\circ}$

KENOIAN I-2

$$Tm = \frac{1347.6}{4\pi(2.5)} = 42.9\ ft^2/d$$



JACOBS STRAIGHT LINE METHOD



STAMINA MILLS RI/FS
PUMPING TEST

JACOBS STRAIGHT LINE METHOD

JACOBS METHOD

M. Freitas I-12

$$T = \frac{264\ (Q)}{\Delta s} = \frac{264\ (7\ \text{gpm})}{(8-3)\ \text{ft}} = 369.9\ \text{gpd/ft} = 49.5\ \text{ft}^2/\text{d}$$

$$S = \frac{0.3\ (369.9\ \text{gpd/ft})(270\ \text{min})}{1440\ (245\ \text{ft})^2} = 3.5\ \text{E-}4$$

Post Office I-31

$$T = \frac{264\ (7)}{(10\ -\ 3.7)} = 293.3\ \text{gpd/ft} = 39.2\ \text{ft}^2/\text{d}$$

$$S = \frac{0.3\ (293.3)(250)}{1440\ (790)^2} = 2.5\ \text{E-}5$$

Trudel I-28

$$T = \frac{264\ (7)}{(9.8\ -\ 1.9)} = 233.9\ \text{gpd/ft} = 31.3\ \text{ft}^2/\text{d}$$

$$S = \frac{0.3\ (233.9)(220)}{1440\ (675)^2} = 2.4\ \text{E-}5$$

Lovett I-37

$$T = \frac{264\ (7)}{(4.4\ -\ 1.5)} = 637.2\ \text{gpd/ft} = 85.2\ \text{ft}^2/\text{d}$$

$$S = \frac{0.3\ (637.2)(280)}{1440\ (570)^2} = 1.1\ \text{E-}4$$

J. Freitas I-13

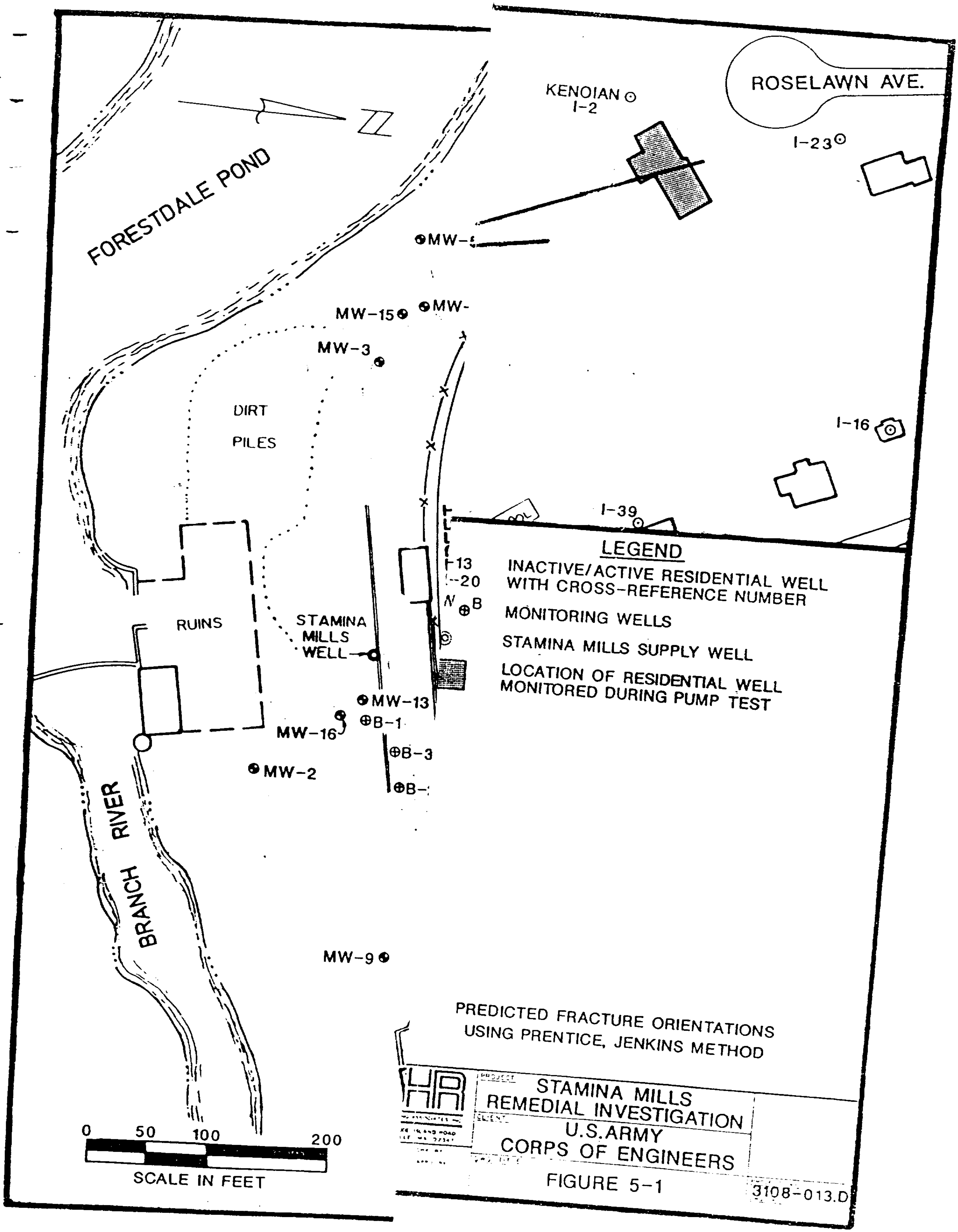
$$T = \frac{264\ (7)}{(13.5\ -\ 6.9)} = 280\ \text{gpd/ft} = 37.4\ \text{ft}^2/\text{d}$$

$$S = \frac{0.3\ (280)(93)}{1440\ (190)^2} = 1.5\ \text{E-}4$$

Kenoian I-2

$$T = \frac{264\ (7)}{(10.2\ -\ 0.75)} = 195.5\ \text{gpd/ft} = 26.1\ \text{ft}^2/\text{d}$$

$$S = \frac{0.3\ (195.5)(83)}{1440\ (265)^2} = 4.8\ \text{E-}5$$



LEGEND

INACTIVE/ACTIVE RESIDENTIAL WELL WITH CROSS-REFERENCE NUMBER

MONITORING WELLS

STAMINA MILLS SUPPLY WELL

LOCATION OF RESIDENTIAL WELL MONITORED DURING PUMP TEST

PREDICTED FRACTURE ORIENTATIONS USING PRENTICE, JENKINS METHOD

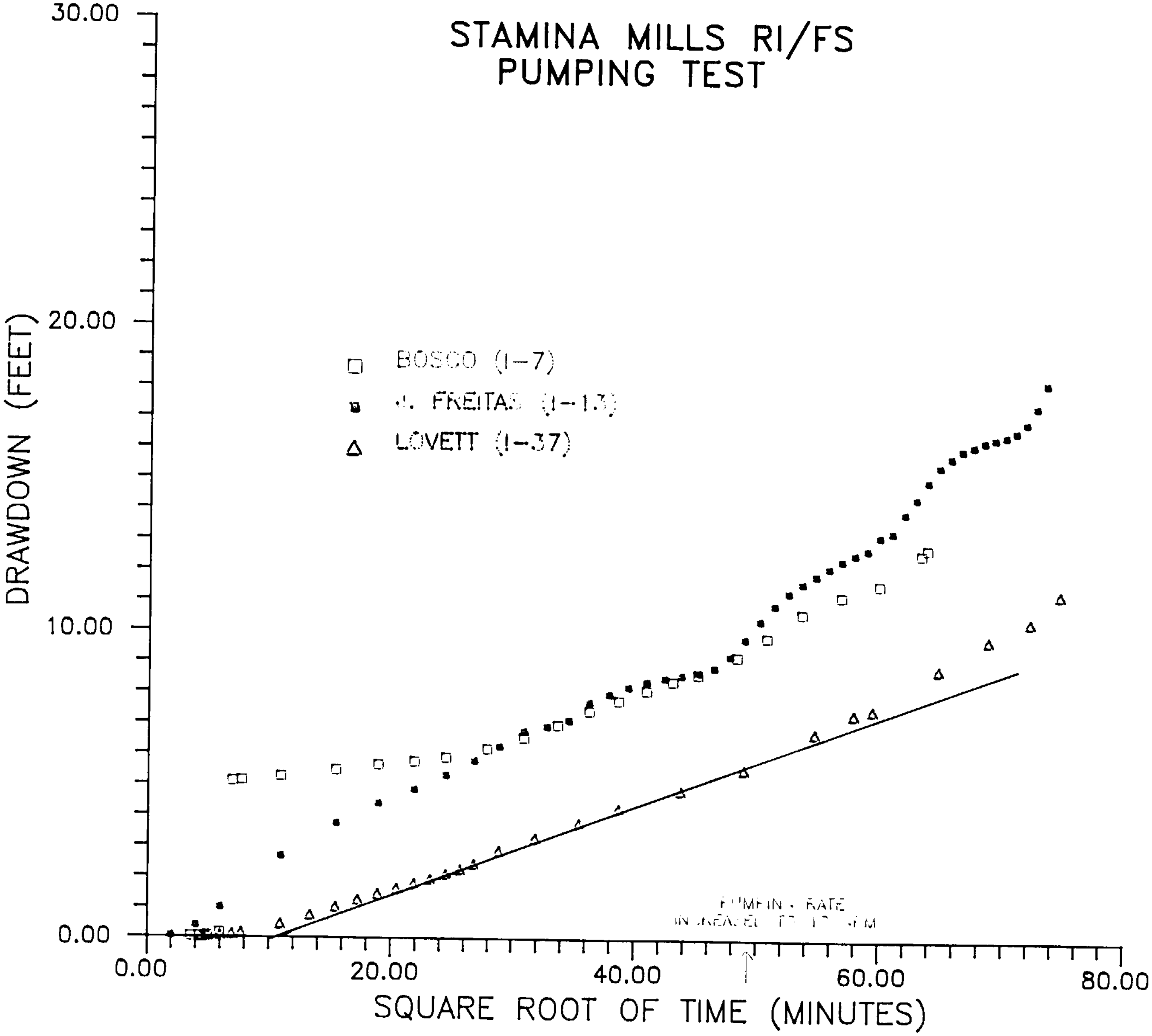
STAMINA MILLS
REMEDIAL INVESTIGATION
U.S.ARMY
CORPS OF ENGINEERS

FIGURE 5-1

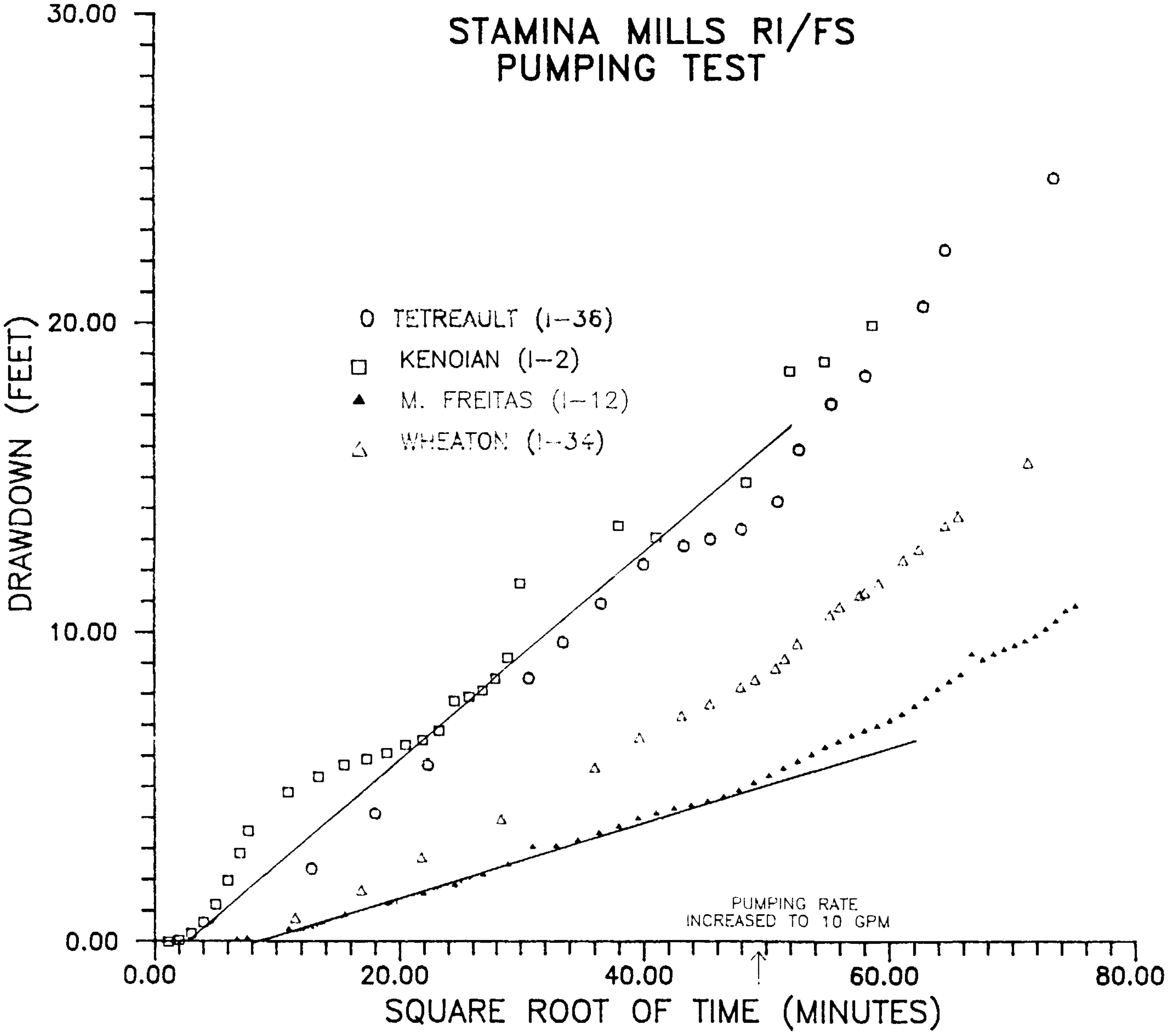
3108-013.D

APPENDIX M

JENKINS, PRENTICE CALCULATIONS

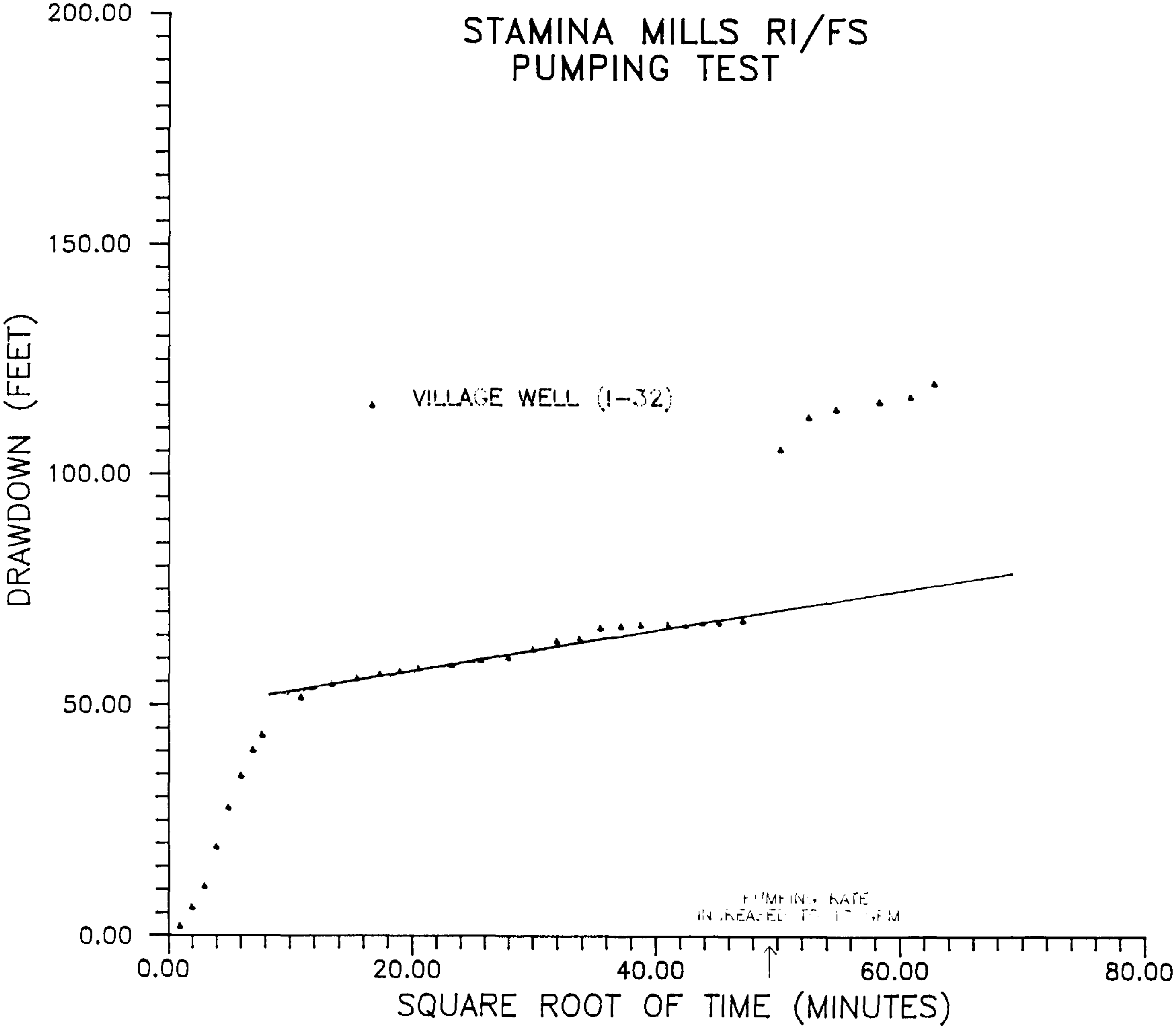


JENKINS AND PRENTICE MODEL



JENKINS AND PRENTICE MODEL

STAMINA MILLS RI/FS
PUMPING TEST



JENKINS AND PRENTICE MODEL

JENKINS-PRENTICE MODEL

1. M. Freitas - Lovett

1. Lovett I-37 r = 568		2. M. Freitas I-12 r = 247
$\sqrt{t_0}$ = 10.5	$\Delta\theta$ = 24°	$\sqrt{t_0}$ = 8

$$\theta_2 = \tan^{-1}\left[\frac{568\ (8)\ \sin 24}{568\ (8)\ \cos 24 - 247\ (10.5)}\right] = 49.88°$$

$$\theta_1 = \theta_2 - \Delta\theta$$

$$= 49.88 - 24 = 25.88°$$

$$X_1 = 568 \sin 25.88 = 247.9 \text{ ft}$$

$$X_2 = 247 \sin 49.88 = 188.88 \text{ ft}$$

2. Kenoian - M. Freitas

1. Kenoian I-2 r = 259'		2. M. Freitas I-12 r = 247'
$\sqrt{t_0}$ = 2.5	$\Delta\theta$ = 103°	$\sqrt{t_0}$ = 8

$$\theta_2 = \tan^{-1}\left[\frac{259\ (8)\ \sin 103}{247\ (2.5) - 259\ (8)\ \cos 103}\right] = 61.8°$$

$$\theta_1 = \theta_2 + \Delta\theta = 61.8 + 103 = 165°$$

$$X_1 = 259 \sin 165 = 68 \text{ ft}$$

$$X_2 = 247 \sin 61.8 = 217.7 \text{ ft}$$

TARGET SHEET

THE MATERIAL DESCRIBED BELOW
WAS NOT SCANNED BECAUSE:

(X) OVERSIZED

() NON-PAPER MEDIA

() OTHER:

DESCRIPTION: DOC# 6942, Pump Test of the Forestdale Water Association Well, Site Plan 1.

THE OMITTED MATERIAL IS AVAILABLE FOR REVIEW
BY APPOINTMENT
AT THE EPA NEW ENGLAND SUPERFUND RECORDS CENTER,
BOSTON, MA