18. FOCUSED SUPPLEMENTAL RI REPORT, VOL. I, 3-92

New York State
Department of Environmental Conservation

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New York State Department of Environmental Conservation

MEMORANDUM

TO: David Rubinton, Esq., Region 3, White Plains
FROM: John Barnes, Bureau of Eastern Remedial Action, DHWR
SUBJECT: COSCO/CPC SITE NUMBER 344035

DATE: JAN - 8 1993

This is a follow up to our telephone conversation of January 6, 1993 regarding the above-referenced site.

The Division of Hazardous Waste Remediation disagrees with Mr. Hanna's position that there are insufficient data to conduct a Remedial Design/Remedial Action (RD/RA) at this time. To date, a Remedial Investigation/Feasibility Study (RI/FS) with a Record of Decision and two post RI/FS studies have been conducted in Spring Valley. There are more than sufficient data to move on to the RD/RA stage.

There is some data, such as aquifer parameters (hydraulic conductivity, etc.) which will be needed to finalize a remedial design. These types of data are generally collected during the design stage.

The Department should push forward with the RD/RA consent order. It might be appropriate to have a side order or a side letter to the order addressing the issue of the three additional piezometers. These additional piezometers could be installed etc., parallel to the remedial design work. The Division will not agree to a side order or side letter in which preconceived conclusions or other strings are attached. There is no guarantee that the data from these piezometers will give us conclusive answers.

If you have any questions regarding this matter, please feel free to contact me at (518) 457-3395. Thank you for your continued assistance in this matter.

JB/dd
cosco11

c: S. Ervolina/S. McCormick
C. Magee
K. Davis
A. McCarthy

FOCUSED SUPPLEMENTAL REMEDIAL INVESTIGATION REPORT, SPRING VALLEY WELL FIELD, SPRING VALLEY, NEW YORK

VOLUME I - TEXT, TABLES AND FIGURES

Prepared for

The New York State Department of Environmental Conservation

March 1992

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Project Number 89C3517-09

The Focused Supplemental Remedial Investigation consisted of an aquifer test (pump test) conducted at the Spring Valley Well Field in Spring Valley, New York. The goal of the Focused Supplemental Remedial Investigation was to determine whether the former Cosco West Street facility (Cosco) and the former Continental Plastics Company facility (CPC) are within the capture zone[1] of the Spring Valley Well Field. If Cosco/CPC are outside the capture zone, they are not responsible for the continuing solvent-contamination problem at the SVWF, and the well-field investigation should shift to closer, more likely sources, such as the leaky sewers on Maple and Main Streets, the former Craemer Construction yard located in the well field, or the former municipal landfill located just 200 yards southeast of the well field.

At the start of the pump test, three possibilities presented themselves as illustrated on Figure ES-1:

1. Cosco/CPC are outside of the capture zone (Area 1 on Figure ES-1) and ground water flow is driven eastward or southeastward by the regional flow gradient not northward toward the Spring Valley Well Field (Particle 1);

2. Cosco/CPC are outside the capture zone of the Spring Valley Well Field but inside the radius-of-influence[2] (Area 2) and ground water flow is influenced but not captured by the SVWF (particle 2); or,

3. Cosco/CPC are inside the capture zone of the Spring Valley Well field (Area 3) and ground water in the bedrock aquifer below the Cosco/CPC facilities flows to the well field (particle 3).

[1] Capture zone simply means the area from which the Spring Valley Well Field captures or draws its water.

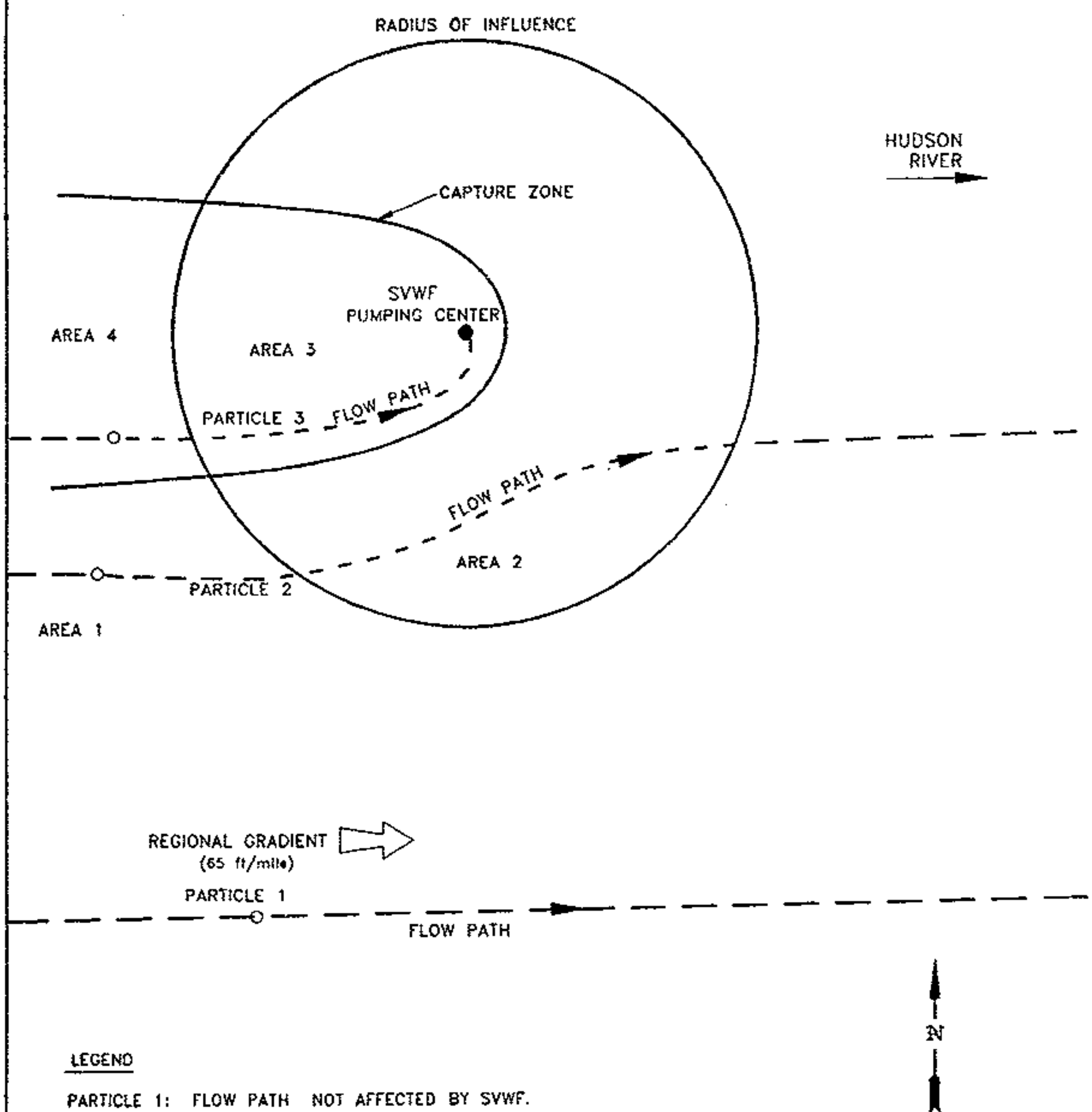
[2] Radius-of-influence is the circular area around a pumping well within which water levels are effected by pumping.

Woodward-Clyde Consultants carefully evaluated the pump test data using standard, accepted hydrogeologic methods and concluded that the Cosco/CPC facilities are located outside the capture zone (Area 2). The ground water flow is deflected by the well field but not captured by it. The regional ground water flow is strong enough to resist the pumping forces exerted by the well field and sweep the ground water to the east and southeast toward the Hudson River. Woodward-Clyde Consultants evaluated both geological and hydrogeologic lines of evidence, all of which converged upon the same conclusion--Cosco/CPC are outside the capture zone of the SVWF.

The results of the pump test confirm the conclusion of the Supplemental Remedial Investigation (SRI) that bedrock ground-water flow in the immediate vicinity of Cosco/CPC is eastward. The pump test findings expand upon the SRI results by showing that the bedrock ground water flow continues eastward from Cosco/CPC until it reaches Pascack Brook and then turns southeastward, away from the Spring Valley Well Field.

The conclusions reached by GHR Engineering Associates in 1989 in the Spring Valley Well Field Remedial Investigation Report were not supported by the pump test. The GHR report concluded that ground water flowed north from the Cosco/CPC facilities directly toward the Spring Valley Well Field. This conclusion was reached using a single line of monitoring wells that were not designed for making hydrogeological determinations. The hydrologic data in the GHR report as well as the analytical methods were inappropriate for determining ground water flow direction.

Our understanding of the bedrock aquifer has progressed greatly since the GHR Report was written. During the pump test, Woodward-Clyde Consultants evaluated a greater quantity and quality of data using appropriate methods to reach its conclusion regarding the capture zone. WCC is confident that the findings in this report will stand up to further scrutiny.



LEGEND

PARTICLE 1: FLOW PATH NOT AFFECTED BY SVWF.

PARTICLE 2: FLOW PATH DEFLECTED BUT NOT CAPTURED BY THE SVWF.

PARTICLE 3: FLOW PATH CAPTURED BY THE SVWF.

SVWF = SPRING VALLEY WELL FIELD

Woodward-Clyde Consultants
ENGINEERS, GEOLOGISTS, AND ENVIRONMENTAL SCIENTISTS

SCHEMATIC CAPTURE ZONE AND RADIUS OF INFLUENCE UNDER "REGIONAL GRADIENT" CONDITIONS

DESIGN: TD	CHK'D: DMH	PROJECT NO.	FIG. NO.
DRAWN: LM	DATE: [illegible]	89C3517	ES-1

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF APPENDIXES

1.0
INTRODUCTION

The Focused Supplemental Remedial Investigation (FSRI) consisted of a pump test conducted at the Spring Valley Well Field (SVWF) in Spring Valley, New York between 8 January 1992 and 23 January 1992 to evaluate the capture zone of the SVWF. This report summarizes data collected during the pump test and presents Woodward-Clyde Consultants' (WCC's) analysis and interpretation of the test data. The organization of the report is as follows:

- Section 1.0--Introduction;
- Section 2.0--Drilling and Piezometer-Installation Methods and Information;
- Section 3.0--Aquifer-Test Program Data Collection and Presentation; and,
- Section 4.0--Analysis Methods and Results.

This FSRI report is being submitted to the New York State Department of Environmental Conservation (NYDEC) in accordance with an Order on Consent (Order) dated 17 January 1992. According to the Order, the Spring Valley Water Company (SVWC) and Cosco/Sara Lee Corporation must each submit a report summarizing the results of a joint pump test at the SVWF. According to the order, this report must include "all data generated and all other information obtained during the implementation of the approved Work Plan (Work Plan for Pump Test at the Spring Valley Well Field, Spring Valley, New York, December 9, 1991)". The raw field data was sent to NYDEC in a previous submittal on January 31, 1992. This report contains the same data, but summarized in tables and hydrographs.

WCC prepared this FSRI Report for Cosco/Sara Lee Corporation. The SVWC's consultant, Leggette, Brashears and Graham (LBG), has, we are advised, prepared a report based on the same data. The actual pump test was conducted jointly by WCC and LBG with oversight by NYDEC. This FSRI Report will focus on the main goal of the pump test; to evaluate the capture zone of the SVWF.

1.1 BACKGROUND

In 1978, the Rockland County Health Department (RCHD) detected Trichloroethylene (TCE) and Tetrachloroethylene (PCE) in ground water from the SVWF which is operated by the SVWC.

A remedial investigation titled "Remedial Investigation Report, Spring Valley Well Field" (SVWF RI) was completed in February 1989 by GHR Engineering Associates (GHR) for the NYDEC. GHR concluded in its RI report that the former Cosco West-Street facility (Cosco facility) and the former Continental Plastics Company facility (CPC) were potential sources of VOC contamination observed in the SVWF.

WCC reviewed the GHR RI Report for Cosco/Sara Lee Corporation on 2 May 1989, and discovered serious data gaps and inconsistencies. The two primary data gaps were:

1) Lack of data for determining ground water flow direction in the bedrock aquifer; and,

2) Failure to consider other potential sources of contamination, thereby preventing identification of the problem requiring remediation.

The first data gap was partly answered by the Supplemental Remedial Investigation (SRI), conducted by Cosco/Sara Lee in 1990, and is comprehensively addressed by this FSRI report. The second data gap has yet to be addressed, but the pump test did produce information which is relevant to this issue (see Section 2.2.5). The following paragraphs further describe data gap 1 and the progress made toward closing it.

The GHR RI concluded that the Cosco/CPC facilities were within the capture zone and that ground water flowed northward from Cosco/CPC to the SVWF. This conclusion was shown by WCC to be unsupported because:

1. Open-borehole bedrock monitoring wells were used to measure water levels instead of piezometers specifically designed for that purpose. The monitoring wells also lacked a discrete screened interval which made the water level data difficult, if not impossible, to interpret.

2. The bedrock monitoring wells were aligned along a linear path between the SVWF and Cosco/CPC. Three-dimensional ground water flow cannot be accurately assessed with a single line of open-borehole monitoring wells.

3. There was potential for leakage of ground water from the glacial till into the bedrock wells because of the open-borehole construction. Leakage would invalidate the monitoring wells as bedrock monitoring points.

4. GHR reached conclusions regarding ground water flow that could not be supported by the data collected. Ground water flow direction was therefore a major data gap in the original RI.

NYDEC also concluded that the SVWF RI wells "are insufficient to determine the direction of ground water flow in the study area" (Letter from NYDEC to WCC dated 15 November 1990) and authorized the SRI to further investigate the ground water-flow-direction issue.

The SRI was conducted in 1990, by Cosco/Sara Lee, with work-plan approval and oversight by NYDEC. Four piezometers were installed in the vicinity of Cosco/CPC during the SRI to investigate the three-dimensional ground water flow conditions at shallow and intermediate levels in the bedrock aquifer. The SRI data established that the bedrock ground water flow direction was eastward at Cosco/CPC, not north toward the SVWF as concluded in the GHR RI report. After the SRI, NYDEC delisted the SVWF as a hazardous waste site because no source had been unambiguously associated with the SVWF contamination (verbal communication with NYDEC).

The SVWF pump test was proposed by NYDEC and the SVWC to further fill the data gap pertaining to the lack of ground-water-flow information for the bedrock aquifer. The pump test was designed to supply detailed information regarding three-dimensional ground water flow conditions in the areas west, south, and east of the well field. This was achieved by installing piezometers similar to those used during the SRI, not open borehole monitoring wells as used in the SVWF RI. The ultimate goal of the pump test was to evaluate the capture zone of the SVWF.

1.2 GEOLOGIC SETTING

This subsection presents a basic description of the geology of the Spring Valley area. The geology of the Brunswick Formation bedrock is emphasized because it is the medium through which ground water flows to the SVWF. The geologic information presented here is drawn from:

- WCC's drilling experience during the SRI and SVWF pump test;
- the SVWF RI Report; and
- review of the published literature.

The Triassic-Jurassic Brunswick Formation (renamed Passaic Formation in 1980) is the primary bedrock unit in the Spring Valley area. The Brunswick Formation is very coarse grained (cobbles and boulders) along the Ramapo Fault on the west edge of the Newark Basin and becomes progressively finer grained toward the east. The Brunswick formation is approximately 7000 ft thick below the study area, and consists primarily of conglomerate and sandstone with a few thin shale beds. Geologic information collected from the borings drilled by WCC is consistent with this characterization. The bedrock encountered while drilling the Pump Test Piezometer Nest (PTPN) borings consisted of a uniform coarse-grained sequence of sandstone and conglomerates with a few 6-in shale zones.

The study area lies within the gravely sandstone facies of the Brunswick Formation as defined by Savage (Savage, 1967). The regional strike of the Brunswick Formation varies between north and northeast and the dip varies between 5 and 15 degrees to the west/northwest.

All six SVWC wells were completed as open boreholes in the Brunswick Formation with total depths of 446 to 506 ft. All of the PTPN's, SRI piezometers, and SVWF RI monitoring wells MW-7B, MW-8B, MW-9B and MW-17B were completed in the Brunswick Formation.

The Brunswick formation is overlain by unconsolidated glacial deposits. The glacial deposits consist of tills, glacial-lacustrine sediments, and coarse-grained, outwash deposits. During drilling of PTPN-22, 23, 24 and 25, WCC discovered that the glacial deposits are much thicker east of Pascack Brook (150 to 190 ft) than they are west of the Brook (15 to 70 ft).

1.3 HYDROGEOLOGIC SETTING

WCC analyzed the pump-test data using methods appropriate for hydrogeologic settings with a regional gradient and an aquifer that is isotropic[1] and homogeneous[2]. The hydrogeologic information discussed below supports this approach.

1.3.1 Regional Gradient

A strong eastward to southeastward regional gradient exists in the bedrock aquifer in the Spring Valley area. The following data support this conclusion:

1. The potentiometric-surface map (Figure 1) developed from regional ground water level data (Perlmutler, 1959) indicates an eastward gradient ranging from 50-90 ft per mile in the Spring Valley area;

2. The regional gradient calculated from piezometers PTPN-26 and SRI-3 during the pre-monitoring period is 65 ft per mile; and

3. The bedrock water levels drop approximately 400 ft between Spring Valley and the Hudson River located just 7 miles to the east. The regional gradient calculated on this basis is approximately 57 ft per mile.

The presence of a regional gradient is an important feature because "capture zone" and "radius-of-influence" have different meanings when a regional gradient is present. Under regional flow conditions, ground water flow can be influenced by SVWF pumping, but

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[1] Isotropic means that ground water can more through the aquifer with equal ease in any direction. In technical terms, it means that the aquifer properties have the same magnitude regardless of direction.

[2] Homogeneous means that the aquifer has a uniform character and consists of essentially one material. More technically speaking, it means the aquifer's properties are the same regardless of position in the aquifer.

not captured by it. This situation is illustrated on Figure 2. Figure 2 shows the regional ground water (Area 1) flowing east under the influence of the Hudson River (Particle 1). Prior to the well field's installation, all of Spring Valley's ground water was captured by the Hudson River or the tributaries flowing into it, such as Pascack Brook. After the well field was constructed, the ground water in Area 3 was captured by the well field (see flow path of Particle 3). In Area 2, the eastward flowing ground water (particle 2) was influenced and deflected by the well field, but continued eastward. Area 2 is outside the capture zone, but within the radius of influence of the well field. In area 1, the ground water flow was not affected by the SVWF and moves eastward (particle 1) under the influence of the regional flow gradient. The purpose of the pump test was to evaluate whether Cosco/CPC lie within Areas 1, 2, or 3. Both areas 1 and 2 lie outside the capture zone.

1.3.2 Ground Water Flow in the Bedrock Aquifer

WCC investigated the nature of ground water flow in the bedrock aquifer during the pump test. An inspection of the stream bed of Pascack Brook southeast of the well field indicated that the Brunswick Formation sandstones are cut by at least two sets[3] of near-vertical joints (see photograph on Figure 3). These joints represent one pathway for ground water movement through the formation.

The rock core collected from PTPN-26 indicated a second pathway for ground water migration, namely, flow through pores in the rock (secondary porosity) caused by removal (leaching) of limestone particles and the calcite cement that holds the rock together (see Figure 3A). Small voids (pores) were visible throughout the cores and some intervals were full of voids (some up to 2 centimeters across). Loss of water circulation was noted in one such interval during drilling at a depth of 76 ft. Two samples from leached zones were tested for porosity and permeability. The porosity ranged from 20.6 to 22.3 percent and the permeability ranged from 1.4×10^{-3} to 3.5×10^{-4} cm/sec. These values indicate that the leached zones are more permeable than normal sandstones (Freeze and Cherry, 1978) and are more consistent with karstic limestone (see Section 2.2.2.3 for a discussion of the porosity and permeability data). It is WCC's

[3] A joint set consists of many joints with the same orientation.

judgement that the combination of near-vertical joints and permeable pathways caused by leaching are the primary pathways for ground water movement.

1.3.3 Geologic Data Pertaining to Isotropy Versus Anisotropy and Homogeneity Versus Inhomogeneity In the Bedrock Aquifer

WCC determined that the bedrock aquifer in the Spring Valley area is essentially isotropic and homogeneous and used this finding in its capture zone analysis (see Section 4.0). WCC supports this finding with both hydrogeologic and geologic data. The geologic evidence for homogeneous and isotropic conditions includes:

1. The bedrock consists of coarse grained sandstones and conglomerates with only a few thin shale and siltstone beds. The relatively uniform lithology is considered to correspond with relatively uniform hydrogeologic properties.

2. The combination of multiple, near-vertical joint sets (Figure 3) and widespread permeable zones related to leaching (Figure 3A) are likely to create numerous flow channels with a variety of orientations. Multiple flow channels are consistent with isotropic and homogeneous conditions.

The hydrogeologic analysis in Section 4.2 was carried out using a variety of analytical methods. The results of these analyses suggest an anisotropy ratio of less than 2:1. It is WCC's judgement that an anisotropy ratio of less than 2:1 is negligible when considering large-scale ground water flow.

Small-scale anisotropy exists in the Brunswick Formation in the form of joints and leached zones. These small-scale features can be ignored at the scale of the problem at hand because the spacing of the joints and leached zones is small considering that the distance from Cosco/CPC to the well field is about 3000 ft. This approach is consistent with the continuum approach for hydrologic analysis (Bear, 1979).

1.3.4 Natural Springs

Spring Valley was named for a large bedrock spring along Pascack Brook. According to [illegible]al records, innumerable bedrock springs were once present along Pascack Brook (Penfold, et. al., 1944). Although the springs are no longer present, WCC detected a residual hydraulic influence below the location of the former springs. This influence was evident in the potentiometric maps created from the steady-state pump test data (see Section 4.1). The area once occupied by the springs continues to be influenced by upward vertical gradients. The net effect of these upward vertical gradients is to create a "potentiometric ridge" in the vicinity of Pascack Brook. The ridge is illustrated schematically on Figures 4 and 4A. Upward vertical gradients are consistent with an area of former ground water discharge.

The anomalously high water levels and upward vertical gradients encountered in PTPN-21 cannot be understood without consideration of the historical discharge zone. The resultant potentiometric ridge is important because it diverts the eastward flow of ground water from Cosco/CPC to the south-southeast parallel to Pascack Brook.

2.0 DRILLING AND PIEZOMETER INSTALLATION METHODS AND INFORMATION

2.1 DRILLING AND PIEZOMETER INSTALLATION METHODS

Eleven piezometer nests were installed in conjunction with the pump test program between 12 December 1991 and 7 January 1992 according to the procedures contained in the approved pump test work plan (Work Plan for Pump Test ant the Spring Valley Well Field, Spring Valley, New York, December 9, 1991). WCC drilled five Pump Test Piezometer Nest Borings (PTPNB) (PTPNB-22 through PTPNB-25) and installed five piezometer nests (PTPN-22 through 25) just prior to the SVWF pump test. PTPN-26 was a late addition to the pump test program but was installed in time (January 14, 1992) to collect background information during the recovery and drawdown phases of the pump test. All of the WCC piezometer nests consisted of one shallow and one deep piezometer.

LBG drilled four PTPNB's (PTPNB-17R, PTPNB-19, PTPNB-20 and PTPNB-21) and installed six piezometer nests (PTPN-8, PTPN-9, PTPN-17R. PTPN-19, PTPN-20, and PTPN-21). Two of LBG's piezometer nests (PTPN-8 and PTPN-9) were installed in existing bedrock monitoring wells (MW-8B and MW-9B) as retrofits. The retrofits consisted of one shallow and one deep piezometer. LBG piezometers PTPN-17R, PTPN-19, PTPN-20 and PTPN-21 consisted of one shallow, one intermediate and one deep piezometer per nest.

This section of the report will review the drilling and piezometer installation procedures for the piezometer nests installed by WCC. LBG's FSRI report will review their procedures. The focus of this section will be on NYDEC approved field modifications to the pump test work plan. The work plan called for some procedures to be established in the field. These field calls will also be reviewed in this section.

2.1.1 Piezometer Locations

WCC installed nested piezometers at PTPN-22 through 26 (Figure 5). The locations of PTPN-22 through 25 were selected to allow the steady-state capture curve of the SVWF to be accurately delineated. The location for PTPN-26 was selected to give background information regarding the regional ground water gradient. The locations of PTPN-22, PTPN-24, and PTPN-25 conform to the locations indicated in the work plan.
PTPN-23 was drilled at the specified location but was later abandoned when a large boulder trapped the drill steel in the hole. Boring 23 was drilled 10 ft into bedrock (Total Depth 164 ft) before it was abandoned. Boring 23 was replaced by Boring 23A located about 900 ft southeast of the original location. NYDEC was consulted prior to drilling Boring 23A and approval was given for the new location. This move was made to avoid the difficult drilling conditions encountered in Boring 23.

PTPN-26 was added after the drilling program was in progress so no location was specified in the work plan. WCC had originally planned to collect a core in one of the piezometer borings 22 through 25. WCC decided to drill a separate boring for the core hole to avoid delaying the piezometer-installation program. A location was chosen where piezometers could be installed in the core hole to supply background water level information. NYDEC approved the location prior to drilling (see Figure 5 for the location of PTPN-26). PTPN-26 was installed in a four-inch diameter core hole using 1/2-inch PVC risers. Drilling took place between January 11 and January 14 1992. These changes were reviewed and approved by NYDEC.

2.1.2 Drilling Methods

Drilling was performed using mud-rotary in the glacial deposits and air-rotary in the bedrock. WCC's drilling subcontractor was Frank Gregory International (formerly Warren George Inc) from Jersey City, New Jersey. Mud rotary drilling was performed with Failing 1500 Holemasters equipped with a 9 3/8-inch tricone bits. Air rotary drilling was performed with a Shram air rig equipped with a 5 7/8-inch percussion bit. Coring in PTPN-26 was performed with a Failing 1500 Holemaster equipped with a high speed gear and an HQ wireline core barrel.

Drilling methods conformed with the work plan procedures in Section 2.0 (Additional Piezometer Installation), Appendix B-1 (Modifications to the Detailed Procedures Contained in Sections 2 and 3) and Appendix B-2 (Quality Assurance and Quality Control Procedures for Piezometer Installation). Some minor field modifications were made with NYDEC approval. These modification are summarized in Table 2.

2.1.3 Geophysical Logging Procedures

The following geophysical logs were run in all of the PTPN borings:

1. Gamma Ray;
2. Caliper; and
3. Single point resistivity.

WCC and LBG each had responsibility for logging their own borings. WCC's geophysical subcontractor was Delta Geophysical Services from Clinton, New Jersey. LBG logged their own borings (see LBG report). The logs, along with drilling information, were used to select screen zones. PTPNB-26 was not logged because higher quality geologic information was available from the continuous core collected in this boring.

The logs and logging settings used by Delta Geophysical are contained in Appendix A. Appendix A includes a short report prepared by Delta Geophysical explaining their procedures and settings.

The caliper log for PTPN-23A should be used with caution because of electrical interference from a buried electrical cable located a few feet from the borehole. The spikes that occur at regular intervals are artifacts of the electrical interference.

2.1.4 Piezometer Installation Procedures

WCC installed PTPN-22 through 26 in accordance with the following sections of the work plan; Section 2.7 (Piezometer Installation), Appendix B-1 (Modifications to the Detailed Procedures Contained in Sections 2 and 3) and Appendix B-2 (Quality Assurance and Quality Control Procedures for Piezometer Installation). Some minor field modifications were made with NYDEC approval. These modifications are summarized in Table 3.

Screen zones were placed in the most permeable interval of the boring based upon drilling information (soft zones and zones of increased water production) and geophysical information (mainly zones of hole enlargement based upon the caliper log). The most reliable indicator of high permeability is increased water production during air drilling. The soft drilling zones and zones of hole enlargement corresponded to either permeable leached zones or soft silt and shale layers.

2.1.5 Survey Procedures

WCC was responsible for surveying the PTPN's and staff gages in Pascack Brook. WCC's surveying subcontractor was GEOD corporation from Newfoundland, New Jersey. GEOD also surveyed the SRI piezometers for WCC in 1990.

The survey met or exceeded the accuracy requirements stated in the work plan (elevations within .01 ft and horizontal coordinates within .1 ft). All of the survey data was tied to Rockland County Monument 34-7. An Orange and Rockland (O&A) utility company benchmark was originally tied into the survey for quality control purposes. This benchmark is located on a bridge over Pascack Brook (east branch) on the access road to O&R's Pascack Road substation. It was later learned that the O&R benchmark was surveyed incorrectly by the utility company's surveyor. O&R is planning to resurvey this benchmark. The O&R benchmark was not used for quality control purposes and was not used as a reference point for the survey.

2.2 INFORMATION COLLECTED FROM THE DRILLING PROGRAM

2.2.1 Drilling Conditions Encountered

Difficult drilling conditions were encountered in all of the PTPNB's drilled east of Pascack Brook. PTPNB's 22, 23 and 24 were drilled on a topographically high area that was later interpreted as a north-south trending drumlin. The drumlin was composed of sandy till with layers of gravel, cobbles and boulders. WCC had expected a maximum of 80 feet of glacial drift and an average of 50 ft. The actual thicknesses east of Pascack Brook ranged from 154 to 190 ft. Boulders were encountered in all of these borings and one boring was lost when a large boulder shifted and trapped the drill steel. Borings that WCC had expected to take three days took an average of eight days to complete.

Drilling difficulty was also encountered on PTPN-23A. The driller thought he had encountered bedrock at a depth of 83 ft and casing was set. When air drilling commenced, it became clear that bedrock had not been reached because sand and gravel was caving into the hole. The boring was air drilled to bedrock at 98 ft and the casing was hammered from 83 to 96 ft. The boring was then cleaned and deepened to 100 ft and 100 gallons of grout added to the bottom of the hole using a tremie pipe to seal the remaining 2 ft of un-cased hole. The grout plug was completed and the hole was air drilled successfully the following day.

PTPN-25 and PTPN-26 were drilled in areas with relatively thin overburden and did not present major drilling difficulties.

Coring in PTPN-26 progressed smoothly. Excessive diamond bit wear was not encountered. One bit was used to collect all 90 ft of core. Recoveries were close to 100 % except in core 1 where only 1.5 feet were recovered because the core barrel failed to latch. The coring rate was nearly constant at 3.5 minutes per foot. Circulation was lost in a permeable zone at 76 ft. The average Rock Quality Designation (RQD) for the entire cored interval was .91.

2.2.2 Geologic Information Collected

Geologic information collected during the drilling program consisted of the following:

- Boring logs (Appendix B);
- Piezometer Installation Sheets (Appendix C);
- Core Logs (Appendix D); and,
- Core Photographs (Appendix E).

This information is contained in the Appendices B through E. The following paragraphs briefly review how the information was collected and presented.

2.2.2.1 Boring Logs

The boring logs contain the following information:

- Date;
- Type of rig;
- Drilling Contractor;
- Name of inspector;
- Drilling conditions;
- Drill rate;
- Rate of water production;
- Depth and type of samples collected;
- Lithology;
- HNu readings on drilling mud, water, background (air), and boring (air); and
- Total depth.

Boring-log information was collected in the field by a WCC field inspector according to the procedures in Sections 2.2 and 2.3 of the work plan and Appendix B-2. The lithology information for the glacial drift should be used with caution. The glacial drift was drilled with mud rotary. Information regarding the fines was somewhat masked by the drilling mud. Mud samples were collected with a strainer and then washed with water to obtain the lithology samples. The cutting samples were retained in 8-ounce glass jars and stored at the Cosco Church Street facility.

HNu readings labeled "sample" on the boring logs were taken on samples of drilling mud and on the water produced during air drilling. Readings were taken immediately and again after the samples had been warmed for one hour. The one-hour readings are presented on the boring logs.

Down-pressure was not recorded on the boring logs because most of the drilling was performed without down-pressure. Heavy drill collars were used to provide downward force. The collars eliminated the need for additional down-pressure from the rig.

The boring log for PTPN-26 covers the depth interval of 0 to 29 ft. The remainder of the boring (29 to 120 ft) was cored. Refer to the core description in Appendix D for lithology and drilling information for the cored interval.

2.2.2.2 Core Logs and Core Photographs

Detailed core logs were prepared for the core collected in PTPN-26. The cores were examined wet and dry, but the descriptions were based on wet core because greater detail was evident. The core logs are contained in Appendix D. Each core segment was labeled individually. The segments in core one were labeled 1A, 1B, etc.

Most of the core breaks indicated on the core logs are probably caused during drilling and during core removal from the core barrel and have nothing to do with in-situ fractures. WCC noticed that mechanical breaks created during core removal most often corresponded with zones of weakness related to soft shale clasts or beds and highly leached zones. The only breaks that definitely represent in-situ fractures are those with secondary mineralization (labeled "FR" on Core Logs in Appendix D). Core breaks of unknown origin should simply be called breaks, not bedding plane fractures.

The zones of leaching were very weak, and the cores commonly were broken into small sections in these zones. It is WCC's judgement that most of the soft zones encountered during drilling correspond to leached zones. These zones were called bedding plane fractures in the GHR RI report because the drill bit dropped quickly giving the impression that an opening or crack was encountered. The term bedding plane fracture is misleading, is not consistent with the core data, and, therefore, should be abandoned.

Breaks that occurred while the cores were being removed from the core barrel are labeled "DB" for driller breaks. Breaks of unknown origin are labeled "BR" for break. Shale clasts are labeled "sh" for shale. In-situ fractures are labeled "FR" for fracture.

Core photographs were taken of wet cores from a distance of 5 ft. Two photographs were taken of each core box and joined to produce the core photos in Appendix E. The inside length of the core box is 3.8 feet. The join between the two photographs is not perfect because of angular distortions near the edges of the photographs (only the center of the photographs represents a view vertically downward).

2.2.2.3 Porosity and Permeability Data from Core Samples

Five core samples were submitted for porosity (total porosity) and vertical permeability testing at WCC's Clifton Laboratory Facility in Clifton, New Jersey. These tests were not specified in the work plan. Sara Lee/Cosco chose to test for porosity and permeability in order to further develop the hydrogeologic model of the bedrock aquifer, and to compare to the regional hydraulic data collected during the pump test.

The laboratory data are summarized in Table 5. Two values are presented for each core parameter, one for the unconfined measurement (top) and one for the parameter measured under a confining pressure of 5 PSI (bottom).

The samples were selected based on qualitative visual estimates of porosity and permeability. Two samples were submitted from highly leached zones with abundant macroscopic porosity (Samples 6F and 7E). Two sandstone samples (3T and 4G) were selected randomly from cores considered representative of the bulk of the cored interval. Sample 6C was selected from a highly cemented conglomerate layer with no macroscopic porosity.

The sample number corresponds to the core segment used for the test. For example, sample 7E was the "E" segment of core 7. Refer to the core logs (Appendix D) for lithologic descriptions of the sample intervals.

Permeability was measured using ASTM Method D5084-90. Porosity was calculated from measurements of specific gravity (ASTM D854-83), sample volume, dry weight, and water saturated weight. Water saturation was achieved by injecting water into the sample at a pressure of 100 PSI. Porosity and permeability were measured under a confining pressure of 5 PSI.

The porosity and permeability data is consistent with the qualitative porosity and permeability estimates based upon visual core examination.

The leached zones, (samples 6F and 7E) have porosities of 20.6 to 22.3 percent and permeabilities of 1.4×10^{-3} to 3.5×10^{-4} cm/sec. The permeabilities of the leached zones are more consistent with karstic limestone than normal sandstone (Freeze and Cherry, 1979). These core permeabilities are roughly consistent (within an order of magnitude) with the horizontal permeabilities calculated during the pump test. This correspondence may indicate that ground water flow to the well field occurs partly along leached zones like those encountered in the cores.

The representative sandstone samples (3T and 4G) had porosities of 10.1 to 11.8 percent and permeabilities of 6.7×10^{-6} to 8.2×10^{-6} cm/sec. These permeability values fall in the mid-range for sandstones.

The lowest porosity and permeability sample was the highly-cemented conglomerate sample (6C). This sample had a porosity of 5.3 % and a permeability of 2.3×10^{-6} cm/sec.

No porosity or permeability measurements were made on bedrock cores during the SVWF RI. The porosity and permeability data reviewed in this section represent the first direct measurements of these important aquifer parameters in the Spring Valley area.

2.2.3 Geophysical Information Collected

The geophysical data collected in the field consisted of the resistivity, gamma ray and caliper logs which can be found in Appendix A. Appendix A also describes how the logs were collected and the equipment settings used. Gamma ray was the only log run within the cased interval because it is the only one that can read through the casing. The single point resistivity and caliper logs start near the bottom of the casing and continue to total depth. The geophysical logs, along with drilling data, were used to select high-permeability intervals for the PTPN screen zones.

WCC primarily used the caliper log as an indicator of permeable zones because this log could identify zones of hole enlargement associated with poorly-cemented, high-permeability leached zones. Zones of hole enlargement corresponded with the leached zones because the weak rock in the leached zones was eroded during drilling causing a wider than average borehole.

2.2.4 Geochemical Information Collected

The only geochemical data collected from the PTPN borings during the pump test consisted of HNu readings on the drilling mud and water produced during air rotary drilling. In general, the HNu readings were very low. WCC detected the highest readings (4-5 ppm) reading while drilling through the former municipal dump at PTPN-25. All other HNu readings were less than 1 ppm and may have been caused by water vapor interference.

The SVWC analyzed a ground water sample from SVWC-17 for volatile organic compounds (VOC's) during the pump test as part of their routine monitoring program. The sample from SVWC-17 had the following VOC concentrations: 40 ppb TCE, 27.9 ppb PCE and 4.2 ppb DCE. SVWC-65, located east of the SVWF, was not sampled during the pump test. When it was last sampled on November 1, 1990 it had no detectable VOC's.

2.2.5 New Data Collected Regarding Potential Sources of Contamination to the SVWF

As pointed out in the introduction, the SVWF RI had two major data gaps; one regarding the lack of ground water flow data for the bedrock aquifer, and one regarding incomplete investigation of potential sources. The pump test was not designed to evaluate potential sources, but the following information was uncovered incidentally during the pump-test field work:

1. WCC drilled through a layer of garbage and debris while drilling PTPN-25 in Memorial Park. This layer exhibited a foul odor and had elevated HNu readings (4-5 ppm) at a depth of 26 ft. The recreational coordinator for the park, Mr. David Storch, informed WCC that the park was built on top of the old municipal landfill. WCC also learned that the baseball diamond had been closed because of glass from the buried landfill. Newspaper articles reported that the landfill was closed in 1945. The SVWF RI did not mention the existence of a municipal landfill within 200 yards of the SVWF. The old landfill is a significant potential source for the chemicals measured in the SVWF.

2. WCC noticed sewer work in progress on Maple Street during the SVWF pump test. WCC questioned the sewer crew (Allstate, Inc.), and discovered that they were testing and repairing the Rockland County sanitary sewers using an automated system. Each pipe joint was pressure tested and then injected with a gel grout if it failed to hold 7 psi pressure. According to the crew, 40 percent of the joints on Maple street leaked and required repair. This information is important because the SVWF RI soil-gas survey identified elevated levels of TCE along the Main Street sewer. The RI concluded that the TCE was produced by a vapor leak in the sewer. Given the findings from the sewer repair work, the local sewers could leak TCE contaminated liquids as well as vapor. The sewers were therefore not adequately investigated during the SVWF RI.

2.2.6 Survey Data Collected

The survey data for all of the PTPN's, and staff gages are presented on Table 6. All elevation data is in feet relative to the National Geodetic Vertical Datum (NGVD). Horizontal coordinates are referenced relative to the State Plane Coordinate System and latitude/longitude. Vertical elevations are certified by the surveyor to be accurate to within 1/100th of a foot. Horizontal coordinates are certified accurate to within onetenth of a second of arc). Survey data for the SVWF RI monitoring wells and SRI piezometers is contained in the work plan (Appendices 4-4 and 4-5).

2.2.7 Piezometer Installation Data Collected

Piezometer installation sheets are provided in Appendix C. These sheets contain the following completion information for the PTPN Piezometers installed by WCC:

- Survey elevations (top of PVC risers and top of flush mount casing);
- Depth of screens, sand pack, seal, bottom of casing, and bottom of hole; and,
- Materials used (type of screen and riser, grout mix, type of bentonite pellets, and grade of sand).

3.0 AQUIFER TEST PROGRAM DATA COLLECTION AND PRESENTATION

The following four types of hydrogeologic data were collected during the SVWF pump test:

- Ground water elevations (Section 3.1);
- Surface water elevations and flow measurements for Pascack Brook (Section 3.2);
- Climate data (Section 3.3); and
- Pumping rates for the SVWF and Cosco Church Street Well (Section 3.4).

These data were used in the SVWF capture zone evaluation to estimate aquifer parameters, and to evaluate interference effects such as rainfall. Ground water elevation data are the focus of the capture zone analysis and constitutes the bulk of the data collected. The surface water data were collected to evaluate the potential for Pascack Brook and associated alluvium to contribute water to the well field and thereby effect the capture zone. The climate data were collected in order to assess interference effects (water level changes attributable to rainfall and barometric pressure changes). Pumping data were collected from the SVWF pumping wells for use in calculations of aquifer parameters such as storativity, and transmissivity. Pumping rate data from the Cosco Church Street facility was used to evaluate interference effects on nearby piezometers.

This section describes how the four types of data were collected, reviewed for quality assurance and quality control (QA/QC) purposes, and summarized in tables and graphs. Some observations regarding interference effects from weather and local pumping wells are also discussed.

The SVWF pump test consisted of three, five-day segments or phases: pre-monitoring; recovery; and drawdown. The pre-monitoring phase took place from 9:00 am, January 8, 1992 through 9:00 am, January 13, 1992 while the SVWF was pumping at slightly over its normal rate (1500 gpm versus normal rate of 1300 gpm). This phase was used to establish the normal pattern of ground water flow for normal, constant pumping conditions. The capture zone of the SVWF can be best evaluated from potentiometric maps of the ground water data collected during this phase.

The SVWF was shut down at the start of the recovery phase of the pump test (January 13, 1992 at 9:00 am through January 18, 1992 at 9:00 am). After the well field was shut down, the water levels rose, or recovered, from the influence of SVWF pumping. This portion of the test is also called a transient-state phase of the pump test because water levels near the well field changed with time throughout this period in response to the cessation of pumping. The water level data from recovery portion of the test were used to evaluate certain useful hydrogeologic aquifer properties such as transmissivity, storativity, and the apparent degree of anisotropy.

The final portion of the pump test, the drawdown phase, began when the SVWF was turned on again after the five day recovery period (9:00 am January 18, 1992 through 9:00 am January 23, 1992). The drawdown phase, like the recovery phase, is a transient-state period. Data from this phase of the test were not specifically analyzed because the start-up of the pumping wells was staggered (i.e., Well 1A did not start pumping until January 20) and the discharge rate to the well field was not constant.

The focus of this report will be on the pre-monitoring, steady-state portion of the test because this provides the most relevant information regarding the capture zone. The potentiometric-head plots (Figures 6, 7 and 8) used to determine capture zone were prepared using the pre-monitoring phase data.

3.1 GROUND WATER ELEVATION DATA

3.1.1 Ground Water Elevation Data Collection

Throughout the pre-monitoring, drawdown and recovery phases of the pump test WCC and LBG monitored a network of 51 piezometers and monitoring wells at 24 locations (see Figure 5). The production wells in the SVWF were monitored by the SCADDA automated data collection system. The monitoring duties were split between WCC and LBG. Table 1 shows the respective monitoring assignments. Water level data was collected manually with electronic water level indicators and automatically with data loggers equipped with pressure transducers. Piezometers PTPN-17R, PTPN-22, PTPN-23, PTPN-24, PTPN-25 and MW-13D were equipped with data loggers. WCC made periodic measurements of the monitoring points assigned to LBG, and LBG made periodic measurements of the monitoring points assigned to WCC. Manual backup measurements were made on piezometers WCC equipped with the data loggers.

At the end of the pump test, WCC and LBG exchanged data and both parties supplied copies of the data to the NYDEC.

Completion details (elevation of ground surface, measuring point (top of PVC riser), and top and bottom of screened intervals) for all 51 monitoring points are contained in Table 4. Monitoring well and piezometer installation data sheets for the SVWF RI monitoring wells and SRI piezometers are contained in Appendices 4-4 and 4-5 of the work plan. The SRI piezometer nests contain both well point and pneumatic piezometers. Only the well point piezometers were monitored during the pump test. Appendix C of this report contains the piezometer installation data sheets for the PTPN piezometers installed by WCC. LBG's report contains the piezometer installation data sheets for their PTPN's.

The following subsections of Section 3.1.1 will summarize how the manual and remote monitoring data was collected in the field.

Manual Measurements

The bulk of the water level measurements were collected by field personnel using manual measuring techniques. Manual measurements were made according to Section 3.4.3 of the work plan and were recorded on field data sheets. Manual measurements were performed with M-scopes (three Slope Indicator Company Model 51670830 and one Slope Indicator Model 51453). The M-scopes used by WCC were electrical devices equipped with visual and audible alarms. The alarms were triggered when the probe made contact with the water surface, thereby closing an electrical circuit. The M-scope probe was lowered down inside of the PVC riser until the water interface was detected. At the point where the water interface was encountered, the M-scope's cable was referenced to a mark on the well casing. Depth markers were attached to the cable by the manufacturer at one or two-hundredth of a foot intervals. Prior to water-level testing the following QA/QC procedures were carried out:

- Markings on the probes were checked against a steel measuring tape to assure accurate measurements;
- Probe responses were tested in a pail of water and the sensitivity settings were fixed at the optimum level for accurate readings.

At the end of the pump test, all three probes (Model 51670830) used by WCC to measure water levels in the PTPN's were tested in PTPN-21D to insure continued calibration and accuracy. The following measurements were obtained (72.3 ft, 72.29 ft and 72.31 ft). The smaller diameter probe (Model 51453) used to measure water levels in the SRI piezometers gave a reading of 72.43. The small difference between the two probe types may be related to differential stretching of the cables.

The M-scopes were decontaminated between readings by rinsing with deionized water. Soiled probes and cables were washed with a detergent solution (Alconox) and then rinsed with deionized water.

Remote Monitoring Devices

Both WCC and LBG collected water-level data at selected locations (Table 1) by means of portable remote-data-collection systems. Remote systems were used by WCC in the piezometer nests with high frequency monitoring schedules, and in piezometer nests located in high crime areas where it would have been dangerous to take manual readings at night. LBG installed data loggers in PTPN-17R and the Allen Well. The remote monitoring procedures for the LBG locations are contained in their report.

WCC installed remote monitoring devices in Piezometers PTPN-22S, 22D, 23S, 23D, 24S, 24D, 25S, 25D and MW-13D. The remote systems consisted of data loggers, transducers and portable computers (to download the data). WCC used HERMIT 1000B data loggers (In Situ, Inc.) to collect the remote data. One data logger was installed at each location and programmed to record data from two transducers (one installed in the shallow piezometer and one installed in the deep piezometer). MW-13D was equipped with a single transducer. The data loggers were placed in sealed 55-gallon drums to prevent tampering. The PVC risers were extended into the drums with three-foot sections of PVC pipe (extenders). The transducer cable was securely taped to the top of the PVC riser with duct tape.

The data loggers were capable of recording data at variable programmable sequences including linear and logarithmic intervals. For QA/QC and data-security purposes, the data logger measurements were transferred to a portable lap-top computer on a daily basis.

Pressure transducers (In Situ Model PTX-161/D) with a pressure rating of 10 PSI, or approximately 23 feet of head, were used with the data loggers to measure water-level submergence. The pressure transducer's standard measuring accuracy is 0.1 percent of the full range, or plus or minus .023 ft.

The water column above the transducers in PTPN-22 and 25 temporarily exceeded the maximum head the transducers could register. This caused the transducers to shut-off. The problem was remedied by raising the level of the transducers and recalibrating the data loggers. Manual readings continued to be collected during the period the transducers were shut-off. The transducer in PTPN-24D malfunctioned during the recovery portion of the test. Manual data continued to be collected during this period.

Monitoring Frequency

The monitoring frequency depended upon both the piezometer/monitoring well location and time into the pump test. Bedrock piezometers near the well field had the highest frequency monitoring schedules. The more distant bedrock piezometers (the SRI piezometers) and the glacial drift monitoring wells were monitored less frequently than the bedrock piezometers near the well field. Monitoring frequencies in all of the piezometers and monitoring wells were increased during the 24-hour period following shutoff and start-up of the SVWF in order to record rapid initial responses. WCC monitored the wells assigned to LBG twice each day as an audit of their measurement methods and for QA/QC purposes. Monitoring frequencies for both the LBG and WCC locations are summarized in Table 1. Additional details regarding the frequency of measurements in the LBG piezometers/wells can be found in their report.

WCC was responsible for monitoring water levels in three groups of piezometer nests and wells:

- Monitoring wells (MW-1, MW-10, MW-11, MW-12, MW-13D, MW-15, and MW-16);
- SRI piezometers (SRI-1, 2, 3, and 4); and
- PTPN piezometers (PTPN-22, 23, 24, 25 and 26).

During the 15-day aquifer test program, the water levels of the monitoring wells and the SRI piezometers were measured approximately every 3 hours. During the 24-hour period following the SVWF shut-down (09:00, 1/13/92) and start-up (09:00, 1/18/92), the monitoring wells were measured approximately once every hour and the SRI piezometers were measured approximately once every half hour.

The water levels in PTPN piezometers (22 through 25) were monitored every half hour by remote measuring devices during the 15-day aquifer test program (Section 2.2.2). The only exceptions were the 24-hour periods following the SVWF shut-down and start-up when the frequency changed to a logarithmic schedule that started with ten second intervals and gradually increased to half-hour intervals. Additionally, manual measurements were taken at the PTPN piezometers (22 through 25) on a daily basis as back-up. PTPN-26 was installed part way into the pump test (January 15, 1992) and was monitored at a low frequency as a background piezometer (once per day).

3.1.2 Data Compilation and Quality Assurance/Quality Control

The manual and remote data were compiled daily onto LOTUS computer spreadsheets for field-graphing purposes, and were later compiled into a computer data base (DBASE) in WCC's Chicago office to facilitate data plotting and analysis. The data went through QA/QC procedures at both the field and office stages of compilation. Daily hydrographs were prepared from the LOTUS spreadsheets to check for data outliers. Outliers were evaluated to determine if they represented data entry problems, equipment malfunction, real data, or measurement errors.

Hydrographs were prepared in the office after the WCC and LBG data were entered into the DBASE database. The hydrographs were plotted using GRAPHER graphics software. All monitoring well and piezometer hydrographs and were again checked for outliers. All outliers were checked against field data sheets and were cross-checked against back-up data (i.e. - WCC data was checked against LBG data and LBG data was checked against WCC data). The hydrographs presented in Appendices F, G, and H have gone through both the field and office QA/QC review processes.

When the Hermit data were plotted against the manual measurements in PTPN-22 through 25, the HERMIT data did not always match the manual readings. The 0.1 to 0.2 foot discrepancies are probably related to inaccuracies in the manual data caused by the water level probe cable twisting around the transducer cable.

3.1.3 Presentation of Ground Water Elevation Data

WCC has summarized both the LBG and WCC water level data using the following three types of hydrographs for each monitoring location:

1. A hydrograph for the entire pump test was plotted at a linear scale to evaluate overall pumping effects and interferences (Appendix G);

2. A hydrograph of the pre-monitoring period was plotted at a linear scale to evaluate possible interference effects or trends during this period (Appendix F); and,

3. A hydrograph of the recovery period, with time plotted logarithmically, was used to calculate aquifer parameters such as transmissivity and storativity (Appendix H).

These hydrographs were evaluated for trends and interference effects. The following subsections present observations pertaining to the summary hydrographs.

Observations Pertaining to the Pre-monitoring Phase Hydrographs

WCC's capture zone analysis was based upon an assumption of steady-state flow conditions occurring during the pre-monitoring period. The pre-monitoring hydrographs were evaluated to determine if the pre-monitoring period represented steady-state flow conditions. Except for some minor water level fluctuations, observations confirm that steady-state conditions prevailed during the pre-monitoring phase.

The pre-monitoring phase hydrographs in Appendix F were evaluated for interference effects caused by factors such as rainfall, barometric pressure changes and private and industrial pumping wells. Interference effects were evaluated to identify factors, unrelated to the SVWF, which might be misinterpreted as well field pumping effects. Some interference effects were observed in the pre-monitoring data but they were small in comparison to the water level fluctuations that were caused by the SVWF shut-down and start-up. These factors are discussed below.

The Spring Valley area experienced light rainfall on January 9, 1992. This event caused water levels to rise slightly (less than 0.2 feet) in the monitoring wells screened in the unconsolidated zone (glacial drift). Water levels in the piezometers screened in the intermediate or deep bedrock zones did not respond to this rain event.

Appendix I contains an overlay presenting the barometric pressure versus time during the aquifer test. This overlay can be placed on the Appendix F hydrographs to evaluate barometric effects. The barometric pressure fluctuated between 991 to 1008 mbars during the pre-monitoring period. This pressure fluctuation had minimal to non-measurable effects on the water levels in the monitoring wells screened in the unconsolidated zone, but may have caused small water-level fluctuation in the piezometers screened in the bedrock. In general, the bedrock piezometer water levels rose about 0.4 feet and did not exceed a rise of 0.6 feet during the pressure drop on January 9. This correlation, along with other evidence (hydraulic analysis), indicates that the bedrock aquifer is confined. This finding is important because it effects the mathematical procedures used to calculate the aquifer parameters (see Section 4.2).

Water levels measured in all monitoring points remained relatively constant during the pre-monitoring phase, with three exceptions. First, monitoring well MW-12 fluctuated approximately 0.6 feet between readings throughout the entire aquifer test program. This was considered to be caused by local pumping of the unconsolidated zone (alluvium and glacial drift). Second, the water levels in MW-7B fluctuated at approximately the same amount as MW-12. This is likely due to a second shallow pumping influence since the wells are 2000 ft apart.

Thirdly, the water levels in PTPN-23D (deep piezometer) were clearly influenced by pumping at SVWC Production Well 65 (Well 65). Water levels began rising on January 9, 1992, at 4:00 pm and continued to rise until January 16, 1992, at 11:00 am, when they dropped approximately two feet. These fluctuations correspond to the shut-off and start-up of Well 65. An overlay of the pumping schedule for Well 65 pumping is provided in Appendix I. This overlay fits over the hydrographs in Appendix G.

The operation of the Cosco Church Street Well had negligible effects on water levels measured in nearby monitoring points during the aquifer test. This conclusion was reached by comparing the pumping schedule for the Cosco Well (Appendix J) to the pre-monitoring hydrographs.

Overall, the pre-monitoring period is considered a stable period of ground water flow and represents steady-state conditions. The minor interferences discovered are unlikely to effect capture zone analysis or aquifer test calculations.

Observations Pertaining to the Recovery-Phase Hydrographs

Recovery-phase (transient) data were used by WCC to calculate aquifer parameters such as storativity[4] and transmissivity[5]. Only the first 1500 minutes of the recovery phase were used because of interference effects (rainfall and barometric pressure changes) caused by a strong storm system after this period. Local weather forecasters compared the barometric pressure in this storm to a small hurricane. This and other interferences occurring during the recovery phase will be evaluated in this section using the hydrographs in Appendix G. Observations of total recoveries caused by shut-down of the well field will also be discussed.

The rainfall event occurred on the second day of the recovery phase. Appendix I contains a graph (hydrograph overlay) that depicts rainfall intensity versus time. As in the pre-monitoring phase, this rain event initially raised the water levels in the wells screened in the unconsolidated zone (glacial drift wells). The effects of the rain event on the glacial drift wells ranged from negligible in MW-13S, to a rise in water level of approximately one foot in MW-16. The barometric pressure had negligible effects on the water levels measured in the alluvial wells.

Water levels measured in the wells and piezometers completed in the deeper bedrock zones rose slightly on January 15. This may be attributed to the rain event on January 14. However, more likely, this rise in water levels was caused by the drop in barometric pressure on January 15. Appendix I contains a graph (hydrograph overlay) of barometric pressure versus time over the entire aquifer test program.

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4 Storativity is a technical term used to describe the amount of water that can be extracted from a given volume of rock or sediment. The technical definition is, "the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head."

5 Transmissivity is a technical term that describes the ease with which ground water can move through an aquifer. The technical definition is, "the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient."

Piezometers SRI-1S and SRI-1D were flooded during the rain event when storm water runoff from Collins Street flowed into the loosely sealed wells (the expandable plugs had been loosened to allow for barometric equilibration during water level monitoring). Water levels in these piezometers did not recover from the flooding until approximately 48 hours later (see hydrographs in Appendix G). Due to this complication, hydraulic analysis was conducted on the data prior to this event (see Section 4.0 - Analysis Methods and Results).

Water levels monitored in almost all of the PTPN piezometers (Nos. 17 through 25) and the SRI piezometers (Nos. 1 through 4) responded to the pump shut-off on January 13, 1992, except for PTPN-17S and PTPN-23A-S. Figure 9 presents the total recoveries during the recovery phase for piezometers screened between elevation 250 and 300 ft above mean sea level (MSL). Figure 10 presents the recoveries during the first 1500 minutes (prior to rain event effects) of the recovery phase for the same piezometers. Recovery is defined as the rise in water levels due to pump shut-off. Table 8 provides the recoveries for all the wells and piezometers during the recovery phase and the first 1500 minutes of the recovery phase. The greatest recovery during the pump-off phase was 52 feet in PTPN-20D. This was likely due to the affects of partial penetration of the piezometer with respect to the pumping wells and the piezometer's location near SVWC No. 17. The affects of partial penetration of monitoring points are further discussed in Section 4.2.4.

The shut-off of Well 65 on January 9th, 1992, caused a significant recovery in PTPN-23A-D, however, the January 13, 1992, SVWF shut-off event (recovery phase) is still evident on the hydrograph as a change in slope (see hydrograph for PTPN-23A-D in Appendix G).

Water levels measured in the monitoring wells screened in the unconsolidated zone generally did not respond to the pump shut-off. However, levels in monitoring wells MW-13S, MW-15, MW-15P, and MW-7S showed slight recoveries. MW-15 showed the largest recovery of the alluvial wells of approximately 0.5 ft.

Figure 11 and Table 8 present the lag times to the beginning of water level recovery. Lag time is defined as the time required for the water level in a piezometer to respond (rise or fall) to a change in pumping conditions (pump-on or pump-off). For this report, lag time was considered to be the time required for water levels to change 0.25 feet.

Observations Pertaining to the Drawdown-Phase Hydrographs

Drawdown-phase data were not used to calculate aquifer parameters by WCC because:

1) complications resulting from a rain event during the recovery phase;

2) steady state recovery conditions were not reached during the drawdown phase;

3) the SVWF pumping wells were returned to service in stages; and,

4) information provided during the recovery phase were adequate to calculate aquifer parameters.

The SVWC wells SVWC-04 and SVWC-06 were turned on at 9:00 am January 18, 1992. Well SVWC-17 was turned on approximately 1.5 hours later. Well SVWC-1A was turned on at 12:20 pm on January 20, 1992, because of a frozen water line. The result of this staggered pump start-up can be seen on the hydrographs for the PTPN and SRI piezometers (Appendix G and pumping overlay in Appendix J). The drawdown occurs at one rate and then increases as SVWC-1A comes on-line (i.e., the hydrograph curve slopes downward at one slope and then the slope becomes steeper).

As was observed in the recovery phase, the glacial drift wells generally did not respond to changes in pumping conditions. Only monitoring wells MW-13S, MW-15, MW-15P, MW-7S, MW-7P, MW-8S and MW-9S indicated a response to the SVWF start-up. The most significant drawdown measured in the alluvial wells occurred in MW-15 (approximately 0.4 feet). The drawdowns in all of the above mentioned wells were delayed approximately two days, except for MW-13S which seemed to respond immediately to pump start-up.

The observations made from the hydrographs indicated that a sufficient quality and quantity of data was collected to conduct a successful capture-zone analysis. The pre-monitoring data demonstrated that the interference effects of private pumping wells, precipitation, and barometric pressure changes were relatively minor compared with the water level responses related to start-up and shut-off of pumping at the SVWF. The observations made from the recovery-phase data indicated that the first 1500 minutes of this phase were free of interference effects and that this data could be used for calculating aquifer parameters such as hydraulic conductivity, storativity and transmissivity. The observations of the drawdown-phase data will not be summarized since this data was not used in the capture-zone analysis.

3.2 SURFACE WATER DATA

3.2.1 Data Collection

Surface water flow in Pascack Brook was monitored with staff gauges and flow measuring devices (flumes and pygmy flow meters) during the pump test to evaluate if water from the brook was being drawn into the SVWF.

Four staff gauges were installed along Pascack Brook prior to the 15-day aquifer test program. The locations of these staff gauges are shown on Figure 5. The staff gauges were surveyed by GEOD Corporation on January 22, 1992. Measurements of the stream surface elevation were obtained on a daily basis at each staff gauge location.

Stream discharge was estimated at two locations on Pascack Brook during the aquifer test (upstream and downstream of the well field). The upstream discharge was evaluated by making flow measurements in two tributaries located just north of Staff Gauge No. 1 (Figure 5). The flow in the west tributary, which is a concrete-lined ditch, was estimated by measuring the velocity of the stream at several locations with a pygmy flow meter and computing the approximate cross-sectional area of each location. The Work Plan (Section 3.4.4) describes this procedure in detail. On January 18, 1992, approximately midway through the aquifer test program, this procedure was simplified by narrowing the west tributary to approximately one-foot in width with a piece of sheet metal, and measuring the average velocity of this small cross-section with the pygmy meter. A Cut-throat Flume (Baski Inc.) was installed in the north tributary and the downstream (Maple Street) location to evaluate flow. The water level in the flume was read from a small gauge attached to the flume and a simple calculation was made to arrive at the flow values. Appendix K contains the equation used to convert the flume readings to flow values. During rainfall events, when the brook's flow exceeded the flume capacity, the pygmy flow meter was used to obtain flow measurements. The calculation used is also presented in Appendix K.

Surface water data were recorded on data sheets. Calculations, such as conversion of pygmy meter readings to flows, were conducted after each reading. All calculations were checked upon return to the office.

3.2.3 Presentation of the Surface Water Elevation and Flow Data

Surface water elevation and flow data for Pascack Brook are summarized in Table 9. Surface water hydrographs are contained in Appendix K. Staff-gauge and flow measurements during the drawdown phase suggest that Pascack Brook may be losing water into the glacial drift. The following paragraphs review the surface water data during the three phases of the pump test. The last phase, the drawdown phase, contains the strongest evidence for losses from Pascack Brook into the SVWF.

The hydrographs do not indicate significant changes in water levels during the pre-monitoring phase. The recovery-phase data, however, was affected by a significant interference factor, the January 14th rainfall event which raised water levels 0.4 feet at Staff Gauge Nos. 1, 2, and 3 and raised the water level almost 0.7 feet at Staff Gauge No. 4. This event made the surface-water data difficult to interpret because the large impact from precipitation may have masked subtler effects related to SVWF pumping. The water levels in the brook did not return to their pre-monitoring-phase levels until the end of the recovery phase (January 18, 1992).

During the drawdown phase, the water levels at Staff Gauge Nos. 1, 2, and 3 remained at the same levels as the pre-monitoring phase. However, the water level at Staff Gauge No. 4, which is located downstream of the Spring Valley pump field, decreased, suggesting that the brook may have recharged the glacial drift and bedrock near the Spring Valley pumping wells.

Flow data from the Pascack Brook is summarized in Appendix K. A figure titled "Difference in Discharge" in Appendix K displays the difference between the upstream flow and the downstream flow. This figure suggests that the brook is gaining, or increasing in flow, during the pre-monitoring phase. The rain event on January 14, 1992 during the recovery phase increased the flow in the brook significantly. The flow data during this period are not completely accurate because flow rates exceeded the limits of the measuring devices. Flow rates returned to their pre-monitoring phase levels on January 18, 1992. During the drawdown phase, the downstream flows generally decreased relative to the upstream flow. This suggests that the brook was losing water to the alluvium and glacial drift (see the flow data for January 21 and 23, 1992). These changes in flow rates and stream elevation might be explained by the start-up of the SVWF pumps.

No conclusive findings were possible from the surface-water data regarding the percentage of the SVWF's production that is derived from Pascack Brook. The drawdown-phase data did indicate a potential contribution from the brook, but this contribution was difficult to quantify because of rainfall interference effects.

3.3 CLIMATE DATA

A rain gauge was maintained and operated in the field by SVWC personnel. The rain gauge was located on the roof of the booster pump house in the Spring Valley Well Field. Readings (in inches per hour) were recorded remotely by SCADDA on a 10-minute basis. Field measurements were accurate to within one-hundredth of an inch. Precipitation data were also obtained from the Northeast Regional Climate Center Station in West Nyak, New York as back-up data. As mentioned in previous sections, Appendix I presents a graph of rainfall intensity versus time for the duration of the aquifer test program.

Barometric pressure was recorded by LBG during the aquifer test. A graph of the barometric pressure versus time for the duration of the aquifer test is included in Appendix I.

The climate data was used to evaluate potential interference effects caused by rainfall and barometric-pressure changes. Interference effects occurred, but their impacts were relatively minor. The only significant interference effect was the January 14th rainfall impact on the surface-water data.

4.0
ANALYSIS METHODS AND RESULTS

The goal of the SVWF pump test was to evaluate the capture zone of the Spring Valley Well Field. This objective was reached in three steps during the analysis process:

Step 1. summarize and depict the three-dimensional steady-state potentiometric surface around the SVWF using the pre-monitoring phase data;

Step 2. evaluate the direction and degree of horizontal anisotropy in the bedrock, if any; and,

Step 3. evaluate the three-dimensional ground-water-flow patterns associated with the SVWF based upon the results of steps 1 and 2.

The summary and depiction of steady-state flow conditions (Step 1) involved plotting of the water-level data collected during the pre-monitoring phase (see Section 4.1). These maps (Figures 6, 7 and 8) represent the normal, or steady-state, distribution of horizontal potentiometric heads around the SVWF at three levels in the bedrock aquifer. Standard steady-state hydraulic methods were employed to plot two horizontal potentiometric surface maps and one inclined potentiometric surface map at an angle of 65 ft/ mile (regional gradient).

The value and direction of anisotropy around the well field were evaluated in Step 2 in order to determine if ground water flow directions could be evaluated directly from the steady-state potentiometric surface maps prepared in Step 1. Anisotropy was evaluated using the following four methods:

- Analysis of water level recoveries during the recovery phase;
- Analysis of the steady-state distribution of potentiometric heads around the SVWF;

- Analysis of the direction and magnitude of anisotropy using quantitative calculations of aquifer parameters (hydraulic conductivity and transmissivity) calculated using the data from the recovery phase; and

- Analysis of lag times following shut-off of the SVWF wells.

Each method is reviewed in Section 4.2 and the results discussed.

In Step 3, the three-dimensional flow patterns around the SVWF were evaluated using the potentiometric maps in Item 1. The flow analysis and capture zone conclusions are contained in the Summary and Conclusions section (Section 4.3).

Data collected from the recovery (transient) phase of the aquifer test program were also analyzed to evaluate aquifer parameters such as transmissivity, storativity, and hydraulic conductivity. These parameters were used in the anisotropy evaluation and to further define aquifer characteristics. These calculations were performed using accepted hydraulic analytical methods and used techniques that assume both isotropic and anisotropic conditions. Section 4.2 describes the methods and assumptions used in the analysis of the transient state conditions.

4.1 EVALUATION OF THE THREE DIMENSIONAL POTENTIOMETRIC SURFACE AROUND THE SVWF

Step-one in the analysis process was to summarize and depict the distribution of potentiometric heads in the vicinity of the SVWF. This was an important step because the potentiometric heads drive the groundwater flow system. A fundamental law of hydrogeology (and hydraulics in general) is that ground water moves from areas of high potentiometric head to areas of low potentiometric head, or, in other words, from areas of high potential energy to areas of low potential energy. Potentiometric-head contour maps are the best way to summarize and depict a large volume of water level data. If an aquifer is homogeneous and isotropic, these contour maps can easily be used to determine groundwater flow directions because ground water will flow perpendicular to the contour lines (equal potential lines).

Section 4.1.1 reviews the conditions that must be met in the Spring Valley area in order to determine capture zone using the distribution of steady-state potentiometric heads.

4.1.1 Existing Hydrologic Conditions

The potentiometric-head plots (Figures 6, 7, and 8) were prepared and evaluated using the methods for steady-state analysis. These methods require that the following conditions are met:

1) Steady-state conditions occurred during the pre-monitoring period;
2) A strong east to southeast regional potentiometric gradient is present;
3) The aquifer is isotropic and homogeneous near the well field and study area; and,
4) The aquifer is confined.

The following subsections demonstrate that each of the four hydrologic conditions were satisfied during the pump test.

Steady-State Ground Water Flow Conditions

The development and interpretation of the steady-state potentiometric maps required the existence of steady-state conditions[6] during the pre-monitoring phase of the pump test. If steady-state conditions existed during this phase, then the capture zone determined from the potentiometric-head maps accurately reflects the long-term average position of the capture zone.

Water levels at the SVWF have had over 50 years to reach steady-state, equilibrium, conditions after over 50 years of continuous pumping. Establishment of steady-state

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6 Steady-state conditions occur when recharge to the aquifer has come into balance with withdrawals due to pumping and natural discharge.

conditions is indicated by the relatively constant historical well yields and drawdowns in the SVWF pumping wells (LBG, 1982).

Pumping rates during the pre-monitoring phase (1500 gpm) were similar to the average rate (1300 gpm) during the four-year period leading up to the pump test. This data also supports the existence of long-term steady-state conditions during the pre-monitoring phase.

Ground-water data collected in all of the observation wells during the pre-monitoring phase remained nearly constant (Appendix F). Some minor changes in water levels occurred due to precipitation and changes in barometric pressure. The constant water levels indicated that steady-state conditions also were also present on a time scale measured in days rather than years.

Based upon the above observations, methods for steady state conditions were applied to evaluate the distribution of potentiometric heads and ground-water flow directions around the SVWF during the pre-monitoring phase.

Presence of a Regional Gradient

This subsection reviews evidence pertaining to the existence of a regional ground-water potentiometric gradient. If there were no regional gradient, the capture-zone analysis would have been simple and steady-state potentiometric analysis would not have been required. This subsection provides convincing evidence that a regional gradient is present and that steady-state potentiometric analysis is the appropriate method for determining the capture zone.

The evidence for a large regional gradient consists of:

1) The inherent topography of the region slopes from the Ramapo mountains (elevation 1000 ft) in the west to the Hudson River (elevation near sea level) in the east. This topographic relief provides the driving energy for the eastward to southeastward directed regional gradient.

2) Water levels in the bedrock aquifer drop 400 ft between Cosco/CPC and the Hudson River located 7 miles to the east. The regional gradient calculated on this basis is 57 ft/mile to the east.

3) The potentiometric-surface map developed from regional water level data (Figure 1) indicates an eastward gradient of 50 to 90 ft per mile in the Spring Valley area. The regional potentiometric map was prepared from a 1959 publication titled "The Geology and Ground water Resources of Rockland County, New York". The data plotted on Figure 1 was collected between 1951 and 1957 from a variety of wells completed in the Newark Group (Brunswick Formation), including: private and municipal wells, observations wells, test wells, and unused and abandoned wells. All water levels represent non-pumping levels. The potentiometric map is viewed as a regional average because the water levels were collected at different times.

4) The regional gradient calculated from piezometers PTPN-26 and SRI-3, located away from the well field, during the pre-monitoring period is 65 ft per mile.

All four lines of evidence support the existence of a strong regional gradient. The steady-state bedrock flow system in the Spring Valley area can therefore be characterized as steady-state pumping conditions produced by the SVWF superimposed upon a steady-state eastward to southeastward regional gradient (see Figure 2). A simple "radius-of-influence equal capture-zone" approach will not work under these conditions. The best method to determine the capture zone under these conditions is to plot and evaluate the distribution of steady-state potentiometric heads in the vicinity of the SVWF.

Generally Isotropic and Homogeneous Conditions

The method used by WCC to interpret the potentiometric-head maps and to determine the capture zone of the SVWF required that the aquifer be isotropic and homogeneous. Under isotropic and homogeneous conditions, groundwater flows perpendicular to the contour lines plotted on the potentiometric maps (Figures 6, 7 and 8). As discussed in Section 1.3.3, both geologic and hydrogeologic lines of evidence support the presence of isotropic and homogeneous conditions in the bedrock aquifer in the Spring Valley area.

Four hydrogeologic methods were used to evaluate anisotropy, all of which indicated generally isotropic conditions. These methods are reviewed in Section 4.2. The geologic information supporting isotropic and homogeneous conditions was presented in Section 1.3.3.

Since the bedrock aquifer is essentially isotropic and homogeneous, groundwater flow paths on the potentiometric-head maps and hydrogeologic cross sections can be drawn at right angles to the contour lines.

Confined Aquifer Conditions

Confined aquifers are evaluated using different methods and equations than unconfined aquifers. For this reason, the degree of confinement of the Brunswick Formation aquifer was evaluated using hydraulic analyses of the recovery-phase water-level data. The bedrock was determined to be under confined conditions based on these analyses (see Section 4.2)

Barometric-pressure effects observed in the bedrock water-level data also supported the conclusion that the Brunswick Formation is a confined aquifer. Section 3.1.3 discussed the response of bedrock water levels to barometric-pressure changes. The water level responses are also consistent with the calculated storage coefficients presented in section 4.2.

Based on the evidence presented above, WCC used methods for confined aquifers to evaluate aquifer parameters such as hydraulic conductivity, storativity, and transmissivity. Hydraulic conductivity was then used to evaluate anisotropy.

All of the conditions required to determine the capture zone by evaluating potentiometric heads are satisfied in the Spring Valley area. The methods selected are therefore appropriate for the site.

4.1.2 Procedures for Preparing Steady-State Potentiometric Maps and Cross Sections

Three steady-state potentiometric maps were prepared for this report to summarize the large volume of water-level data collected during the pump test (Figures 6, 7 and 8). These maps were interpreted (Section 4.1.3) to evaluate the directions of ground water flow (both vertical and horizontal) and the capture zone of the SVWF. Hydrogeologic cross sections (Figures 14 through 19) were prepared to help construct the potentiometric maps and check their accuracy.

Potentiometric head distributions at the SVWF site were evaluated mainly by graphical methods, which include construction of vertical hydrogeological cross sections and horizontal and near-horizontal potentiometric surface maps. Six sets of hydrogeologic cross-sections A-A' to F-F' were drawn (Figures 14 to 19).

The January 9 pre-monitoring water levels are plotted on the cross sections. The January 9th data was used to avoid possible interference effects caused by irregular pumping of production well SVWC-65 (located east of Spring Valley) which occurred after the 9th. During the pre-monitoring phase of the aquifer test program, all production wells except SVWC-65 were pumping at normally scheduled rates. The impact of the irregular pumping at SVWC-65 is not noticeable except at piezometer PTPN-23A and possibly at PTPN-24 (Reference Section 3).

Vertical gradients at each piezometer nest were calculated from the centers of the screened intervals (Table 7). Piezometer nests located nearer to the well field have downward vertical gradients. These downward gradients are a result of the cone of depression caused by the well field. Upward vertical gradients were observed in piezometer nests located south of the well field and close to the Pascack Brook. It is WCC's judgement that the upward gradients in these piezometers are related to former natural ground-water discharge areas.

The calculated upward or downward vertical gradients were either interpolated or extrapolated to elevations of 250 and 300 ft msl to obtain the ground water elevations plotted on the maps and cross sections. Ground water elevations at 300 ft and 250 ft msl were selected because most of the piezometers are screened in this interval.

Interpolation and extrapolation during cross-section and map preparation was minimized by selecting these mapping elevations.

The interpolated/extrapolated ground water elevations at 300 ft and 250 ft msl were transposed at each piezometer location onto base maps. The transposed data was contoured to prepare horizontal potentiometric surface maps at elevations of 300 ft and 250 ft msl (Figures 6 & 7).

An inclined potentiometric surface map was constructed at the angle of the regional gradient (a slope of 65 ft/mile) originating at PTPN-19 (Figure 8). This map was generated by determining the elevation of the intersection between the 65 ft/mile inclined plane and each piezometer. Then, the potentiometric head for each piezometer nest was interpolated or extrapolated based on vertical gradients (Table 7).

The horizontal potentiometric surface maps were checked by transposing equipotential lines (contours) onto vertical hydrogeological cross sections (Figures 14 through 16). The equipotential lines on the vertical cross sections indicate the same potentiometric slopes as the horizontal potentiometric surface maps.

4.1.3 Results of Capture Zone Analyses

The potentiometric maps discussed in Section 4.1.2 were graphically interpreted to evaluate the capture curve of the SVWF. The first step in this process was to evaluate groundwater flow paths, or streamlines, across the site. Since the bedrock aquifer is essentially isotropic and homogeneous, flow paths can be easily drawn from the potentiometric-surface contours on Figures 6, 7 and 8 because flow lines must intersect the potentiometric contours at right angles. The capture zones shown on Figures 6, 7 and 8 represent the dividing line (dividing streamline) that separates ground water flowing horizontally to the SVWF from ground water flowing to the east and southeast parallel to Pascack Brook. The dividing streamline defines the capture zone of the well field.

The flow path for groundwater passing below the Cosco/CPC site is shown on all three potentiometric-surface maps. A particle of groundwater originating at the Cosco/CPC site would first flow east, and then bend to the south-southeast after it encountered the potentiometric ridge which runs parallel to Pascack Brook (the potentiometric ridge is described in detail below). The point where the flow line bends to the south-southeast can be described as a potentiometric trough. This trough is bounded by two 340 ft contour lines. This trough widens to the south, thereby imparting a component of southerly flow to ground water in the trough.

Figure 20 extends further to the south than Figures 6, 7 and 8, and provides a more comprehensive view of the flow path followed by a ground water particle originating at Cosco/CPC. This figure shows why the potentiometric trough widens to the south. The 340 ft contour bounding the east side of the trough deviates from the western 340 ft contour because of a control point located where the stream bed of Pascack Brook drops below 340 ft. The 340 ft contour on the east side of the trough must connect with this control point. Bedrock is exposed in the stream bed near the control point and there is very little vertical gradient in the area (as indicated by PTPN 26).

The 340 ft contour bounding the west side of the trough does not bend to the east but continues south parallel to the regional contour lines shown on Figure 1. This contour line is constrained by the water levels measured in the SRI piezometers.

In addition to delineating the capture zone, the potentiometric surface maps provide other information on ground-water flow. The three horizontal potentiometric surface maps and the hydrogeologic cross-sections indicate four zones of ground-water flow:

1) An area surrounding the well field with concentric equipotential lines. This area is within the cone of depression and capture zone caused by pumping at the SVWF (i.e., ground water flows from PTPN-19 & 22 towards the well field).

2) An area of anomalously high water levels occurs south of the well field, starting in the vicinity of PTPN-21 and running southeast parallel to Pascack Brook. This area constitutes a potentiometric ridge and ground water divide. This feature is present on all three maps (Figures 6, 7, and 8). Ground water flows in opposite directions along the crest of the divide.

3) An area with steep gradients occurs west and southwest of the well field. The general direction of ground water flow in this area is towards the east. This gradient and direction of flow coincides with the regional gradient. A steeper gradient would be expected on the upgradient side of a well field superimposed on regional gradient. The regional horizontal gradient in the spring valley area was estimated from water levels collected in piezometers SR1-3 and PTPN-26 on January 9, 1992. The calculated gradient is 65 ft/mile to the east.

4) The area ~~west~~ east of the well field around SVWC-65 shows another small cone of depression and ground water divide. This cone of depression is caused by pumping of production well SVWC-65. PTPN-23A is located relatively close to production well SVWC-65, and has a downward vertical gradient. The downward vertical gradient is caused by pumping from production well 65. Hydrographs for PTPN-23A indicate that water levels fluctuated with the pumping cycle of SVWC-65 (see pumping overlay in Appendix I and the hydrograph for PTPN-23A in Appendix G).

The area of high water levels and upward gradients (area 2) coincides with an area where ground water within the Brunswick Formation once discharged upward into Pascack Brook and created natural springs. This situation is illustrated schematically on Figures 4 and 4A. During this historical period, upward vertical gradients occurred along the Pascack-Brook valley (Figure 4). These upward vertical gradients are still present today (refer to vertical gradients for PTPN-21 and PTPN-25 in Table 7) but discharge to the surface is not likely occurring due to the drawdown of water levels caused by the well field and possibly other local and regional wells (Figure 4A). The superposition of the SVWF pumping on this historical discharge area has modified ground water flow, but the upward vertical gradients still create a "potentiometric ridge" (Figure 4A). The ridge depicted in Figures 4 and 4A represents a potentiometric surface mapped on a horizontal plane.

The presence of the potentiometric ridge is an important factor in delineation of the SVWF capture zone. This area results in the diversion of easterly-flowing ground water from Cosco/CPC to a more south-southeasterly direction.

4.2 ANALYSIS OF ANISOTROPY AND AQUIFER PARAMETERS

The value and direction of anisotropy around the well field were evaluated in order to determine if ground water flow directions could be evaluated directly from the steady-state potentiometric surface maps. Anisotropy was evaluated using the following five methods:

- Analysis of water-level recoveries during the recovery phase (Section 4.2.1);
- Analysis of lag times following shut-off of the SVWF wells (Section 4.2.2);
- Analysis of the steady-state distribution of potentiometric heads around the SVWF (Section 4.2.3);
- Analysis of the direction and magnitude of anisotropy using quantitative methods (Aniaqx Software) for anisotropic assumptions (Section 4.2.4); and,
- Analysis of aquifer parameters using quantitative methods for isotropic conditions (Isoaqx Software) and comparison of these values to the same parameters calculated using anisotropic assumptions (Section 4.2.4).

Each of these methods is reviewed in the following subsections.

Generally accepted hydraulic analysis methods were used to calculate aquifer parameters and to quantify the degree and direction of anisotropy. These analyses indicate that the Brunswick aquifer is generally isotropic at the scale of this investigation. The significance of this finding was previously discussed in Section 4.1.1. This section will focus on the methods used to evaluate anisotropy.

4.2.1 Analysis of Anisotropy Using Water-Level Recovery Data

The response of water levels in piezometers surrounding a pumping well or well field can be used to evaluate the degree of anisotropy in the pumped aquifer. Piezometers at generally equal distances from the pumped well will drawdown or recover approximately the same amount under isotropic conditions. Under anisotropic conditions greater responses will be observed in piezometers located near or along the principal direction of anisotropy (where greater transmissivity exists). Lines of equal drawdown or recovery (Figure 9) around a pumped well in a generally isotropic aquifer will form concentric circles. Lines of equal drawdown of recovery in a significantly anisotropic aquifer will form ellipses elongated with the principal transmissive zone.

Contour maps of total ground water recoveries (Jan 13 to Jan 18) and recovery for first 1500 minutes from the start of the recovery test were plotted (Figs 9 & 10). These values represented the maximum rise or recovery of water levels measured during each time period. Water levels at 0900 hrs on January 13, 1992 were subtracted from water levels at 0900 hrs on January 18, 1992 to obtain total recoveries (Table 8). Recoveries were calculated for piezometers screened below an elevation of 300 ft; in what is considered a more transmissive zone. This is evident from larger recoveries and drawdowns measured in this zone as compared to recoveries in piezometers completed at a higher elevation.

The contours of equal recovery of water levels for the total length of the recovery test (Figure 9) indicate a generally concentric pattern around the well field. In addition, the contours of equal recovery for the first 1500 minutes of the recovery test also indicate a generally concentric pattern. The generally, concentric pattern indicates that recoveries were not preferentially greater in any one direction from the well field.

The results of the recovery analysis support other assessments and indicate that the aquifer is generally isotropic. The ratio of recoveries ranged from 1:1 to 2:1, when comparing recoveries in directions south-southeast to those west-southwest. This may suggest that the transmissivities are slightly larger along the trend south-southeast than west-southwest (if other hydraulic factors are not influencing these recoveries). The slight degree of anisotropy observed in these recovery data indicate that the primary transmissivity trend is at an obtuse angle to the line between Cosco/CPC and the well field. Consequently, lower transmissivities would be expected along the south-southwest trend than those along the south-southeast trend.

Only areas south and southeast of the well field indicated slightly larger recoveries in comparison to other areas. The presence of the potentiometric ridge and the operation of well SVWC-65 may have influenced the recovery of water levels in nearby piezometers. Consequently, the greater degree of recovery in the south-southeast direction may not reflect a preferential flow zone or principal permeability direction, but rather the effects from other hydraulic influences in the area.

4.2.2 Analysis of Anisotropy using Lag Times

An additional analysis of water level responses was performed to assess anisotropy. This included an evaluation of the "lag time" between pump shut-off and water level rise. The faster an observation well responds to pumping start-up or shut-down, the higher the transmissivity in that direction. Plots of response time (lag time) provide another tool in evaluating the presence of higher transmissivity zones or anisotropy. The period of time required for ground water levels to respond (rise or fall) in observation wells from the time of pump-on or pump-off in production wells is called lag time. Lag times were estimated for the recovery period using a minimum rise of 0.25 ft of water level as the marker from the start of the recovery phase (fig 11). Lag times for observation wells located equidistant in x and y-direction from the pumping well can provide a qualitative measurement of to the degree of anisotropy.

A comparison of lag times between PTPN-19 and SRI-2, which are approximately equidistant and at right angles from the well field, shows that the water levels in SRI-2 responded 1.5 times faster than those in PTPN-19. A similar comparison between PTPN-23 and SRI-4 indicates that water levels south of the well field responded 2.5 times faster than those east of the pumping field (PTPN-23). These lag times suggest that there is a difference in the rate of transmissivity between piezometers located west-southwest and east-southeast of the well field. The differences in lag times in different directions may be due to anisotropy; (with a major axis located along a south-southeast direction) or may be due to the presence of other hydraulic influences (eg SVWC 65).

4.2.3 Analysis of Anisotropy using the Steady-State Distribution of Potentiometric Head at the SVWF

As discussed in Section 4.1.3, the area immediately surrounding the well field has concentric equipotential lines. This area is within the cone of depression and capture zone of the SVWF. The roughly circular shapes of the contours provides qualitative evidence that the aquifer is isotropic.

4.2.4 Analyses of Anisotropy and Aquifer Parameters Using Quantitative Methods

Aquifer parameters were evaluated to determine the general properties of the Brunswick Formation aquifer. These parameters also provided two of the five methods for evaluating anisotropy. Aquifer parameters were evaluated using analytical methods incorporated in software "Isoaqx" and "Aniaqx" (Hydralogic, 1989). These programs employ methods described by Hantush (Hantush, 1966), Theis (Theis, 1935), and Grimstead (Grimstead, 1989) but also include other analytical procedures. Aniaqx calculates aquifer parameters regardless whether the aquifer is isotropic or anisotropic. If the aquifer is anisotropic, the program also calculates the degree and direction of anisotropy. Isoaqx calculates aquifer parameters assuming that the aquifer is isotropic.

Results from the Aniaqx program supported the generally isotropic theory of ground water flow within the Brunswick Formation aquifer discussed previously. In addition, aquifer parameters calculated using Aniaqx agree (within less than a half order of magnitude) with those calculated using Isoaqx and assuming isotropic conditions (Section 4.2.3). This agreement indicates that anisotropy is not a significant factor.

The following paragraphs review some of the methods and considerations used for both the Aniaqx and Isoaqx evaluations of the aquifer parameters. Each analytical method will then be reviewed separately.

Anisotropic analyses used data collected from the recovery phase of the pump test when transient flow conditions existed. Transient (unsteady state) flow occurs when the pumped water comes from the reduction in storage within the aquifer. This condition was satisfied at the spring valley well field site during the drawdown and recovery phases

of the aquifer test program. The steady state condition at the well field consisted of the normal pumping of the wells. This was discussed previously in Section 3.0. The analysis of this shutoff or recovery phase was performed by treating data as those occurring in a standard pump-drawdown phase of an aquifer test. The method of images was used to superimpose an equivalent recharge well on the recovering well field and then analyze the recovery of water levels as drawdown, and not as residual drawdown.

Both the Aniaqx and Isoaqx programs required data regarding the distance between the pumping well and the monitoring points. Since the SVWF consists of more than one well, it was modeled as a single well pumping at an average pumping rate of the four combined production wells (SVWC-1A, SVWC-04, SVWC-06, and SVWC-17). The average rate for each of the production wells was determined from the 5 day pre-monitoring period. The averages were combined to develop a total average flow rate from the well field. Appendix O presents these calculations. A total average flow of 1485 gallons per minute (gpm) was calculated.

The well field was modeled as a single well because the observation points are located far from the well field. Water-level response at these distances are related to the net discharge from all four wells. Consequently, the well field was modeled as a single discharge point. The center of pumping for this discharge point was calculated using a center of moments method. These calculations are presented in Appendix N. The center of pumping was estimated to be near SVWC-02.

The evaluation of vertical leakage from Pascack Brook and the overlying alluvium and glacial deposits could not be completed using either Isoaqx or Aniaqx from the existing database. The complicating factors affecting the leakage analysis were:

- The recovery phase did not last long enough to allow for typical late time leakage (or boundary) conditions to be quantified;
- Rain events prior to, and during, the recovery phase interfered with the interpretation of water level responses in the bedrock piezometers, alluvial wells and stream gaging locations; and

- Barometric-pressure fluctuations may have also interfered with the analysis of leakage at late times.

Aniaqx Analysis of Aquifer Parameters and Anisotropy

Analysis using the Hantush, 1966 and Grimstead, 1989 (Aniaqx program) method can be applied under the following general assumptions regarding hydrologic conditions above:

1) The aquifer is homogenous, anisotropic, and of uniform thickness over the area influenced by the test;

2) Prior to pumping, the piezometric surface is generally horizontal over the area influenced by the test;

3) The aquifer is pumped at a constant discharge rate;

4) The well penetrates the entire thickness of the aquifer and is finite in diameter;

5) The observation wells are outside of partial penetration effects; and

6) The aquifer is confined.

These hydrologic conditions were established for this analysis based on the following supporting information:

1) Homogeneous conditions were assumed based upon geologic data, and anisotropic conditions were assumed to exist in order to perform the analyses;

2) Although the potentiometric surface is not horizontal, (due to the regional gradient) the relative change in potentiometric head in relation to aquifer thickness is small and therefore hydraulic effects are assumed to be negligible (Hantush, 1964);

3) The rate of pumping for all four active production wells was assumed to be constant based upon the pre-monitoring data (Appendix O);

4) Production wells generally penetrate the upper 500 ft of the Brunswick formation and the piezometers are only partially completed in this unit. However, most of the piezometers are outside the effects of partial penetration because they are located at distances greater than 1.5 to 2.0 times the saturated thickness of the aquifer (Hantush, 1962). In addition, although SVWF consists of multiple, large-diameter wells. The center of their pumping (Appendix N) and the total flow rate (for all wells) can be used to model the discharge from the aquifer. Modeling of the well field as a single well is possible due to the large distances between observation points and the well field.

5) Early time data during the recovery phase best represent confined, elastic response; similar to that solved by the Theis (Theis, 1935). Consequently, Theis methods can be applied to early time data. This portion of the test data is also less affected by leakage, recharge events, barometric fluctuations and other hydraulic influences identified during the test.

Aniaqx calculates aquifer parameters with assumptions that either the aquifer is horizontally isotropic or anisotropic. Aniaqx uses Hantush's (Hantush, 1966) method as modified by Grimstead (Grimstead, 1989) and described by Theis (Theis, 1935). This program requires drawdown data from a group of minimum of three piezometers, and can calculate simultaneously drawdown data for a maximum of nine piezometers. Piezometer combinations ranging from a group of three to six piezometers were analyzed. Piezometers located upgradient and downgradient of the well field (PTPN-22 and PTPN-19) were used in combinations to reduce the effect of inclined potentiometric surface (regional gradient). The simultaneous solving process of Aniaqx should average-out the affects of the regional gradient when observation points are located at the extremes of the sloping surface (upgradient and downgradient).

Aniaqx calculates transmissivities, storativities, and the angle that represents a major and minor axes of transmissivity or hydraulic conductivity. The major axis of transmissivity represents the angle from a reference point (PTPN-22) where the primary (higher) transmissivity direction occurs, and the minor axis is an angle perpendicular to the major and represents a lower transmissivity. The results from the analysis using Aniaqx are presented in Table 10 and Appendix M. The ratio of transmissivity or hydraulic conductivity along the major to minor axes suggests the ratio of anisotropy.

Piezometer locations used for the anisotropic analyses were: PTPN-8D, PTPN-22D, PTPN-10, PTPN-19D, PTPN-25D and SRI-2D.

Recovery phase data (drawdown) from piezometers within the more transmissive zone (below 300 ft msl) were analyzed except for PTPN-20 and PTPN-23A and PTPN-24. PTPN-20 is located approximately 500 ft from the production well SVWC-17, and is approximately 1000 ft from calculated center of pumpage of the well field, is considered to be within the partial penetration effects. The saturated thickness of aquifer is considered 500 ft, based upon the maximum depths of the production wells. Effects of a partially penetrating well is negligible if piezometers are located 750 ft to 1000 ft (1.5 to 2 times) away from the production wells (Hantush, 1961).

Piezometer PTPN-23A was not incorporated into aquifer test analysis because it is influenced by pumping at SVWC-65. In addition, PTPN-24 was not used because it was also suspected to have been slightly influenced by SVWC-65.

Recovery data after 1500 minutes from the start of the recovery phase was not used, because on January 14, 1992 heavy precipitation and a very low barometric pressure was observed. Also, water levels in all the piezometers did not reach the equilibrium by the end of the recovery phase.

Initial analyses using the Aniaqx program involved multiple piezometer groupings at a variety of assumed anisotropic ratios. These ratios were varied from 10:1 to 2:1 during the use of the program. An anisotropic ratio of 2:1 was eventually found to provide the best Theis-Curve match and the least error during the analyses. Consequently, these results are presented in Table 10 and Appendix M.

The calculated transmissivities, assuming a 2:1 ratio for different groups of piezometer combinations, indicates that the transmissivity values along the angle of principal axis range from 5000 ft^2/day to 6000 ft^2/day (10 to 12 ft/day). These values are similar to the geometric average of transmissivity calculated using isotropic or 1:1 ratios. Transmissivity values along the minor axis ranges from 2500 ft^2/day to 3000 ft^2/day (5 to 6 ft/day) (Table 11).

The angle of the major axis ranges between 40 to 80 degrees from a line located between PTPN-22 and the center of pumping. This direction corresponds to the trend of Pascack Brook. This trend represents an approximate location of a slightly more transmissive zone. However, other analyses (Section 4.2.1 and Section 4.2.3) tend to support more isotropic conditions exist than were calculated here.

Isoaqx Analysis of Aquifer Parameters Using Quantitative Methods for Isotropic Conditions

The following sections present the approach and results of analyses of aquifer parameters assuming isotropic conditions (Isoaqx). This approach provided a check to anisotropic calculation methods and also provided information on storativity and the degree of confinement of the aquifer. The information calculated using isotropic methods assists in establishing hydrologic conditions presented earlier (Section 4.1).

Isoaqx calculates aquifer parameters transmissivity and storage coefficient (storativity) under the assumptions that the aquifer is horizontally isotropic, homogenous, of uniform thickness, confined, is fully penetrated by the pumping well, and pump at a constant discharge rate. This program calculates parameters for each individual observation response.

Recovery phase data (drawdown) from all piezometers were analyzed except for PTPN-20, PTPN-23A and PTPN-24. PTPN-20 is located approximately 500 ft from production well SVWC-17, and is approximately 1000 ft from the calculated center (Section 4.2.2) of pumpage of the well field. Therefore it is considered to be within the region affected by partial penetration effects. The saturated thickness of aquifer is considered 500 ft (one of the production wells is 500 ft deep). The effect of a partially-penetrating well is negligible if the piezometers are located 750 ft to 1000 ft (1.5 to 2 times) away from the production wells (Hantush, 1961). Analytical results using Isoaqx are presented in Table 11. Piezometer PTPN-23A was not incorporated into the aquifer test analysis because it is influenced by pumping at SVWC-65. In addition, PTPN-24 was not used because it was also suspected to have been slightly influenced by SVWC-65.

The Theis (1935) method of analysis is applicable to wells pumping from confined aquifers, in unsteady state conditions. Transient (unsteady state) flow occurs when the pumped water comes from the reduction in storage within the aquifer. This condition was satisfied at the SVWF site during the drawdown and recovery phases of the aquifer test program. This was discussed previously in Section 4.1. Consequently, transient conditions were created only after shut-off of the pumps. The analysis of this shut-off or recovery phase was performed by treating the data as those occurring in a standard pump-drawdown phase of an aquifer test. The method of images was used to superimpose an equivalent recharge well on the well field and to analyze the recovery of water tables as drawdown, and not as residual drawdown.

Analysis using the Theis method can be applied under the same general assumptions as presented in Section 4.2.2 for anisotropic analyses with the exception that the aquifer is isotropic and not anisotropic.

This assumptions was made based upon recovery responses, general configuration of drawdown cone of depression, and results of quantitative anisotropic analyses.

The Theis analyses were performed using a computer enhanced method (Isoaqx, 1991). This program was operated assuming confined conditions and using the Theis method. Results of Isoaqx calculations are presented in Appendix L and summarized in Table 11.

The calculated transmissivities at individual piezometer locations ranged from 2500 ft^2/day to 8500 ft^2/day (5 to 17 ft/day). The geometric average transmissivity of all results is 5000 ft^2/day (10 ft/day) (Table 11). This is very comparable to the range of transmissivity calculated assuming a 2 to 1 anisotropy ratio.

The degree of anisotropy determined from the five methods described above was small and can be considered insignificant on the scale of interest. The analyses indicate a range of anisotropy from 2:1 to 1:1 (or isotropic conditions). The aquifer parameters calculated using anisotropic and isotropic methods were similar; suggesting that the bedrock system can be characterized as isotropic. Water level recovery data also support the conclusion that the bedrock aquifer responds under generally isotropic conditions.

4.3 SUMMARY AND CONCLUSIONS

Analysis of aquifer test data established that Cosco/CPC are outside the capture zone of the well field. Generally-accepted hydrologic methods were used to analyze the data collected during each phase of the pump tests. The steady-state methods used to evaluate the capture zone required the following conditions in the Brunswick Formation aquifer:

- the presence of a regional gradient in the area of the well field;
- aquifer characteristics which are isotropic and homogeneous at the scale of the study area;
- presence of confined conditions; and
- presence of steady-state water-level conditions in the pre-monitoring phase.

Data collected during the pump test program confirmed these conditions. In addition, the data collected during the pump test are consistent with other sources of geologic and hydrologic information. Specifically, the regional gradient established during the pump test (65 ft per mile) is consistent with that measured from regional potentiometric map (50 to 90 ft per mile). The determination of generally-isotropic conditions from pump test response data is consistent with geologic information collected from the bedrock cores and outcrops. The presence of the potentiometric ridge near Pascack Brook is consistent with the locations of historical springs and is consistent with the upward gradients measured at several piezometers in this area. Finally, the pumping rates and drawdowns measured at the SVWF during the pump test were similar to those measured previously at the well field and are therefore considered representative of historical conditions.

Other interpretations of the site data were considered in evaluating the hydrogeologic conditions, however, these interpretations were not as consistent with the regional and historical facts. The interpretations presented in this report fit very well with the hydrologic and geologic characteristics of the area.

The determination of the capture zone for the SVWF was based upon the following analytical methods:

- evaluation of steady state potentiometric surface maps and hydrogeologic cross-sections to determine horizontal and vertical hydraulic gradients (Section 4.1 and Figures 6, 7, & 8);
- evaluation of steady-state conditions using pre-monitoring water level data, historical water level data, and pumping data for the SVWF (Section 3.0 and Appendices F and J);
- evaluation of regional gradient using regional water level data and background water levels at the site (Section 4.1.1 and Figure 1);
- evaluation of the potentiometric ridge by constructing hydrogeologic cross sections, schematic flow nets and potentiometric surface maps, and by reviewing historical data pertaining to the former springs along Pascack Brook (Section 4.1.2 and Figures 6, 7 & 8);
- evaluation of anisotropy by comparing aquifer parameters calculated assuming anisotropy to parameters calculated assuming isotropic conditions. These analytical methods were used to quantify the degree and direction of anisotropy (Section 4.2.4 and Appendix M) ;
- evaluation of anisotropy in the bedrock aquifer using lag times (Section 4.2.2 and Figure 11);
- evaluation of anisotropy using the steady-state distribution of potentiometric heads (Section 4.2.3 and Figures 6, 7 and 8);
- evaluation of anisotropy using water levels measured during the recovery phase of the pump test (Section 4.2.1 and Figures 9 & 10); and
- evaluation of homogeneity using geologic data collected from the PTPN borings, geologic data collected from outcrop inspections and porosity and permeability data obtained from cores (Section 1.3.3 and Appendix E).

The interpretation of the hydrogeologic analyses presented in this report have resulted in three primary conclusions regarding ground water flow near the SVWF:

1) The capture zone of the well field extends approximately 2,500 feet toward Cosco/CPC, but does not reach the facilities. Consequently, ground water originating from the facilities does not flow to, and is not captured by, the well field. Information presented in this report supports previous conclusions that ground water below Cosco/CPC flows to the east. In addition, the report established the presence of a potentiometric ridge which diverts ground water flowing east to a southeast-south direction away from the well field.

2) The degree of anisotropy quantified by hydraulic analyses and evaluated based on recovery data is small and can be considered insignificant on the scale of interest. The analyses indicate a range of anisotropy from 2:1 to 1:1 (or isotropic conditions). The aquifer parameters calculated using anisotropic and isotropic methods were similar; suggesting that the bedrock system can be characterized as isotropic. Water level recovery data also support the conclusion that the bedrock aquifer responds under generally isotropic conditions.

   The small degree of anisotropy which was calculated has the primary axis of transmissivity along the valley of Pascack Brook (trending northwest to southeast). The primary axis, which represents the direction of highest transmissivity, is not aligned between the well field and Cosco/CPC, but runs at an obtuse angle to this line. Consequently, lower transmissivity values would be expected in the direction between the well field and the Cosco/CPC. In other words, the relative location of the capture zone, given the small degree of calculated anisotropy, does not affect Cosco/CPC.

   Aquifer parameters calculated using methods assuming isotropic and anisotropic conditions indicated a range of transmissivities between 2500 to 8000 ft^2/day and an average of about 5000 ft^2/day. The range of storage coefficients for the bedrock ranged from 8.4×10^{-4} to 1.1×10^{-3}.

3) The bedrock was found to be generally homogeneous on the scale of the site investigation. Geologic boring logs from the piezometer borings indicate that sandstone is the dominant lithology. Geologic conditions observed in the cores collected from PTPNB 26 and cores collected during the SVWF RI also indicate that the bedrock is dominantly sandstone. In addition, laboratory permeability testing of the core resulted in values of permeability for the more porous zones which were comparable to those

calculated on a site wide basis during the aquifer test. The more porous zones are a result of leaching of the matrix cement. Leached zones and joints are considered to be the controlling factors in the flow of ground water within the bedrock. The similarity of hydraulic conductivity calculated during the aquifer test and those measured in the cores suggest that permeable zones are distributed in a generally homogeneous manner.

The above conclusions are supported by information presented in the report and are considered to be the best scientific interpretation of the pump test data and the definition of the capture zone.

5.0
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TABLE 1
SUMMARY OF MONITORING ASSIGNMENTS AND FREQUENCIES FOR AQUIFER TEST PROGRAM

Well ID Number	Primary Responsibility	Pre-test Monitoring Frequency	Recovery Test Frequency		Drawdown Test Frequency	
			24-Hrs Following Shut-down	Remaining 4-days	24-Hrs Following Shut-down	Remaining 4-days
COSCO-CHURCH	WCC	8/day	8/day	8/day	8/day	8/day
MW-1	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-10	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-10P	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-11	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-12	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-13D	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-13S	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-15	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-15P	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-16	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
PTPN22D	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN22S	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN23D	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN23S	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN24D	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN24S	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN25D	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN25S	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN26D	WCC	N/A	N/A	N/A	N/A	1/day
PTPN26S	WCC	N/A	N/A	N/A	N/A	1/day
SRI-1-D	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-1-S	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-2-D	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-2-S	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-3-D	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-3-S	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-4-D	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-4-S	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day

Notes: 1/2 hour = approximently 30 minutes between readings.
Rapid = readings taken more frequently than twice per hour.

TABLE 1
SUMMARY OF MONITORING ASSIGNMENTS AND FREQUENCIES FOR AQUIFER TEST PROGRAM
(Continued)

Well ID Number	Primary Responsibility	Pre-test Monitoring Frequency	Recovery Test Frequency		Drawdown Test Frequency	
			24-Hrs Following Shut-down	Remaining 4-days	24-Hrs Following Shut-down	Remaining 4-days
COSCO-CHURCH	WCC	8/day	8/day	8/day	8/day	8/day
MW-1	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-10	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-10P	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-11	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-12	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-13D	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-13S	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-15	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-15P	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
MW-16	WCC	8/day	every 1 hour	8/day	every 1 hour	8/day
PTPN22D	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN22S	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN23D	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN23S	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN24D	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN24S	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN25D	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN25S	WCC	1/2 hour	Rapid/ 1/2 hour	1/2 hour	Rapid/ 1/2 hour	1/2 hour
PTPN26D	WCC	N/A	N/A	N/A	N/A	1/day
PTPN26S	WCC	N/A	N/A	N/A	N/A	1/day
SRI-1-D	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-1-S	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-2-D	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-2-S	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-3-D	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-3-S	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-4-D	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day
SRI-4-S	WCC	8/day	every 1/2 hour	8/day	every 1/2 hour	8/day

Notes: 1/2 hour = approximently 30 minutes between readings.
Rapid = readings taken more frequently than twice per hour.

TABLE 2

NYDEC Approved Field Modifications to the Drilling Methods Contained in the Work Plan

Work Plan Section	Approved Field Modification
Drilling Methodologies	The first 20 ft of glacial drift in boring 25 was drilled with an ODEX air rotary system. The ODEX system did not perform well and the drilling was continued using mud rotary.
Drilling Methodologies	Biodegradable drilling foam was used to help lift the drill cuttings in PTPN 23A and PTPN 25.
Coring Methodology	HQ wireline core barrel used instead of NX in order to produce a larger hole and higher core recoveries. HQ core diameter was 2.5 inches. Hole diameter was 4 inches.
Formation Sampling	No field modifications.
Equipment Decontamination	No field modifications.
Disposal of Generated Waste Material	The drill cuttings and drilling mud have yet to be disposed of. These materials will be sampled and analyzed in the spring after they have thawed. The drilling wastes will then be disposed of according to the work plan.
Appendix B-2	No field modifications.
Health and Safety Procedures	No field modifications.

TABLE 3

NYDEC Approved Field Modifications to the Piezometer Installation Methods Contained in the Work Plan

Work Plan Section	Approved Field Modification
Piezometer Installation	WCC used bentonite pellets instead of grout to backfill Piezometers PTPN 22, PTPN 24 and PTPN 26 to the shallow completion zones.
Piezometer Installation	PTPN 26 was installed in a 4-inch borehole so 1/2-inch PVC screen and riser was used instead on 1-inch to avoid bridging problems.
Appendix B-1	The actual screen depths did not correspond to the planned depths because a thick deposit of glacial drift east of Pascack Brook resulted in deeper screen depths. The actual screen settings are shown on the piezometer installation sheets (Appendix C) and on Table 4.
Appendix B-2	A water jet was not used to wash the screen intervals immediately after backfilling with grout to the shallow screen zone in order to avoid disturbing the grout.

TABLE 4
SUMMARY OF MONITORING POINT SPECIFICATIONS FROM AQUIFER TEST PROGRAM

Well ID Number	Ground Surface Elevation (ft MSL)	Measuring Point Elevation (ft msl)	Screened Interval Top (ft bgs)	Screened Interval Bottom (ft bgs)	Screened Interval Top (ft msl)	Screened Interval Bottom (ft msl)
ALLEN WELL *	460.00	460.00				
COSCO-CHURCH *	463.00	463.00	40.0	227.0	423.0	236.0
MW-1	468.70	468.20	16.1	21.6	452.6	447.1
MW-3	464.50	466.52	4.0	15.1	460.5	449.4
MW-7B *	455.00	454.07	42.0	96.0	413.0	359.0
MW-7D	454.30	453.81	30.4	35.9	423.9	418.4
MW-7P	453.72	453.72	6.0	10.0	447.7	443.7
MW-7S	454.50	454.08	20.2	25.7	434.3	428.8
MW-8S	449.90	452.04	10.8	21.9	439.1	428.0
MW-9S	466.20	465.69	12.1	17.6	454.1	448.6
MW-10	448.40	447.44	7.4	12.9	441.0	435.5
MW-10P	448.40	447.59	17.0	21.0	431.4	427.4
MW-11	436.60	439.05	24.6	37.7	412.0	398.9
MW-12	458.20	457.57	14.0	19.5	444.2	438.7
MW-13D	447.07	449.15	65.5	76.6	381.6	370.5
MW-13S	447.70	449.99	12.9	24.0	434.8	423.7
MW-15	467.20	466.44	32.4	37.9	434.8	429.3
MW-15P	467.20	465.93	23.3	28.3	443.9	438.9
MW-16	465.30	467.30	7.0	12.5	458.3	452.8
MW-18	464.60	467.25	10.9	22.0	453.7	442.6
MW-18P	464.60	467.30	31.0	36.0	433.6	428.6
PTPN8D	450.26	449.75	171.0	176.0	279.3	274.3
PTPN8S	450.26	449.61	130.0	135.0	320.3	315.3
PTPN9D	466.19	465.52	175.0	180.0	291.2	286.2
PTPN9S	466.19	465.61	126.0	131.0	340.2	335.2
PTNP17D	463.66	465.43	202.0	207.0	261.7	256.7
PTNP17I	463.66	465.31	163.0	168.0	300.7	295.7
PTNP17S	463.66	465.38	80.0	85.0	383.7	378.7
PTPN19D	465.19	464.47	185.0	190.0	280.2	275.2
PTPN19I	465.19	464.68	122.0	127.0	343.2	338.2
PTPN19S	465.19	464.90	75.0	80.0	390.2	385.2
PTPN20D	461.97	461.13	240.0	245.0	222.0	217.0
PTPN20I	461.97	461.12	183.0	188.0	279.0	274.0
PTPN20S	461.97	461.05	95.0	100.0	367.0	362.0
PTPN21D	433.94	433.09	240.0	245.0	193.9	188.9
PTPN21I	433.94	433.20	157.0	162.0	276.9	271.9
PTPN21S	433.94	433.27	91.0	96.0	342.9	337.9
PTPN22D	525.35	524.67	264.2	269.2	261.1	256.1
PTPN22S	525.35	524.65	234.8	239.8	290.6	285.6
PTPN23D	401.45	400.78	227.0	232.0	174.5	169.5
PTPN23S	401.45	400.79	140.0	145.0	261.5	256.5
PTPN24D	491.21	490.51	237.0	242.0	254.2	249.2

TABLE 4
SUMMARY OF MONITORING POINT SPECIFICATIONS FROM AQUIFER TEST PROGRAM
(Continued)

Well ID Number	Ground Surface Elevation (ft MSL)	Measuring Point Elevation (ft msl)	Screened Interval Top (ft bgs)	Screened Interval Bottom (ft bgs)	Screened Interval Top (ft msl)	Screened Interval Bottom (ft msl)
PTPN24S	491.21	490.66	190.0	195.0	301.2	296.2
PTPN25D	436.81	435.96	189.0	194.0	247.8	242.8
PTPN25S	436.81	435.91	140.0	145.0	296.8	291.8
PTPN26D	356.76	356.27	113.0	118.0	243.8	238.8
PTPN26S	356.76	356.31	76.5	81.5	280.3	275.3
SRI-1-D	465.28	463.73	191.0	193.0	274.3	272.3
SRI-1-S	465.28	464.54	91.0	93.0	374.3	372.3
SRI-2-D	457.84	457.14	191.0	193.0	266.8	264.8
SRI-2-S	457.84	457.21	91.0	93.0	366.8	364.8
SRI-3-D	467.02	466.29	191.0	193.0	276.0	274.0
SRI-3-S	467.02	466.20	91.0	93.0	376.0	374.0
SRI-4-D	463.01	461.39	191.0	193.0	272.0	270.0
SRI-4-S	463.01	461.80	91.0	93.0	372.0	370.0
SVWC 1	455.10	455.00	50.0	500.0	405.1	-44.9
SVWC 2	447.90	447.00	50.0	500.0	397.9	-52.1
SVWC 3	445.40	445.00	70.0	500.0	375.4	-54.6
SVWC 4	452.30	452.00	55.0	256.0	397.3	196.3
SVWC 6	442.60	442.00	121.0	252.0	321.6	190.6
SVWC 17	447.30	447.00	77.0	305.0	370.3	142.3
SVWC 65	388.00	388.00	34.0	404.0	354.0	-16.0

* approximate elevations

TABLE 5

SUMMARY OF LABORATORY PERMEABLITY TESTS PERFORMED ON ROCK CORE TEST SPECIMENS COSCO PROJECT

BORING NO.	SAMPLE NO.	DEPTH	WATER CONTENTS	TOTAL UNIT WGTS	DRY UNIT WGTS.	SPECIFIC GRAVITY	POROSITY	STRESS	TIME OF CONSOL./	PERMEANT/	COEFFICIENT OF PERM. K,	REMARKS
		(FT)	INITIAL/ POST CONSOL (%)	INITIAL/ POST CONSOL (PCF)	INITIAL/ POST CONSOL (PCF)		INITIAL/ POST CONSOL	EFFECTIVE/ BACK PRESSURE (psi)	VOLUMETRIC STRAIN DAYS/(%)	INITIAL GRADIENT	(@ 20 C) cm/sec	
PTPN26	3T	52.20	1.5	153.3	151.1	2.71	0.105	5.0	1	WATER	6.7E-6	
			2.5	155.7	151.9		0.101	100.0	0.51	20		
PTPN26	4G	59.45	2.2	151.5	148.3	2.70	0.119	5.0	1	WATER	8.2E-6	
			3.1	153.2	148.6		0.118	100.0	0.18	20		
PTPN26	6C	74.60	1.3	160.9	158.9	2.70	0.056	5.0	1	WATER	2.3E-6	
			2.0	162.5	159.4		0.053	100.0	0.34	23		
PTPN26	6F	75.95	5.5	138.5	131.2	2.68	0.213	5.0	1	WATER	3.5E-4	
			8.7	144.0	132.5		0.206	100.0	1.00	3		
PTPN26	7E	83.35	5.5	133.9	127.0	2.67	0.236	5.0	2	WATER	1.4E-3	
			8.4	140.1	129.2		0.223	100.0	1.74	1		

FILE: 89C3517.XLS PROJECT NO.: 89C3517-16 PREPARED BY: PD REVIEWED BY: PD DATE: 3/3/92

TABLE 6
SUMMARY OF SURVEY DATA
FROM AQUIFER TEST PROGRAM

Well ID Number	Ground Surface Elevation (ft MSL)	Measuring Point Elevation (ft msl)	Location	
			Northing (deg–min–sec)	Easting (deg–min–sec)
PTPN8D	450.26	449.75	74–02–46.75	41–06–52.21
PTPN8S	450.26	449.61	74–02–46.75	41–06–52.21
PTPN9D	466.19	465.52	41–06–54.37	74–02–55.02
PTPN9S	466.19	465.61	41–06–54.37	74–02–55.02
PTNP17D	463.66	465.43	41–06–40.19	74–03–04.27
PTNP17I	463.66	465.31	41–06–40.19	74–03–04.27
PTNP17S	463.66	465.38	41–06–40.19	74–03–04.27
PTPN19D	465.19	464.47	41–07–02.52	74–03–08.28
PTPN19I	465.19	464.68	41–07–02.52	74–03–08.28
PTPN19S	465.19	464.90	41–07–02.52	74–03–08.28
PTPN20D	461.97	461.13	41–07–00.75	74–02–49.09
PTPN20I	461.97	461.12	41–07–00.75	74–02–49.09
PTPN20S	461.97	461.05	41–07–00.75	74–02–49.09
PTPN21D	433.94	433.09	41–06–49.39	74–02–36.02
PTPN21I	433.94	433.20	41–06–49.39	74–02–36.02
PTPN21S	433.94	433.27	41–06–49.39	74–02–36.02
PTPN22D	525.35	524.67	41–07–07.01	74–02–22.00
PTPN22S	525.35	524.65	41–07–07.01	74–02–22.00
PTPN23D	401.45	400.78	41–07–01.12	74–01–58.91
PTPN23S	401.45	400.79	41–07–01.12	74–01–58.91
PTPN24D	491.21	490.51	41–06–56.61	74–02–22.56
PTPN24S	491.21	490.66	41–06–56.61	74–02–22.56
PTPN25D	436.81	435.96	41–06–57.02	74–02–35.78
PTPN25S	436.81	435.91	41–06–57.02	74–02–35.78
PTPN26D	356.76	356.27	41–06–22.26	74–01–57.13
PTPN26S	356.76	356.31	41–06–22.26	74–01–57.13

89C3517

TABLE 7– SUMMARY OF POTENTIOMETRIC HEADS AND VERTICAL GRADIENTS

Location	Elevation of Top of PVC	09:00 1/08/92 Elevation of Water	Vertical Gradient	Potentiometric Head (ft msl) at 250 ft	300 ft	350 ft	00:00 1/9/92 Elevation of Water	Vertical Gradient	Potentiometric Head at (ft msl) 65 ft/msl	250 ft	300 ft	350 ft	400 ft
PTPN–8S	449.61	345.36	0.18	333.10	342.15	351.19	345.34	0.18	338.44	333.06	342.12	351.18	360.24
PTPN–8D	449.75	337.94					337.91						
PTPN–9S	465.61	374.50	0.04	371.12	373.05	374.97	374.48	0.03	373.05	371.99	373.41	374.83	376.25
PTPN–9D	465.52	372.61					373.09						
PTPN–17S	465.38	422.46	0.28	392.15	399.43	413.71	422.10	0.28	398.63	392.21	399.20	413.41	411.57
PTPN–17I	465.31	399.16	0.15				398.94	0.14					
PTPN–17D	465.43	393.48					393.49						
PTPN–19S	464.90	437.42	0.48	391.63	404.45	419.34	437.33	0.46	404.68	390.88	404.68	420.15	442.94
PTPN–19I	464.68	414.88	0.26				415.91	0.28					
PTPN–19D	464.47	398.73					398.52						
PTPN–20S	461.05	383.31	0.87	301.38	327.03	370.68	383.60	0.88	311.24	301.43	327.08	370.91	414.75
PTPN–20I	461.12	306.49	0.19				306.45	0.19					
PTPN–20D	461.13	295.49					295.64						
PTPN–21S	433.27	349.35	0.01	349.39	349.00	349.43	349.17	0.01	348.44	349.13	348.75	349.27	349.78
PTPN–21I	433.20	348.78	–0.02				348.49	–0.03					
PTPN–21D	433.09	350.85					350.67						
SRI 1S	464.54	410.36	0.15	392.04	399.47	406.90	410.62	0.14	399.88	393.39	400.38	407.37	414.36
SRI 1D	463.73	395.50					396.64						
SRI 2S	457.21	393.04	0.42	344.33	365.35	386.38	393.77	0.42	357.54	344.99	366.04	387.10	408.15
SRI 2D	457.14	350.99					351.66						
SRI 3S	466.20	412.55	0.20	387.35	397.43	407.51	413.39	0.20	396.33	388.40	398.39	408.39	418.38
SRI 3D	466.29	392.39					393.40						
SRI 4S	461.80	419.21	0.22	391.99	403.24	414.48	420.28	0.23	403.33	392.44	403.94	415.45	426.95
SRI 4D	461.37	396.72					397.27						
PTPN 22S	524.65	290.93	–0.07	293.44	290.13	286.83	290.93	–0.07	293.01	293.44	290.13	286.83	283.62
PTPN 22D	524.67	292.87					292.87						
PTPN 23S	400.79	341.59	0.26	339.26	352.31	365.37	341.59	0.26	335.27	339.26	352.31	365.37	378.04
PTPN 23D	400.78	318.87					318.87						
PTPN 24S	490.66	301.27	–0.04	303.40	301.21	299.02	301.27	–0.04	303.09	303.40	301.21	299.02	296.89
PTPN 24D	490.51	303.33					303.33						
PTPN 25S	435.91	297.52	–0.23	307.50	296.24	284.97	297.52	–0.23	303.14	307.50	296.24	284.97	274.05
PTPN 25D	435.96	308.56					308.56						
PTPN 26S *	356.31	339.32	0.02	339.44	340.43	341.41	340.96	0.02	340.07	340.41	341.39	342.38	343.36
PTPN 26D *	356.27	340.04					340.24						

* water level elevations derived from relationship to SRI–3

is this valid field data ?

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TABLE 7– SUMMARY OF POTENTIOMETRIC HEADS AND VERTICAL GRADIENTS (continued)

Location	09:00 1/13/92					09:00 1/18/92					09:00 1/23/92				
	Elevation of Water	Vertical Gradient	Potentiometric Head at (ft msl) 250 ft	300 ft	350 ft	Elevation of Water	Vertical Gradient	Potentiometric Head at (ft msl) 250 ft	300 ft	350 ft	Elevation of Water	Vertical Gradient	Potentiometric Head at (ft msl) 250 ft	300 ft	350 ft
PTPN–8S	345.51	0.18	333.15	342.27	351.39	365.26	0.09	359.13	363.65	368.18	356.49	0.16	345.76	353.68	361.59
PTPN–8D	338.03					361.55					350.00				
PTPN–9S	374.99	0.03	372.45	373.90	375.35	387.80	0.03	384.79	386.51	388.22	382.19	0.02	380.31	381.38	382.45
PTPN–9D	373.57					386.12					381.14				
PTPN–17S	423.01	0.29	392.47	398.98	413.90	422.72	0.20	400.70	406.29	416.47	423.12	0.23	397.99	404.28	415.96
PTPN–17I	398.74	0.13				406.08	0.11				404.05	0.13			
PTPN–17D	393.66					401.72					399.14				
PTPN–19S	437.27	0.44	390.71	404.88	420.55	438.90	0.39	400.29	411.58	424.36	438.01	0.40	393.38	407.52	422.78
PTPN–19I	416.42	0.28				420.77	0.23				419.02	0.28			
PTPN–19D	398.56					406.54					401.21				
PTPN–20S	384.44	0.89	301.36	327.33	371.62	392.56	0.43	351.64	365.12	386.40	390.55	0.83	316.12	337.25	378.59
PTPN–20I	306.49	0.19				355.10	0.13				317.79	0.06			
PTPN–20D	295.44					347.66					314.19				
PTPN–21S	348.85	0.01	349.21	348.61	348.91	364.67	0.00	364.71	364.54	364.70	359.19	0.00	359.48	359.06	359.22
PTPN–21I	348.46	–0.03				364.45	–0.01				358.97	–0.02			
PTPN–21D	351.01					365.34					360.70				
SRI 1S	410.70	0.14	393.50	400.48	407.45	415.92	0.12	401.45	407.32	413.19	414.23	0.12	399.08	405.22	411.37
SRI 1D	396.75					404.18					401.94				
SRI 2S	393.99	0.42	345.08	366.19	387.30	398.21	0.30	363.76	378.63	393.50	398.81	0.37	356.10	374.53	392.97
SRI 2D	351.77					368.47					361.94				
SRI 3S	413.27	0.20	388.55	398.44	408.32	415.07	0.18	393.15	401.92	410.68	415.70	0.18	393.15	402.17	411.19
SRI 3D	393.50					397.54					397.66				
SRI 4S	420.25	0.23	392.60	404.02	415.45	424.52	0.19	401.60	411.07	420.54	423.03	0.19	400.21	409.64	419.07
SRI 4D	397.40					405.58					404.17				
PTPN 22S	292.35	–0.11	296.35	291.09	285.82	316.85	0.04	315.51	317.27	319.03	304.38	–0.01	304.72	304.27	303.82
PTPN 22D	295.44					315.81					304.64				
PTPN 23S	342.80	0.19	341.15	350.40	359.66	343.38	0.18	341.77	350.79	359.81	343.66	0.19	341.97	351.41	360.86
PTPN 23D	326.69					327.68					327.22				
PTPN 24S	301.90	–0.05	304.11	301.84	299.56	320.21	0.02	319.46	320.23	320.99	311.68	–0.02	312.64	311.65	310.66
PTPN 24D	304.04					319.49					312.61				
PTPN 25S	298.81	–0.24	309.40	297.45	284.97	327.71	–0.17	335.09	326.76	284.97	310.69	–0.24	321.44	309.31	284.97
PTPN 25D	310.52					335.87					322.58				
PTPN 26S *	340.66	0.02	340.45	341.44	342.42	344.12	0.02	343.93	344.92	345.90	344.37	0.02	344.18	345.17	346.15
PTPN 26D *	339.98					343.43					343.69				

TABLE 8
SUMMARY OF GROUND WATER RESPONSE DATA FROM AQUIFER TEST PROGRAM

Well ID Number	Recoveries at 7200 Minutes (ft)	Recoveries at 1500 Minutes (ft)	Lag Time to Respond Pumps–off (minutes)
PTPN8D	23.60	9.95	12
PTPN8S	19.75	7.90	40
PTPN9D	12.70	5.09	63
PTPN9S	12.89	5.66	102
PTNP17D	8.29	3.43	7138
PTNP17I	4.79	1.07	159
PTNP17S	0.42	0.05	544
PTPN19D	8.03	4.16	712
PTPN19I	5.05	1.39	1112
PTPN19S	1.72	0.95	189
PTPN20D	52.27	32.38	444
PTPN20I	48.65	30.71	31
PTPN20S	8.88	2.72	6
PTPN21D	15.08	6.02	105
PTPN21I	16.52	6.98	95
PTPN21S	16.49	6.32	82
PTPN22D	25.86	13.61	35
PTPN22S	27.11	10.58	14
PTPN23D	1.60	0.57	1459
PTPN23S	0.62	0.32	1079
PTPN24D	16.02	6.66	383
PTPN24S	17.76	3.60	65
PTPN25D	29.24	15.93	49
PTPN25S	31.11	12.44	36
SRI–1–D	7.60	2.79	449
SRI–1–S	5.39	2.05	321
SRI–2–D	16.90	6.72	542
SRI–2–S	4.45	1.59	125
SRI–3–D	4.21	1.25	865
SRI–3–S	1.98	1.08	778
SRI–4–D	8.45	1.40	375
SRI–4–S	30.63*	30.63*	566

* result of the piezometer being flooded during rain event.

TABLE 9
SUMMARY OF SURFACE WATER DATA
FOR AQUIFER TEST PROGRAM

Date	Time	Elevation of Water Surface (ft msl) *				Flow (cfs)			
		Staff Gage 1	Staff Gage 2	Staff Gage 3	Staff Gage 4	West Tributary	North Tributary	Maple Street	Upstream** -Downstream
01/07/92	10:00	452.68	444.22	439.01	NR	0.75	0.49	NR	---
01/07/92	15:30	452.68	444.21	439.01	431.71	0.72	0.49	1.42	-0.21
01/09/92	07:15	452.65	444.19	438.99	431.62	0.59	0.35	1.01	-0.07
01/11/92	11:15	452.67	444.22	439.02	431.63	0.51	0.39	1.32	-0.42
01/12/92	NA	452.67	444.17	438.98	431.63	0.40	0.35	1.14	-0.39
01/13/92	08:30	452.65	444.18	438.99	431.63	0.55	0.31	1.12	-0.26
01/13/92	10:15	452.65	444.18	438.99	431.63	0.52	0.31	1.14	-0.31
01/13/92	11:15	452.65	444.18	438.99	431.63	0.41	0.33	1.23	-0.49
01/14/92	02:45	452.64	444.19	438.99	431.63	0.37	0.34	1.16	-0.45
01/14/92	14:30	453.07	444.57	439.35	432.25	15.56	0.79	10.97	5.38
01/16/92	06:45	452.70	444.23	439.02	431.71	0.81	0.49	1.32	-0.02
01/18/92	08:15	452.66	444.18	438.99	431.64	0.40	0.32	1.16	-0.44
01/19/92	02:15	452.64	NR	NR	431.63	0.48	0.27	1.12	-0.37
01/19/92	17:00	452.67	444.20	438.99	431.54	0.36	0.35	1.06	-0.35
01/20/92	NA	452.63	444.17	438.98	431.53	0.23	0.24	0.68	-0.21
01/21/92	12:15	452.63	444.16	438.97	431.57	0.74	0.20	0.71	0.23
01/22/92	NA	452.63	444.17	438.98	431.53	NR	0.24	0.68	---
01/23/92	NA	452.63	444.17	438.99	431.55	0.68	0.27	0.84	0.11

* see Figure 5 for staff gauge locations

** Upstream Flow = West Tributary Flow + North Tributary Flow

NA = not available

NR = no reading

TABLE 10
AQUIFER PARAMETERS
USING ANIAQX SOFTWARE

Well Combination	Transmissivity x-direction (ft2/day)	Transmissivity y-direction (ft2/day)	Storativity	Major Axis Relative to PTPN22 (degrees)	Error (ft)
Assumed Anisotropy of 2:1					
PTPN8D, PTPN22D, PTPN25D, SRI-2D	5973	2987	8.41E-04	44	0.51
PTPN8D, PTPN9D, PTPN25D, SRI-2D	4953	2477	1.17E-03	81	0.39
PTPN8D, PTPN9D, PTPN19D, PTPN20D, PTPN25D, SRI-2D	5756	2878	8.73E-04	44	0.52
PTPN9D, PTPN19D, PTPN22D, PTPN25D	5004	2502	9.66E-04	41	0.42
PTPN8D, PTPN19D, PTPN22D, PTPN25D	5443	2722	9.06E-04	42	0.47
Minimum	4953	2477	8.41E-04	41	0.39
Maximum	5973	2987	1.17E-03	81	0.52
Geometric Mean	5426	2713	9.51E-04	50	0.46

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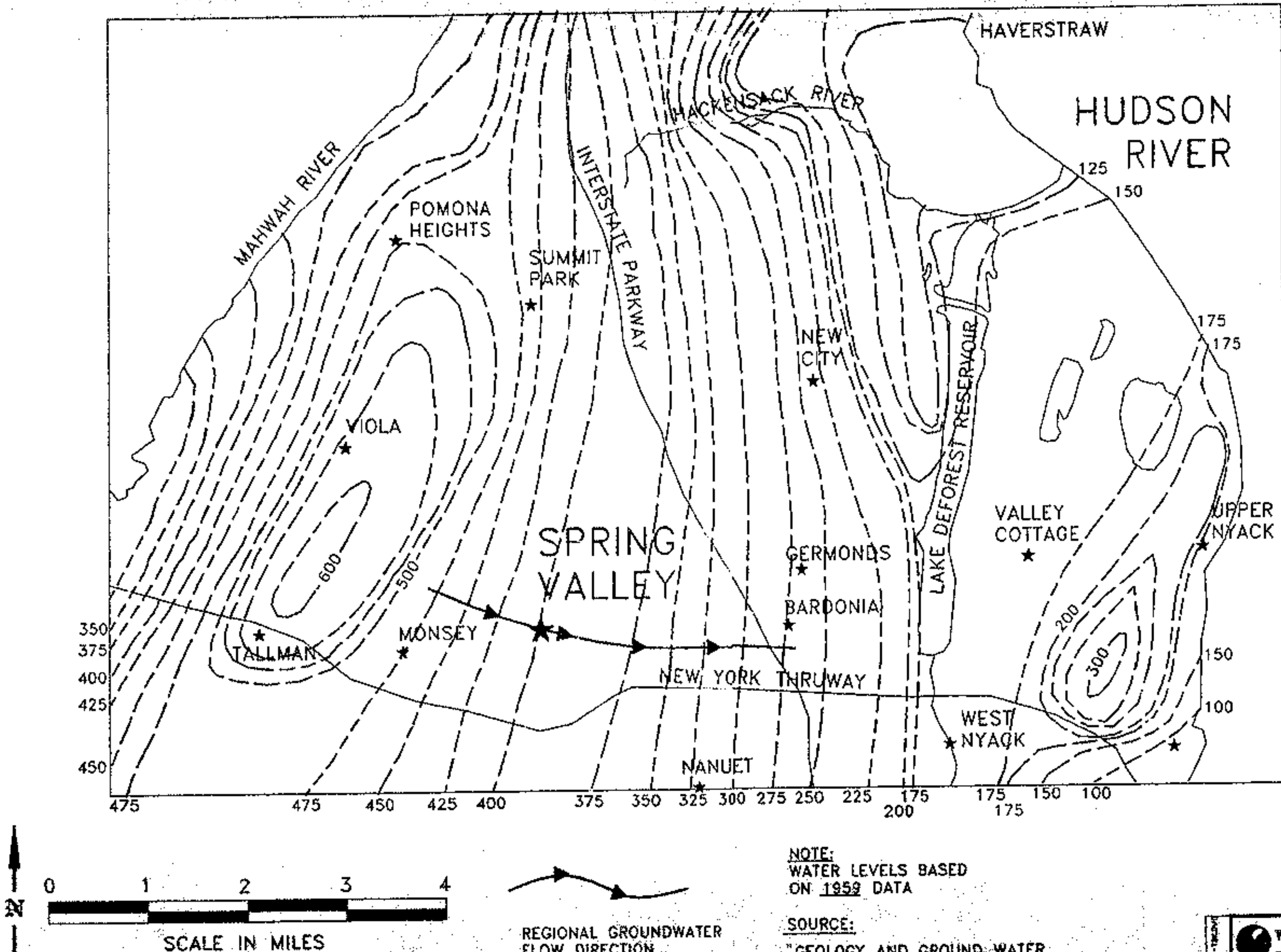
TABLE 11
WATER LEVEL RECOVERY ANALYSIS
USING ISOAQX SOFTWARE

Piezometer Indentification	Distance to Pumping Center (ft)	Bearing relative to PTPN22 (deg)	Transmissivity (ft/day)	Hydraulic Conductivity (ft/day)	Storativity
PTPN-8D	1680	104	4654	9.3	8.20E-04
PTPN-9D	1820	125	8619	17.2	1.53E-03
PTPN-19D	2250	161	7199	14.4	1.34E-03
PTPN-20D	1030	129	2424	4.8	2.77E-04
PTPN-22D	1310	0	4533	9.1	8.49E-04
PTPN-25D	1140	71	3319	6.6	8.83E-04
SRI-2D	2260	97	5314	10.6	7.74E-04
Minimum			2424	4.8	2.77E-04
Maximum			8619	17.2	1.53E-03
Geometric Mean			5152	10.3	9.25E-04



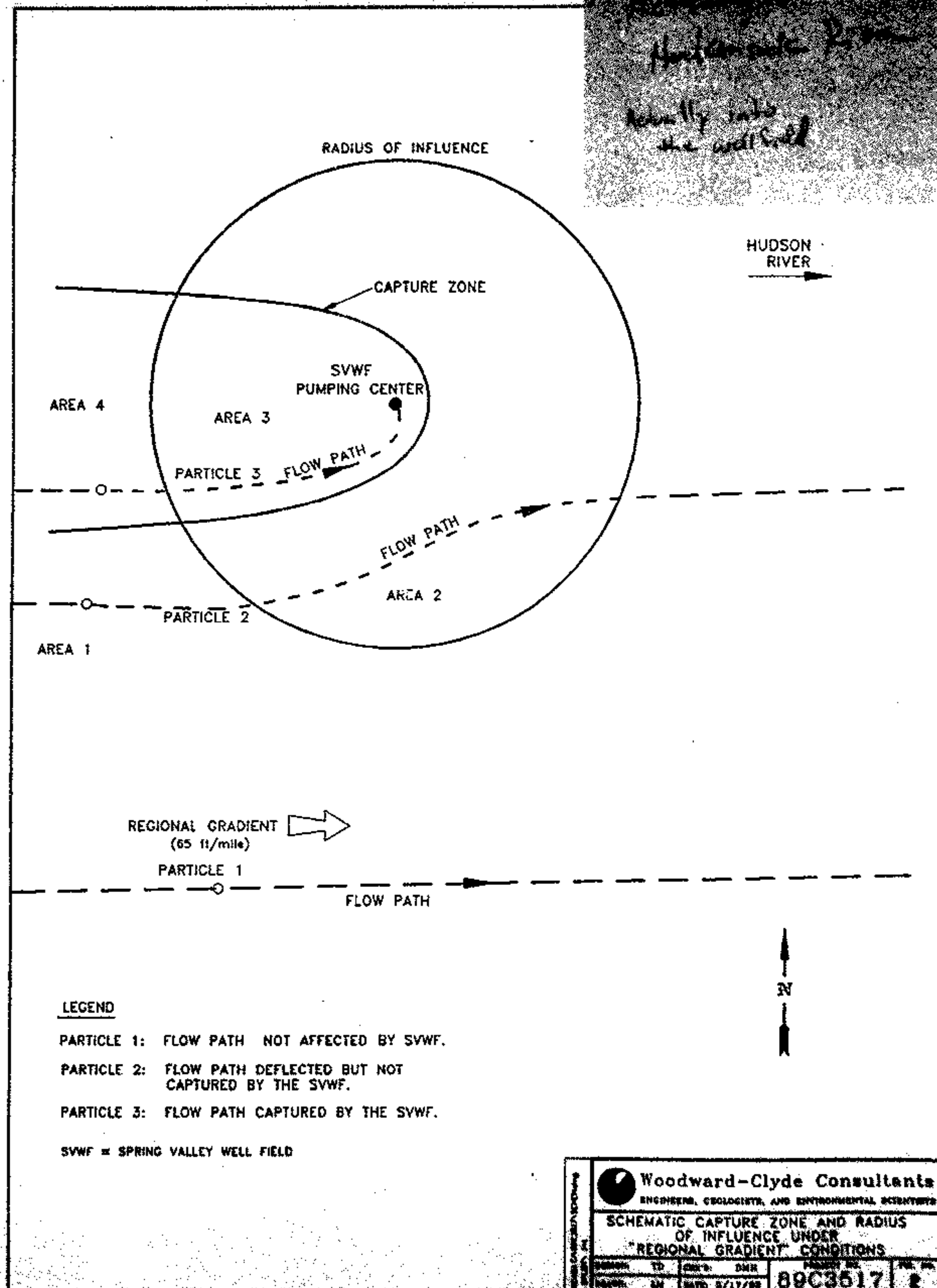
NOTE:
WATER LEVELS BASED ON 1959 DATA

SOURCE:
"GEOLOGY AND GROUND WATER RESOURCES OF ROCKLAND COUNTY, NEW YORK" BY NATHANIEL M. PERLMUTTER U.S. GEOLOGICAL SURVEY BULLETIN GW-42 ALBANY, NY 1959.

Woodward-Clyde Consultants
ENGINEERS, GEOLOGISTS, AND ENVIRONMENTAL SCIENTISTS

REGIONAL GROUNDWATER GRADIENT

89C3517 | 1


RADIUS OF INFLUENCE
HUDSON RIVER
CAPTURE ZONE
SVWF PUMPING CENTER
AREA 4
AREA 3
PARTICLE 3
FLOW PATH
FLOW PATH
AREA 2
PARTICLE 2
AREA 1
REGIONAL GRADIENT (65 ft/mile)
PARTICLE 1
FLOW PATH
N
LEGEND
PARTICLE 1: FLOW PATH NOT AFFECTED BY SVWF.
PARTICLE 2: FLOW PATH DEFLECTED BUT NOT CAPTURED BY THE SVWF.
PARTICLE 3: FLOW PATH CAPTURED BY THE SVWF.
SVWF = SPRING VALLEY WELL FIELD
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SCHEMATIC CAPTURE ZONE AND RADIUS OF INFLUENCE UNDER "REGIONAL GRADIENT" CONDITIONS
89C3517

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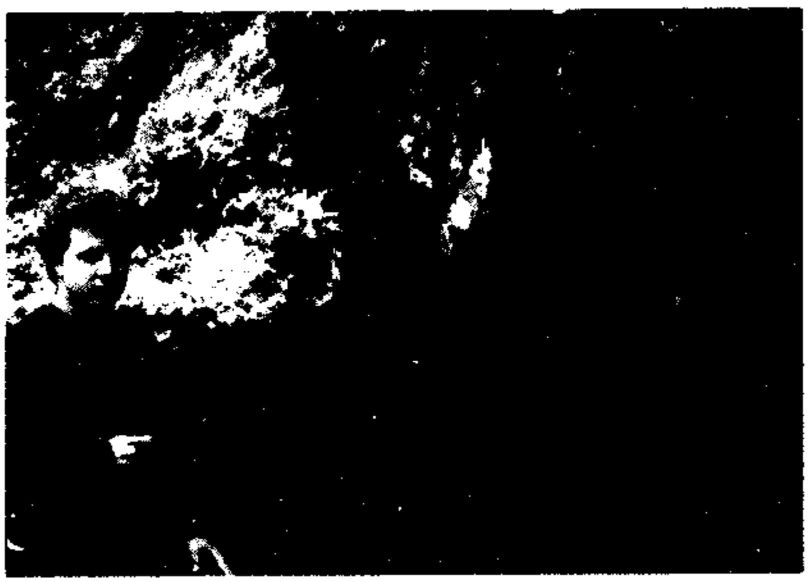
IMAGE AVAILABLE

DUE TO THE

COLOR OF ORIGINAL

DOCUMENT(s)



PHOTOGRAPH OF NEAR-VERTICAL JOINT IN BRUNSWICK FORMATION PEBBLY SANDSTONE ALONG PASCACK BROOK.

FIGURE 3

THIS IS THE BEST

IMAGE AVAILABLE

DUE TO THE

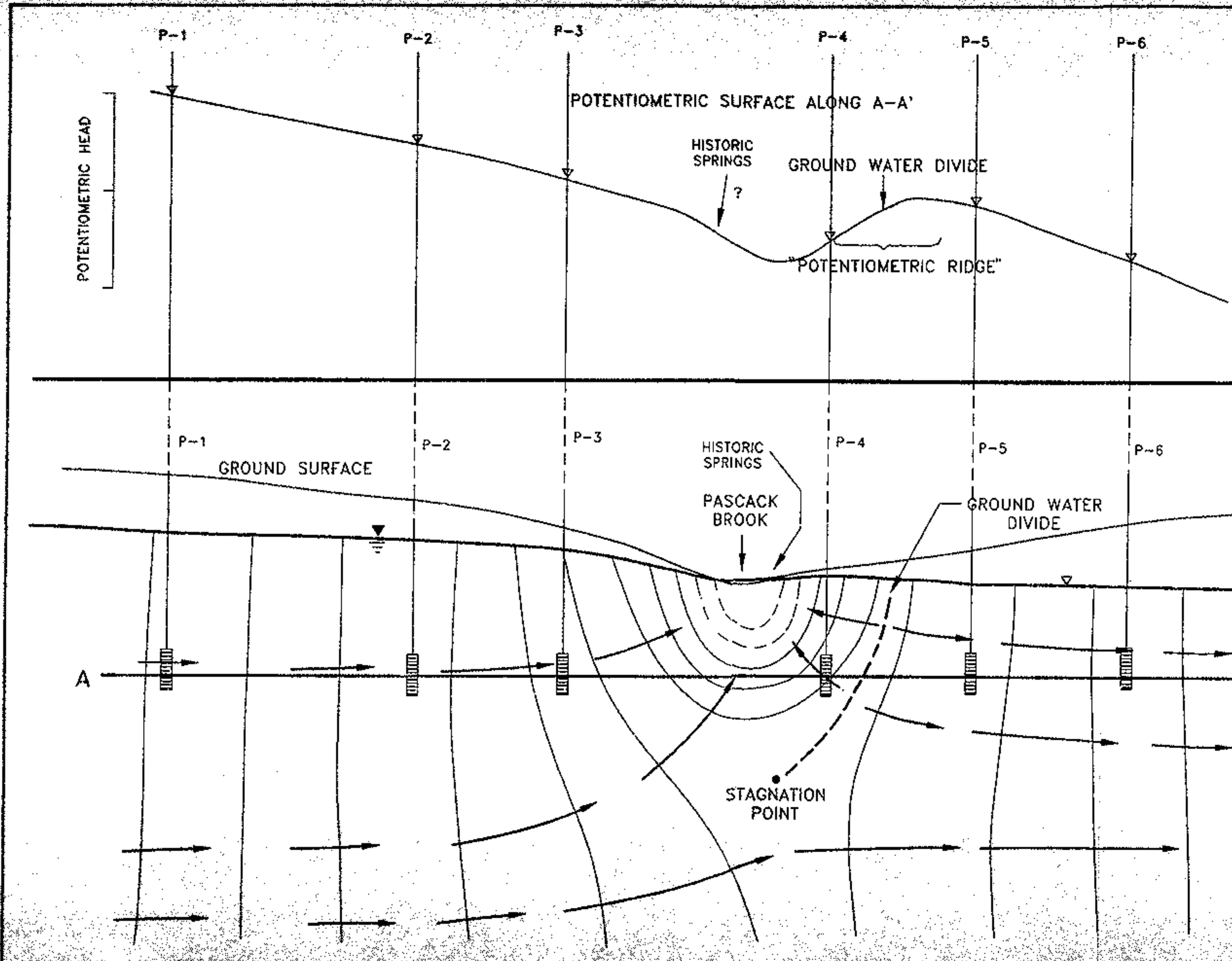
COLOR OF ORIGINAL

DOCUMENT(S)

PHOTOGRAPH OF LEACHED ZONE (BETWEEN ARROWS) IN CORE NO. 7
SHOWING DISSOLUTION OF CARBONATE CLASTS.

PHOTOGRAPH SHOWING SEGMENT OF LEACHED ZONE FROM 83 TO 83.5 FT
IN CORE NO. 7. THIS SEGMENT HAS 22.3 percent POROSITY AND
1.4×10^{-3} cm/sec PERMEABILITY.

FIGURE 3A



SPRING VALLEY WELL FIELD AQUIFER TEST

SCHEMATIC FLOW NET DIAGRAM FOR HISTORIC SPRING VALLEY

88C3517 | 4

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CORRECTION

THE FOLLOWING DOCUMENTS HAVE BEEN REPHOTOGRAPHED TO ASSURE LEGIBILITY

THIS IS THE BEST

IMAGE AVAILABLE

DUE TO THE

COLOR OF ORIGINAL

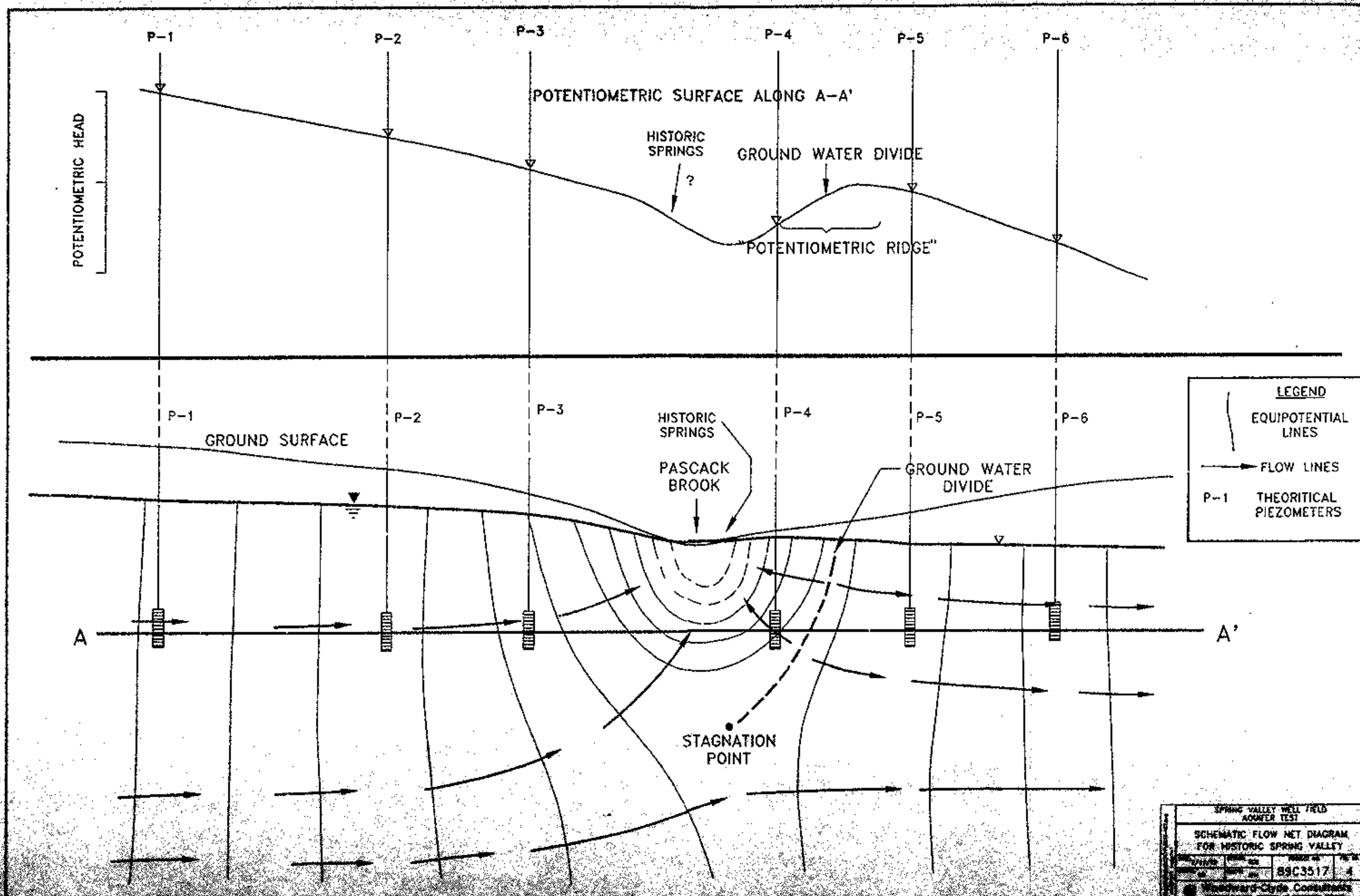
DOCUMENT(S)

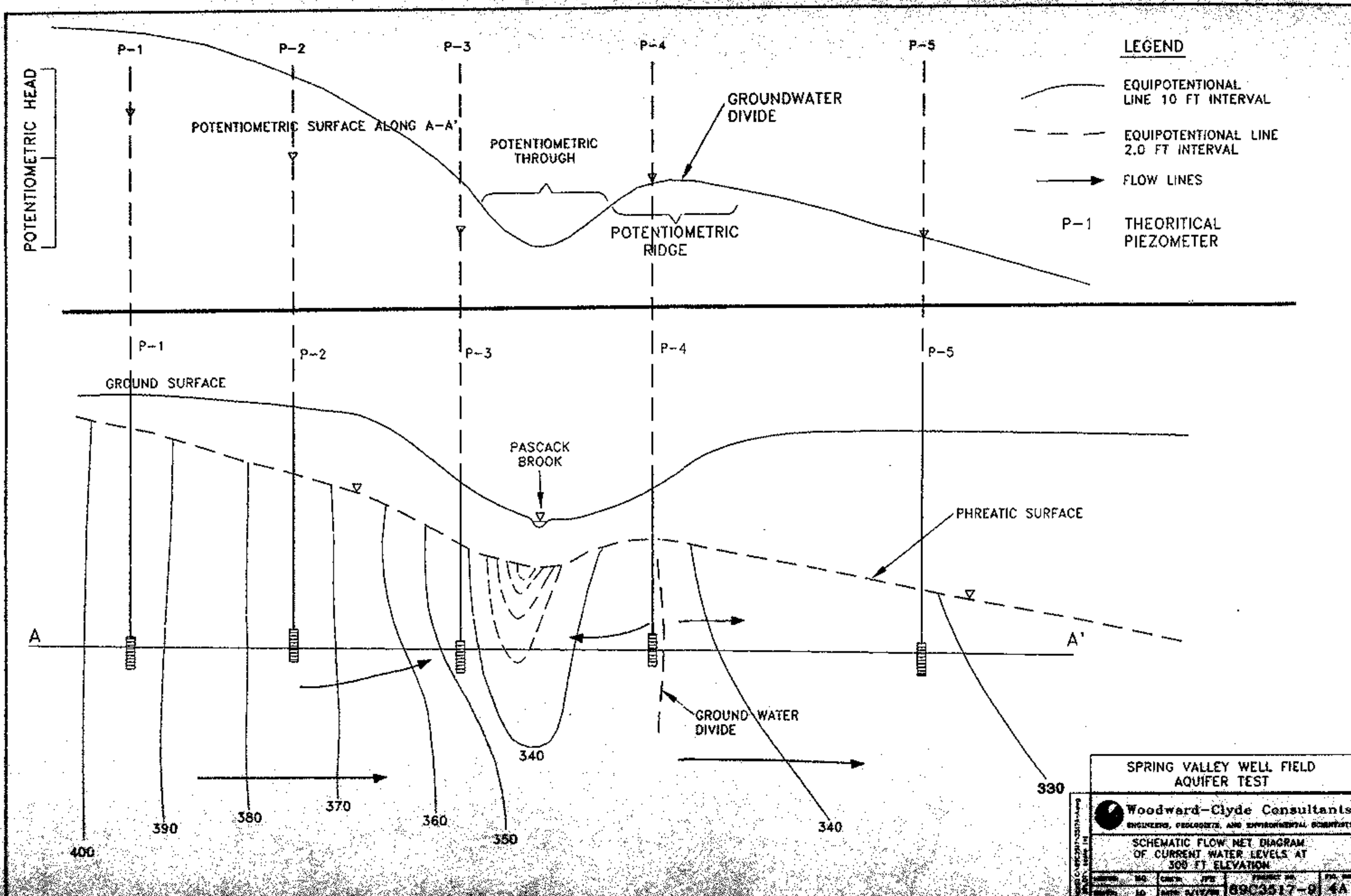
PHOTOGRAPH OF LEACHED ZONE (BETWEEN ARROWS) IN CORE NO. 7
SHOWING DISSOLUTION OF CARBONATE CLASTS.

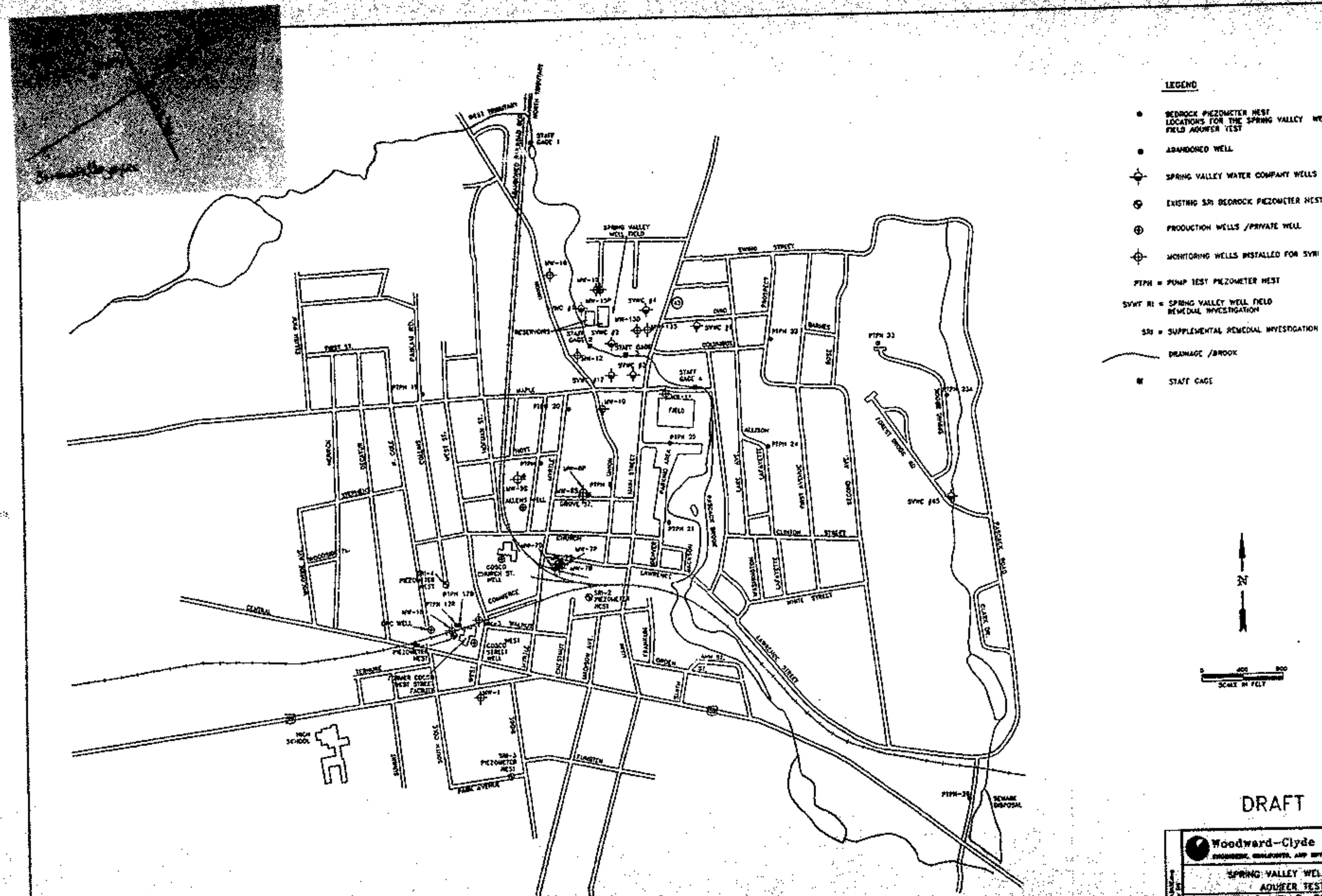
PHOTOGRAPH SHOWING SEGMENT OF LEACHED ZONE FROM 83 TO 83.5 FT
IN CORE NO. 7. THIS SEGMENT HAS 22.3 percent POROSITY AND
1.4×10^{-3} cm/sec PERMEABILITY.

FIGURE 3A

Core segment has an
"induced primary"
Permeability of 10^{-3}
<u>Plus</u> UNK K along bedding
plane Joints No Vert. Jts shown


P-1
P-2
P-3
P-4
P-5
P-6
POTENTIOMETRIC SURFACE ALONG A-A'
POTENTIOMETRIC HEAD
HISTORIC SPRINGS
?
GROUND WATER DIVIDE
"POTENTIOMETRIC RIDGE"
P-1
P-2
P-3
P-4
P-5
P-6
GROUND SURFACE
HISTORIC SPRINGS
PASCACK BROOK
GROUND WATER DIVIDE
A
A'
STAGNATION POINT
LEGEND
EQUIPOTENTIAL LINES
FLOW LINES
P-1 THEORITICAL PIEZOMETERS
SPRING VALLEY WELL FIELD AQUIFER TEST
SCHEMATIC FLOW NET DIAGRAM FOR HISTORIC SPRING VALLEY
89C3517
4
Woodward-Clyde Consultants


P-1
P-2
P-3
P-4
P-5
POTENTIOMETRIC HEAD
POTENTIOMETRIC SURFACE ALONG A-A'
POTENTIOMETRIC THROUGH
GROUNDWATER DIVIDE
POTENTIOMETRIC RIDGE
LEGEND
EQUIPOTENTIONAL LINE 10 FT INTERVAL
EQUIPOTENTIONAL LINE 2.0 FT INTERVAL
FLOW LINES
P-1 THEORITICAL PIEZOMETER
GROUND SURFACE
PASCACK BROOK
PHREATIC SURFACE
A
A'
GROUND WATER DIVIDE
400
390
380
370
360
350
340
340
330
SPRING VALLEY WELL FIELD AQUIFER TEST
Woodward-Clyde Consultants
SCHEMATIC FLOW NET DIAGRAM OF CURRENT WATER LEVELS AT 300 FT ELEVATION
89C3517-9
4A



DRAFT

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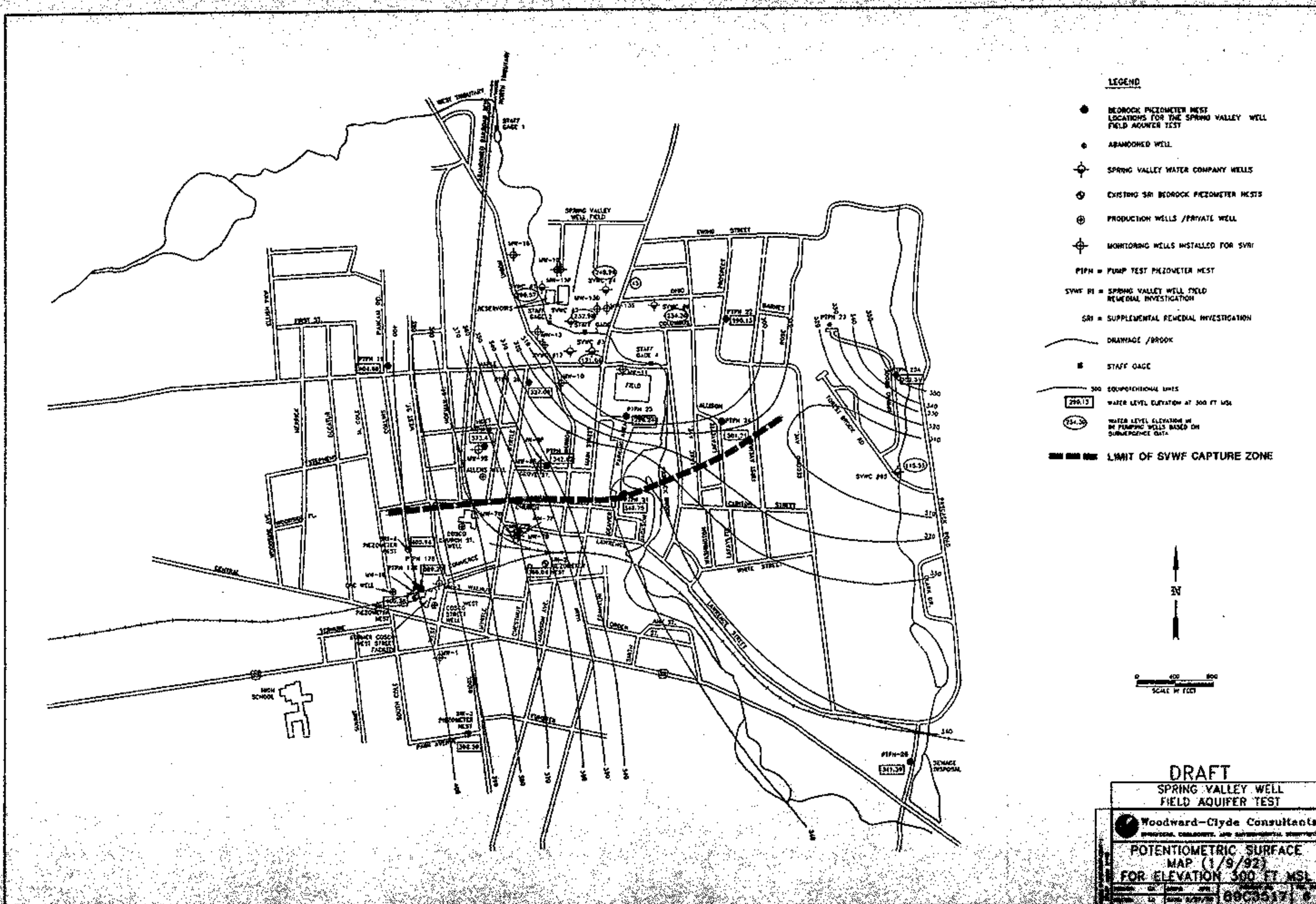
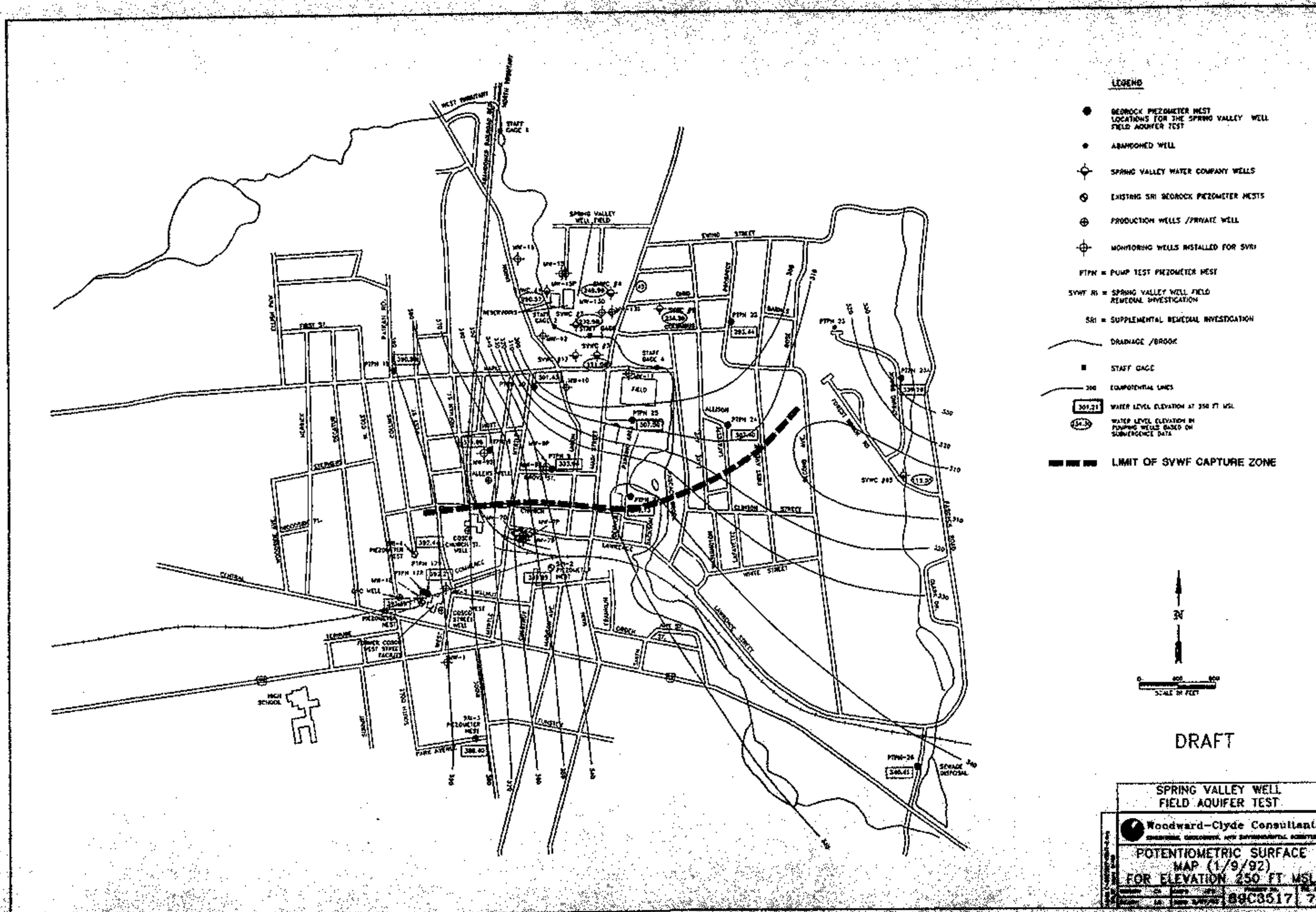
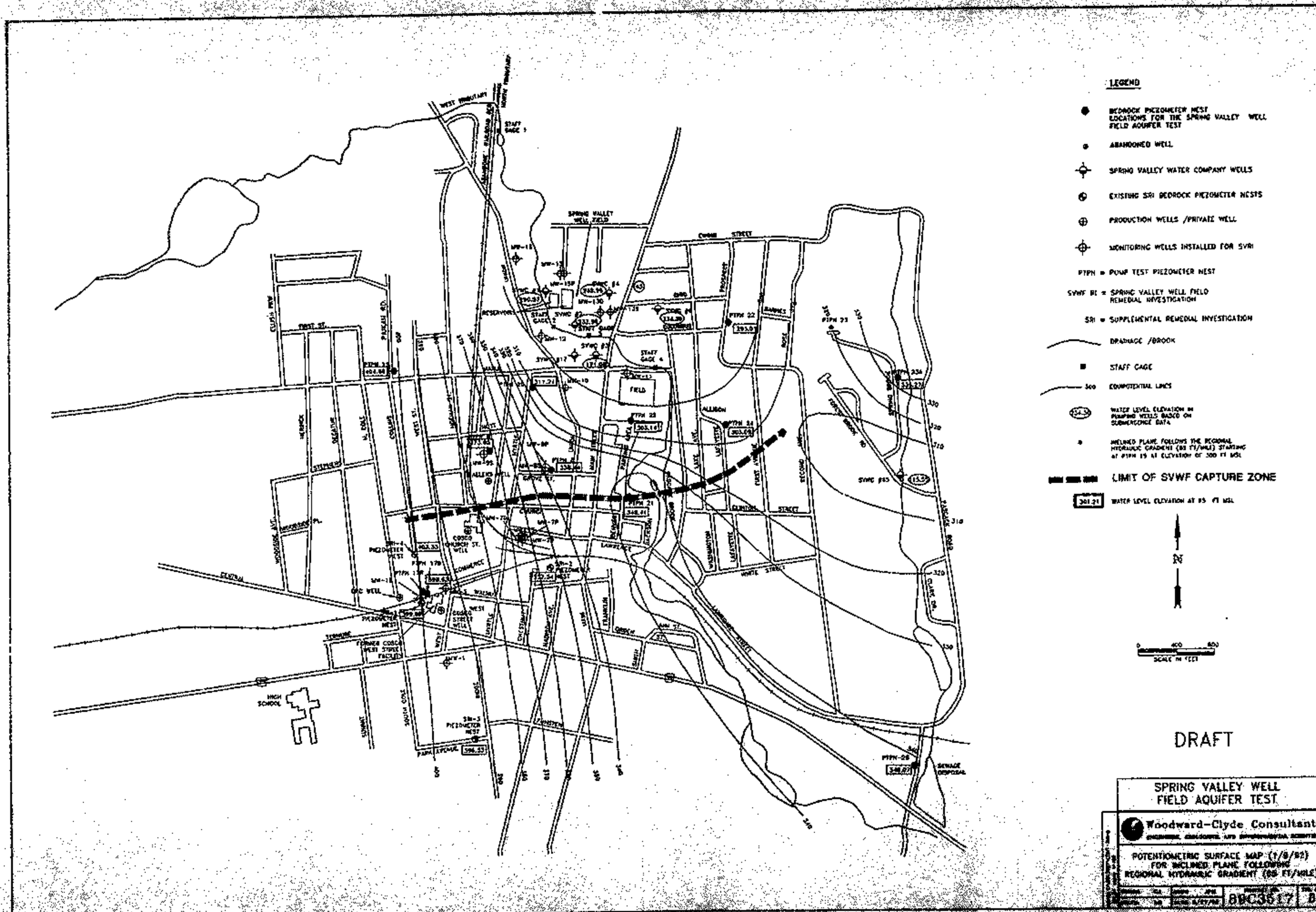
SPRING VALLEY WELL FIELD
AQUIFER TEST

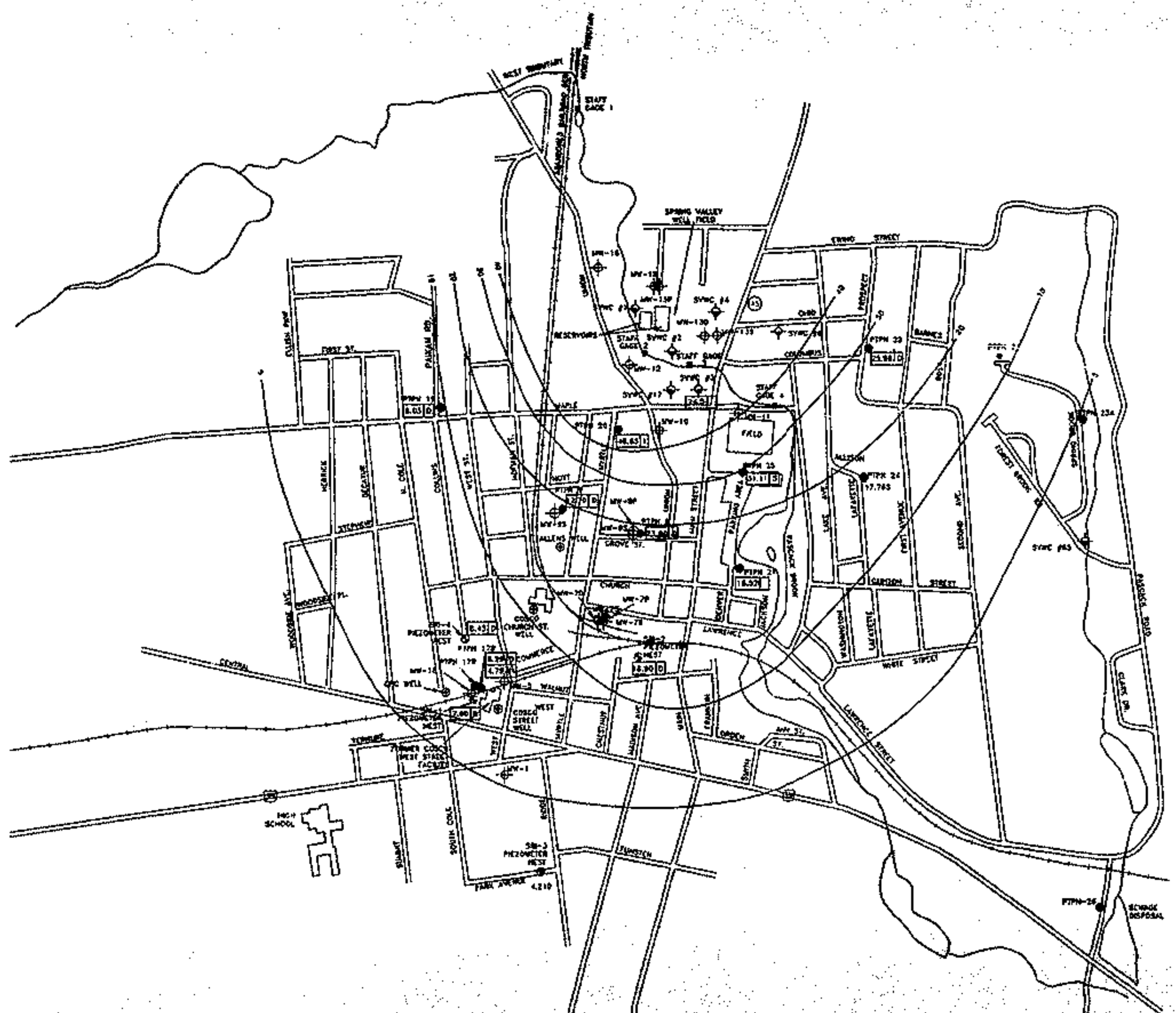
MONITORING WELLS, PIEZOMETERS,
SUPPLY WELLS AND PRIVATE WELLS

89C3517 | 6


LEGEND
BEDROCK PIEZOMETER NEST LOCATIONS FOR THE SPRING VALLEY WELL FIELD AQUIFER TEST
ABANDONED WELL
SPRING VALLEY WATER COMPANY WELLS
EXISTING SRI BEDROCK PIEZOMETER NESTS
PRODUCTION WELLS /PRIVATE WELL
MONITORING WELLS INSTALLED FOR SVRI
PTPN = PUMP TEST PIEZOMETER NEST
SVWF RI = SPRING VALLEY WELL FIELD REMEDIAL INVESTIGATION
SRI = SUPPLEMENTAL REMEDIAL INVESTIGATION
DRAINAGE /BROOK
STAFF GAGE
300 EQUIPOTENTIONAL LINES
WATER LEVEL ELEVATION AT 300 FT MSL
WATER LEVEL ELEVATION IN PUMPING WELLS BASED ON SUBMERGENCE DATA
LIMIT OF SVWF CAPTURE ZONE
SCALE IN FEET
N
DRAFT
SPRING VALLEY WELL
FIELD AQUIFER TEST
Woodward-Clyde Consultants
POTENTIOMETRIC SURFACE
MAP (1/9/92)
FOR ELEVATION 300 FT MSL
89C3517


LEGEND
BEDROCK PIEZOMETER NEST LOCATIONS FOR THE SPRING VALLEY WELL FIELD AQUIFER TEST
ABANDONED WELL
SPRING VALLEY WATER COMPANY WELLS
EXISTING SRI BEDROCK PIEZOMETER NESTS
PRODUCTION WELLS /PRIVATE WELL
MONITORING WELLS INSTALLED FOR SVRI
PTPN = PUMP TEST PIEZOMETER NEST
SVWF RI = SPRING VALLEY WELL FIELD REMEDIAL INVESTIGATION
SRI = SUPPLEMENTAL REMEDIAL INVESTIGATION
DRAINAGE /BROOK
STAFF GAGE
EQUIPOTENTIAL LINES
WATER LEVEL ELEVATION AT 350 FT MSL
WATER LEVEL ELEVATION IN PUMPING WELLS BASED ON SUBMERGENCE DATA
LIMIT OF SVWF CAPTURE ZONE
DRAFT
SPRING VALLEY WELL FIELD AQUIFER TEST
Woodward-Clyde Consultants
POTENTIOMETRIC SURFACE MAP (1/9/92) FOR ELEVATION 250 FT MSL
89C3517
7


LEGEND
SPRING VALLEY WATER COMPANY WELLS
EXISTING SRI BEDROCK PIEZOMETER NESTS
PRODUCTION WELLS /PRIVATE WELL
MONITORING WELLS INSTALLED FOR SVRI
PTPN = PUMP TEST PIEZOMETER NEST
SVWF RI = SPRING VALLEY WELL FIELD REMEDIAL INVESTIGATION
SRI = SUPPLEMENTAL REMEDIAL INVESTIGATION
DRAINAGE /BROOK
STAFF GAGE
LIMIT OF SVWF CAPTURE ZONE
N
DRAFT
SPRING VALLEY WELL
FIELD AQUIFER TEST
Woodward-Clyde Consultants
SPRING VALLEY WELL FIELD
CHURCH ST.
COMMERCE
WALSH
WHITE STREET
CLINTON STREET
LAWRENCE
HIGH SCHOOL



LEGEND

- ● BEDROCK PIEZOMETER NEST LOCATIONS FOR THE SPRING VALLEY WELL FIELD AQUIFER TEST
- • ABANDONED WELL
- SPRING VALLEY WATER COMPANY WELLS
- EXISTING SRI BEDROCK PIEZOMETER NESTS
- PRODUCTION WELLS /PRIVATE WELL
- MONITORING WELLS INSTALLED FOR SVRI
- PTPN = PUMP TEST PIEZOMETER NEST *
- SVWF RI = SPRING VALLEY WELL FIELD REMEDIAL INVESTIGATION
- SRI = SUPPLEMENTAL REMEDIAL INVESTIGATION
- DRAINAGE /BROOK
- STAFF GAGE
- 20 APPROXIMATE CONTOURS OF EQUAL GROUNDWATER LEVEL RECOVERIES FOR 250-300 FT MSL AFTER 7200 MINUTES SINCE WELL FIELD SHUT-OFF
- S SHALLOW
- I INTERMEDIATE
- D DEEP
- 7.40 D = WATER LEVEL RECOVERY FROM MEASUREMENT COLLECTED 9:00 AM JANUARY 13, 1993

SCALE IN FEET

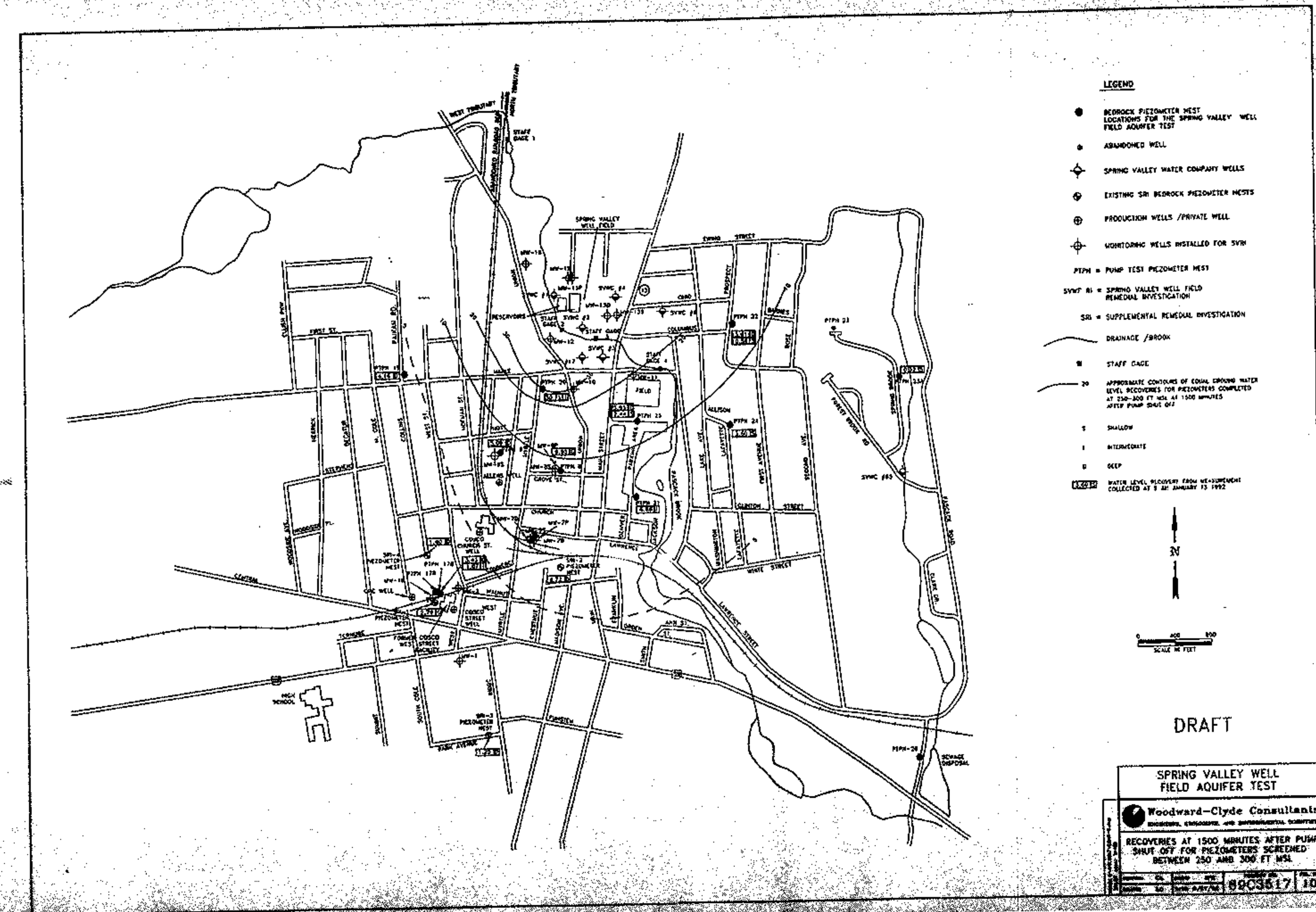
DRAFT

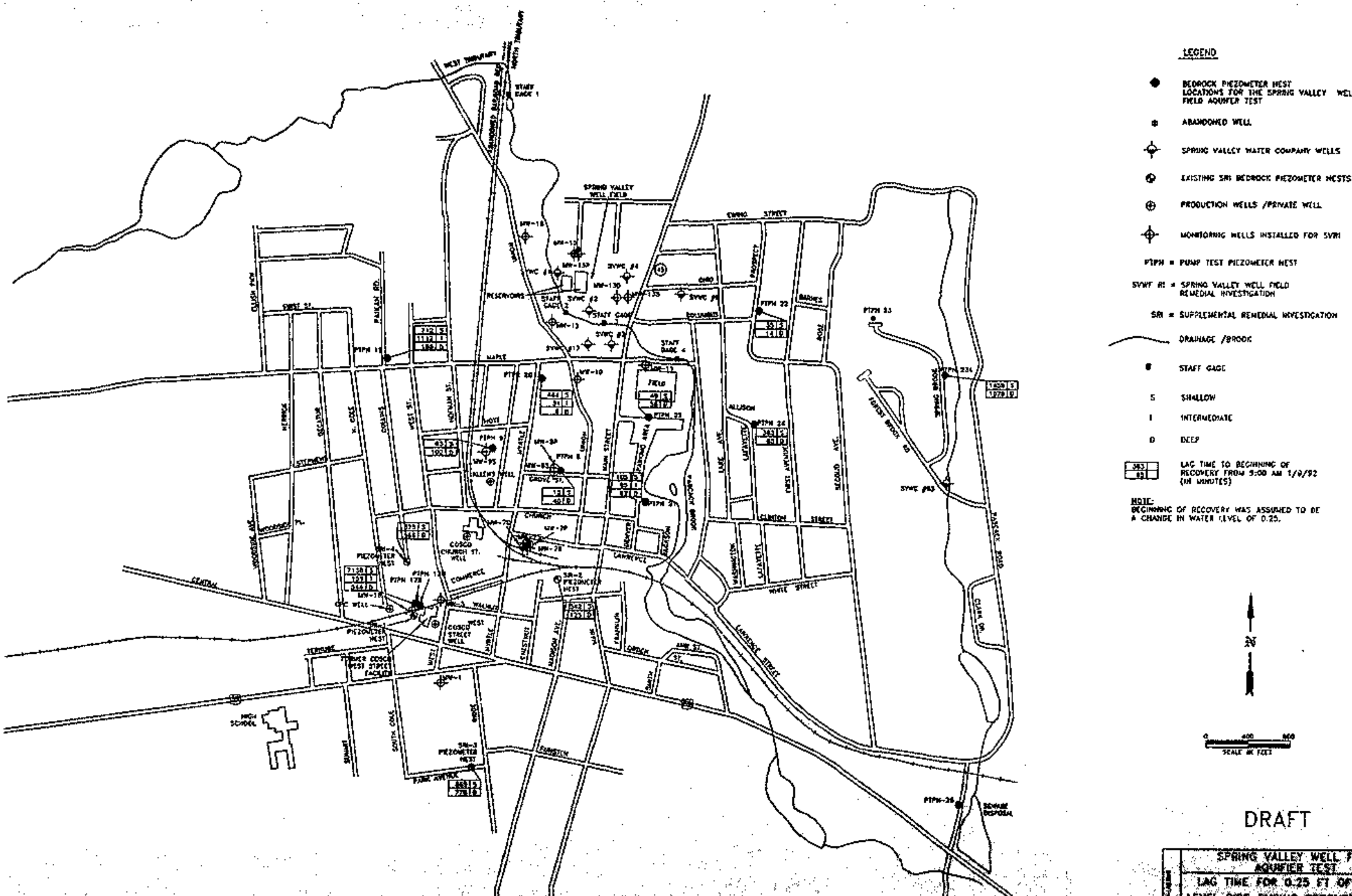
SPRING VALLEY WELL FIELD AQUIFER TEST

Woodward-Clyde Consultants

RECOVERY OF WATER LEVELS 7200 MINUTES AFTER WELL FIELD SHUT-OFF FOR PIEZOMETERS SCREENED BETWEEN 250 AND 300 FT MSL

89C3517 | 9


LEGEND
BEDROCK PIEZOMETER NEST LOCATIONS FOR THE SPRING VALLEY WELL FIELD AQUIFER TEST
ABANDONED WELL
SPRING VALLEY WATER COMPANY WELLS
EXISTING SRI BEDROCK PIEZOMETER NESTS
PRODUCTION WELLS /PRIVATE WELL
MONITORING WELLS INSTALLED FOR SVRI
PTPN = PUMP TEST PIEZOMETER NEST
SVWF RI = SPRING VALLEY WELL FIELD REMEDIAL INVESTIGATION
SRI = SUPPLEMENTAL REMEDIAL INVESTIGATION
DRAINAGE /BROOK
STAFF GAGE
APPROXIMATE CONTOURS OF EQUAL GROUND WATER LEVEL RECOVERIES FOR PIEZOMETERS COMPLETED AT 250-300 FT MSL AT 1500 MINUTES AFTER PUMP SHUT OFF
S SHALLOW
I INTERMEDIATE
D DEEP
WATER LEVEL RECOVERY FROM MEASUREMENT COLLECTED AT 5 AM JANUARY 13 1992
N
SCALE IN FEET
DRAFT
SPRING VALLEY WELL FIELD AQUIFER TEST
Woodward-Clyde Consultants
RECOVERIES AT 1500 MINUTES AFTER PUMP SHUT OFF FOR PIEZOMETERS SCREENED BETWEEN 250 AND 300 FT MSL
89C3617
10
SPRING VALLEY WELL FIELD
SPRING STREET
RESERVOIRS
CLINTON STREET
LAWRENCE STREET
WHITE STREET
CENTRAL
HIGH SCHOOL
SEWAGE DISPOSAL



DRAFT

SPRING VALLEY WELL FIELD AQUIFER TEST

LAG TIME FOR 0.25 FT OF WATER LEVEL RISE DURING RECOVERY PHASE

89C3517 (1)

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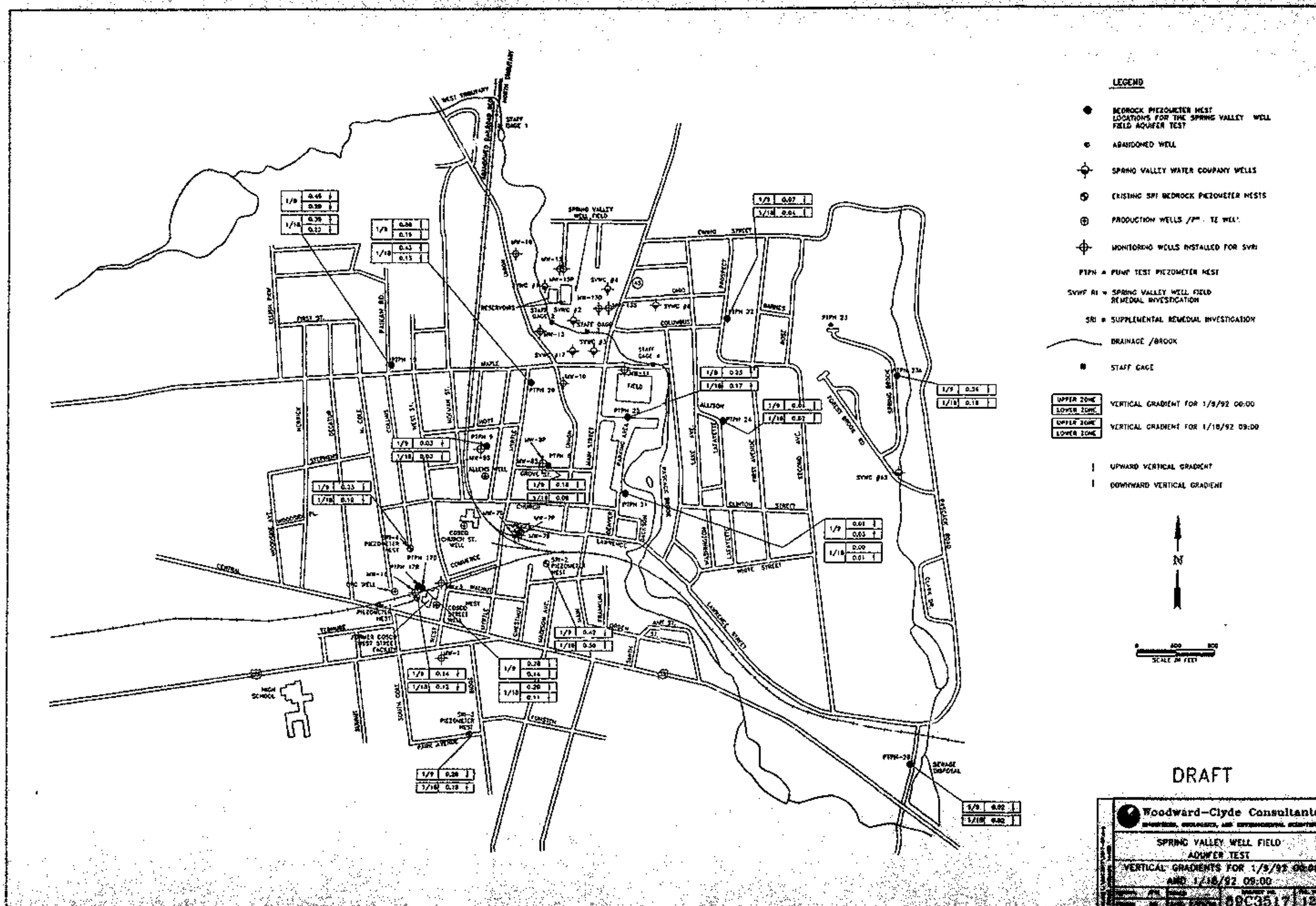
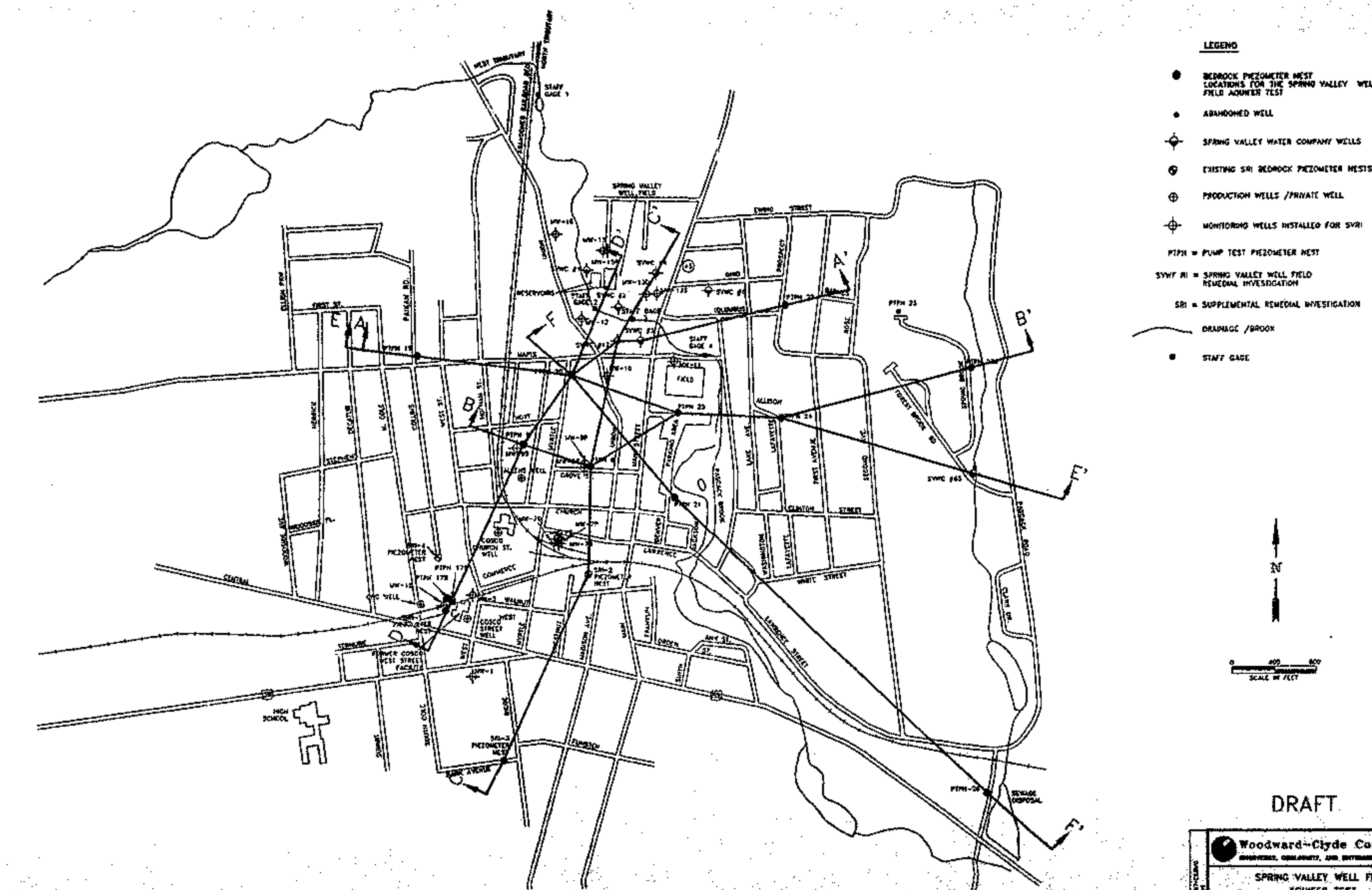

LEGEND
BEDROCK PIEZOMETER NEST LOCATIONS FOR THE SPRING VALLEY WELL FIELD AQUIFER TEST
ABANDONED WELL
SPRING VALLEY WATER COMPANY WELLS
EXISTING SRI BEDROCK PIEZOMETER NESTS
MONITORING WELLS INSTALLED FOR SVRI
PTPN = PUMP TEST PIEZOMETER NEST
SVWF RI = SPRING VALLEY WELL FIELD REMEDIAL INVESTIGATION
SRI = SUPPLEMENTAL REMEDIAL INVESTIGATION
DRAINAGE /BROOK
STAFF GAGE
UPPER ZONE / LOWER ZONE VERTICAL GRADIENT FOR 1/9/92 00:00
UPPER ZONE / LOWER ZONE VERTICAL GRADIENT FOR 1/18/92 09:00
UPWARD VERTICAL GRADIENT
DOWNWARD VERTICAL GRADIENT
N
DRAFT
Woodward-Clyde Consultants
SPRING VALLEY WELL FIELD
AQUIFER TEST
VERTICAL GRADIENTS FOR 1/9/92 00:00
AND 1/18/92 09:00
89C3517
12



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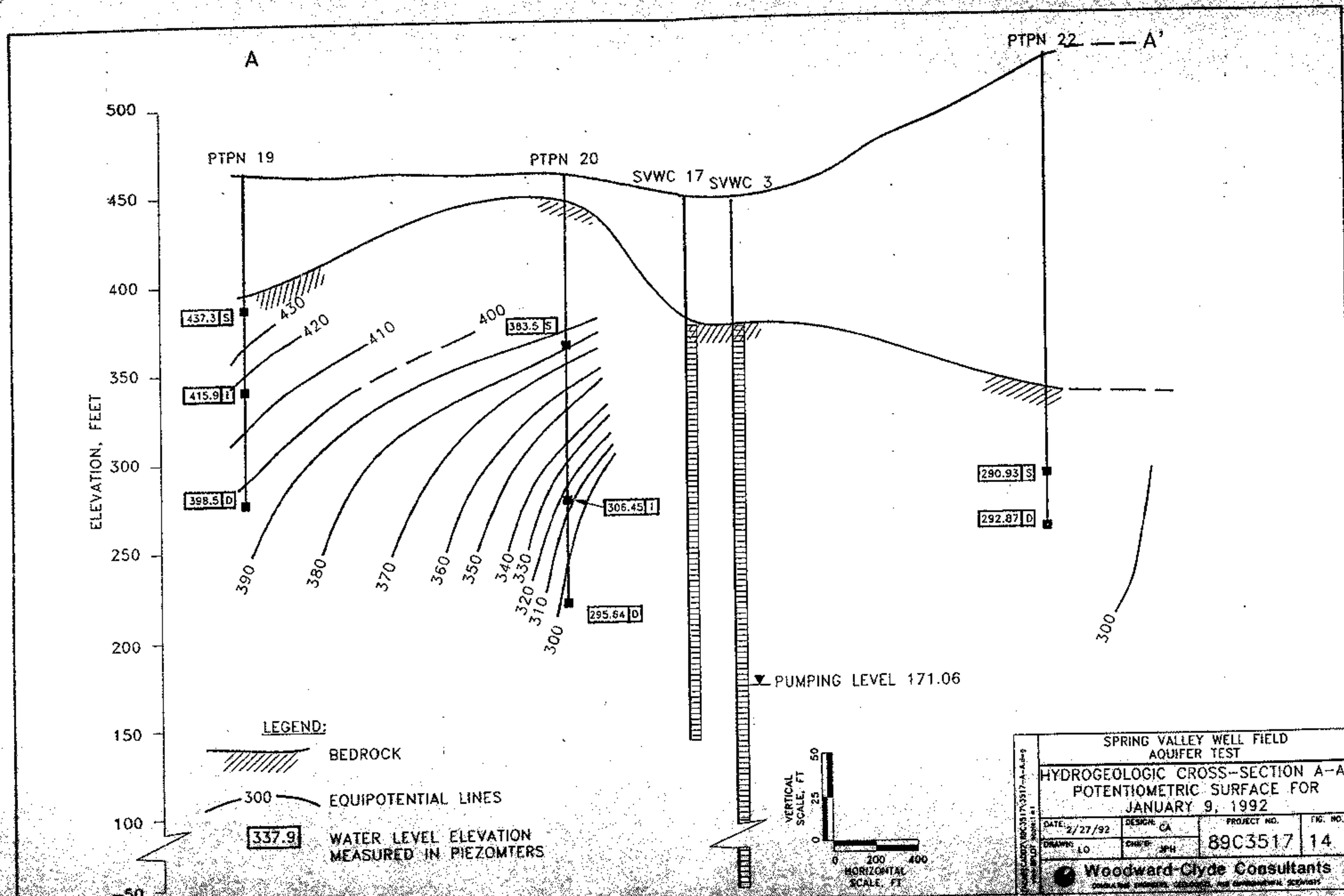
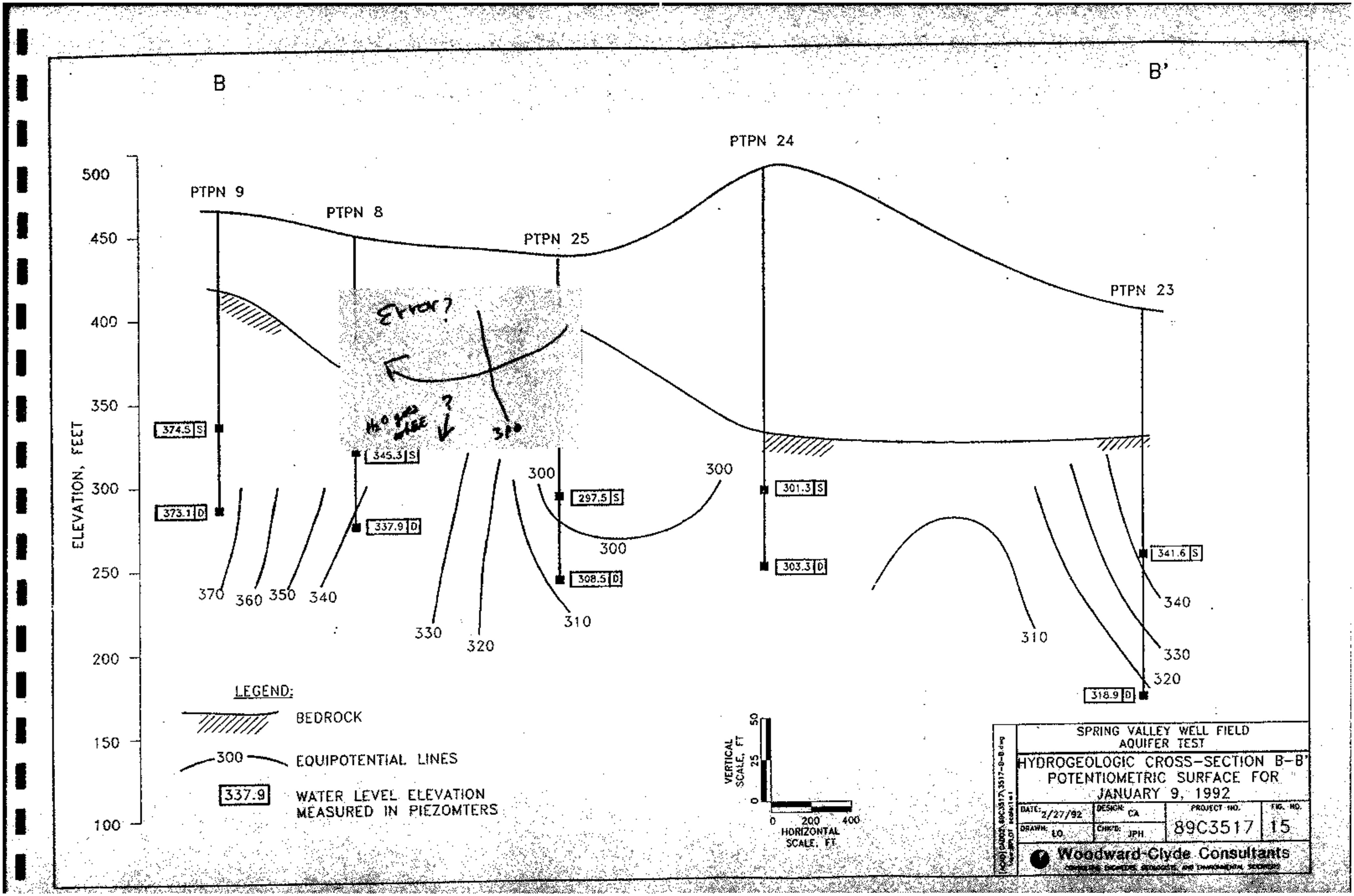
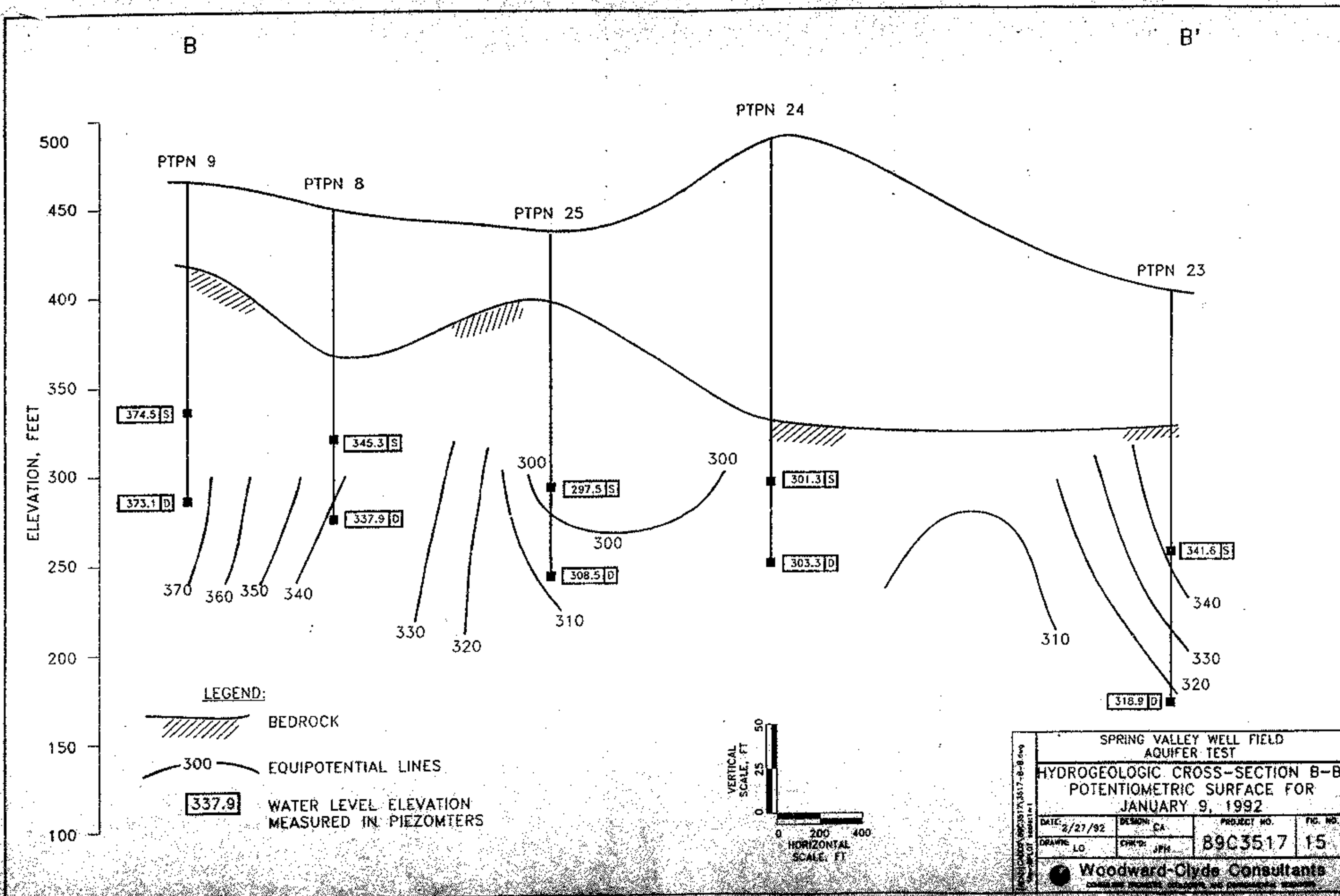
SPRING VALLEY WELL FIELD AQUIFER TEST

VERTICAL CROSS-SECTION LOCATION MAP

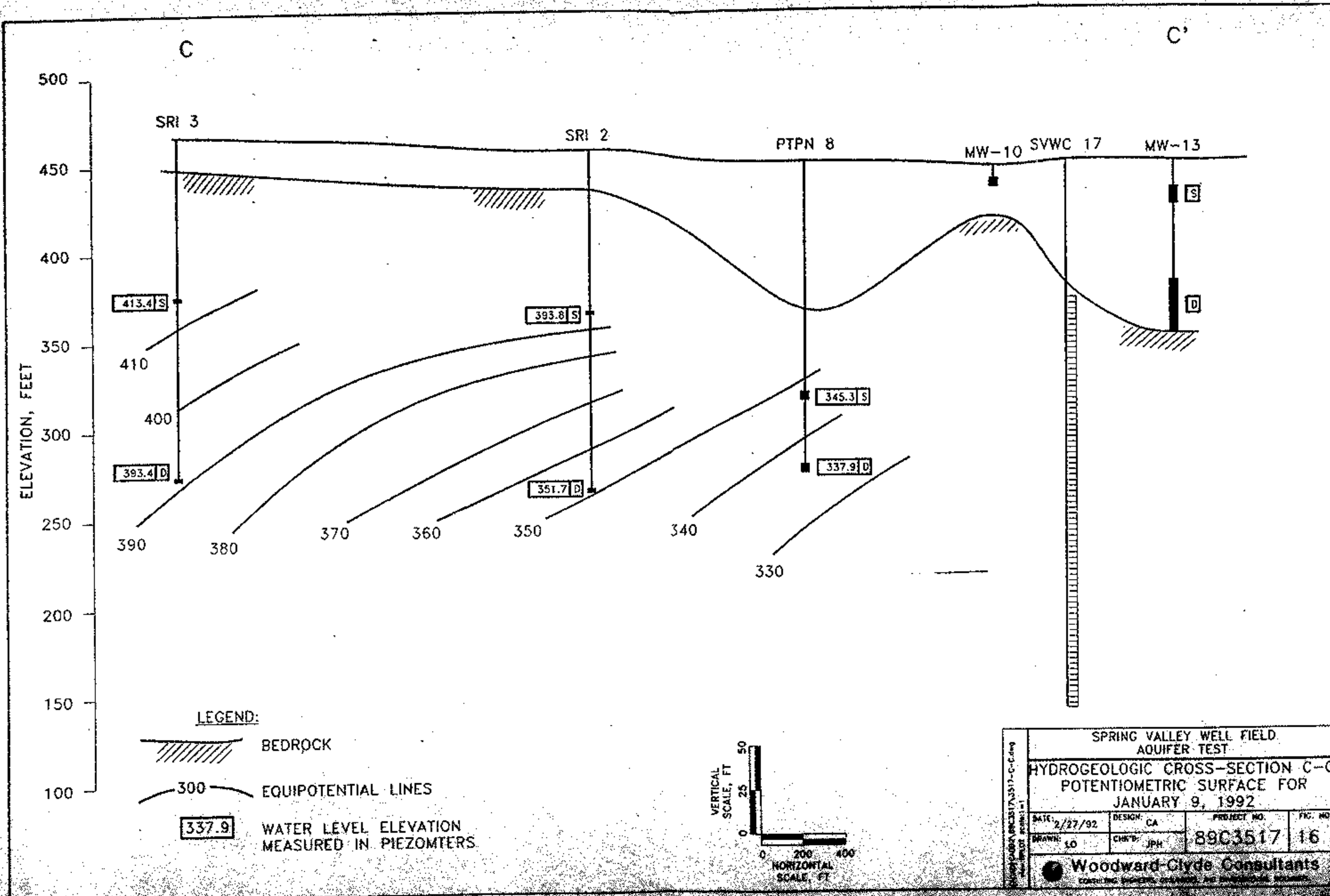
88C9517 | 13

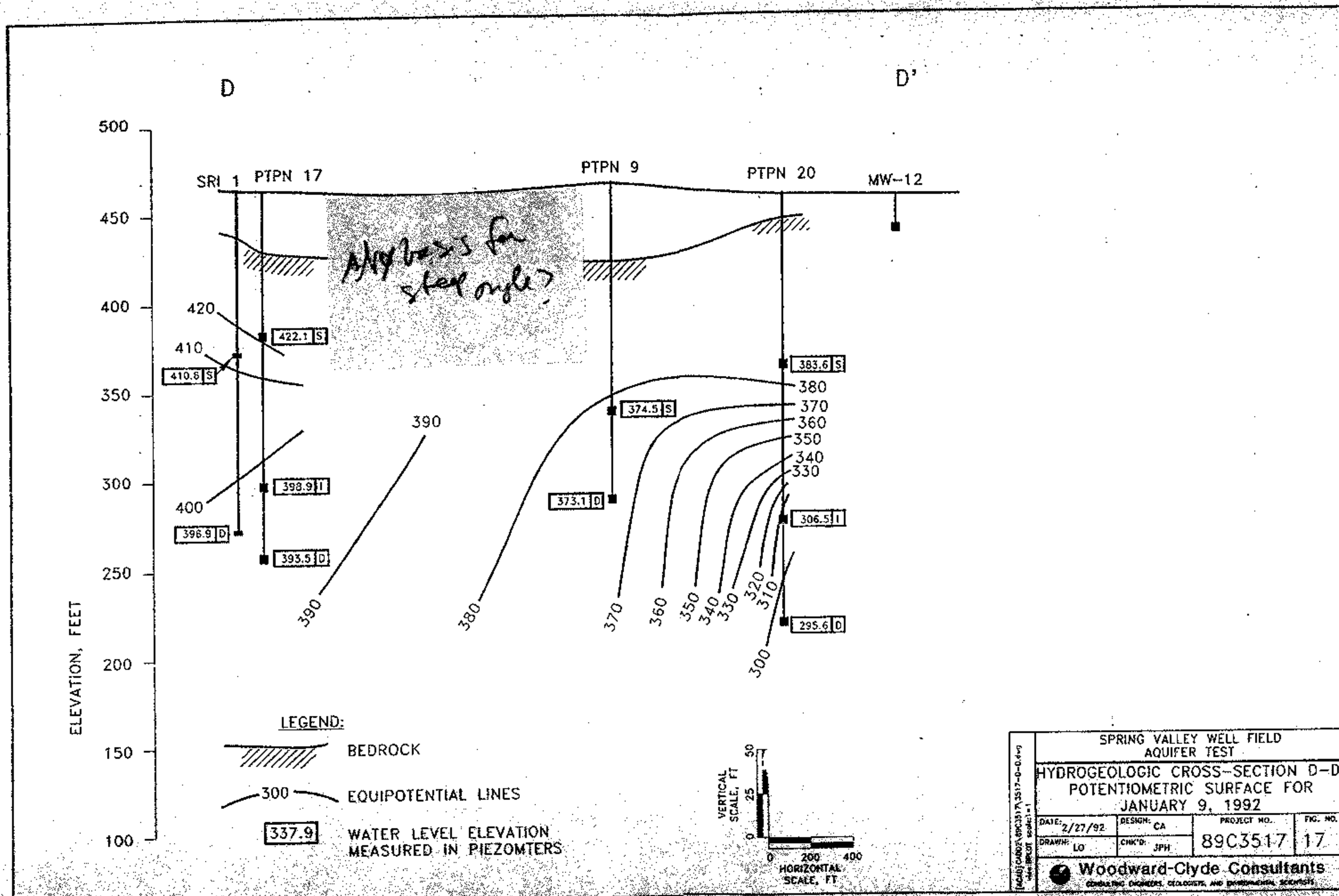

A
A'
PTPN 19
PTPN 20
SVWC 17
SVWC 3
PTPN 22
500
450
400
350
300
250
200
150
100
-50
ELEVATION, FEET
437.3 S
415.9 I
398.5 D
383.5 S
306.45 I
295.64 D
290.93 S
292.87 D
430
420
410
400
390
380
370
360
350
340
330
320
310
300
PUMPING LEVEL 171.06
LEGEND:
BEDROCK
300
EQUIPOTENTIAL LINES
337.9
WATER LEVEL ELEVATION MEASURED IN PIEZOMTERS
VERTICAL SCALE, FT
0
25
50
0
200
400
HORIZONTAL SCALE, FT
SPRING VALLEY WELL FIELD AQUIFER TEST
HYDROGEOLOGIC CROSS-SECTION A-A' POTENTIOMETRIC SURFACE FOR JANUARY 9, 1992
DATE: 2/27/92
DESIGN: CA
PROJECT NO. 89C3517
FIG. NO. 14
DRAWN: LO
CHK'D: JPH
Woodward-Clyde Consultants

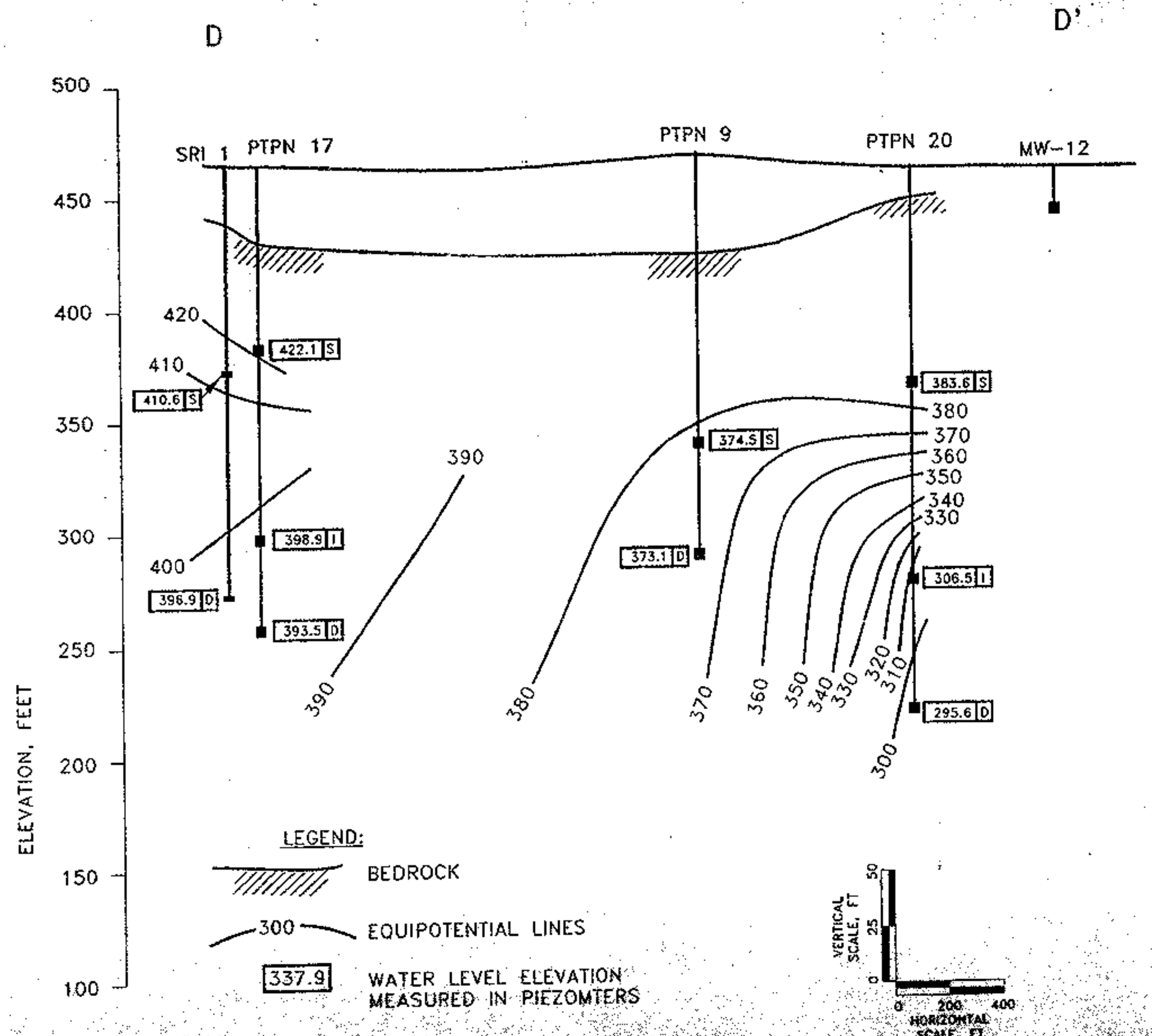

B
B'
PTPN 9
PTPN 8
PTPN 25
PTPN 24
PTPN 23
ELEVATION, FEET
500
450
400
350
300
250
200
150
100
374.5 S
373.1 D
345.3 S
337.9 D
297.5 S
308.5 D
301.3 S
303.3 D
341.6 S
318.9 D
370
360
350
340
330
320
310
300
300
300
310
340
330
320
Error?
LEGEND:
BEDROCK
300
EQUIPOTENTIAL LINES
337.9
WATER LEVEL ELEVATION MEASURED IN PIEZOMTERS
VERTICAL SCALE, FT
0
25
50
0
200
400
HORIZONTAL SCALE, FT
SPRING VALLEY WELL FIELD
AQUIFER TEST
HYDROGEOLOGIC CROSS-SECTION B-B'
POTENTIOMETRIC SURFACE FOR
JANUARY 9, 1992
DATE: 2/27/92
DESIGN: CA
DRAWN: LO
CHK'D: JPH
PROJECT NO.
89C3517
FIG. NO.
15
Woodward-Clyde Consultants



B
B'
PTPN 9
PTPN 8
PTPN 25
PTPN 24
PTPN 23
ELEVATION, FEET
500
450
400
350
300
250
200
150
100
374.5 S
373.1 D
345.3 S
337.9 D
297.5 S
308.5 D
301.3 S
303.3 D
341.6 S
318.9 D
370
360
350
340
330
320
310
300
300
300
310
340
330
320
LEGEND:
BEDROCK
300
EQUIPOTENTIAL LINES
337.9
WATER LEVEL ELEVATION MEASURED IN PIEZOMTERS
VERTICAL SCALE, FT
0
25
50
0
200
400
HORIZONTAL SCALE, FT
SPRING VALLEY WELL FIELD AQUIFER TEST
HYDROGEOLOGIC CROSS-SECTION B-B' POTENTIOMETRIC SURFACE FOR JANUARY 9, 1992
DATE: 2/27/92
DESIGN: CA
DRAWN: LO
CHK'D: JFH
PROJECT NO. 89C3517
FIG. NO. 15
Woodward-Clyde Consultants


C
C'
SRI 3
SRI 2
PTPN 8
MW-10
SVWC 17
MW-13
500
450
400
350
300
250
200
150
100
ELEVATION, FEET
413.4 S
393.4 D
393.8 S
351.7 D
345.3 S
337.9 D
S
D
410
400
390
380
370
360
350
340
330
LEGEND:
BEDROCK
300
EQUIPOTENTIAL LINES
337.9
WATER LEVEL ELEVATION
MEASURED IN PIEZOMTERS
VERTICAL SCALE, FT
0
25
50
0
200
400
HORIZONTAL SCALE, FT
SPRING VALLEY WELL FIELD
AQUIFER TEST
HYDROGEOLOGIC CROSS-SECTION C-C'
POTENTIOMETRIC SURFACE FOR
JANUARY 9, 1992
DATE: 2/27/92
DESIGN: CA
PROJECT NO.
FIG. NO.
DRAWN: LO
CHK'D: JPH
89C3517
16
Woodward-Clyde Consultants


D
D'
SRI 1
PTPN 17
PTPN 9
PTPN 20
MW-12
ELEVATION, FEET
500
450
400
350
300
250
200
150
100
Any basis for steep angle?
422.1 S
410.6 S
398.9 I
396.9 D
393.5 D
374.5 S
373.1 D
383.6 S
306.5 I
295.6 D
420
410
400
390
380
370
360
350
340
330
320
310
300
LEGEND:
BEDROCK
300 EQUIPOTENTIAL LINES
337.9 WATER LEVEL ELEVATION MEASURED IN PIEZOMTERS
VERTICAL SCALE, FT
0
25
50
0
200
400
HORIZONTAL SCALE, FT
SPRING VALLEY WELL FIELD
AQUIFER TEST
HYDROGEOLOGIC CROSS-SECTION D-D'
POTENTIOMETRIC SURFACE FOR
JANUARY 9, 1992
DATE: 2/27/92
DESIGN: CA
PROJECT NO. 89C3517
FIG. NO. 17
DRAWN: LO
CHK'D: JPH
Woodward-Clyde Consultants
CONSULTING ENGINEERS, GEOLOGISTS, AND ENVIRONMENTAL SCIENTISTS

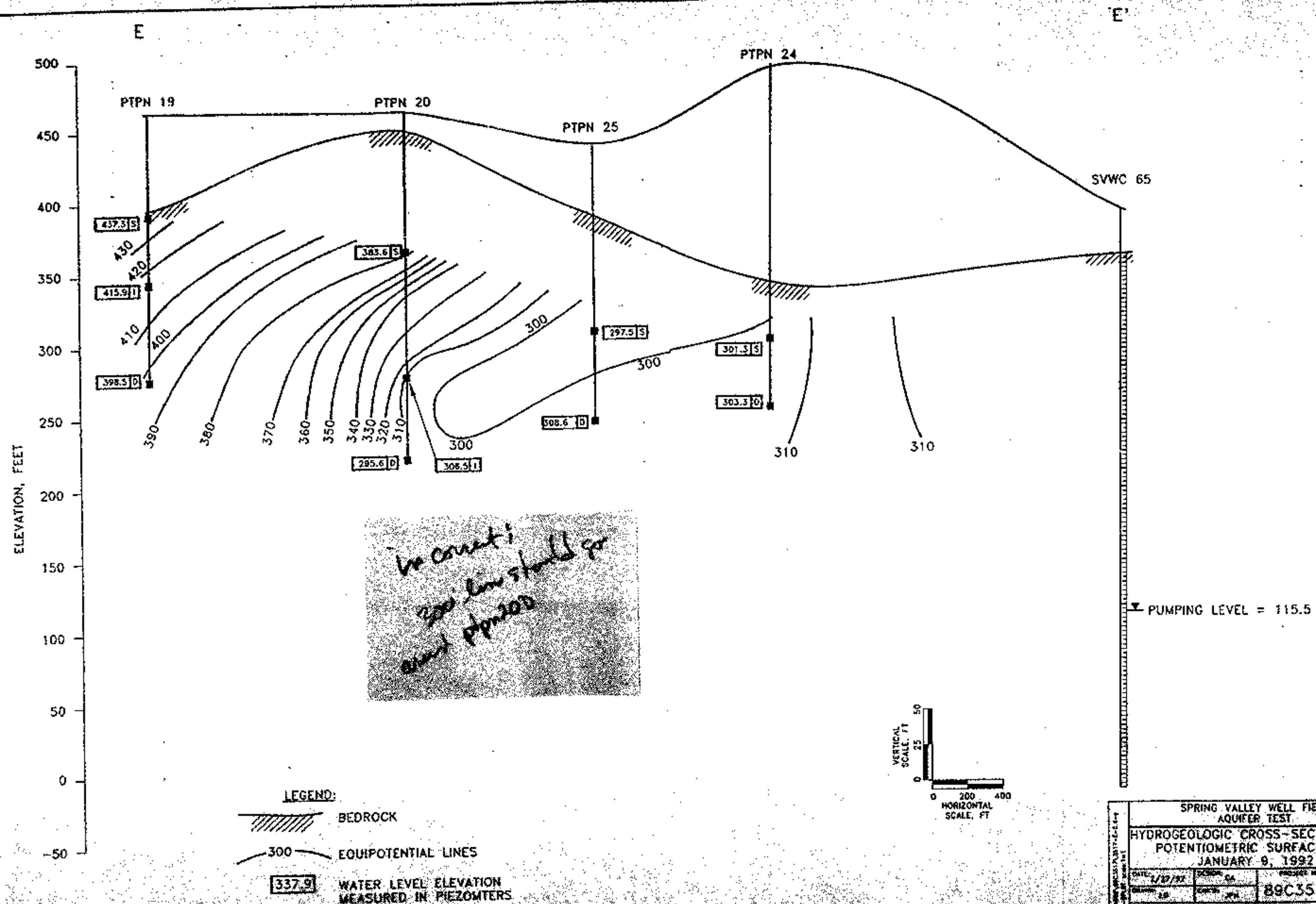


SPRING VALLEY WELL FIELD
AQUIFER TEST

HYDROGEOLOGIC CROSS-SECTION D-D'
POTENTIOMETRIC SURFACE FOR
JANUARY 9, 1992

DATE: 2/27/92	DESIGN: CA	PROJECT NO.	FIG. NO.
DRAWN: LO	CHK'D: JPH	89C3517	17

Woodward-Clyde Consultants
CONSULTING ENGINEERS, GEOLOGISTS, AND ENVIRONMENTAL SCIENTISTS

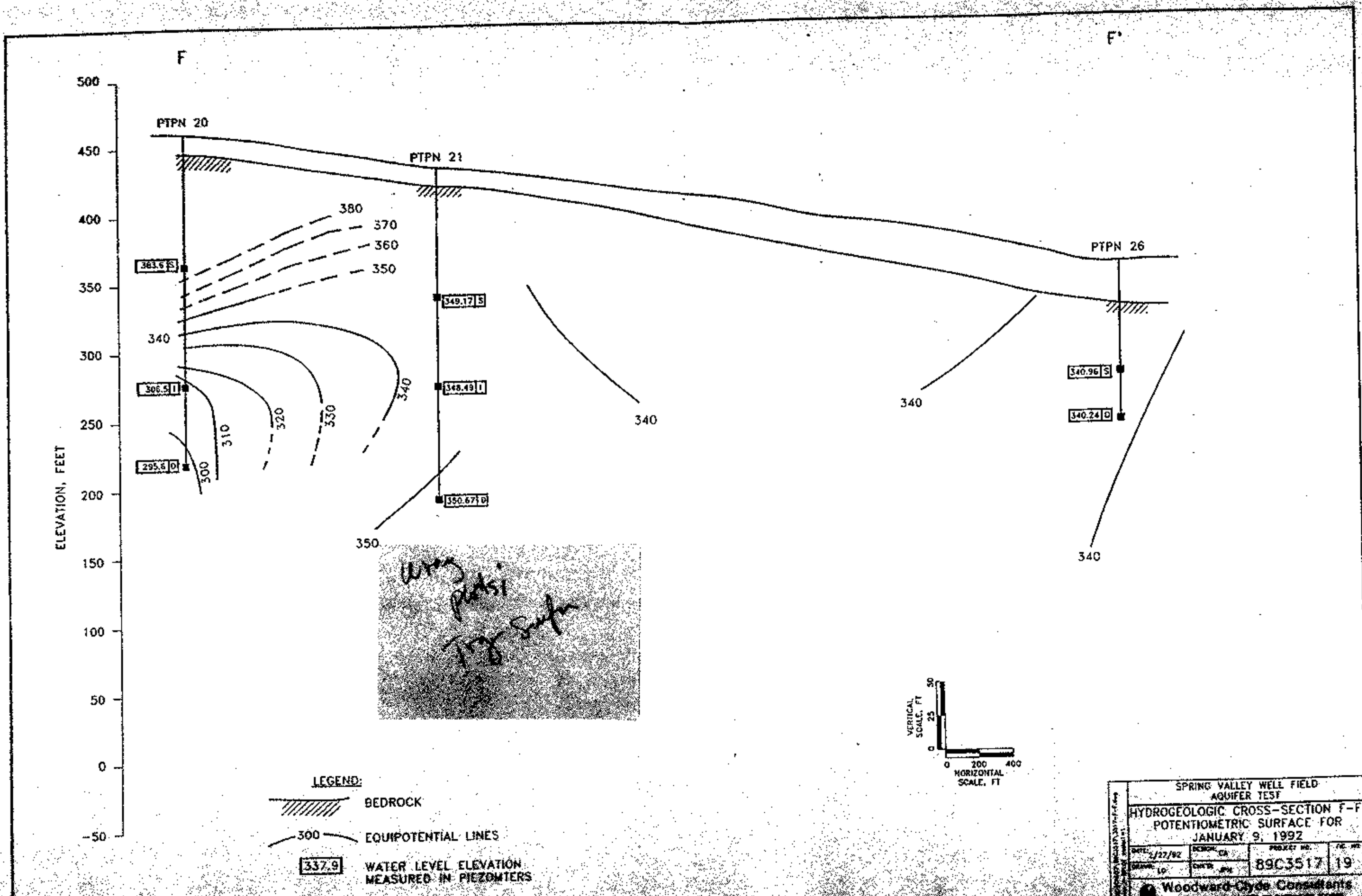


SPRING VALLEY WELL FIELD
AQUIFER TEST

HYDROGEOLOGIC CROSS-SECTION E-E'
POTENTIOMETRIC SURFACE FOR
JANUARY 9, 1992

DATE: 1/27/92	DESIGN: GA	PROJECT NO.	FIG. NO.
DRAWN: LP	CHKD: JFH	89C3517	18

Woodward-Clyde Consultants


F
F'
PTPN 20
PTPN 21
PTPN 26
ELEVATION, FEET
500
450
400
350
300
250
200
150
100
50
0
-50
363.6 S
306.5 I
295.6 D
349.17 S
348.49 I
350.67 D
340.96 S
340.24 D
380
370
360
350
340
330
320
310
300
VERTICAL SCALE, FT
0
25
50
0
200
400
HORIZONTAL SCALE, FT
LEGEND:
BEDROCK
EQUIPOTENTIAL LINES
337.9
WATER LEVEL ELEVATION MEASURED IN PIEZOMTERS
SPRING VALLEY WELL FIELD
AQUIFER TEST
HYDROGEOLOGIC CROSS-SECTION F-F'
POTENTIOMETRIC SURFACE FOR
JANUARY 9, 1992
2/27/92
89C3517
19
Woodward-Clyde Consultants

122 South Michigan Avenue
Suite 1920
Chicago, Illinois 60603
Telephone: 312-939-1000
Fax No. 312-939-4198

Woodward-Clyde Consultants

3/18/92
John Barnes,
An extra copy for your use
Dick Dana

DECEIVE
BUREAU OF EASTERN REMEDIAL ACTION

March 17, 1992

David Rubinton
NYSDEC
Division of Environmental Enforcement
202 Mamaroneck Avenue, Room 304
White Plains, NY 10601-5381

John Barnes
NYSDEC
50 Wolf Road, Rm. 208
Albany, NY 12233-7010

Subject: Focused Supplemental Remedial Investigation Report

Dear Sirs:

At the direction of counsel; Kelley, Drye and Warren and Whiteman, Osterman, and Hanna; Woodward-Clyde Consultants (WCC) is submitting the enclosed "Focused Supplemental Remedial Investigation Report, Spring Valley Well Field, Spring Valley, New York" to the New York State Department of Environmental Conservation as required by an Order on Consent dated 17 January 1992 (Index No. W3-0483-89-02-A, Site # 3-44-035).

The enclosed document consists of two volumes, one containing the text and figures, the other containing appendices. The Focused Supplemental Remedial Investigation Report summarizes the results of a pump test conducted at the Spring Valley Well Field from January 8, 1992 through January 23, 1992.

Very truly yours,

Paul E. Herr
Project Manager

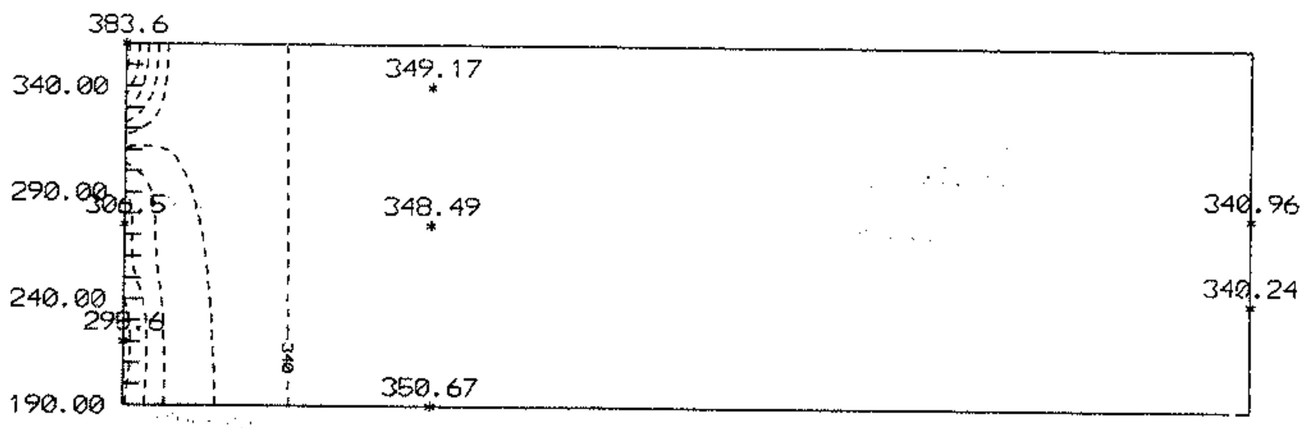
MAR 1992
Received
Division of
Environmental
Enforcement

:bjj

cc: Courtney Price
John Hanna
Paul Becker
Eric Nemeth
Tom West
Ralph Mallory
Sue McCormick
Ralph Manna
David Rubinton
David Markell
Michael J. O'Toole

Consulting Engineers, Geologists
and Environmental Scientists

Offices in Other Principal Cities


383.6
340.00
290.00
306.5
240.00
240.00
190.00
349.17
348.49
350.67
340
340.96
340.24