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CH2M HILL

Engineers
Planners
Economists
Scientists

95101175

Well Field Monitoring Study

Prepared for

City of Renton

June 1988

S20080.B0
EMC

CONTENTS

TABLES

FIGURES

RECOMMENDATIONS

The results of the study show that additional monitoring of the Cedar River aquifer should be conducted. Specifically, the following types of monitoring and supplemental tests are recommended:

1. Three to four additional monitoring wells should be installed on the south side of the Cedar River to better define aquifer properties and the extent of the zone of potential capture.

2. A monitoring well should be installed in the area of the bedrock narrows. The well would help define the thickness and properties of the aquifer in this area. The well should be completed to provide the City of Renton with a means of monitoring contaminant migration from upgradient sources.

3. Selected monitoring wells should be sampled annually to monitor water quality conditions in the Cedar River aquifer.

4. Water levels in the Cedar River aquifer should be monitored on a regular basis (e.g., quarterly) and during periods of extreme conditions (e.g., Cedar River flooding and high pumping following a dry summer). Continued monitoring will be useful in determining whether operation of the replacement wells will have any impact on the conclusions of the study.

5. Slug tests or pumping tests should be performed on selected monitoring wells to determine how aquifer properties vary.

6. A numerical groundwater model should be applied to the Cedar River aquifer. The model should be used to quantify rates and directions of groundwater movement and Cedar River-aquifer interactions. The model should also be used to develop emergency response strategies and to estimate the potential long-term yield of the aquifer.

EXECUTIVE SUMMARY

BACKGROUND

As part of the well field protection study conducted in 1984, available geologic and hydrologic information pertaining to the Cedar River aquifer and contributing recharge areas was reviewed. The study concluded that the available information was not sufficient to determine rates and directions of groundwater movement in the vicinity of the well field. As a result, the well field protection study recommended that water level fluctuations in the aquifer and Cedar River be monitored.

STUDY OBJECTIVES

Based on this recommendation, the City of Renton contracted with CH2M HILL to conduct a well field monitoring study. The original objectives of this study were to determine:

1. Rate and direction of groundwater movement under different pumping conditions

2. Interactions between the Cedar River and the aquifer

The City of Renton subsequently expanded the study to include two additional objectives:

1. Delineation of the boundaries of an aquifer protection area (APA) for the well field to satisfy the provisions of the City of Renton aquifer protection ordinance

2. Groundwater sampling to obtain additional information on existing water quality conditions in the Cedar River aquifer

MONITORING ACTIVITY

To meet these objectives, CH2M HILL designed a monitoring network consisting of 11 groundwater monitoring wells and three Cedar River stage gages. Figure 1 shows the location of each monitoring well and stage gage, as well as the location of the five production wells that constitute the City of Renton well field (PW1, PW2, PW3, PW8, and PW9).[1] Except for MW8 and MW9, all of the monitoring wells shown in Figure 1 were installed during the well field monitoring study.

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[1] Near the end of the well field monitoring study the City of Renton initiated construction of three new wells to replace PW1, PW2, and PW3; the three replacement wells (RW1, RW2, and RW3) are located immediately southeast of PW1 and PW2.

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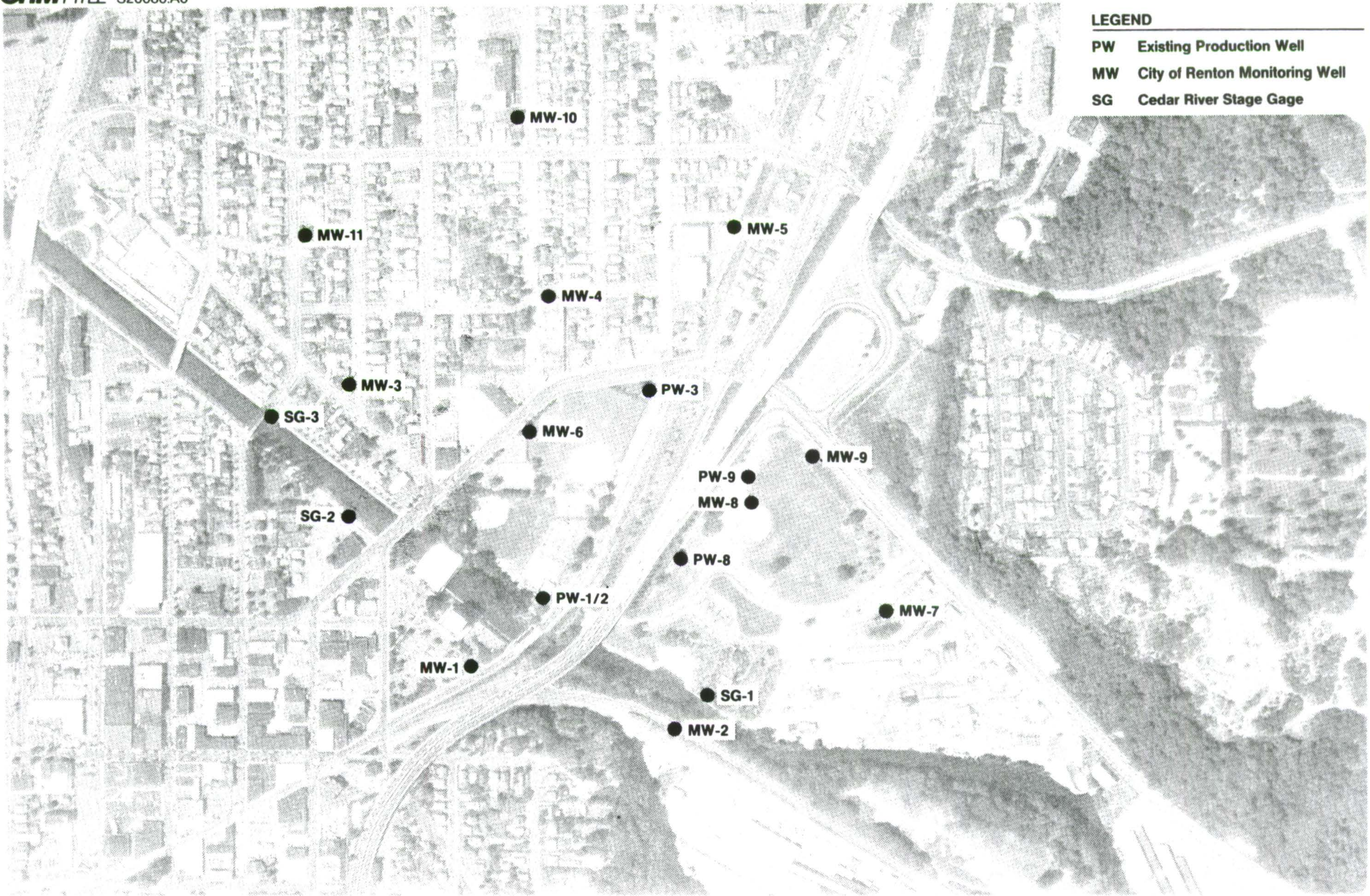

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SCALE (Approx.)

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FIGURE 1
MONITORING NETWORK
CITY OF RENTON, WA

MW8 and MW9 are observation wells installed during the construction and testing of PW9. The three Cedar River stage gages installed during the well field monitoring study are also shown in Figure 1.

CH2M HILL and City of Renton staff monitored water levels in the monitoring wells and production wells and at the Cedar River stage gages 21 times during the period of March 1986 to March 1987. The data were analyzed by contouring water levels to obtain potentiometric maps and by plotting water level variations with time at selected wells or stage gages to obtain hydrographs.

ZONE OF POTENTIAL CAPTURE

Based on the potentiometric maps and hydrographs, a zone of potential capture[1] for the well field was defined by determining probable directions of groundwater movement and Cedar River-aquifer interactions.

Figure 2 is a potentiometric map that shows groundwater elevations and probable directions of groundwater movement under a nonpumping condition (i.e., none of the wells is in operation). This potentiometric map indicates that the regional direction of groundwater movement is generally to the southwest and west, with a component to the northwest. The southwestern and western components are in the same direction as the original Cedar River streambed prior to its diversion towards Lake Washington. The northwestern component is in the direction of Lake Washington.

When one or more of the wells is pumped, a cone of depression forms around the well(s) causing a local reversal in the direction of groundwater movement back toward the well. Figure 3 is a potentiometric map that illustrates this condition.

The boundary between the portion of the Cedar River aquifer wherein groundwater movement continues in the regional direction (i.e., to the northwest) and the portion wherein groundwater movement reverses back toward the well field defines the boundary of the zone of potential capture. This boundary is referred to as a groundwater divide and is illustrated as a dashed line in Figure 3.

[1] The zone of potential capture is that portion of an aquifer wherein all groundwater would flow to a well or well field if it were pumped continuously.

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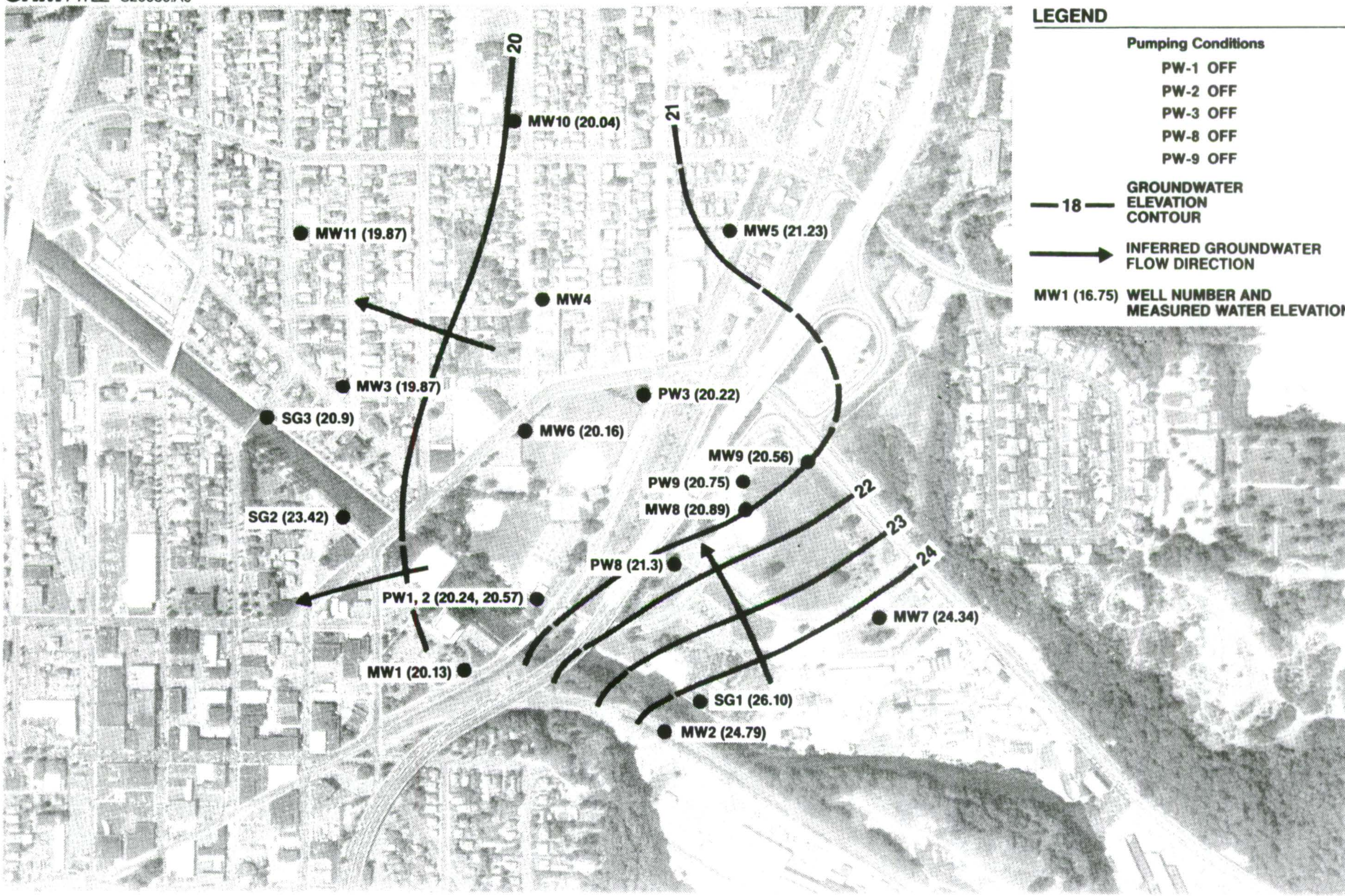

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SCALE (Approx.)

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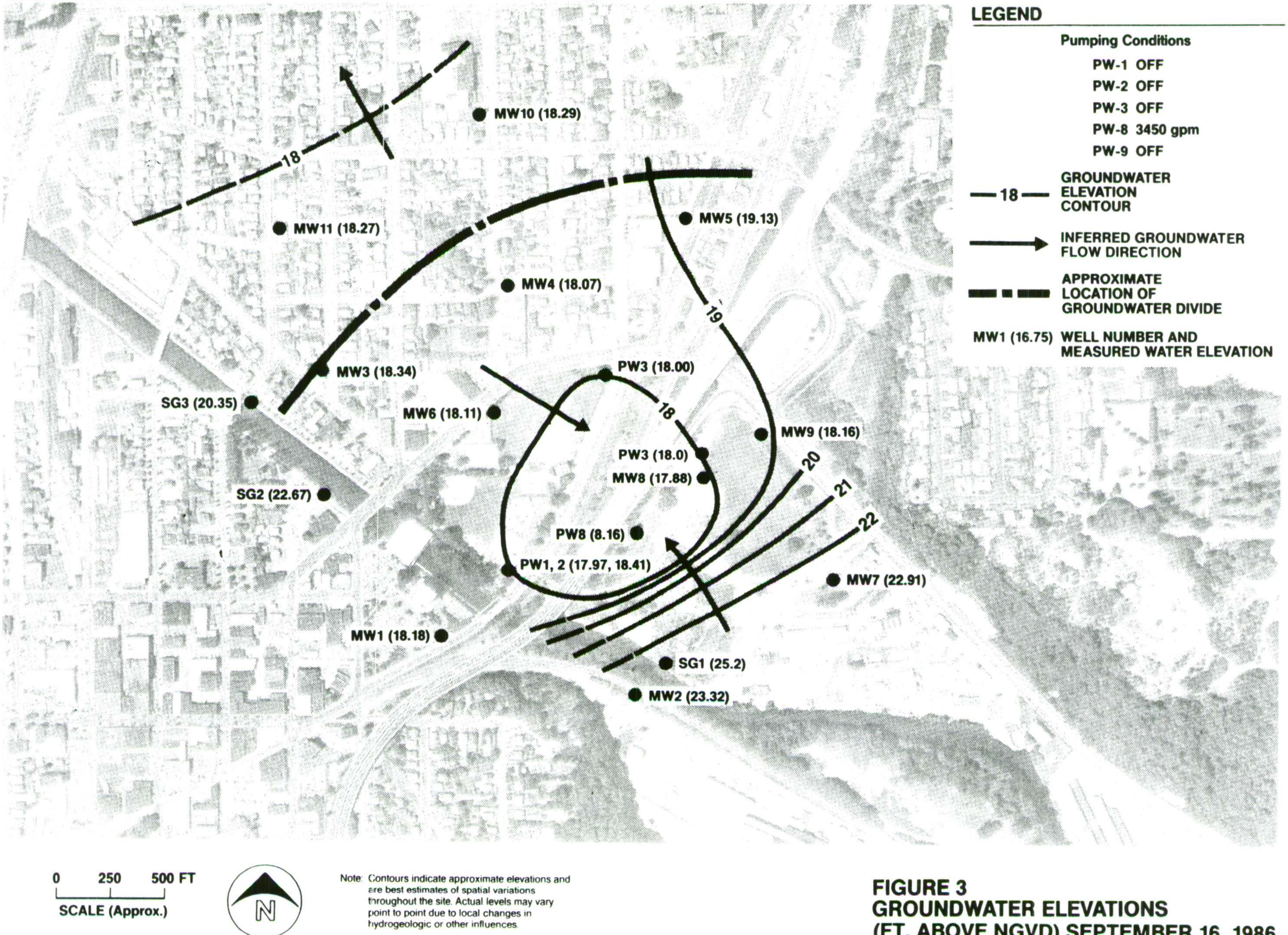
Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 2
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) JANUARY 23, 1987
CITY OF RENTON, WA

CH2M HILL S20080.A0



Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) SEPTEMBER 16, 1986
CITY OF RENTON, WA

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Cedar River-aquifer interactions identified as a result of the well field monitoring study include:

1. The Cedar River acts as a minor source of recharge to the aquifer; in the vicinity of the well field the amount of recharge is small compared to the flow in the Cedar River.

2. Well field pumping, particularly when PW1 and PW2 are in operation, influences groundwater movement on the opposite (south) side of the Cedar River.

Both interactions were tentatively identified based on the data collected during the well field monitoring study; they were confirmed based on additional water level data collected during a well field aquifer test conducted by the City of Renton. Measurements made by the USGS during the aquifer test were unable to detect any difference in Cedar River flow rate upstream and downstream of the well field. Continuous monitoring during the aquifer test showed that water level fluctuations in MW1 (see Figure 1) responded to changes in well field pumping.

Based on the determination of probable directions of groundwater movement and Cedar River-aquifer interactions, a zone of potential capture for purposes of aquifer protection was delineated. The position of the groundwater divide observed while pumping the well field at the current water right of 11,400 gallons per minute was selected as the boundary of the zone of potential capture. This boundary was extended to the opposite side of the Cedar River in recognition of the influence of the well field on groundwater movement south of the river.

AQUIFER PROTECTION AREA DELINEATION

The results of the well field monitoring study and well field protection study provided a basis for delineating a well field aquifer protection area (APA) to satisfy the provisions of the City of Renton aquifer protection ordinance. An APA encompasses the recharge area for a well or well field. The boundary of the well field APA was divided into two segments: a segment regionally downgradient of the well field and a segment regionally upgradient. The regionally downgradient boundary was delineated as the boundary of the zone of potential capture for purposes of aquifer protection (see Figure 4). The regionally upgradient boundary was delineated as the drainage basin boundary for the Cedar River valley.

The APA was subdivided into two zones. Zone 1, as defined in the aquifer protection ordinance, is the area between the 1-year groundwater travel time contour[1] and the well field. The location of the Zone 1 boundary was determined based on probable groundwater velocities. Groundwater velocities were estimated based on available pumping test data and hydraulic gradients estimated from the potentiometric maps.

Zone 2, as defined in the ordinance, is the area between the 1-year travel time contour and the boundary of the APA. Zone 2 encompasses upland areas north and south of the Cedar River valley that contribute recharge to the Cedar River aquifer (see Figure 4).

GROUNDWATER QUALITY

The well field monitoring study also consisted of sampling groundwater from four of the City of Renton monitoring wells. Priority pollutant analyses were conducted on the samples to obtain supplemental data on the quality of the Cedar River aquifer. As shown in Table 1, groundwater in the Cedar River aquifer satisfies current and proposed maximum contaminant levels (MCLs) specified by the Environmental Protection Agency for drinking water.

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[1] The 1-year groundwater travel time contour encompasses that portion of the aquifer wherein groundwater would migrate to the well field within 365 days.

Table 1
COMPARISON OF MAXIMUM CONCENTRATION LEVELS (µg/l) WITH
WATER QUALITY SAMPLING RESULTS
CITY OF RENTON MONITORING WELLS

Constituent	MCL[a] Current	MCL[a] Proposed	June 12, 1986, Sampling Results MW1	MW4	MW5	MW7	Detection Limit
Inorganic							
Arsenic	50		ND	ND	ND	ND	5
Barium	1,000		NM	NM	NM	NM	--
Cadmium	10		ND	ND	2	2	1
Chromium	50		1	1	3	2	--
Selenium	10		ND	ND	ND	ND	5
Lead	50		ND	ND	ND	ND	10
Nitrate	10,000		NM	NM	NM	NM	--
Organic							
Endrin	0.2		ND	ND	ND	ND	0.04
Lindane	4		ND	ND	ND	ND	0.02
Methoxychlor	100		ND	ND	ND	ND	0.1
Toxaphene	0.5		ND	ND	ND	ND	5
2,4-D	100						
2,4,5-TP silvex	10						
Benzene		5	ND	ND	ND	ND	1
Carbon tetrachloride		5	ND	ND	ND	ND	1
1,2-Dichloroethane		5	ND	ND	ND	ND	1
1,1-Dichloroethylene		7	ND	ND	ND	ND	1
p-Dichlorobenzene		750	ND	ND	ND	ND	1
1,1,1-Trichloroethane		200	ND	ND	ND	ND	1
Trichloroethylene		5	ND	ND	ND	ND	1
Vinyl chloride		1	ND	ND	ND	ND	1

[a]Maximum contaminant levels, U.S. Environmental Protection Agency, September 1986.

Note: ND = not detected.
NM = not measured.

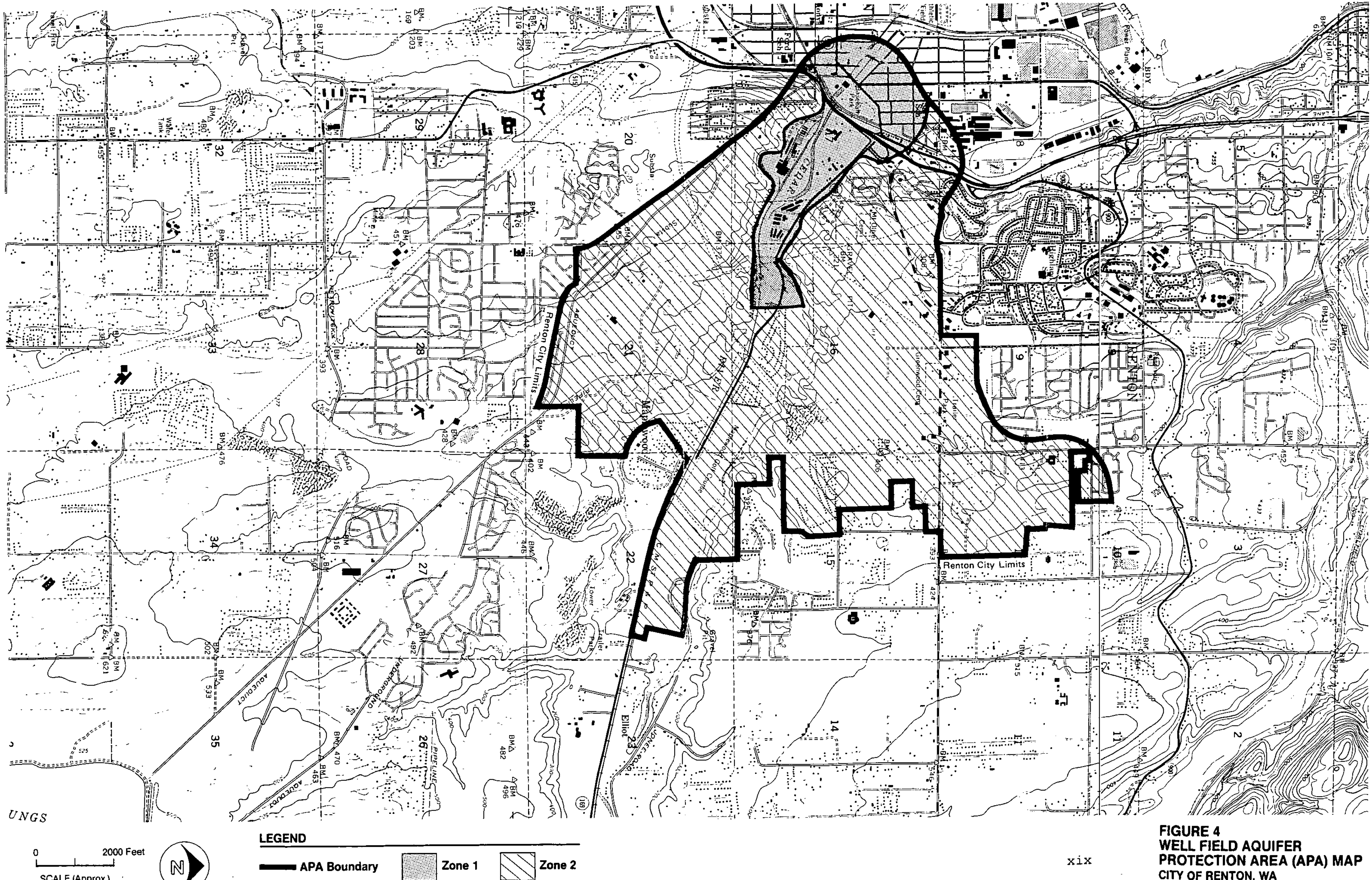

FIGURE 4
WELL FIELD AQUIFER
PROTECTION AREA (APA) MAP
CITY OF RENTON, WA

Section 1
INTRODUCTION

PROJECT DESCRIPTION

Background

In 1984 the City of Renton completed the well field protection study (CH2M HILL, 1984). The scope of this study included:

1. An evaluation of available geologic and hydrologic information pertaining to the Cedar River aquifer and contributing recharge areas

2. An identification of potential contamination sources and their possible impact on the City of Renton well field

3. Development of possible methods for eliminating or controlling potential contamination sources or minimizing their impact on the well field

The well field protection study concluded that the available geologic and hydrologic information was not sufficient to determine rates and directions of groundwater movement in the vicinity of the well field. As a result, the study recommended that Cedar River levels and groundwater elevations be monitored to determine how the Cedar River aquifer responds to different well field pumping conditions and seasonal variations in streamflow and aquifer recharge. Based on this recommendation, the City of Renton contracted with CH2M HILL to conduct the well field monitoring study.

Objectives

The original objectives of the well field monitoring study were to determine:

1. Rate and direction of groundwater movement under different pumping conditions

2. Interactions between the Cedar River and the aquifer

The City of Renton subsequently expanded the study to include two additional objectives:

1. Delineation of the boundaries of an aquifer protection area (APA) for the well field to satisfy the provisions of the City of Renton aquifer protection ordinance

2. Groundwater sampling to obtain additional information on existing water quality conditions in the Cedar River aquifer

SCOPE OF THE REPORT

This report documents the work that was conducted to meet each of the study objectives. The scope of work, as outlined in an engineering services contract between the City of Renton and CH2M HILL, was as follows:

1. Determine the number, location, size, and configuration of groundwater monitoring wells and river stage gages to measure water level fluctuations in the vicinity of the well field

2. Identify required monitoring equipment and develop a monitoring program

3. Subcontract the drilling and construction of the monitoring wells

4. Assist the City of Renton in the installation of the monitoring equipment and in the initiation of data collection

5. Determine rates and directions of groundwater movement based on water level data collected by the City of Renton

6. Delineate the boundaries of an APA for the well field

7. Analyze groundwater samples collected from selected monitoring wells to obtain additional groundwater quality information on the Cedar River aquifer

REPORT ORGANIZATION

The report is organized in four major sections. Section 2 discusses the monitoring network that was installed to measure water level fluctuations in the Cedar River aquifer and Cedar River. This section presents monitoring well and stage gage locations and discusses the methods used to drill and construct the monitoring wells and to measure water levels. Finally, the lateral extent of the Cedar River aquifer is presented based on available geologic information.

Section 3 discusses how the water level data collected by the City of Renton were analyzed to determine directions of groundwater movement in the vicinity of the well field and Cedar River-aquifer interactions. This section also discusses how the estimated directions of groundwater movement were, in turn, used to delineate a "zone of potential capture"[1] for the well field.

Section 4 discusses how the boundary of the zone of potential capture was combined with the Cedar River drainage boundary to delineate the boundary of an APA for the City of Renton well field.

Finally, Section 5 presents water quality sampling results.

RELATED STUDIES

During the same time frame that the well field monitoring study was being conducted, several other studies were conducted in the vicinity of the well field by Ecology and Environment Incorporated (E&E), Olympic Pipe Line Company (OLPC), Pacific Car and Foundary Company (PACCAR), and RH2 Engineering. In addition, the City of Renton drilled three new production wells to replace existing production wells (PW1, PW2, and PW3), and a test well in the Maplewood Golf Course. Investigations conducted as part of these studies provided additional hydrogeologic and groundwater quality information in the vicinity of the well field. Each study is summarized below.

Site Inspection of Pacific Car and Foundary Company (E&E, 1986)

E&E conducted a file review and site inspection of the PACCAR facility in Renton, Washington. This facility is located directly north of the City of Renton well field. The purpose of the study was to evaluate the facility's status within the Environmental Protection Agency (EPA) Uncontrolled Hazardous Waste Site Program. During the site inspection, soil and groundwater samples were collected on the PACCAR facility, and groundwater samples were collected from selected City of Renton monitoring and production wells. Analyses of the groundwater samples produced additional information on groundwater quality in the Cedar River aquifer.

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[1] The zone of potential capture is that portion of an aquifer wherein all groundwater would flow to a well or well field if it were pumped continuously.

Olympic Pipe Line Company Leak Abatement Study (GeoEngineers, Inc., 1986b, 1987a, 1987b, and 1987c)

On October 1, 1986, OLPC initiated a study to evaluate a leak from its two product pipelines that traverse the Cedar River valley approximately 1 mile east and regionally upgradient of the well field. The study initially involved soil-gas reconnaissance to determine the leak location. Subsequently, a hydrogeologic investigation involving the installation of 31 monitoring wells and groundwater sampling was conducted to determine the extent of groundwater contamination. Analyses of groundwater samples found benzene, toluene, and xylene (typical components of petroleum products) to be present in several of the monitoring wells. Measured groundwater elevations showed that groundwater in the vicinity of the leak moves to the southwest and generally discharges to the Cedar River. Little free petroleum product was detected in the monitoring wells; most of it was found to be distributed in the unsaturated zone. Remedial actions implemented at the site include two vapor recovery systems and three fuel recovery wells. Ongoing monitoring of spill cleanup has been conducted.

PACCAR Defense Systems Site Assessment and Remedial Action Plan (Hart-Crowser, 1986a, 1986b, and 1987b)

PACCAR conducted a site assessment of its facility in Renton. The site assessment involved combining the results of a number of earlier studies wherein soil and groundwater sampling was conducted. The study concluded that soils beneath the facility contain elevated concentrations of metals and low concentrations of volatile and semivolatile organic chemicals. Except for arsenic, nickel, and chromium, metal concentrations in groundwater beneath the facility generally met primary drinking water standards. Low concentrations of volatile and semivolatile organic chemicals were detected in onsite monitoring wells. The remedial action plan recommends no remedial actions be implemented at the facility except in one area where high concentrations of polynuclear aromatic hydrocarbons (PAH) were detected in soil. Remedial actions proposed for this area include removal of visually contaminated soil, backfilling the area with clean soil, paving the area with asphalt, and quarterly sampling of groundwater. Since completing the site assessment and remedial action evaluation, PACCAR initiated additional site investigations that included the installation of offsite monitoring wells and monthly water level monitoring. Based on water level monitoring during the period of May to June of 1987, it was concluded that the "capture area" of the Renton well field extends to the southeastern corner of the PACCAR site and that groundwater flow from the PACCAR site to the well field is probably less than 10 gpm.

Well Field Aquifer Test (RH2 Engineering, 1987a and 1987b)

During the period of June 24 to 26, 1987, a well field aquifer test was conducted. The test consisted of an 8-hour nonpumping period to allow the aquifer to recover to relatively static conditions. Next, all of the existing production wells and a recently completed replacement production well were pumped for 24 hours at a rate approximately equal to the current well field water right of 11,400 gallons per minute (gpm). This was followed by an increase in the pumping rate to 15,000 gpm for a period of 25 hours. The test concluded with a 1/2-hour shutdown of all the wells. During the test, water levels in the production wells and selected monitoring wells were measured. The flow rate of the Cedar River was measured upstream and downstream of the well field at the end of the 8-hour nonpumping period and the two pumping periods. The results of the test showed that there was no detectable decrease in flow in the Cedar River as a result of pumping the well field at either 11,400 gpm or 15,000 gpm. The results also showed that pumping of the well field influences groundwater movement south of the Cedar River, indicating that the river does not act as a hydraulic barrier to groundwater movement, as was originally thought.

Maplewood Golf Course Test Well (GeoEngineers, Inc., 1986a)

A test well was drilled at the Maplewood Golf Course to evaluate the potential for developing an additional source of municipal water supply. The 8-inch test well was drilled to a depth of 182 feet below ground surface. During drilling, two aquifer units were encountered, an upper aquifer extending from 15 to 44 feet below ground surface and a lower aquifer extending from 150 to 177 feet below ground surface. A 15-foot well screen was installed between the depths of 157 and 172 feet. Pumping test results indicate that the well could yield between 300 and 500 gpm. Water quality sampling found that manganese exceeded the drinking water standard.

Replacement Production Wells (Hart-Crowser, 1987a)

The City of Renton drilled three new production wells to replace existing production wells PW1, PW2, and PW3; the replacement wells are referred to as RW1, RW2, and RW3. All three wells are located 50 to 100 feet southeast of PW1 and PW2. The wells range in depth from 70 to 96 feet below ground surface and have a maximum design pumping rate of 6,600 gpm.

Section 2
MONITORING NETWORK

Monitoring wells and Cedar River stage gaging stations were constructed to measure water level fluctuations in the vicinity of the well field. This chapter describes monitoring well and stage gage locations, monitoring well drilling and construction methods, and water level measurement procedures. It also presents the approximate extent of the Cedar River aquifer based on available hydrogeologic information.

MONITORING LOCATIONS

Figure 2-1 shows the general location of the five production wells (PW1, PW2, PW3, PW8, and PW9) that form the City of Renton well field. Near the end of the well field monitoring study the City of Renton completed construction of replacement wells RW1, RW2, and RW3. RW1, RW2, and RW3 are located 50 to 100 feet southeast of wells PW1 and PW2 (see Figure 2-1). Once construction is completed, the City of Renton plans to use PW1 and PW2 as observation wells and PW3 as an emergency supply well.

Prior to the initiation of the well field monitoring study there were two monitoring wells (MW8 and MW9) in the immediate vicinity of the well field (see Figure 2-1). A two-phased approach was used to install nine additional monitoring wells. During Phase 1, five monitoring wells (MW1, MW3, MW4, MW5, and MW6) were installed between 500 and 1,300 feet regionally downgradient of the well field (see Figure 2-2). The reason for locating these wells regionally downgradient of the well field was to define the extent to which the well field reverses the regional groundwater gradient back toward the well field when the production wells are in operation. Except for MW1, all of the wells were installed north of the Cedar River because it was originally thought that the river was a significant source of recharge and acts as a hydraulic barrier to groundwater movement. As will be discussed later, the Cedar River is actually a minor source of recharge in the vicinity of the well field and pumping does influence groundwater movement south of the river. The other well installed during Phase 1 (MW7) was located regionally upgradient of the well field (see Figure 2-2).

After monitoring groundwater elevations for several months, it was discovered that the well field influences groundwater movement farther to the northwest than was originally anticipated. Under Phase 2, two additional monitoring wells (MW10 and MW11) were installed regionally downgradient of MW4 (see Figure 2-2). At the same time, permission was granted by Burlington Northern to install another regionally upgradient well (MW2) on the south side of the Cedar River.

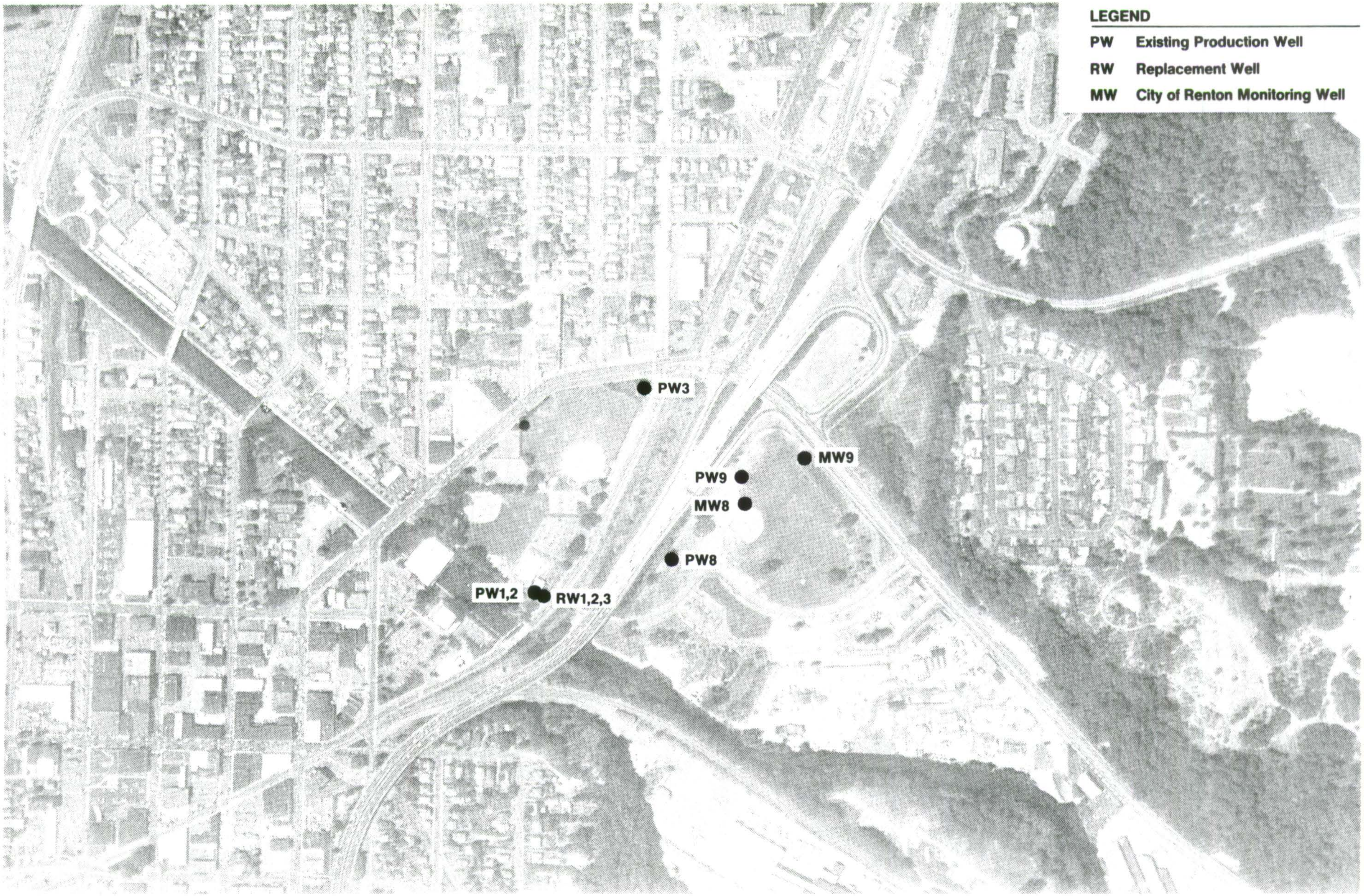

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FIGURE 2-1
WELL FIELD STUDY AREA
CITY OF RENTON, WA

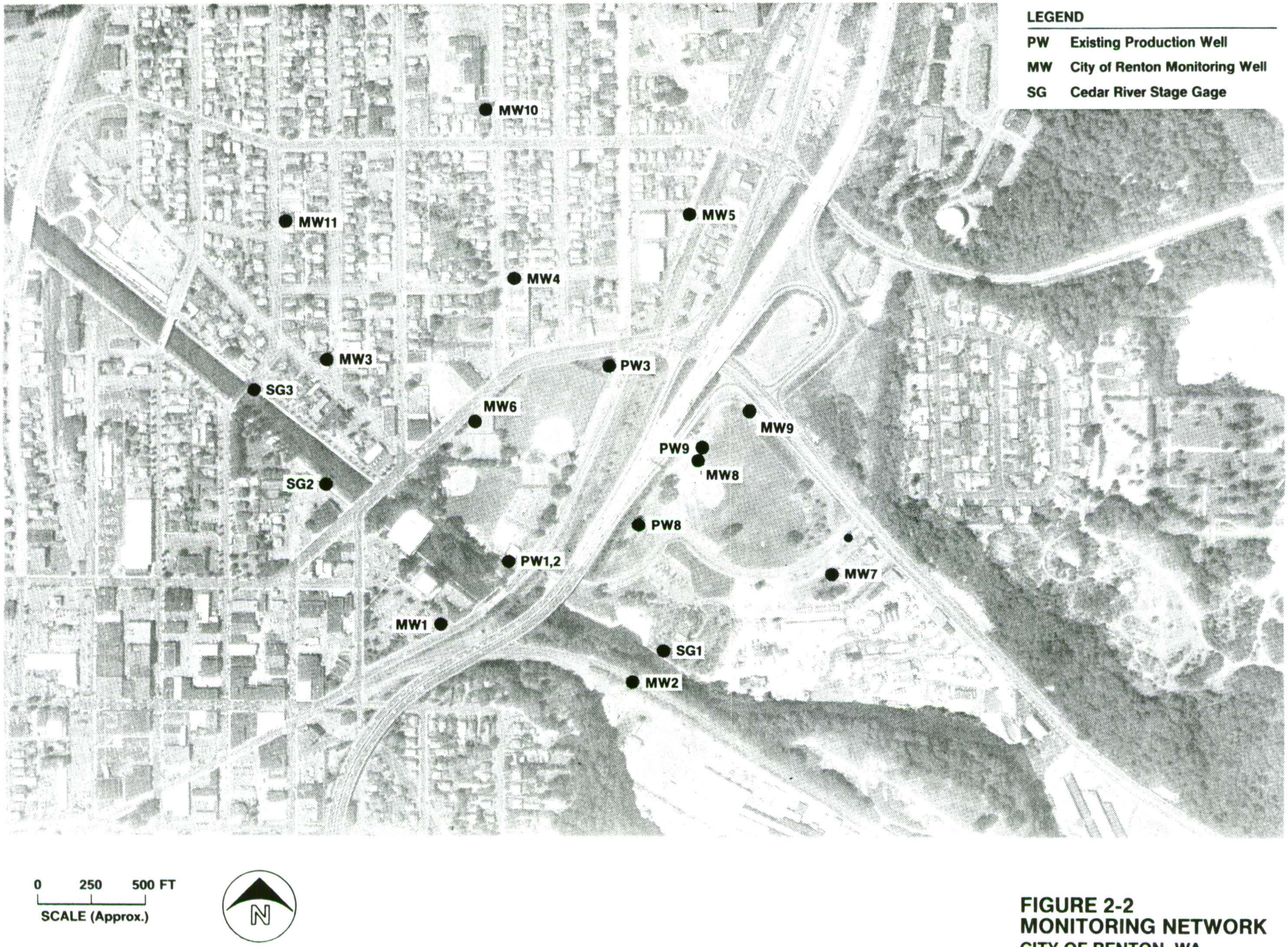


FIGURE 2-2
MONITORING NETWORK
CITY OF RENTON, WA

Detailed site maps showing the specific location of each monitoring well installed during the well field monitoring study are included in Appendix A.

Figure 2-2 also shows the location of the three Cedar River stage gaging (SG) stations. SG1 was located directly across the river from MW2, near Carco Theatre. The staff gage at the USGS gaging station downstream of the Mill Avenue bridge was used for SG2. SG3 was located on the Wells Avenue bridge. Except for SG2, the stage gaging stations consisted of an existing reference point that could be conveniently used to measure the elevation of the Cedar River. Thus, staff gages were not installed at SG1 or SG3. Detailed descriptions of the location of each stage gaging station are presented later in this section.

WELL DRILLING

Hokkaido Drilling and Development drilled, constructed, and developed each new monitoring well.

Prior to drilling, well locations were checked for any underground utilities. The private firm, Underground Utility Locators, was contacted and informed of the proposed well locations. Leaflets explaining the purpose of the project and the likelihood of noise were distributed to the residents living near each well prior to beginning drilling operations.

All monitoring wells were drilled using the cable-tool method. The method consists of lifting and dropping a string of tools suspended on a cable. The bit at the bottom of the tool string rotates a few degrees between each stroke so that the cutting face of the bit strikes a different area of the hole with each stroke. Cuttings were bailed from the hole after advancing the bit anywhere from 2 to 10 feet. Sections of 8-inch steel casing were driven ahead of the bit to keep the hole open after the cuttings were bailed. Boring logs were kept by a geologist. After the desired depth was reached, the drill string was pulled from the hole, and well construction was initiated.

Appendix B contains well logs for each monitoring well describing the types of geologic materials encountered while drilling. Well logs for the existing and replacement production wells and the Maplewood Golf Course test well are provided in Appendix C.

WELL CONSTRUCTION AND DEVELOPMENT

Figure 2-3 shows the general construction of each monitoring well. PVC casing (2-inch) was assembled and lowered into the borehole, and centering guides were placed at both ends of the screen to assure an even sand pack around the screen.

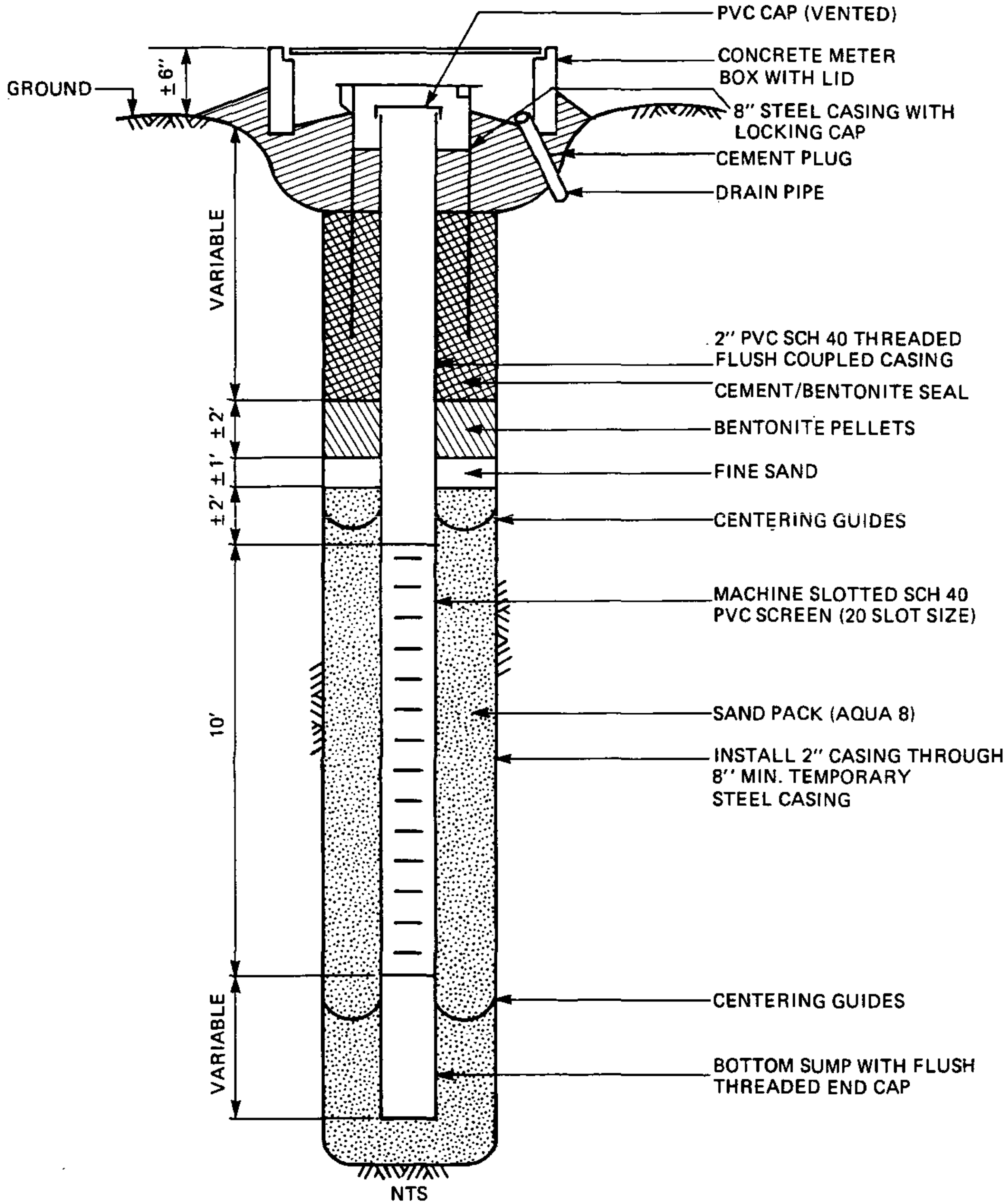


FIGURE 2-3
GENERALIZED WELL CONSTRUCTION
CITY OF RENTON MONITORING WELLS
CITY OF RENTON, WA

The 8-inch steel casing was pulled back about 3 feet to allow the native formation to cave around the bottom sump, thus anchoring the well casing. Sand pack was then placed to a level of about 2 feet above the top of the screen as the 8-inch steel casing was removed. Fine sand, bentonite pellets, and a cement/bentonite seal were placed around the well casing as shown in Figure 2-3.

Concrete meter boxes were used to complete the wells at the surface (see Figure 2-3). A locking cap was placed over each well. The PVC cap used to cover the well casing was vented to allow the water level in the wells to change freely. A drain pipe was installed to allow any water collecting in the meter box to drain away. The surface completion details apply to all wells except for MW2. MW2 is completed with an 8-inch steel casing extending 2-1/2 feet above ground.

After the installation was complete, the wells were developed. The development process removed fines in and around the sand pack and also removed nonformation water introduced during the drilling process. The wells were developed using compressed air introduced into the bottom sump to produce a surge-and-lift action. Development was continued until visibly clear water was produced from the wells, usually within about 1/2 hour.

Appendix B contains well construction information for each well. Table 2-1 provides the total well depth, screened interval, and sump length for each monitoring well.

Table 2-1
MONITORING WELL CONSTRUCTION DETAILS

Well Number	Total Depth (ft)	Screened Interval (ft)	Sump Length (ft)
MW1	49	38 to 48	1
MW2	50	35 to 45	5
MW3	53	38 to 48	5
MW4	50	35 to 45	5
MW5	50	35 to 45	5
MW6	50	35 to 45	5
MW7	50	35 to 45	5
MW10	37	22 to 32	5
MW11	40	25 to 35	5

WATER LEVEL ELEVATIONS

Each well and stream gage was surveyed to determine the elevation of a convenient point for measuring water levels. Table 2-2 lists the measuring point elevation for each production and monitoring well. Table 2-3 provides the same information for each stage gage, including the location of the measuring point.

During the period of March 1986 to March 1987, groundwater and Cedar River elevations were measured 21 times. The first two rounds of monitoring were conducted by CH2M HILL staff on March 7 and 12, 1986. Subsequent rounds were conducted by City of Renton staff. CH2M HILL provided City of Renton staff with training on proper water level measurement procedures and assisted City of Renton staff on several of their first monitoring rounds. To promote consistency in the collection and reporting of water level monitoring results, the City of Renton was provided a standard form for recording measurements (see Figure 2-4). CH2M HILL and the City of Renton made all water level measurements with an electronic water level sounder. Table 2-4 summarizes all the water level data collected during the study.

Table 2-4 also contains the water levels measured by CH2M HILL during the well field aquifer test. Water levels in all of the monitoring wells were measured three times: (1) at the end of the initial 8-hour recovery period, (2) after pumping the well field at 11,400 gpm for 24 hours, and (3) after pumping the well field at 15,000 gpm for 25 hours.

EXTENT OF THE CEDAR RIVER AQUIFER

Monitoring well, replacement well, and test well installation provided additional hydrogeologic information useful in delineating the approximate extent of the Cedar River aquifer (see Figure 2-5). It is important to recognize that the aquifer limits shown in Figure 2-5 do not necessarily represent distinct boundaries that separate geologic materials containing groundwater. Rather, these limits represent the extent of the highly productive sand, gravel, and cobble deposits found within the Cedar River valley and west of the mouth of the valley. Groundwater occurs in less productive materials beyond the limits shown in Figure 2-5; these less productive materials contribute recharge to and accept discharge from the Cedar River aquifer. The limits of the aquifer are described below.

Lateral Extent

The lateral (northern and southern) extent of the aquifer is defined by the Cedar River valley walls. The walls delineate the contact between the alluvial and delta deposits of the aquifer and the glacial drift, till, and outwash deposits of the uplands.

Table 2-2
SURVEYED ELEVATION OF EACH NEW MONITORING WELL
AND EXISTING OBSERVATION AND PRODUCTION WELLS

Well	Elevation (NGVD)[a]	Description of Measuring Point
MW1	40.91	Top of PVC casing[b]
MW2	53.32	Top of PVC casing[b]
MW3	35.50	Top of PVC casing[b]
MW4	36.44	Top of PVC casing[b]
MW5	38.32	Top of PVC casing[b]
MW6	38.83	Top of PVC casing[b]
MW7	47.16	Top of PVC casing[b]
MW8	45.21	Top of steel casing[b]
MW9	46.26	Top of steel casing[b]
MW10	34.12	Top of PVC casing[b]
MW11	32.24	Top of PVC casing[b]
PW1	39.4	Access port for transducer (red bushing)[c]
PW2	39.79	Access port for well casing[d]
PW3	30.9	Access port for transducer (red bushing)[c]
PW8	45.70	Top of 1-inch pipe providing access to casing[b]
PW9	45.13	Top of 1-inch pipe providing access to casing[b]

[a]National Geodetic vertical datum.

[b]With cap removed.

[c]Offset of access port from well casing accounted for in measured elevation.

[d]Marked in black "MP."

Upgradient Extent

Based on available information, it is difficult to delineate the upgradient (i.e., eastern) extent of the aquifer. The aquifer appears to extend at least several miles upgradient of the bedrock narrows (see Figure 2-5). Monitoring wells installed as part of the Olympic Pipe Line leak abatement study (GeoEngineers, Inc., 1986b) encountered alluvial sands and gravels, as did a test well installed at the Maplewood Golf Course (GeoEngineers, Inc., 1986a); Figure 2-5 shows the location of the test well.

CITY OF RENTON
Public Works Department

WATER LEVEL MEASUREMENTS (Field)

Measured by ______________________________

Weather Conditions ______________________________

DATE	TIME	LOCA-TION	Meas. Point Elevation	Depth to Water	Transducer Elevation	Transducer Reading	Water Elevation **	Pumping Rate (gpm)
		PW1	39.4		-29.1			
		PW2	39.79					
		PW3	31.00		-21.4			
		PW8	45.70		-23.8			
		PW9	45.13		-29.7			
		MW1	40.91					
		MW2	53.32					
		MW3	35.50					
		MW4	36.44					
		MW5	38.32					
		MW6	38.83					
		MW7	47.16					
		MW8	45.21		-29.9			
		MW9	46.26		-27.6			
		MW10	34.12					
		MW11	32.24					
		SG1	32.6					
		SG2*	15.1					
		SG3	36.5					
		SG4	34.96					

* At SG2 Water Elevation = Staff Gage Reading + 15.1

** Water Elevation = Meas. Point Elevation — Depth to Water and/or Transducer Elevation + Transducer Reading

FIGURE 2-4
WATER LEVEL RECORDING FORM
CITY OF RENTON

Table 2-3
SURVEYED ELEVATION OF EACH STAGE GAUGE

Gage	Elevation (NGVD)[a]	Description of Measuring Point
SG1	32.6	Painted (red) rock near upstream end of rock retaining wall, south of Carco Theatre in Cedar River Park
SG2	15.1[b]	Staff gage on 2x6 post
SG3	36.5	Top painted bolt on guardrail post in centerline, upstream edge of Wells Avenue bridge

[a]National Geodetic vertical datum.

[b]River elevation at SG2 is equal to staff gage reading plus 15.1 feet.

Downgradient Extent

The downgradient (i.e., northwest, west, and southwest) extent of the aquifer is also difficult to delineate because of the complex interlayering of the alluvial and delta deposits of the Cedar River with the deposits of Lake Washington. The alluvial and delta deposits consist of coarse gravel and cobbles near the mouth of the Cedar River valley. These deposits become progressively finer grained in a radial outward direction, grading from sand and gravel to silty sands. Ultimately, silts and layers of peat, indicative of lake-type deposits, are encountered.

This trend is illustrated in a geologic cross-section which starts at PW1 and progresses north through the PACCAR facility (see Figure 2-6). Near PW1 the aquifer materials are predominantly sand, gravel, and some cobbles. As one moves to the north, the predominance of sand increases. In the vicinity of HC4I and MW10, aquifer materials transition from sand to silty sand and silt. Another transition occurs in the vicinity of LW12, with the occurrence of peat layers. It is this transition that indicates the probable northern boundary of the Cedar River aquifer.

Figure 2-7 shows the location of the wells used to construct the cross-section in relationship to the City of Renton monitoring well network and a network of "deep" monitoring wells installed on and near the PACCAR facility.

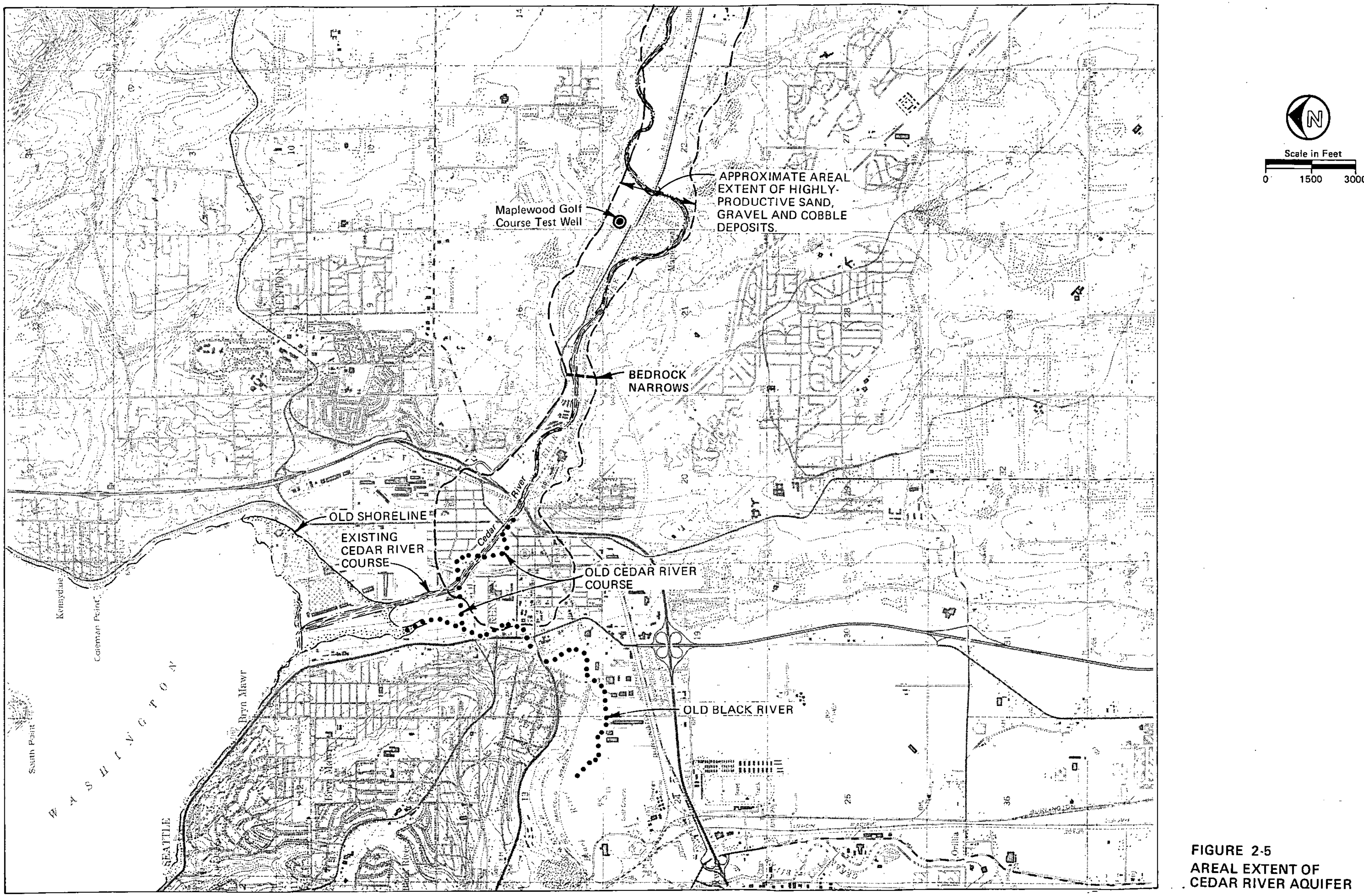


FIGURE 2-5
AREAL EXTENT OF CEDAR RIVER AQUIFER

Table 2-4
SUMMARY OF WATER LEVELS MEASURED DURING THE WELL FIELD MONITORING STUDY AND WELL FIELD AQUIFER TEST (NGVD)[a]

	Well Field Operation					Production Wells					Monitoring Wells											Stage Gages		
Date	PW1	PW2	PW3	PW8	PW9	PW1	PW2	PW3	PW8	PW9	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8	MW9	MW10	MW11	SG1	SG2	SG3
3/7/86				X		19.37	20.94	NM	NM	20.86	20.88	NM	20.97	21.02	22.27	20.9	25.07	20.8	NM	NM	NM	27.2	27.0[b]	23.2
3/12/86	X			X	X	20.59	19.07	20.9	10.68	14.94	20.92	NM	21.04	21.14	22.3	20.96	25.27	19.05	21.64	NM	NM	27.3	27.2[b]	23.0
6/18/86				X		18.8	19.14	18.6	8.56	18.93	19.03	24.32	19.03	18.79	19.89	18.83	23.71	18.76	18.92	NM	18.94	23.22[b]	23.05	20.96
6/24/86	X	X	X			8.13	8.52	NM	17.1	16.83	16.49	23.85	NM	17.15	18.44	16.68	23.16	16.71	16.79	NM	NM	26.04	22.1	NM
7/8/86	X	X	X			9.10	4.64	18.00	18.48	17.96	16.87	23.85	25.44[b]	17.36	18.67	17.13	23.31	18.08	17.66	17.12	18.04	25.60	22.70	20.53
7/15/86		X	X			13.90	8.46	15.30	18.96	18.43	17.49	23.90	18.15	17.61	18.92	17.60	23.49	18.46	18.10	18.22	18.14	25.37	22.54	20.34
7/28/86	X	X		X		4.70	4.19	17.4	8.00	17.68	16.75	23.42	17.80	17.62	18.92	17.33	22.81	17.64	17.86	18.02	17.89	25.09	22.46	20.26
8/7/86	X		X	X	X	13.64	NM	NM	5.97	10.92	16.36	22.71	17.13	16.02	17.04	15.91	21.86	13.91	14.63	17.2	17.11	25.13	22.52	20.23
8/8/86	X		X	X	X	13.44	NM	NM	6.03	10.63	16.3	22.69	17.05	15.83	16.82	15.77	21.8	13.62	14.43	17.06	16.99	25.08	22.5	20.19
8/18/86	X	X		X		8.09	8.09	16.46	7.09	16.59	15.91	22.92	17.12	16.64	17.84	16.2	22.33	16.51	16.76	19.07[b]	15.34[b]	24.92	22.48	20.18
8/26/86	X	X		X		7.95	8.35	16.16	7.15	20.13[b]	15.67	22.8	17.0	16.44	17.72	16.11	22.23	15.36	16.46	17.2	17.07	25.07	22.46	20.15
8/28/86			X			13.58	13.58	NM	15.82	15.39	16.23	22.57	16.91	15.80	16.92	15.83	21.81	15.31	15.28	16.88	16.81	25.06	22.48	20.13
9/11/86	X	X				8.99	3.92	17.85	18.87	18.55	16.94	23.54	17.85	17.79	19.03	17.58	23.31	18.55	18.41	17.88	17.89	25.21	22.53	20.23
9/16/86				X		17.97	18.41	18.0	8.16	18.0	18.18	23.32	18.34	18.07	19.13	18.11	22.91	17.88	18.16	18.29	18.27	25.2	22.67	20.35
9/17/86				X		18.1	18.5	18.05	8.07	18.05	18.39	23.26	18.45	18.16	19.19	18.23	22.92	17.93	18.11	18.4	18.38	25.21	22.69	20.37
11/6/86			X			19.85	20.19	NM	20.98	24.95[b]	19.81	24.62	19.44	19.21	20.42	19.58	24.51	20.34	20.05	19.34	19.35	26.21	23.28	20.72
11/8/86					X	19.58	19.89	18.88	20.43	9.32	19.65	24.37	19.33	19.04	20.09	19.39	24.30	18.08	18.81	19.30	19.26	25.96	23.02	20.75
11/16/86	X					16.84	17.48	19.59	20.49	20.08	19.01	24.32	19.12	19.22	20.57	19.29	24.25	20.16	20.06	19.4	19.18	26.08	23.2	20.65
12/18/86	X			X		17.17	17.79	19.85	10.02	19.94	19.83	24.97	20.09	20.0	21.32	19.83	24.55	19.87	20.18	20.51	20.20	26.3	23.64	20.96
1/23/87						20.24	20.57	20.22	21.3	20.75	20.13	24.79	19.87	23.84[b]	21.23	20.13	24.34	20.89	20.56	20.04	19.87	26.1	23.42	20.9
3/5/87	X	X		X		10.88	5.91	20.08	11.73	20.71	19.15	26.36	20.09	20.10	21.45	19.73	25.89	20.70	21.03	20.26	20.24	27.58	24.64	21.82
6/24/87[c]						NM	NM	NM	NM	NM	17.74	23.70	19.96	17.02[b]	18.10	17.37	22.91	17.81	17.21	17.70	17.84	NM	NM	NM
6/25/87[c]	X	X	X	X	X	NM	NM	NM	NM	NM	14.98	23.25	17.32	16.16	17.14	15.42	22.61	13.37	15.04	17.64	17.52	NM	NM	NM
6/26/87[c]	X	X	X	X	X	NM	NM	NM	NM	NM	12.56	22.74	16.42	15.04	16.01	13.54	22.02	11.46	13.50	17.09	16.76	NM	NM	NM

[a]National Geodetic Vertical Datum.

[b]Probable measurement error.

[c]Measurements were made during City of Renton well field aquifer test; replacement well RW2 was pumping on June 25, 1987, and replacement wells RW1 and RW2 were pumping on June 26, 1987.

Note: NM = not measured.

Appendix D contains additional geologic cross-sections that illustrate how the delta fan grades progressively to finer-grained materials radially outward from the well field until silt and peat deposts are encountered. These cross-sections were prepared in support of the Cedar River aquifer sole-source aquifer petition (CH2M HILL, 1988).

The downgradient limits of the aquifer were extended to the southwest in the direction of the old Cedar River streambed (see Figure 2-5). Prior to its diversion into Lake Washington in 1916, the Cedar River flowed to the southeast towards the Black River.

SECTION A-A'
(See Figure 2-7 for Plan View)

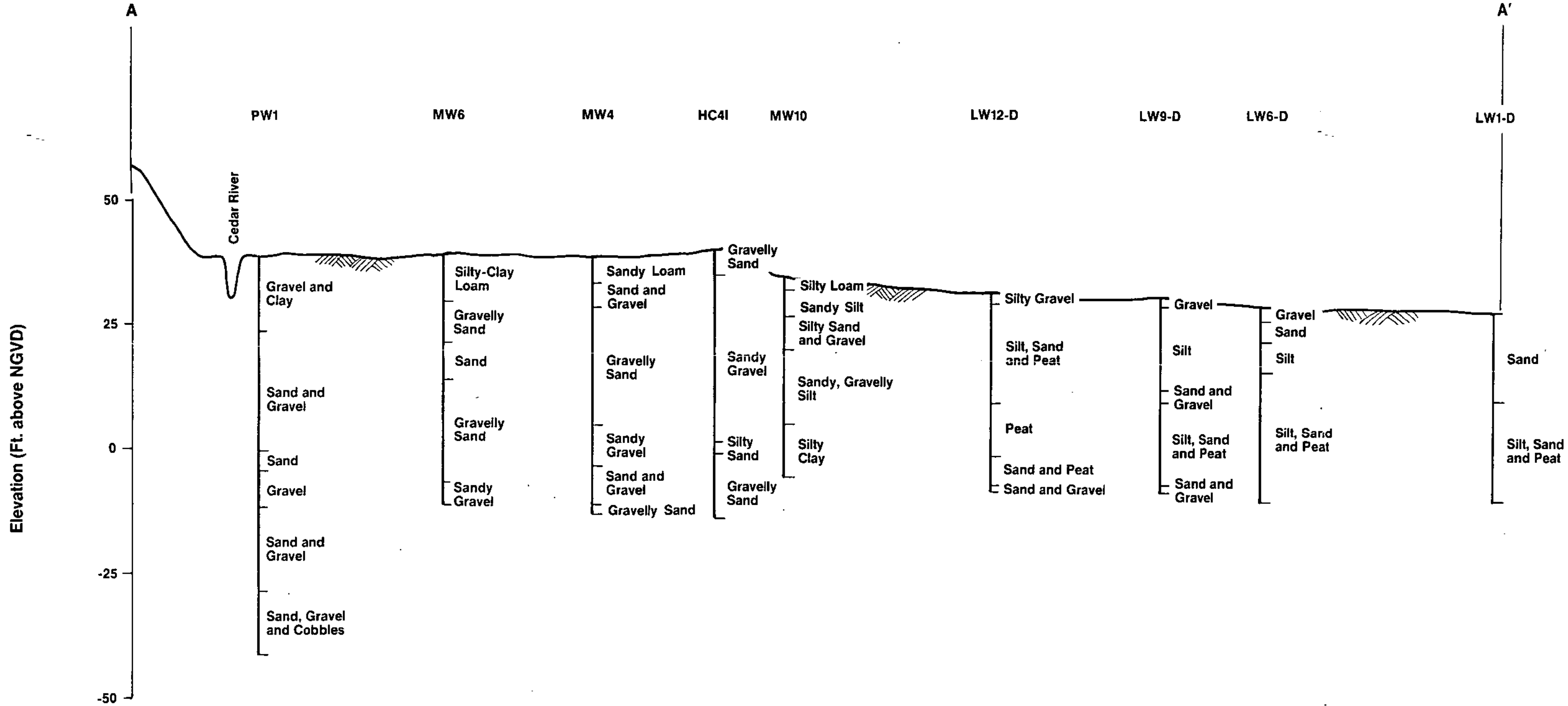


FIGURE 2-6
NORTH-SOUTH
GEOLOGIC CROSS-SECTION
CITY OF RENTON, WA

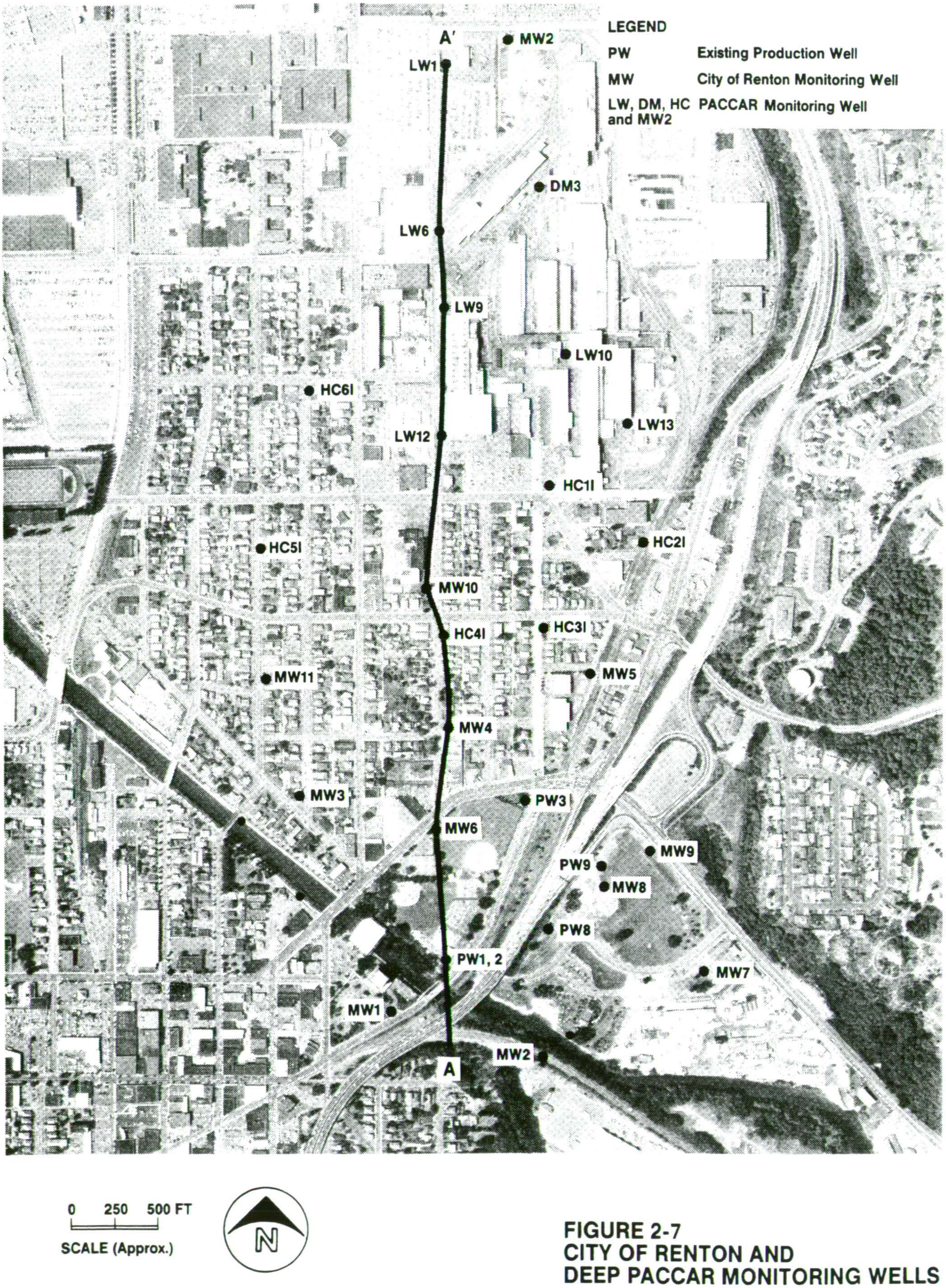


FIGURE 2-7
CITY OF RENTON AND
DEEP PACCAR MONITORING WELLS
CITY OF RENTON

Section 3
WELL FIELD ZONE OF POTENTIAL CAPTURE

When a well is pumped, a cone of depression forms around the well. If the well is pumping in an aquifer with approximately uniform regional flow, a flow net typical of that shown in Figure 3-1 will be created. An important feature of this flow net is the groundwater divide. The groundwater divide bounds the area of the aquifer supplying groundwater to the well (Bear, 1979). The groundwater divide will propagate outward from the well until recharge from regional inflow equals the pumping rate of the well. Thus, the position of the groundwater divide will change, depending upon the well pumping rate and the regional groundwater flow rate.

The area encompassed by the groundwater divide is called the "zone of potential capture." Theoretically, all of the groundwater within the zone of potential capture will be captured if the well is pumped continuously for a long time. Practically, most wells are pumped intermittently and groundwater near the boundary of the zone of potential capture may never reach a well because groundwater travel times are longer than the duration of pumping. Thus, the actual zone of capture for a well is generally smaller than the zone of potential capture.

Because of the overwhelming need to protect the Cedar River aquifer from contamination and because the entire well field is pumped relatively continuously during summer when water demands are the highest, the well field monitoring study focused on delineating the zone of potential capture rather than the actual zone of capture for the well field. The zone of potential capture represents a larger and, therefore, more conservative area for purposes of aquifer protection. In addition, delineation of the actual zone of capture would be difficult based simply on the measurement of water levels; detailed computer modeling would be required.

To define the zone of potential capture for the City of Renton well field, the water level data collected during the well field monitoring study were analyzed to determine:

1. Probable directions of groundwater movement under different pumping conditions

2. Cedar River-aquifer interactions

Probable directions of groundwater movement were determined by constructing contour maps of measured water level elevations (i.e., potentiometric maps). Potentiometric maps were

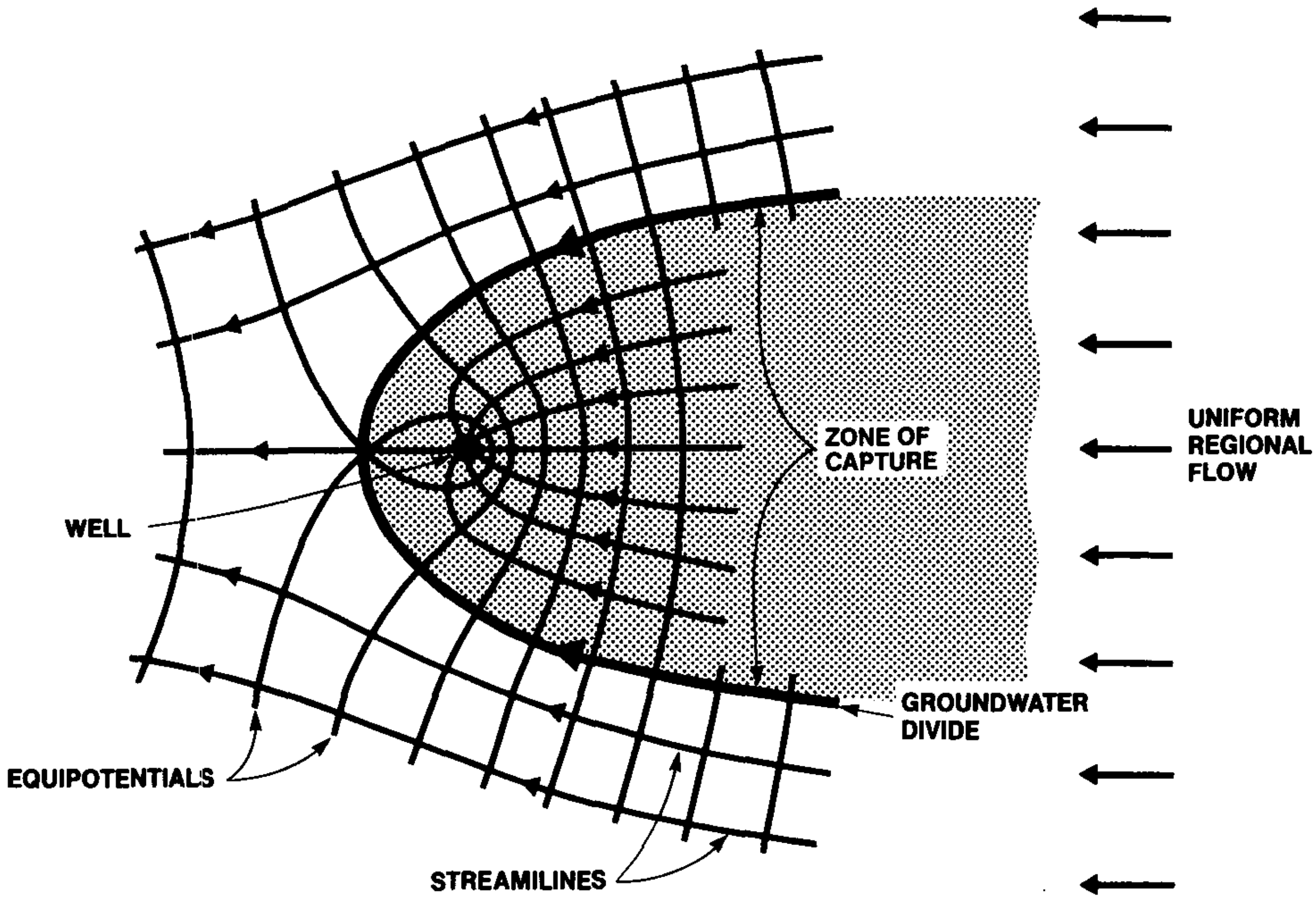


FIGURE 3-1
A SINGLE PUMPING WELL IN UNIFORM FLOW
(Source: Bear, 1979)

constructed for pumping conditions ranging from no wells in operation (i.e., no pumping) to pumping at 15,000 gpm, a pumping rate which is approximately 3,600 gpm above the current well field water right of 11,400 gpm.

Cedar River-aquifer interactions were determined by comparing fluctuations in water levels measured on the opposite side of the river from the well field (i.e., MW1) with fluctuations in Cedar River elevations and well field pumping. Cedar River flow rates, measured by the USGS during the well field aquifer test, were used to confirm the observed interactions.

The remainder of this section discusses further how probable directions of groundwater movement and Cedar River-aquifer interactions were determined. The section concludes with a discussion of how the zone of potential capture, for purposes of aquifer protection, was delineated.

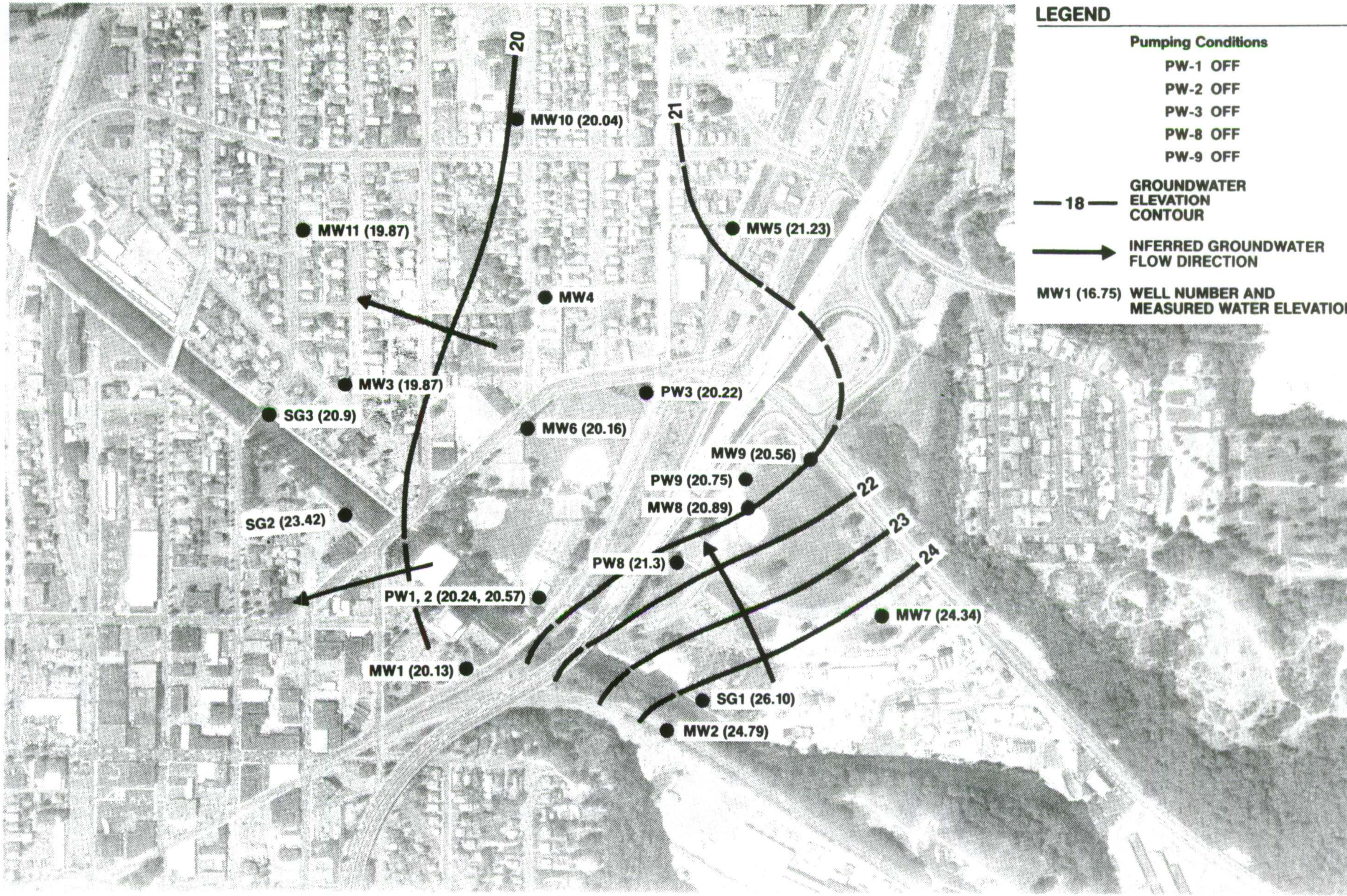
PROBABLE DIRECTIONS OF GROUNDWATER MOVEMENT

Figures 3-2 to 3-9 present potentiometric maps for selected dates when the City of Renton measured water levels. Each map represents a different pumping condition ranging from nonpumping to pumping four out of the five existing production wells. Table 3-1 lists the date of monitoring and pumping condition corresponding to each potentiometric map.

Table 3-1
MONITORING DATE AND WELL FIELD PUMPING CONDITION
FOR EACH POTENTIOMETRIC MAP

Potentiometric Map	Monitoring Date	Production Wells in Operation	Total Pumping Rate (gpm)
Figure 3-2	January 23, 1987	None	0
Figure 3-3	November 16, 1986	PW1	1,700
Figure 3-4	November 8, 1986	PW9	1,150
Figure 3-5	September 16, 1986	PW8	3,450
Figure 3-6	November 6, 1986	PW3	1,500
Figure 3-7	September 11, 1986	PW1, PW2	4,700
Figure 3-8	August 26, 1986	PW1, PW2, PW8	7,760
Figure 3-9	August 8, 1986	PW1, PW3, PW8, PW9	10,375

Figure 3-2 is a potentiometric map for what approximates a nonpumping condition; operational constraints on the City of Renton distribution system made it impossible to shut off all five production wells long enough for complete recovery of the water table. At the time that water levels were

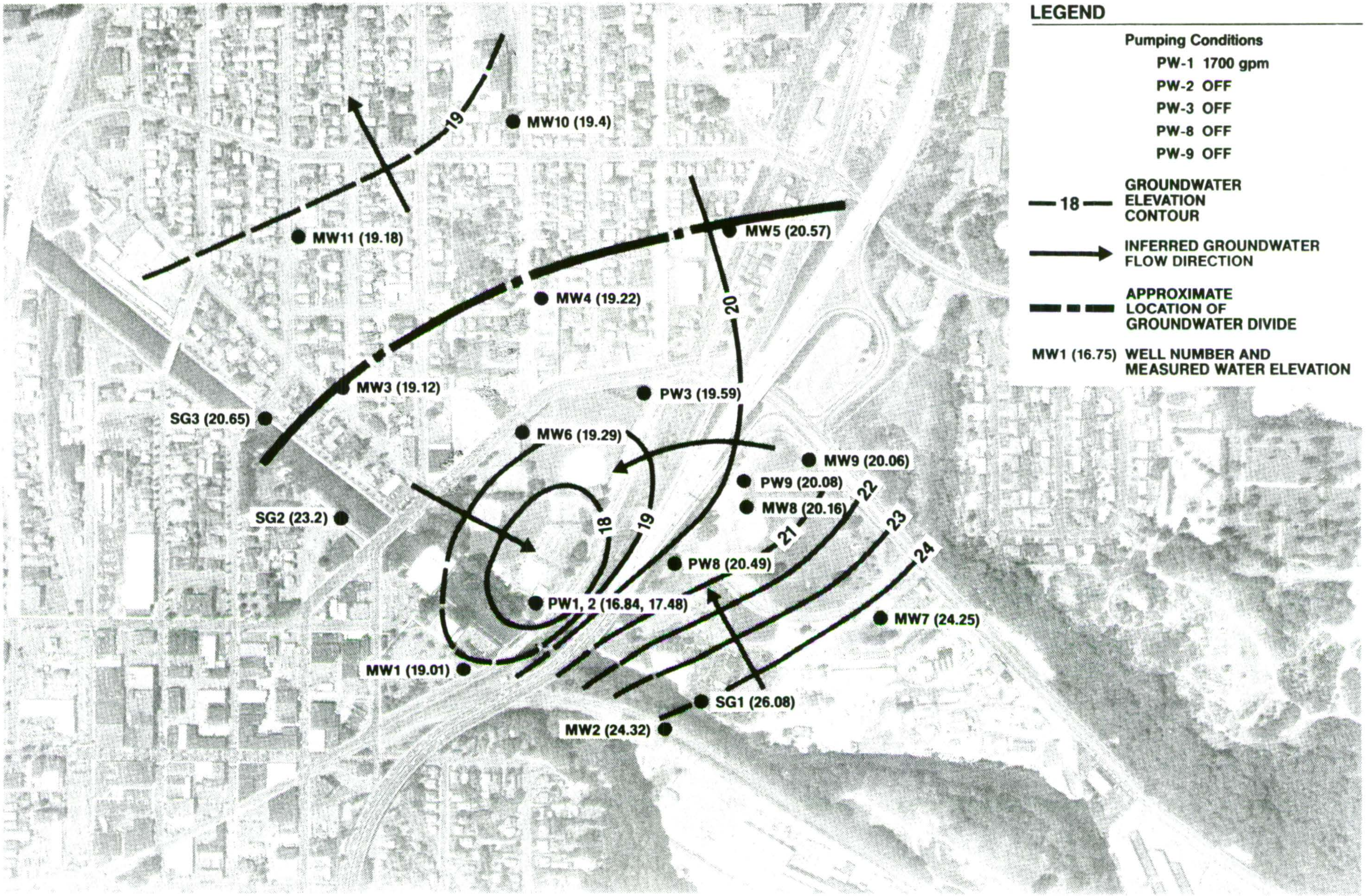


0 250 500 FT
SCALE (Approx.)

N

Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3-2
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) JANUARY 23, 1987
CITY OF RENTON, WA



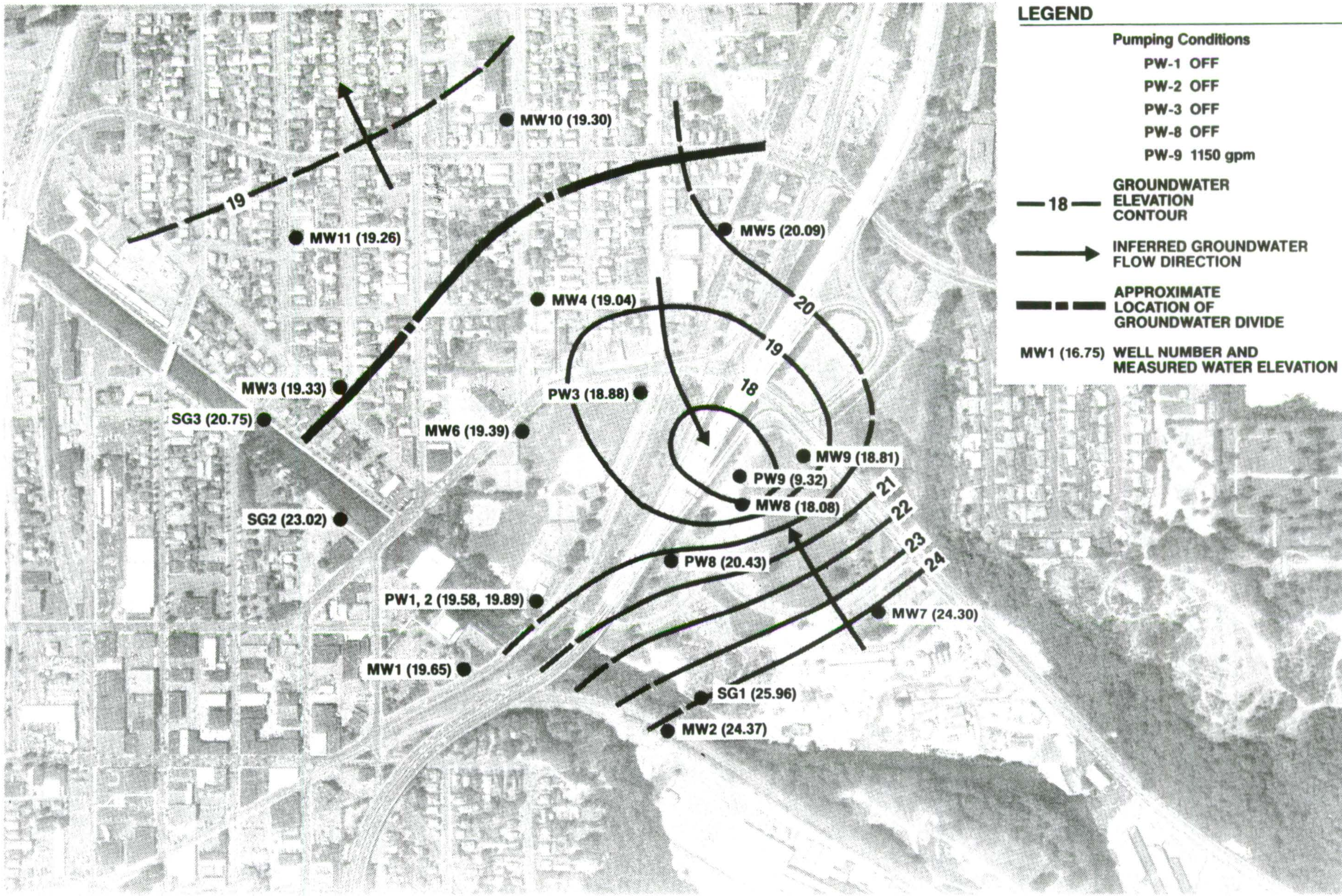
0 250 500 FT

SCALE (Approx.)

N

Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3-3
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) NOVEMBER 16, 1986
CITY OF RENTON, WA



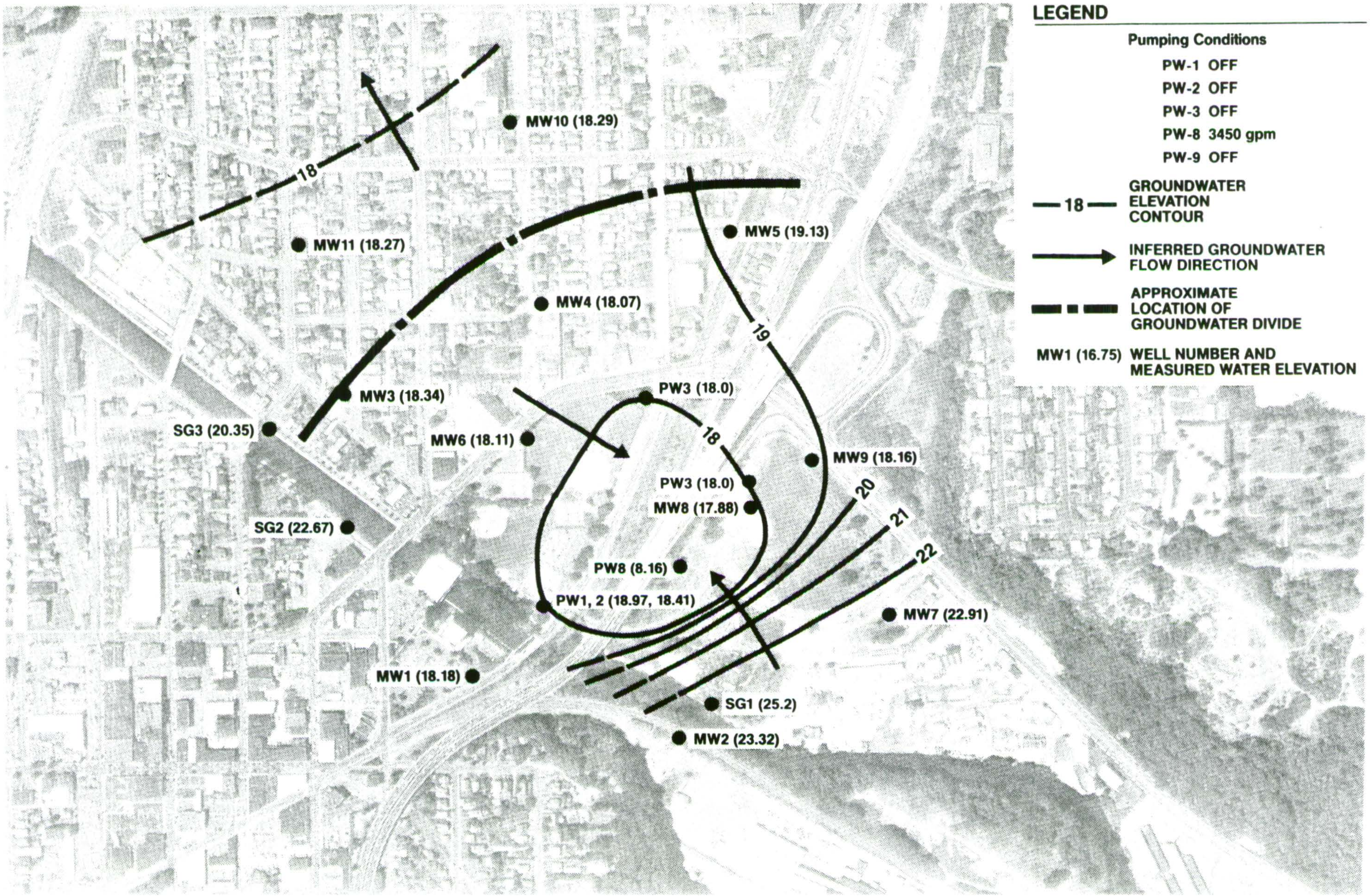
0 250 500 FT

SCALE (Approx.)

N

Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3-4
GROUNDWATER ELEVATIONS (FT. ABOVE NGVD) NOVEMBER 8, 1986
CITY OF RENTON



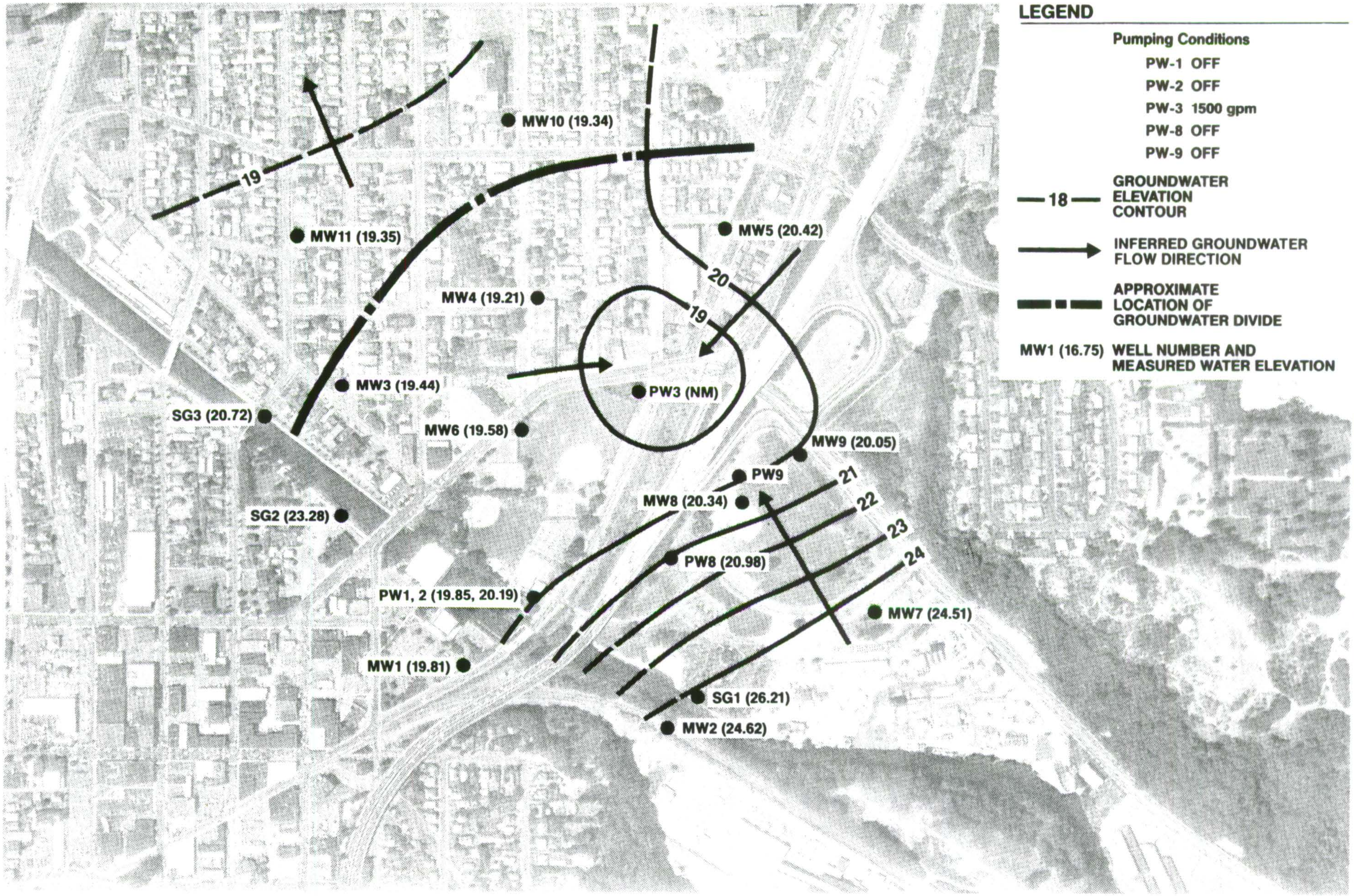
0 250 500 FT

SCALE (Approx.)

N

Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3-5
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) SEPTEMBER 16, 1986
CITY OF RENTON, WA



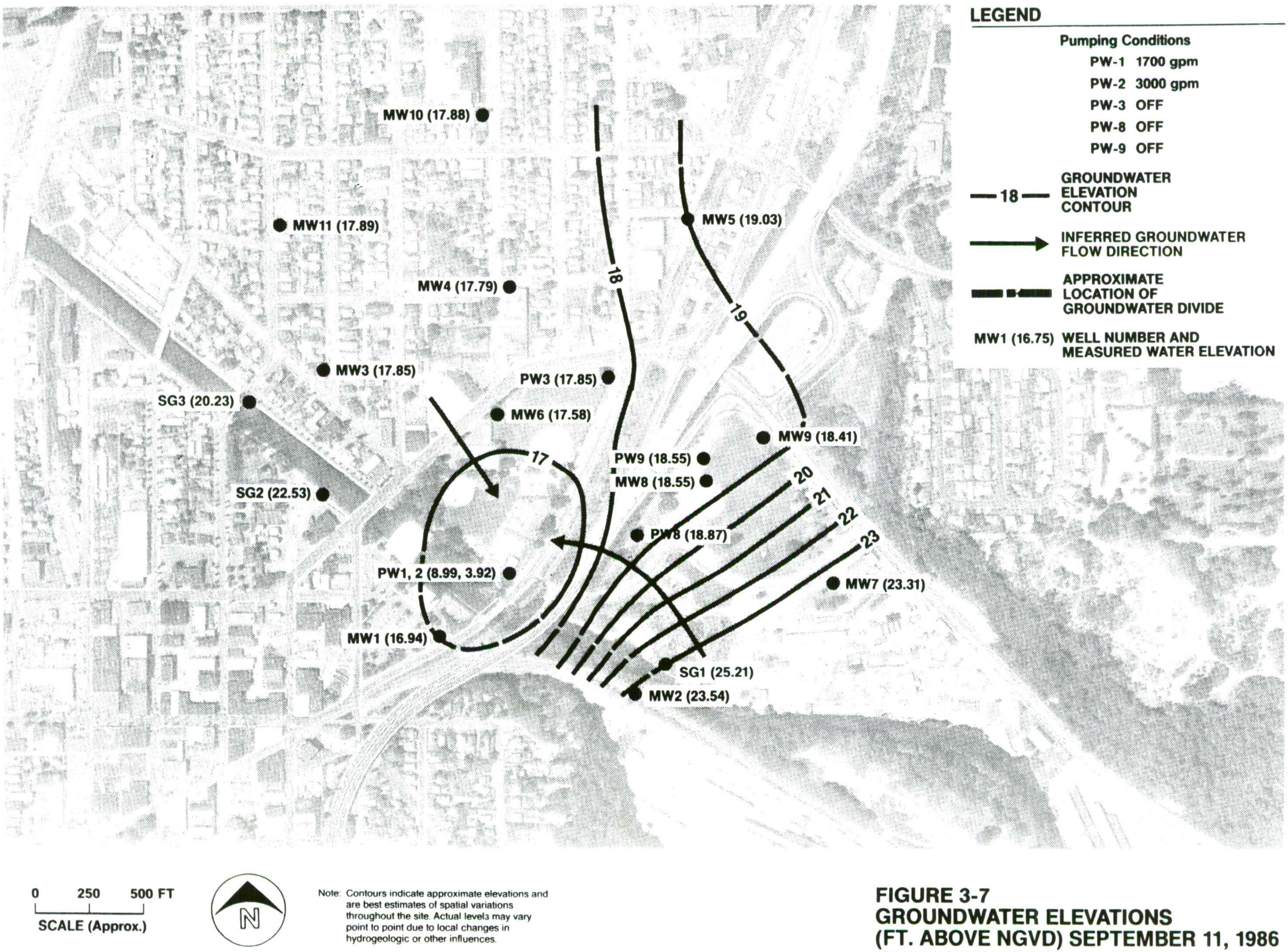
0 250 500 FT

SCALE (Approx.)

N

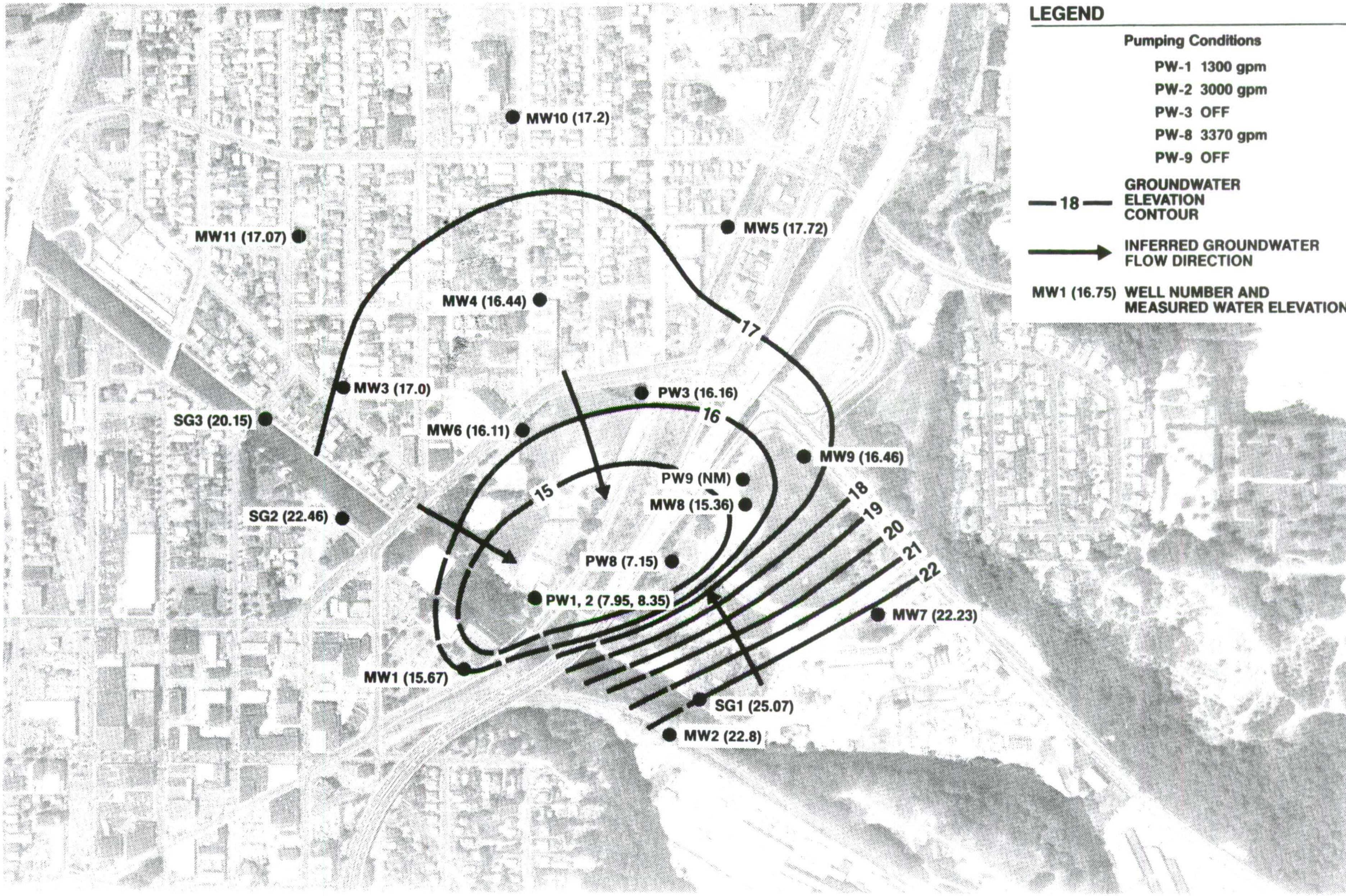
Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3-6
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) NOVEMBER 6, 1986
CITY OF RENTON, WA



Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3-7
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) SEPTEMBER 11, 1986
CITY OF RENTON, WA



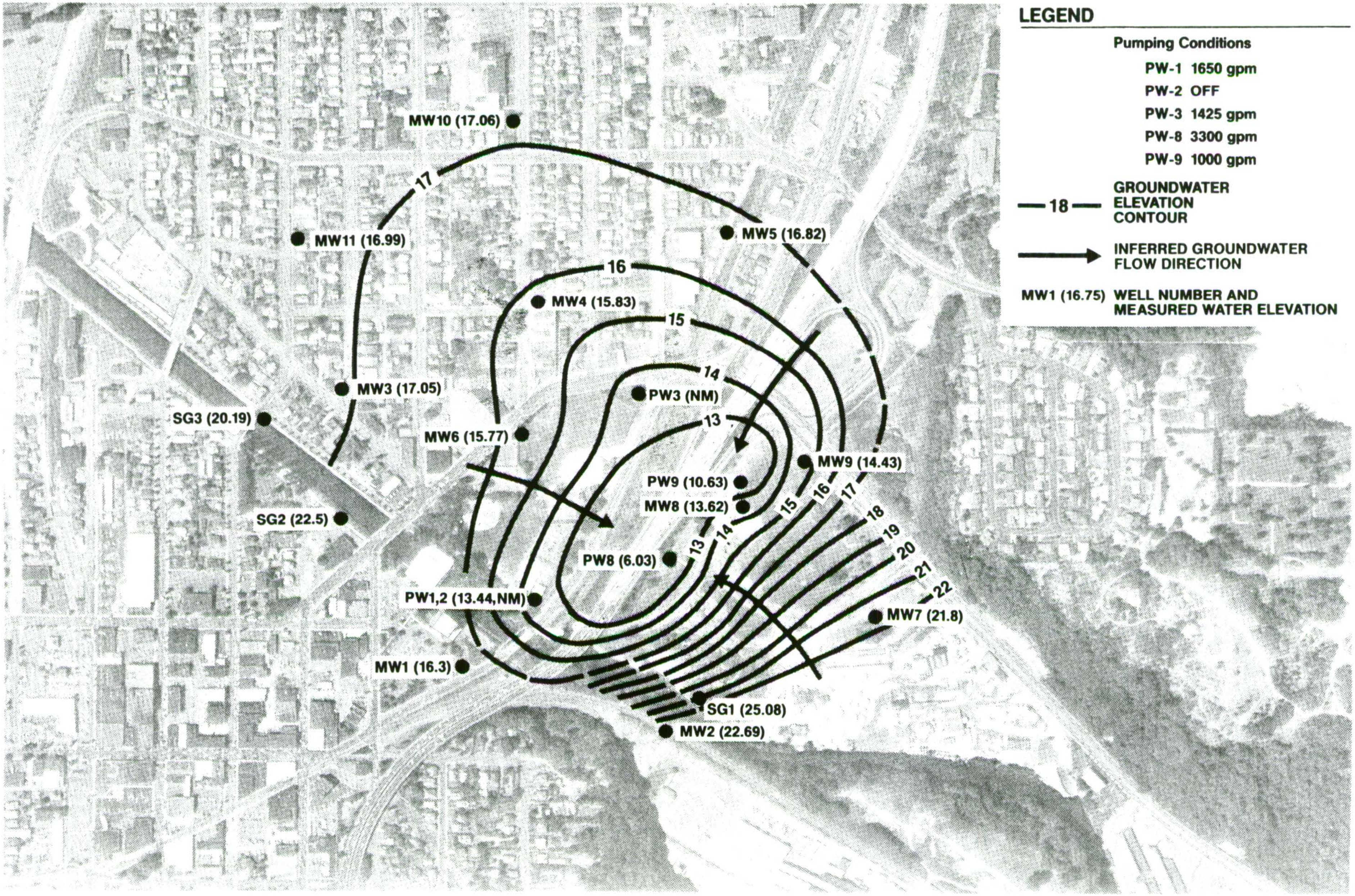
* Measurement Error

0 250 500 FT
SCALE (Approx.)

N

Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3-8
GROUNDWATER ELEVATIONS (FT. ABOVE NGVD) AUGUST 26, 1986
CITY OF RENTON, WA



0 250 500 FT
SCALE (Approx.)

N

Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3-9
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) AUGUST 8, 1986
CITY OF RENTON, WA

measured on January 23, 1987, none of the wells were operating; however, all of the wells had been in operation earlier in the day. Regardless, Figure 3-2 does indicate that the regional direction of groundwater movement is generally to the southwest and west, with a component to the northwest. The southwestern and western components are in the same direction as the original Cedar River streambed prior to its diversion towards Lake Washington. Measured groundwater elevations in the southwestern portion of Renton are lower than those measured near the well field indicating there is a gradient towards the Black River. The northwestern component is in the direction of Lake Washington. Lake Washington is maintained at an elevation of 13 to 15 feet. This elevation range is several feet lower than groundwater elevations measured to the northwest of the well field.

Figure 3-2 illustrates an important feature of the Cedar River aquifer that needs to be considered when constructing potentiometric maps. A comparison of the Cedar River elevation measured at SG1 with the groundwater elevation measured at MW2 shows a difference of just over 1 foot. As will be discussed later, this difference in elevation appears to be due to a zone of low-permeability material that limits communication between the river and the aquifer. Thus, Cedar River elevations are not representative of water table elevations in the vicinity of the well field.

Figures 3-3 through 3-6 are potentiometric maps for single-well pumping conditions. These maps illustrate how a groundwater divide forms regionally downgradient of each pumping well. Between the pumping well and the groundwater divide there is a reversal in the direction of groundwater movement. Beyond the groundwater divide (i.e, farther to the northwest), groundwater movement is in the direction of the regional gradient (see Figure 3-2). The groundwater divide shown in each figure delineates the approximate boundary of the downgradient portion of the aquifer that has the potential to supply water to the pumping well (i.e., the zone of potential capture). Figures 3-3 through 3-6 illustrate the extent of the zone of potential capture when PW1, PW9, PW8, and PW3 are in operation, respectively.

It is important to note that the exact position of the groundwater divide is difficult to determine because the water table is relatively flat in the area bounded by monitoring wells MW3, MW4, MW10, and MW11. Generally, water level elevations measured at these wells are within several tenths of a foot.

Figures 3-7 through 3-9 are potentiometric maps for typical multiple well pumping conditions. With wells PW1 and PW2 pumping (see Figure 3-7), the zone of potential capture expands beyond its position when only well PW1 is pumping (see

Figure 3-3), with the groundwater divide located somewhere beyond monitoring wells MW10 and MW11. When PW8 is pumped in combination with PW1 and PW2 (see Figure 3-8), the groundwater divide is also beyond MW10 and MW11, as it is when wells PW1, PW3, PW8, and PW9 are operating (see Figure 3-9).

Because the zone of potential capture extends beyond the City of Renton monitoring well network under high pumping conditions (see Figures 3-7 through 3-9), it was not possible to determine the position of the groundwater divide based only on data collected during the well field monitoring study. Additional water level data from the Olympic Pipe Line leak abatement study (GeoEngineers, 1986b), PACCAR defense systems site assessment study (Hart-Crowser, 1986a), and the well field aquifer test (RH2 Engineering, 1987a and 1987b) were used. Figures 3-10 through 3-13[1] are regional potentiometric maps that illustrate the probable position of the groundwater divide for:

- Late July of 1986 with PW2 pumping
- Mid-November of 1986 with PW1, PW2, and PW8 pumping
- June 25, 1987, with PW1, PW2, PW3, PW8, PW9, and RW2 pumping
- June 26, 1987, with PW1, PW2, PW3, PW8, PW9, RW1, and RW2 pumping

A comparison of the position of the groundwater divide shown in Figures 3-10 through 3-13 shows that the zone of potential capture expands to the northwest as well field pumping increases. On November 6, 1986, PW3 was pumping at a rate of 1,500 gpm (see Figure 3-10); on July 28, 1986, the well field was pumping at 7,700 gpm (see Figure 3-11); on June 24, 1987, the well field was pumping at the current well field water right of 11,400 gpm (see Figure 3-12); and on June 25, 1987, the well field was pumping at 15,000 gpm (see Figure 3-13).

CEDAR RIVER-AQUIFER INTERACTIONS

Cedar River-aquifer interactions were determined by:

1. Comparing groundwater elevations measured in MW1 and MW2 with measured Cedar River elevations and with well field pumping
2. Evaluating the results of the City of Renton well field aquifer test

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[1] Figures 3-10 through 3-13 are located in pockets at the end of the report.

Monitoring of Cedar River and groundwater elevations during the well field monitoring study found that the Cedar River is typically higher in elevation than the water table. Figure 3-14 shows hydrographs for monitoring well MW2 and stage gage SG1. A comparison of the elevations measured at these two locations shows a difference of 1 to 3 feet. The same relationship holds between MW1 and SG2. This difference in elevation appears to be due to a zone of low-permeability material that limits communication between the river and the aquifer. Drillers logs for RW1, RW2, and RW3 show the presence of a low-permeability material that may underlie the Cedar River in the vicinity of the well field (Hart-Crowser, 1987a). This material probably limits the amount of groundwater recharge coming from the river. Further evidence of the presence of this material is that pumping tests on RW1, RW2, and RW3 (Hart Crowser, 1987a) and RW9 (Hart Crowser, 1983) indicate that locally the aquifer behaves as a semi-confined aquifer.

Monitoring of water level fluctuations in MW1 during the well field monitoring study found that well field pumping probably influences groundwater movement on the south side of the Cedar River. Figures 3-15 through 3-17 compare water level fluctuations in MW1 with those for PW1 and PW2, PW8, and PW9, respectively. Fluctuations in Cedar River elevations at SG1 are also plotted in each figure. All three figures show that water level fluctuations in MW1 generally correspond to those measured at SG1. On August 26, 1986, November 16, 1986, and March 5, 1987, however, MW1 shows a slight response to the pumping of PW1 and PW2 (see Figure 3-15). This response indicates that pumping of PW1 and PW2 influences groundwater movement on the opposite side of the river. As will be discussed later, the results of the well field aquifer test more clearly demonstrate the influence of PW1 and PW2. As Figures 3-16 and 3-17 indicate, pumping of PW8 and PW9 appears to have little or no effect on groundwater movement south of the river, probably because of the distance of these wells from the river. This finding is consistent with the results of the PW9 hydrogeologic analysis (Hart-Crowser, 1983).

The well field aquifer test provided an opportunity to confirm some of the observations made based on the well field monitoring study results. Cedar River streamflow measurements made by the USGS while the well field was pumping at the current water right of 11,400 gpm and a rate of 15,000 gpm confirmed that in the vicinity of the well field the amount of Cedar River water recharging the aquifer is small compared to the river flow rate. Within the accuracy of the flow rate measurements (i.e., ±5 percent), the USGS was unable to detect any difference in flow rate upstream and downstream of the well field under either pumping condition (RH2 Engineering, 1987b). The mean and standard

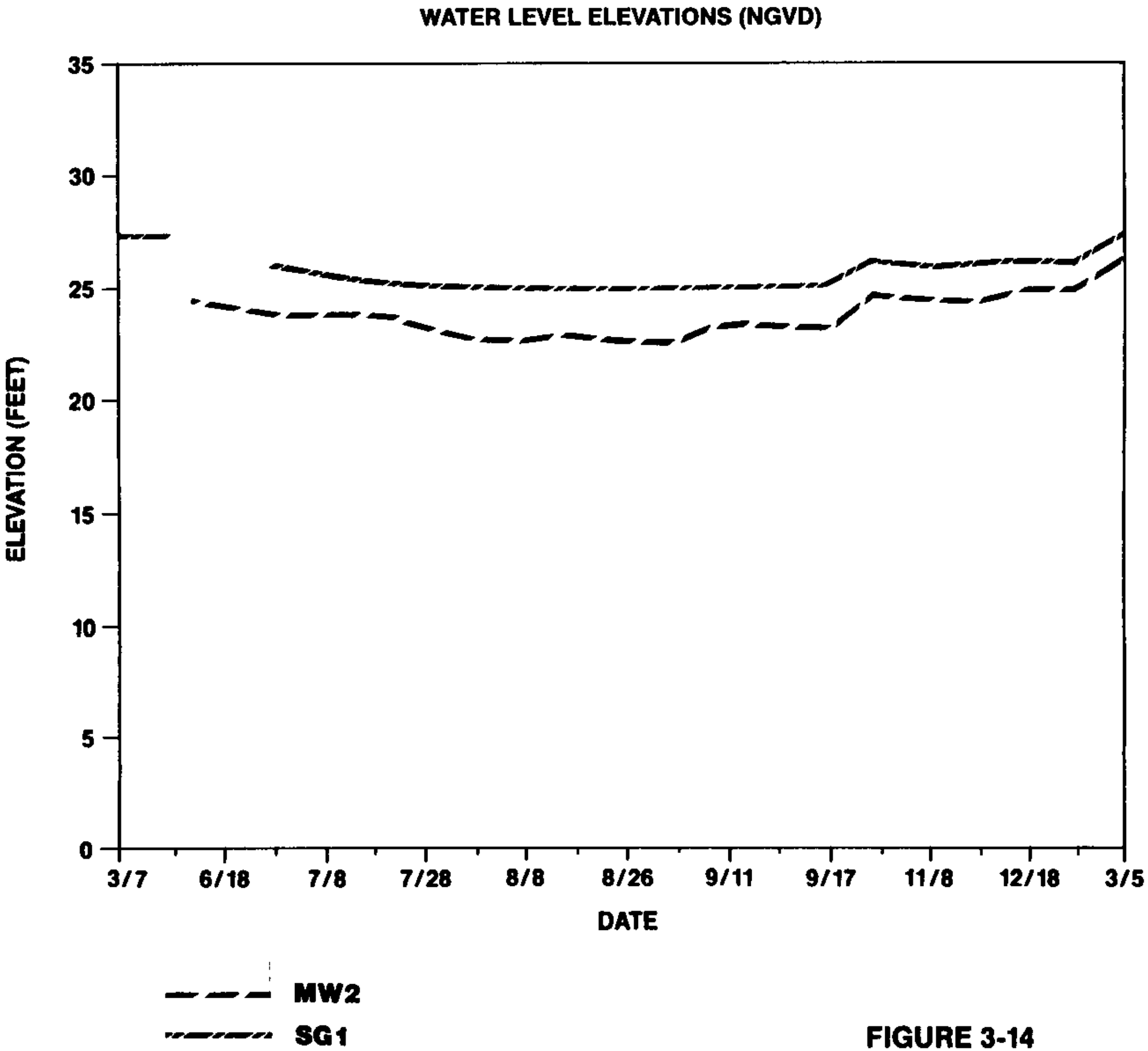

FIGURE 3-14
HYDROGRAPHS FOR MONITORING WELL MW2 AND STAGE GAGE SG-1
CITY OF RENTON, WA

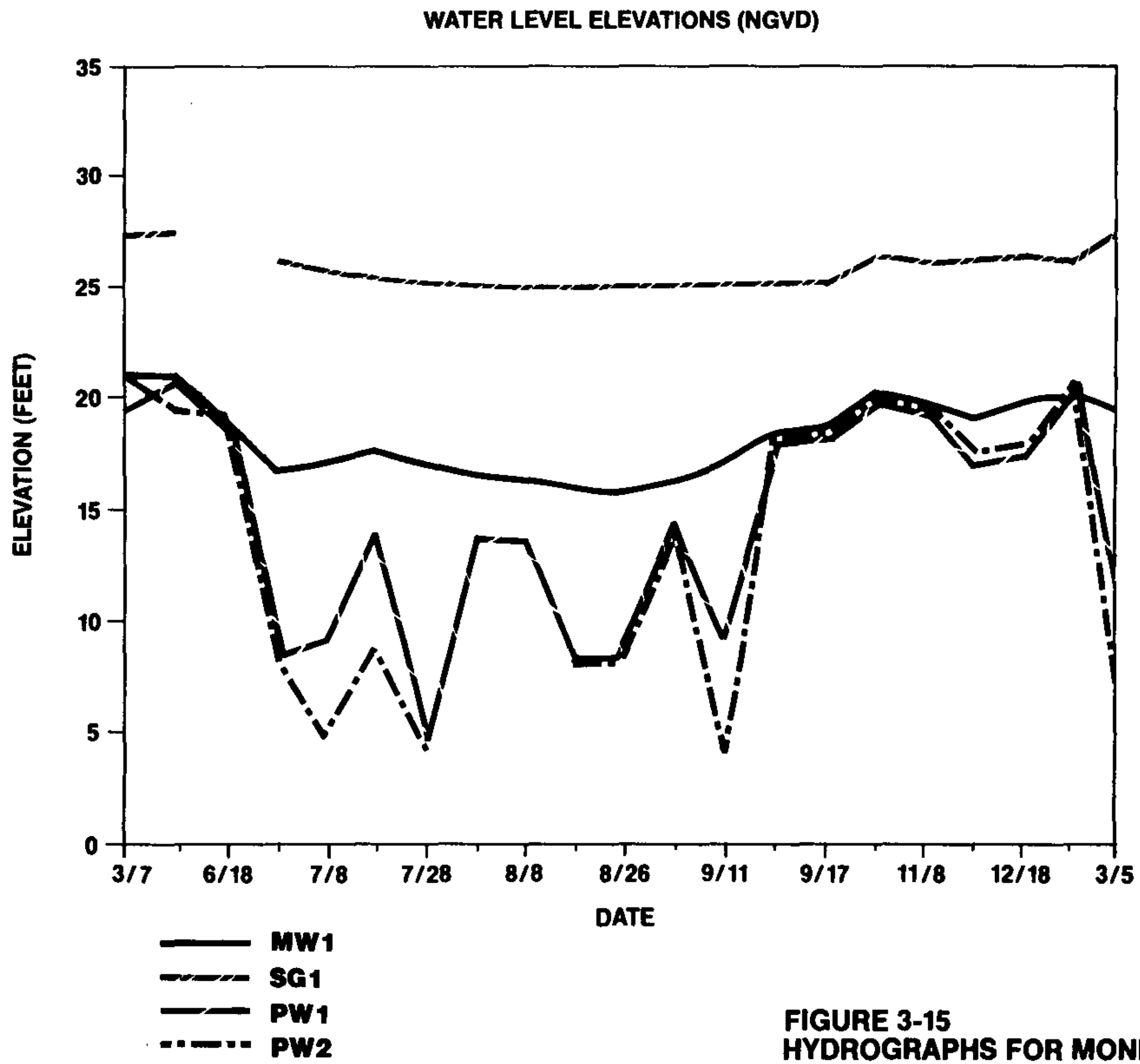

FIGURE 3-15
HYDROGRAPHS FOR MONITORING WELL MW1, STAGE GAGE SG1, AND PRODUCTION WELLS PW1 AND PW2
CITY OF RENTON, WA

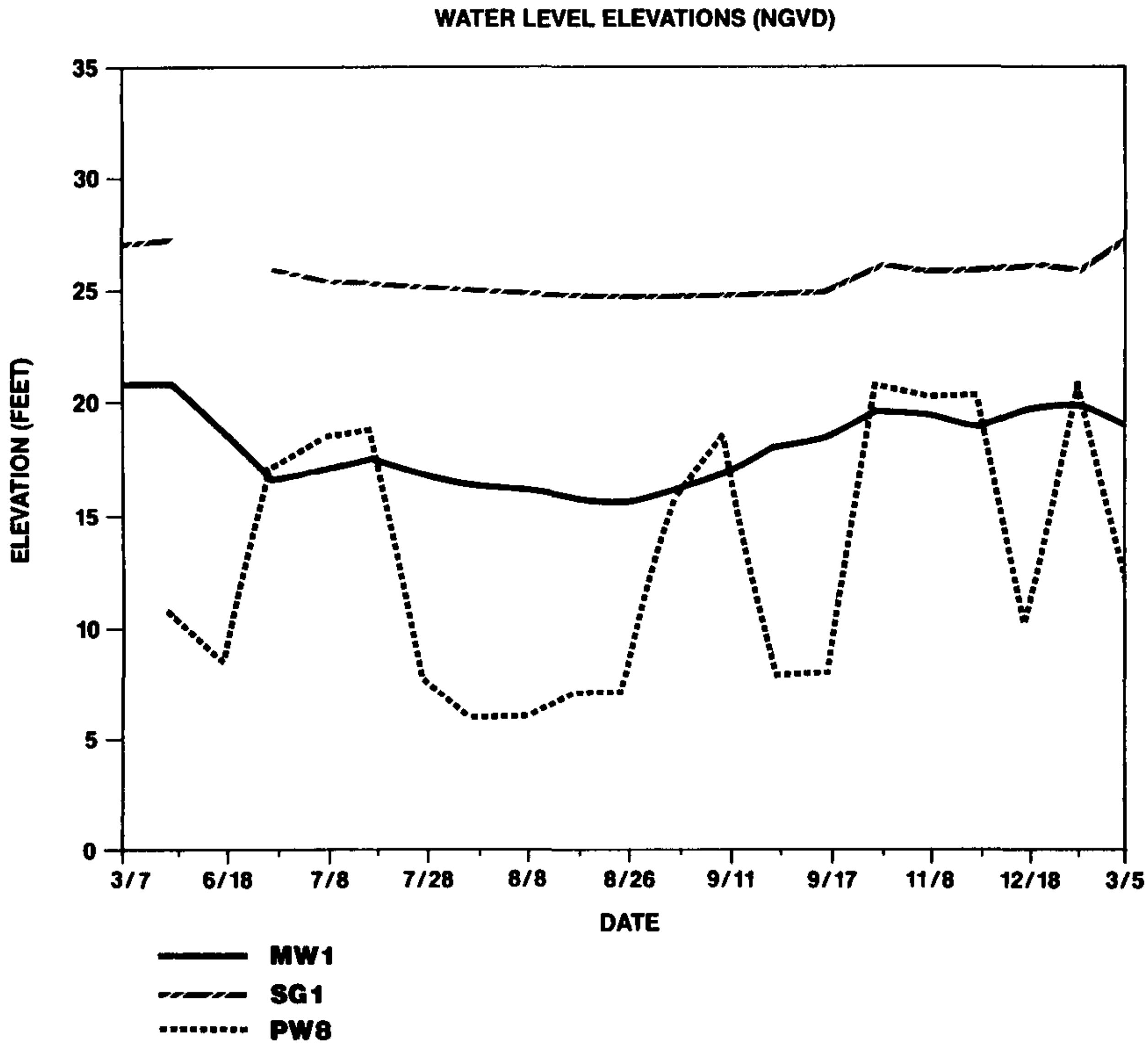

FIGURE 3-16
HYDROGRAPHS FOR MONITORING WELL MW1, STAGE GAGE SG1, AND PRODUCTION WELL PW8
CITY OF RENTON, WA

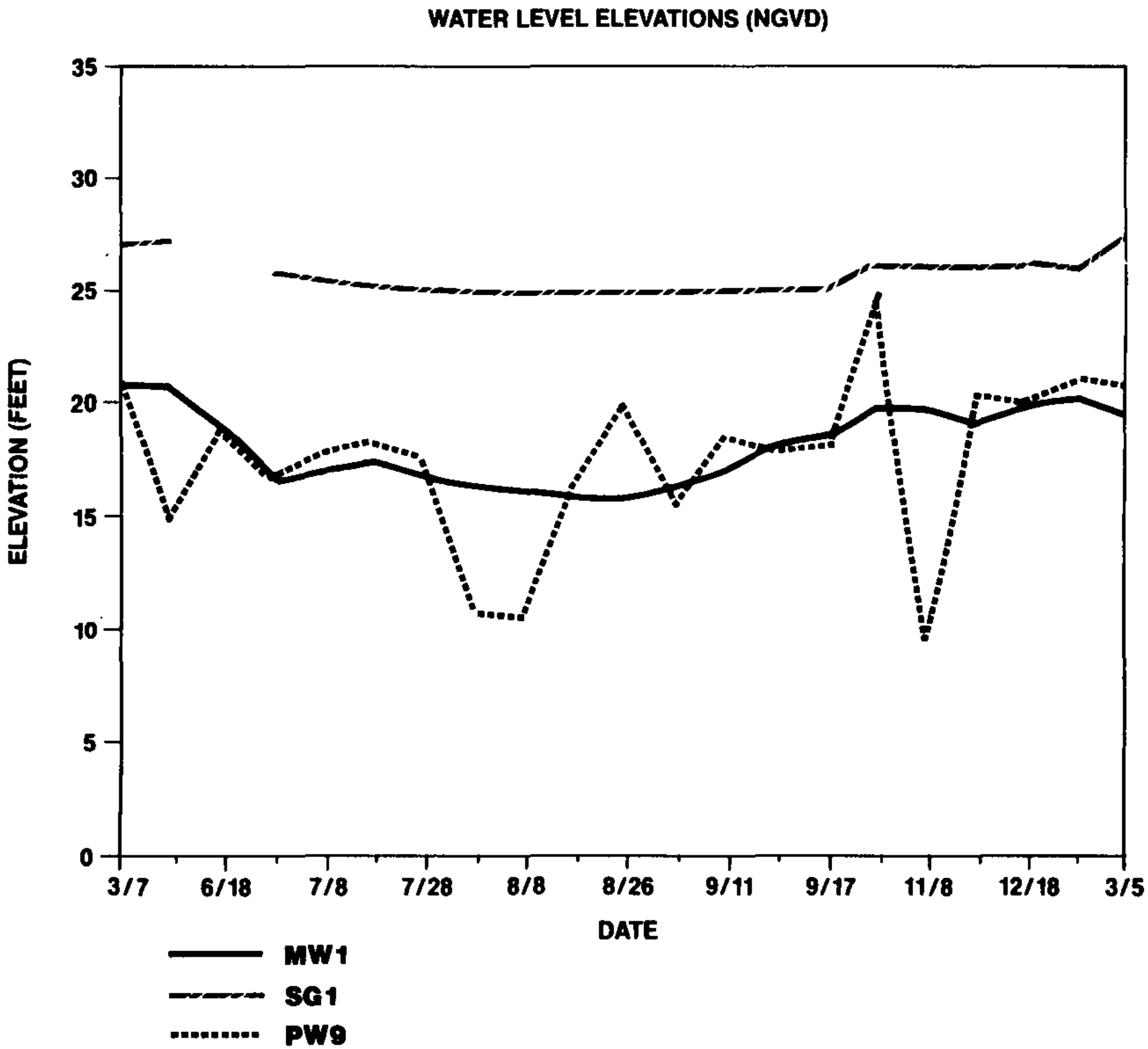

FIGURE 3-17
HYDROGRAPHS FOR MONITORING WELL MW1, STAGE GAGE SG1, AND PRODUCTION WELL PW9
CITY OF RENTON, WA

deviation of the 14 Cedar River streamflow measurements made by the USGS were 335.9 cubic feet per second (cfs) and 10.6 cfs, respectively (RH2 Engineering, 1987a).

Continuous water level measurements made during the City of Renton well field aquifer test confirmed that water levels in MW1 respond to the pumping of PW1 and PW2. Figure 3-18 shows how measured water levels in MW1 changed with time during the test. Figure 3-19 shows how well field pumping varied during the test, and Figure 3-20 shows the variation in Cedar River stage during the test. The water level fluctuations in MW1 correlate well with changes in well field pumping. As Figure 3-18 illustrates, water levels in MW1 recovered during the 8-hour nonpumping period and then declined in response to well field pumping. The sudden decline 32 hours after the start of the test represents the response of MW1 to the increase in well field pumping rate from 11,400 gpm to 15,000 gpm. As Figure 3-20 illustrates, the elevation of the Cedar River was relatively constant throughout the test.

ZONE OF POTENTIAL CAPTURE

In reviewing the potentiometric maps discussed earlier (see Figures 3-2 through 3-13), the largest observed zone of potential capture occurred when the well field was pumping at 15,000 gpm (see Figure 3-13). This well field pumping rate does not represent a current pumping condition in that it is 3,600 gpm higher than the current well field water right. The next largest observed zone of potential capture occurred at a pumping rate of 11,400 gpm (see Figure 3-12). Because this pumping rate is representative of current conditions, it was selected for purposes of aquifer protection. The groundwater divide delineating the boundary of this zone of potential capture was extended south of the Cedar River to encompass that portion of the aquifer wherein the probable direction of groundwater movement is toward the well field. Figure 3-21[1] shows the resultant boundary of the zone of potential capture delineated for purposes of aquifer protection.

[1]Figure 3-21 is in a pocket at the end of the report.

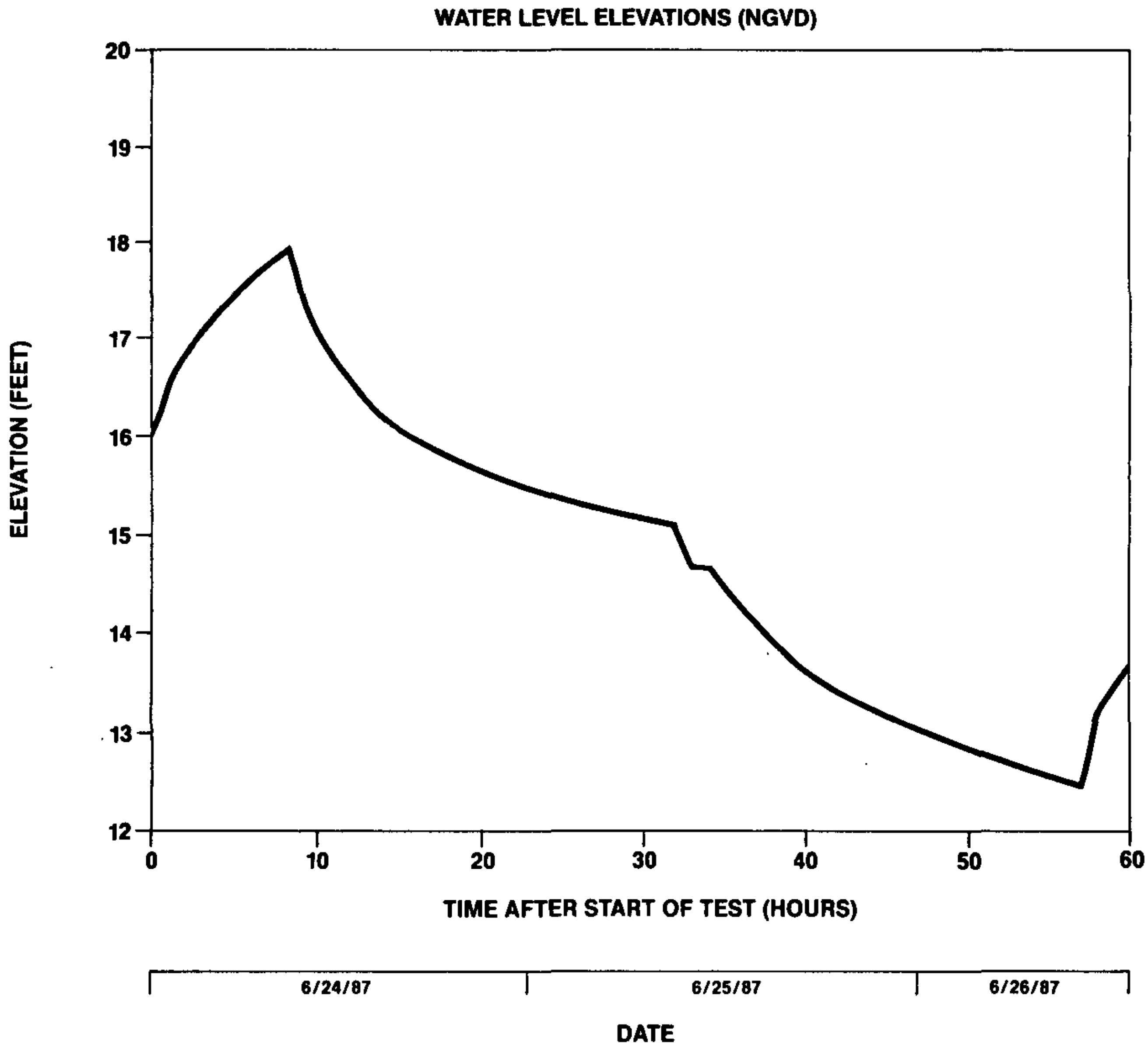

FIGURE 3-18
HYDROGRAPH FOR MW1
DURING WELL FIELD AQUIFER TEST
CITY OF RENTON, WA

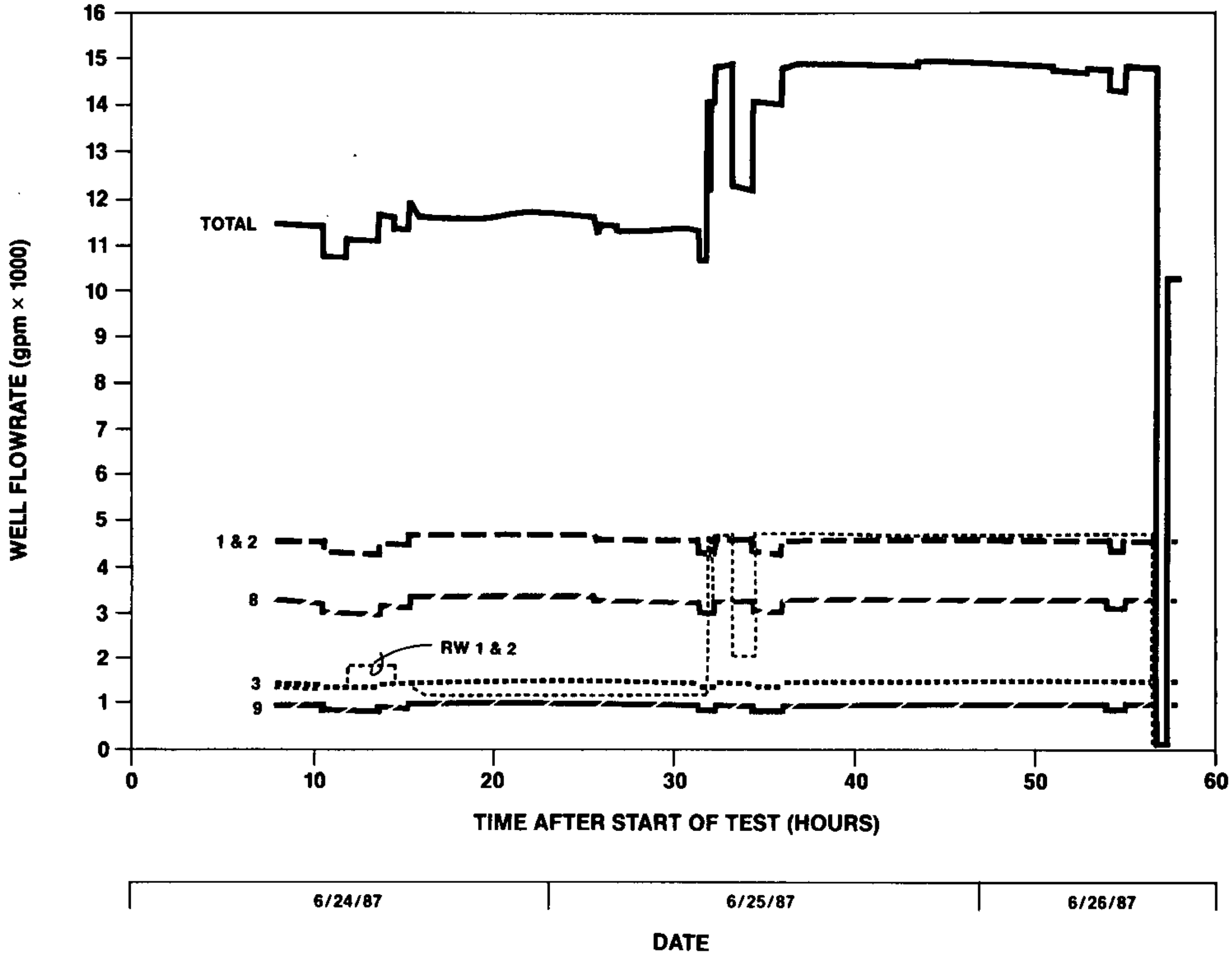

FIGURE 3-19
PRODUCTION WELL FLOWRATES
DURING WELL FIELD AQUIFER TEST
CITY OF RENTON, WA

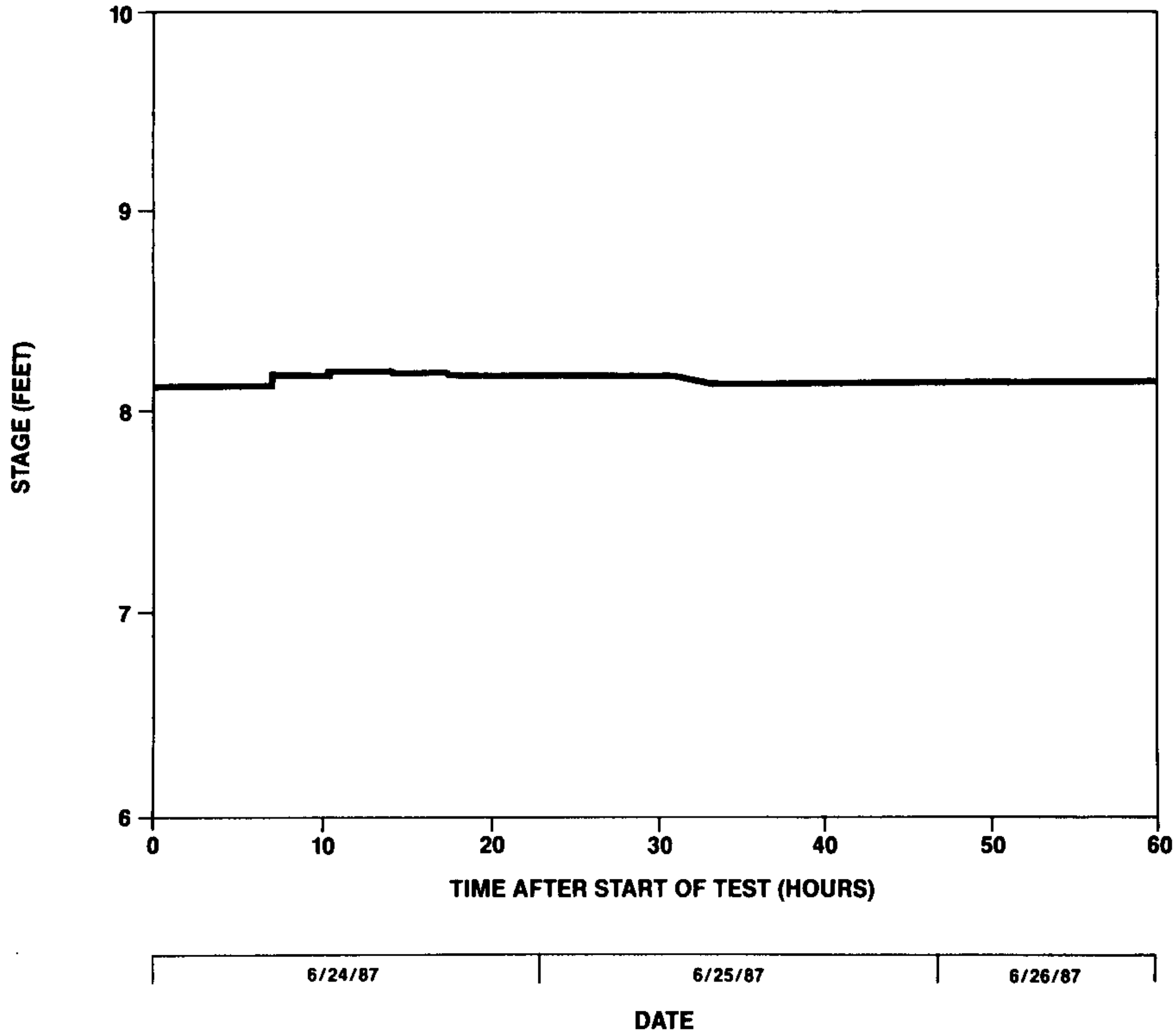

FIGURE 3-20
CEDAR RIVER STAGE
AT GAGE NO. 12119000
DURING WELL FIELD AQUIFER TEST
CITY OF RENTON, WA

Section 4
AQUIFER PROTECTION AREA

The City of Renton aquifer protection ordinance will require that an APA be delineated around each well, well field, or spring owned or operated as a potable water supply. An APA encompasses the recharge area for a well, well field, or spring. Each APA may be subdivided into two zones, each having a different level of protection. For a well or well field, Zone 1 is defined as the area between the well or well field and the 1-year groundwater travel time contour.[1] Zone 2 is defined as the area between the 1-year groundwater travel time contour and the overall boundary of the APA.

The decision as to whether or not to subdivide an APA into one or two zones will be based on the susceptibility of the well or wells in that APA to contamination. An APA that contains at least one shallow well that is susceptible to contamination will be divided into two zones. An APA that contains only deep wells that are protected by overlying geologic materials will not be subdivided; in this case, the entire APA will be classified as a Zone 2 area.

This section discusses how the APA for the City of Renton well field was delineated, given the boundary of the zone of potential capture (discussed in Section 3), estimates of probable groundwater travel times, and the hydrogeologic characterization performed during the well field protection study. This section also discusses how the well field APA was subdivided into two zones.

APA DELINEATION

The APA was delineated by determining the boundary of the area contributing recharge to the well field. This boundary was divided into two segments: a segment regionally downgradient of the well field and a segment regionally upgradient. The regionally downgradient segment corresponds to the boundary of the zone of potential capture selected for purposes of aquifer protection (see Figure 3-21). Under current pumping conditions (i.e., under the current water right of 11,400 gpm), groundwater within this boundary could be captured by the well field. The regionally upgradient segment encompasses those portions of the uplands north and

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[1] The 1-year contour bounds that portion of the aquifer wherein the time for groundwater to move to a well is approximately equal to or less than 365 days.

south of the Cedar River that contribute recharge to the Cedar River aquifer. Although the entire Cedar River drainage basin theoretically contributes recharge to the aquifer, it is not practical to include the entire basin in the APA. Figure 4-1 shows how the two segments were merged to obtain an overall boundary for the APA. The eastern boundary of the APA corresponds to the Renton city limits.

DELINEATION OF ZONES

As was stated earlier, Zone 1 is the area situated between the well field and the 1-year groundwater travel time contour. Conceptually, Zone 1 encompasses groundwater that is within a 1-year travel time of the well field, assuming continuous pumping. To delineate the boundary of Zone 1, probable groundwater velocities and associated travel times under different pumping conditions were calculated.

The average groundwater velocity is directly related to the gradient (i.e., slope of the water table), hydraulic conductivity, and effective porosity in the following manner.

$$V = Ki/n_e$$

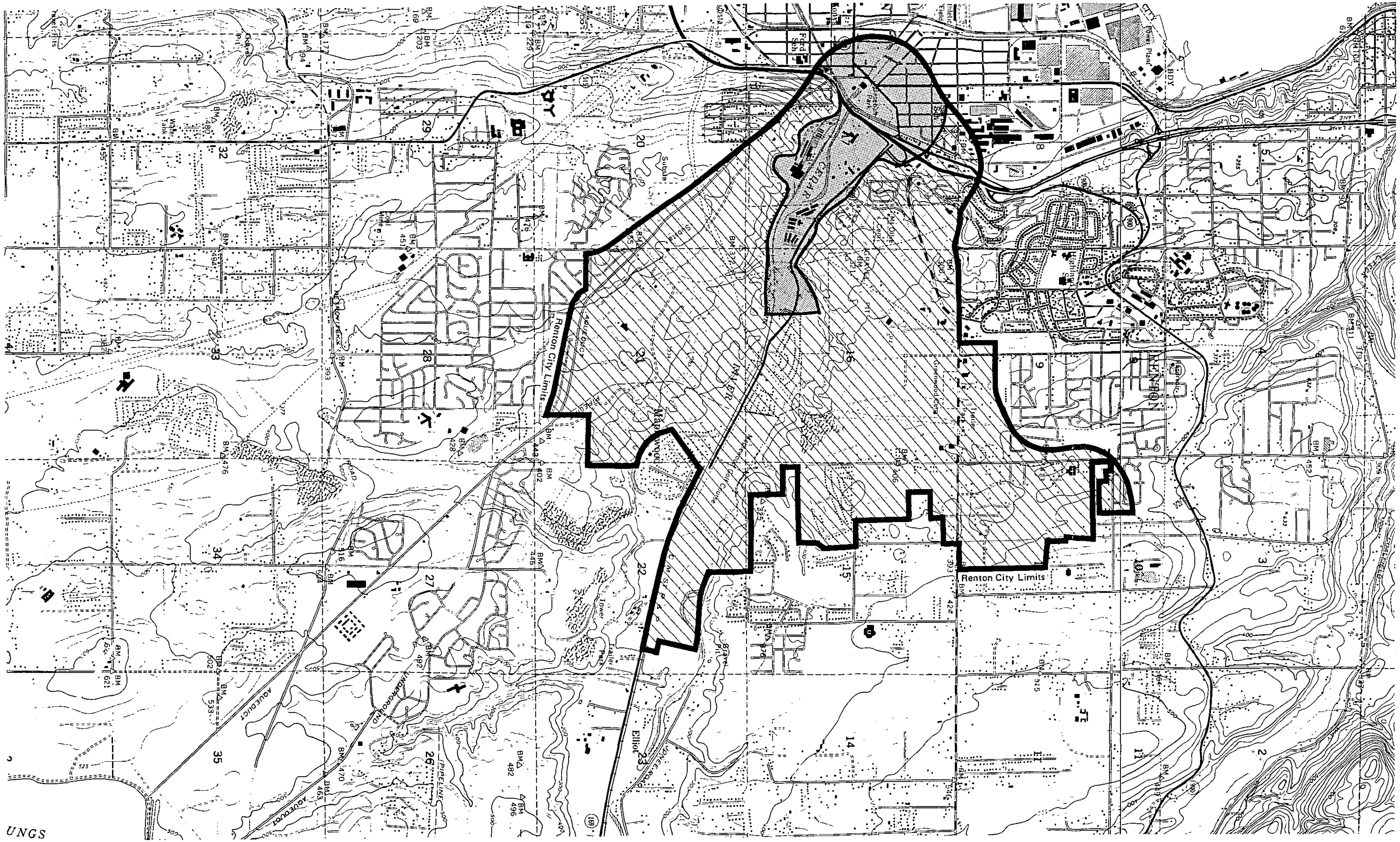
where

V = average linear groundwater velocity, ft/day
K = hydraulic conductivity, ft/day
i = gradient, ft/ft
n_e = effective porosity, dimensionless

Table 4-1 summarizes information available on Cedar River aquifer properties. Pumping tests in the vicinity of the production wells indicate that the transmissivity is on the order of 1,000,000 gpd/ft. Upgradient of the bedrock narrows the transmissivity decreases to about 55,000 gpd/ft.

Table 4-1
CEDAR RIVER AQUIFER PROPERTIES

Location	Transmissivity (gpd/ft)	Storage Coefficient	Reference
Production Well 9	2,300,000	0.02	Hart-Crowser, 1983
Replacement Wells 1, 2, and 3	1,000,000	0.025	Hart-Crowser, 1987a
Olympic Pipe Line Monitoring Wells	55,000	-	GeoEngineers, Inc., 1986b



0 2000 Feet

SCALE (Approx.)

N

LEGEND

APA Boundary | Zone 1 | Zone 2

FIGURE 4-1
WELL FIELD AQUIFER PROTECTION AREA (APA) MAP
CITY OF RENTON, WA

Assuming the transmissivity of 1,000,000 gpd/ft is representative of the entire Cedar River aquifer downgradient of the bedrock narrows, a hydraulic conductivity of 1,900 feet per day was estimated as follows, using an average saturated thickness of 70 feet.

$$K = T/b$$

where

T = transmissivity, gpd/ft
b = saturated thickness, ft

Upgradient of the bedrock narrows, the estimated hydraulic conductivity is 460 feet per day, assuming a 15-foot saturated thickness.

The silty sands and silts to the northwest and southwest of the Cedar River aquifer have a comparatively low hydraulic conductivity. Information in the PACCAR site assessment (Hart-Crowser, 1987b) suggests that the hydraulic conductivity for these materials could be on the order of 0.4 foot per day.

The effective porosity of all the aquifer materials was assumed to be 0.25.

The gradient varies throughout the Cedar River aquifer, depending upon well field operation and regional groundwater flow conditions. Table 4-2 summarizes ranges in average gradients between the well field and some of the potential contamination sources identified in the well field protection study (see Figure 4-2). Table 4-2 also summarizes ranges in average gradients between the well field and two other locations: the regionally downgradient limits of the zone of potential capture delineated for purposes of aquifer protection (see Figure 3-21) and the bedrock narrows (see Figure 2-5). Gradients were estimated by tracing the groundwater flow path between the potential source and one of the wells in the well field. The potentiometric maps described in Section 3 were used to obtain gradients for a range of pumping conditions. The difference in elevation between the potential source and the well was calculated and then divided by the length of the groundwater flow path. Average gradients for the downgradient limits of the zone of potential capture and bedrock narrows were estimated by determining the shortest and longest groundwater flow paths to one of the wells in the well field. An average groundwater velocity corresponding to each gradient was calculated with the equation above. Each calculated velocity was then converted into a groundwater travel time by dividing the length of the groundwater flow path by the corresponding velocity. Table 4-2 lists ranges of calculated groundwater velocities and groundwater travel times.

Table 4-2
ESTIMATED RANGES OF GRADIENTS, GROUNDWATER VELOCITIES, AND GROUNDWATER TRAVEL TIMES BETWEEN THE WELL FIELD AND SELECTED LOCATIONS

Location	Gradient (ft/ft)	Groundwater Velocity (ft/day)	Groundwater Travel Time (days)
Potential Contamination Sources[a]			
Texaco Service Station	0.002 - 0.016	20 - 120	1 - 90
Union Service Station	0.002 - 0.013	20 - 100	9 - 70
Exxon Service Station	0.004 - 0.007	30 - 50	30 - 50
Abandoned service station	0.004 - 0.013	30 - 100	20 - 50
Stoneway Concrete Plant	0.004 - 0.015	30 - 110	9 - 70
North American Refractories Brick Plant	0.010 - 0.021	80 - 160	7 - 30
Other Locations			
Bedrock Narrows	0.003 - 0.004	20 - 30	160 - 180
Regionally downgradient limits of the zone of potential capture[b]	0.001 - 0.013	8 - 100	20 - 365

[a] Identified in the well field protection study (CH2M HILL, 1984); see Figure 4-2 for locations.

[b] Delineated for purposes of aquifer protection (see Figure 3-21).

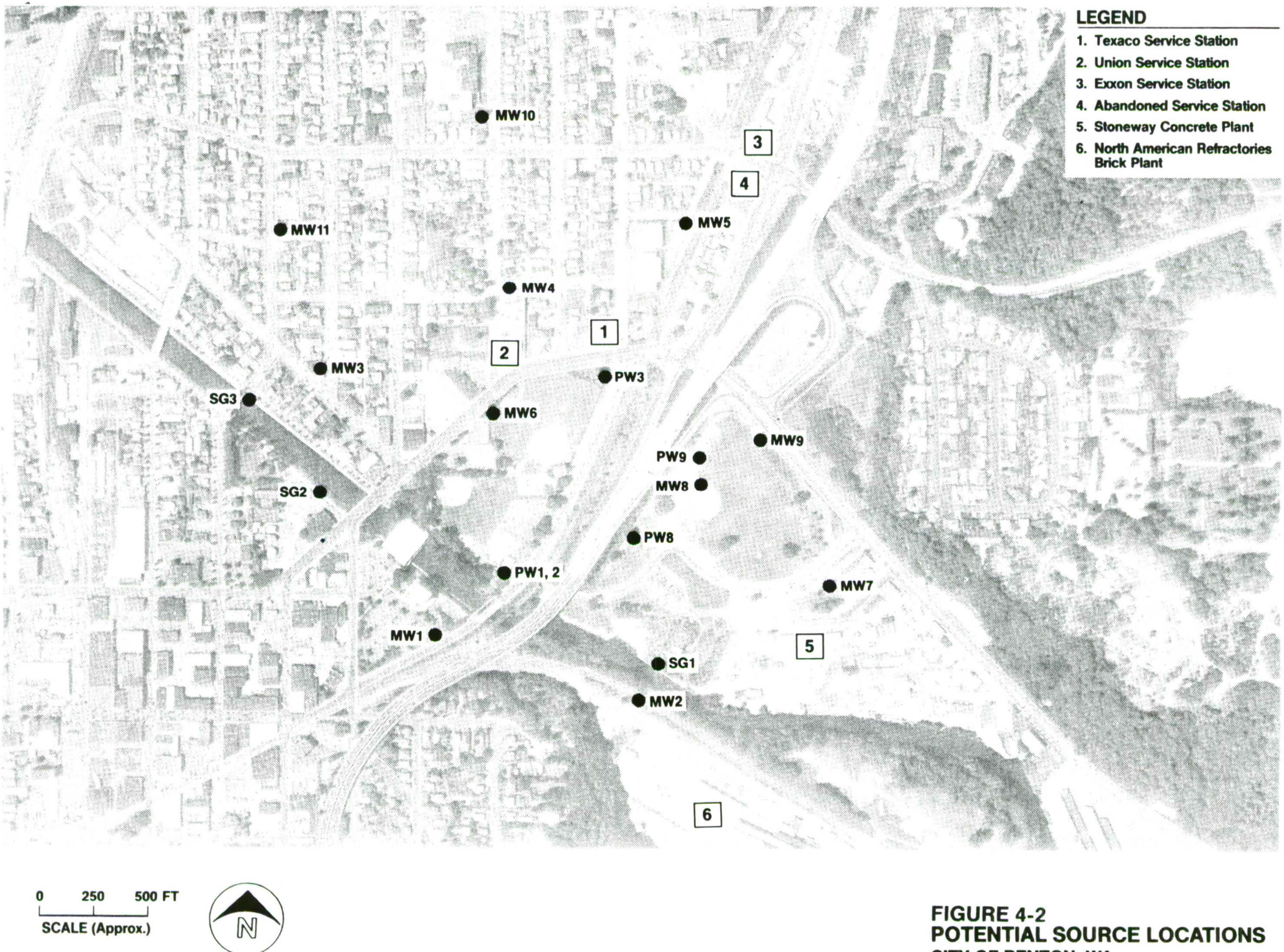


FIGURE 4-2
POTENTIAL SOURCE LOCATIONS
CITY OF RENTON, WA

The results in Table 4-2 show that groundwater travel times from potential sources of contamination range from one day to several months. Contaminants with a low affinity for adsorption to aquifer materials would exhibit similar travel times if the effects of dispersion are neglected. Thus, the time available to respond to a release from one of these sources is relatively short.

The groundwater travel time from the bedrock narrows is estimated to be on the order of 160 to 180 days. Thus, the City of Renton would have more time to respond to a release of contamination from potential sources upgradient of the bedrock narrows. This range of travel times is probably conservatively low because a transmissivity of 1,000,000 gpd/ft was assumed for the entire Cedar River aquifer downgradient of the bedrock narrows; the actual transmissivity of the aquifer between the bedrock narrows and the well field is probably lower.

Travel times from the regionally downgradient limits of the zone of potential capture delineated for aquifer protection purposes range from 20 to greater than 365 days for the conditions that were monitored. Travel times greater than 365 days occur in an area north of the well field where the zone of potential capture extends beyond the limits of the sand, gravel, and cobbles associated with the Cedar River aquifer, into the silt and peat deposits associated with Lake Washington. The relatively low hydraulic conductivity of these lake-type deposits results in small groundwater velocities and long groundwater travel times.

The boundary of Zone 1 was delineated based on the calculated travel times. The regionally downgradient boundary of Zone 1 was delineated as the zone of potential capture boundary (see Figure 3-21) except to the north where the zone of potential capture extends beyond the limits of the Cedar River aquifer (see Figure 2-5). In this area the aquifer limits were used as the Zone 1 boundary. Groundwater velocities in aquifer materials beyond the Cedar River aquifer limits will be relatively low, given the much lower hydraulic conductivity of these materials. In addition, the actual hydraulic conductivity of the materials near the aquifer limits is probably lower than the assumed value of 1,000,000 gpd/ft, given the higher percentage of sands and silty sands. Figure 4-1 illustrates the location of the Zone 1 boundary relative to the overall APA boundary.

Regionally upgradient of the well field, the walls of the Cedar River valley were selected as the boundaries for Zone 1. According to the hydrogeologic characterization performed during the well field protection study, the valley walls represent a distinct hydrogeologic boundary that separates the alluvial deposits comprising the Cedar River aquifer and the glacial drift, till, and outwash deposits that comprise the upland areas. Figure 4-1 shows the regionally upgradient extension of the Zone 1 boundaries.

The position of the eastern, or most upgradient, boundary of Zone 1 was estimated by calculating the distance groundwater upgradient of the bedrock narrows, would travel in 195 days. This timeframe is the difference between the 1-year (365 day) travel time established for the Zone 1 boundary and the average estimated travel time from the bedrock narrows to the well field (i.e., 170 days). Assuming a hydraulic conductivity of 460 feet per day, a gradient of 0.0048 foot per foot, and an effective porosity of 0.25, groundwater would travel a distance of approximately 1,700 feet in 195 days; the gradient was estimated based on groundwater elevations measured during the Olympic Pipe Line Leak Abatement Study (see Figure 3-10). Thus, the eastern boundary of Zone 1 was determined to be 1,700 feet upgradient of the bedrock narrows.

Zone 2 of the APA is the portion of the aquifer between the 180-day groundwater travel time contour and upland areas that contribute recharge to the aquifer (see Figure 4-1).

Section 5
GROUNDWATER QUALITY

Existing groundwater quality conditions in the Cedar River aquifer were evaluated as part of the well field protection study. This evaluation involved the review of available water quality data for the City of Renton production wells. The available data consisted of bacteriological, inorganic, chemical, and physical parameters measured in accordance with the Washington Department of Social and Health Services (DSHS) regulations. Data were also available on turbidity, trihalomethanes, corrosivity, pesticides, and radionuclides.

The available water quality data indicate that, at the time sampling was conducted, groundwater in the Cedar River aquifer satisfied current DSHS drinking water requirements.

To supplement the existing groundwater quality data base, priority pollutant analyses were conducted on water samples from monitoring wells MW1, MW4, MW5, and MW7. All four wells were sampled with a stainless steel bailer on June 12, 1986. Three to five well volumes were purged from each well prior to sampling, and the bailer was decontaminated before sampling each well. Except for the water samples submitted for metals analysis, all of the samples were unfiltered. The samples for metals analysis were filtered in the field with a 0.45-micron filter.

Table 5-1 provides a comparison of current and proposed maximum contaminant levels (MCLs) with the sampling results. MCLs are enforceable standards for drinking water specified by the Environmental Protection Agency under the Safe Drinking Water Act. The results in Table 5-1 show that in June of 1986 groundwater in the Cedar River aquifer satisfied both the current and proposed MCLs.

Appendix E contains the laboratory report for the priority pollutant analyses. No extractable organics or pesticides were detected in any of the samples. The only volatile organics that were detected were methylene chloride and acetone at concentrations ranging from 20 to 64 μg/l and trace to 9 μg/l, respectively. According to the laboratory report (see Appendix E), methylene chloride and acetone are common laboratory solvents, and it is probable that the presence of these compounds is because of unavoidable laboratory contamination.

The metals results (see Appendix E) show that cadmium chromium, copper, nickel, silver, and zinc were detected in concentrations ranging from 1 to 75 μg/l. Table 5-1 shows that both cadmium and chromium were detected at levels below current MCLs.

Table 5-1
COMPARISON OF MAXIMUM CONCENTRATION LEVELS (ug/l) WITH WATER QUALITY SAMPLING RESULTS, CITY OF RENTON MONITORING WELLS

Constituent	MCL[a] Current	MCL[a] Proposed	June 12, 1986, Sampling Results MW1	MW4	MW5	MW7	Detection Limit
Inorganic							
Arsenic	50		ND	ND	ND	ND	5
Barium	1,000		NM	NM	NM	NM	--
Cadmium	10		ND	ND	2	2	1
Chromium	50		1	1	3	2	--
Selenium	10		ND	ND	ND	ND	5
Lead	50		ND	ND	ND	ND	10
Nitrate	10,000		NM	NM	NM	NM	--
Organic							
Endrin	0.2		ND	ND	ND	ND	0.04
Lindane	4		ND	ND	ND	ND	0.02
Methoxychlor	100		ND	ND	ND	ND	0.1
Toxaphene	0.5		ND	ND	ND	ND	5
2,4-D	100						
2,4,5-TP silvex	10						
Benzene		5	ND	ND	ND	ND	1
Carbon tetrachloride		5	ND	ND	ND	ND	1
1,2-Dichloroethane		5	ND	ND	ND	ND	1
1,1-Dichloroethylene		7	ND	ND	ND	ND	1
p-Dichlorobenzene		750	ND	ND	ND	ND	1
1,1,1-Trichloroethane		200	ND	ND	ND	ND	1
Trichloroethylene		5	ND	ND	ND	ND	1
Vinyl chloride		1	ND	ND	ND	ND	1

[a] Maximum Contaminant Levels, U.S. Environmental Protection Agency, September 1986.

Note: ND=Not detected.
NM=Not measured.

All concentrations in µg/l.

Section 6
REFERENCES

Bear, J. Hydraulics of Groundwater. McGraw Hill, Incorporated, New York, New York. 1979.

CH2M HILL. Well Field Protection Study, prepared for the City of Renton, Washington. 1984.

CH2M HILL. Sole-Source Aquifer Petition for the Cedar River Aquifer, prepared for the City of Renton, Washington. 1988.

Ecology and Environment, Inc., Site Inspection Report of Pacific Car and Foundry Company, Renton, Washington, prepared for U.S. Environmental Protection Agency, Region X, Seattle, Washington. 1986.

Hart-Crowser. Summary Report, Hydrogeologic Analysis, Renton Well 9, Renton, Washington, prepared for the City of Renton and RH2 Engineering. November 11, 1983.

Hart-Crowser. Site Assessment, Soil and Groundwater Quality, PACCAR Facility, Renton, Washington, prepared for PACCAR Defense Systems. December 5, 1986a.

Hart-Crowser. Remedial Action Plan, PACCAR Facility, Renton, Washington, prepared for PACCAR Defense Systems. December 5, 1986b.

Hart-Crowser. Replacement Production Wells RW-1, RW-2, and RW-3, City of Renton, Washington, prepared for RH2 Engineering, July 14, 1987a.

Hart-Crowser. Additional Groundwater Flow Assessment Data, PACCAR Defense Systems Facility, Renton, Washington, prepared for PACCAR Defense Systems. October 5, 1987b.

GeoEngineers, Inc. Report of Phase 1 Hydrogeologic Services, Test Well Installation, Maplewood Golf Course, prepared for the City of Renton, Washington. 1986a.

GeoEngineers, Inc. Progress Report No. 1, Geotechnical Engineering Services, Pipeline Leak Abatement, Maplewood Neighborhood, Renton, Washington, prepared for Olympic Pipe Line Company. December 29, 1986b.

GeoEngineers, Inc. Progress Report No. 2, Geotechnical Engineering Services, Pipeline Leak Abatement, Maplewood Neighborhood, Renton, Washington, prepared for Olympic Pipe Line Company. March 6, 1987a.

GeoEngineers, Inc. Progress Report No. 3, Geotechnical Engineering Services, Pipeline Leak Abatement, Maplewood Neighborhood, Renton, Washington, prepared for Olympic Pipe Line Company. May 14, 1987b.

GeoEngineers, Inc. Progress Report No. 4, Geotechnical Engineering Services, Pipeline Leak Abatement, Maplewood Neighborhood, Renton, Washington, prepared for Olympic Pipe Line Company. July 22, 1987c.

RH2 Engineering. Data Report for the City of Renton Cedar River Valley Aquifer Test, prepared for the City of Renton, Washington. 1987a.

RH2 Engineering. Analysis Report for the City of Renton Cedar River Valley Aquifer Test, prepared for the City of Renton, Washington. 1987b.

Appendix A
MONITORING WELL SITE MAPS

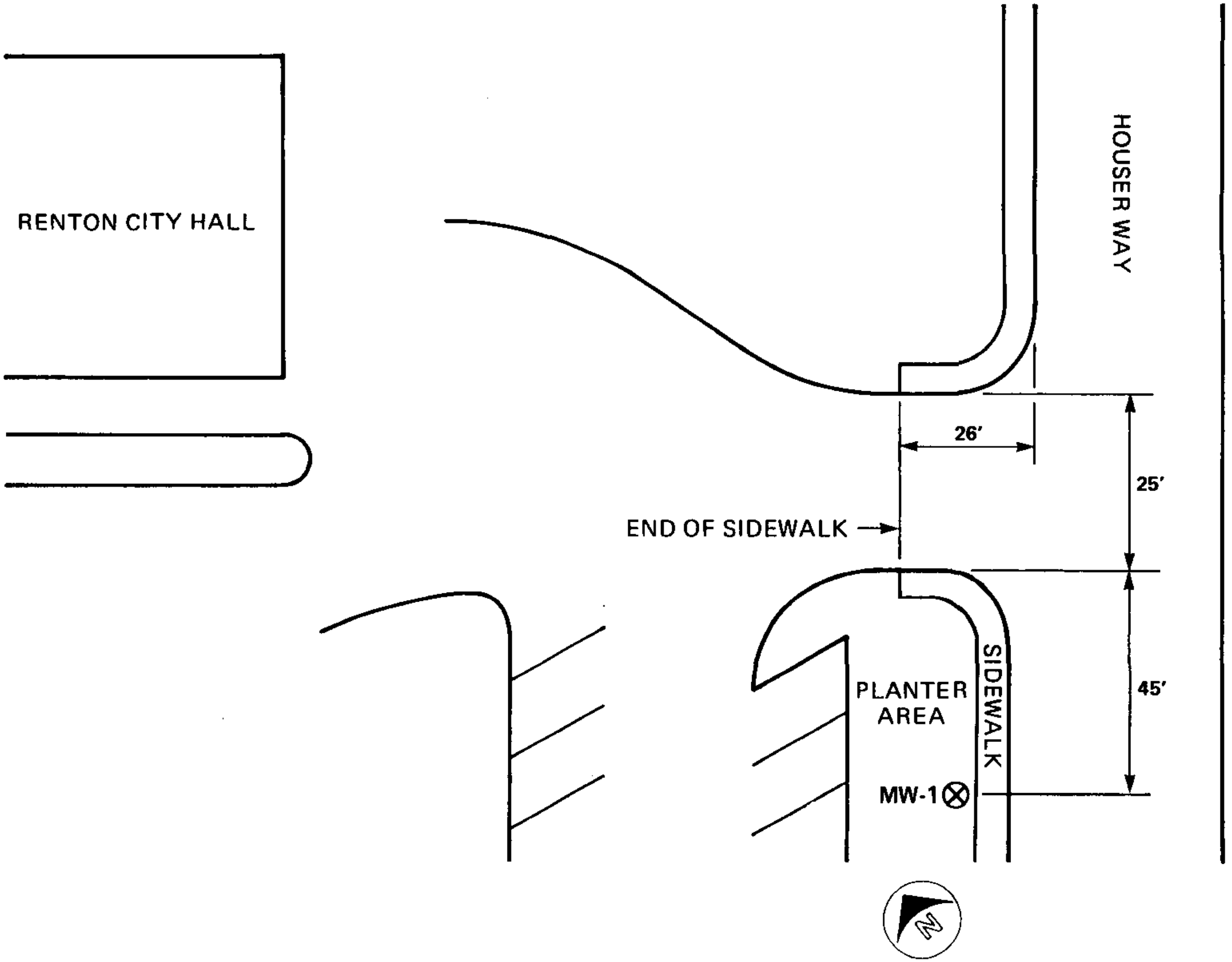


FIGURE A-1
MONITORING WELL MW-1
LOCATION SKIETCH
(Not to Scale)
CITY OF RENTON, WA

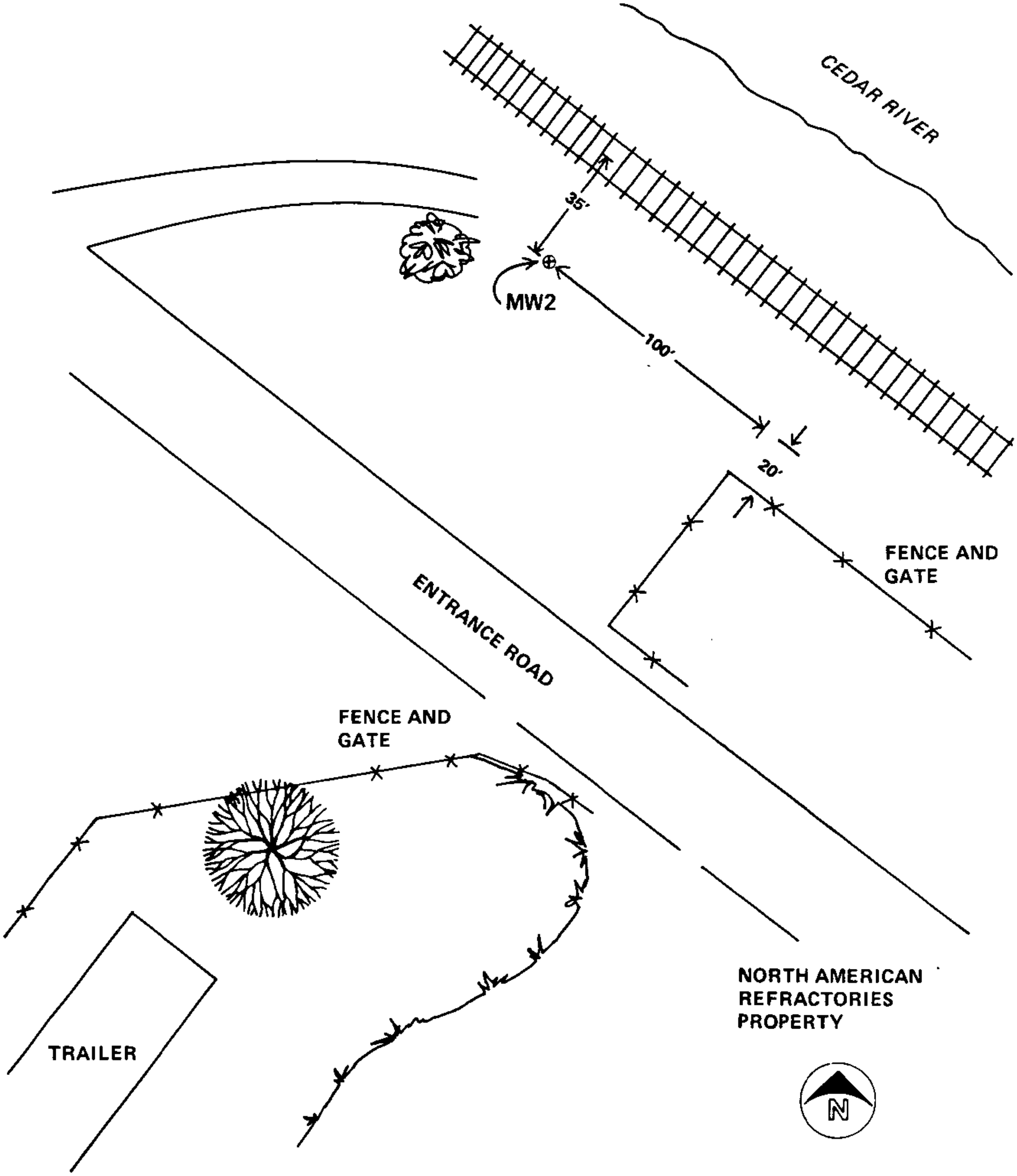


FIGURE A-2
MONITORING WELL MW2
LOCATION SKETCH
(Not to Scale)
CITY OF RENTON, WA

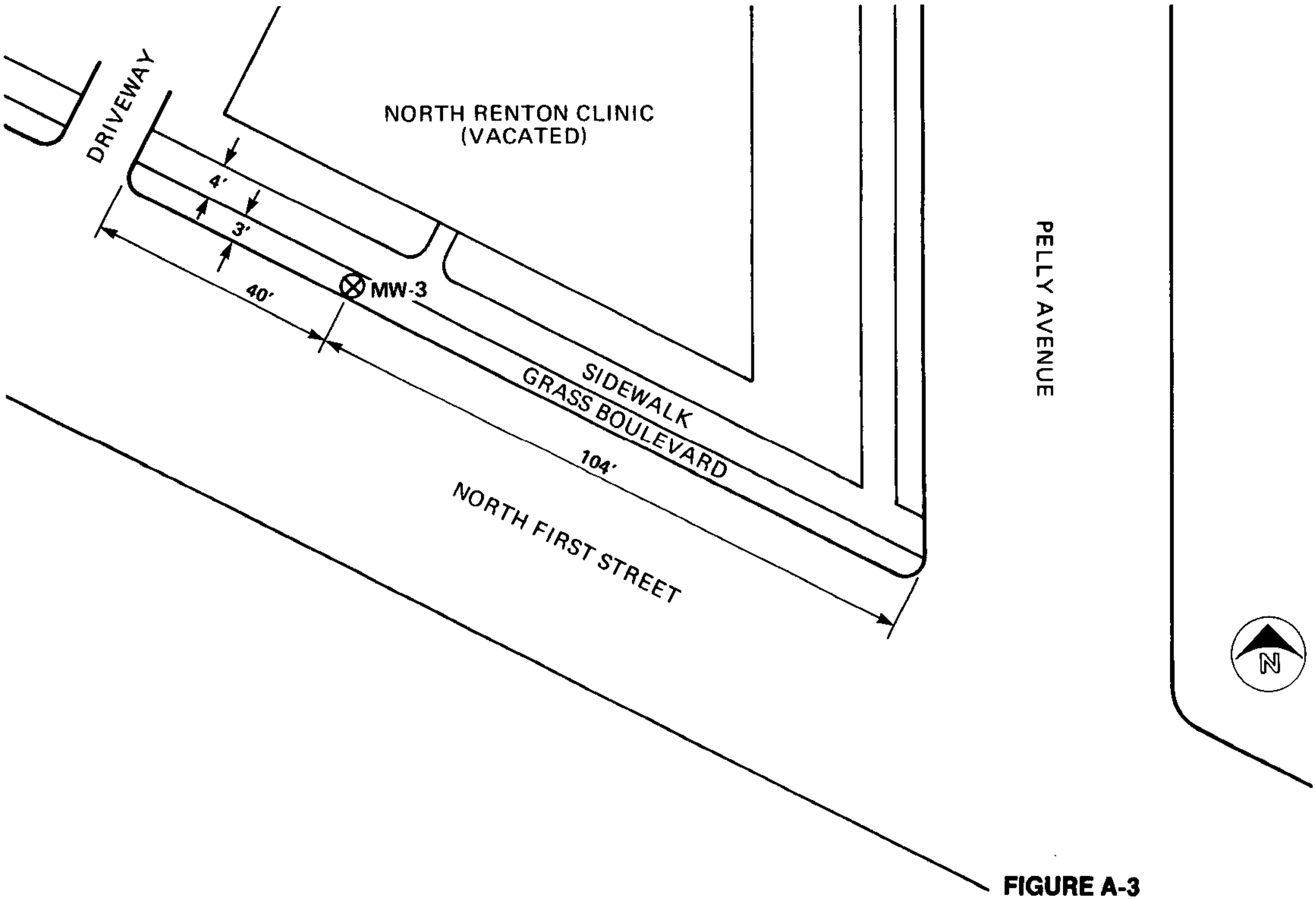


FIGURE A-3
MONITORING WELL MW-3
LOCATION SKETCH
(Not to Scale)
CITY OF RENTON, WA

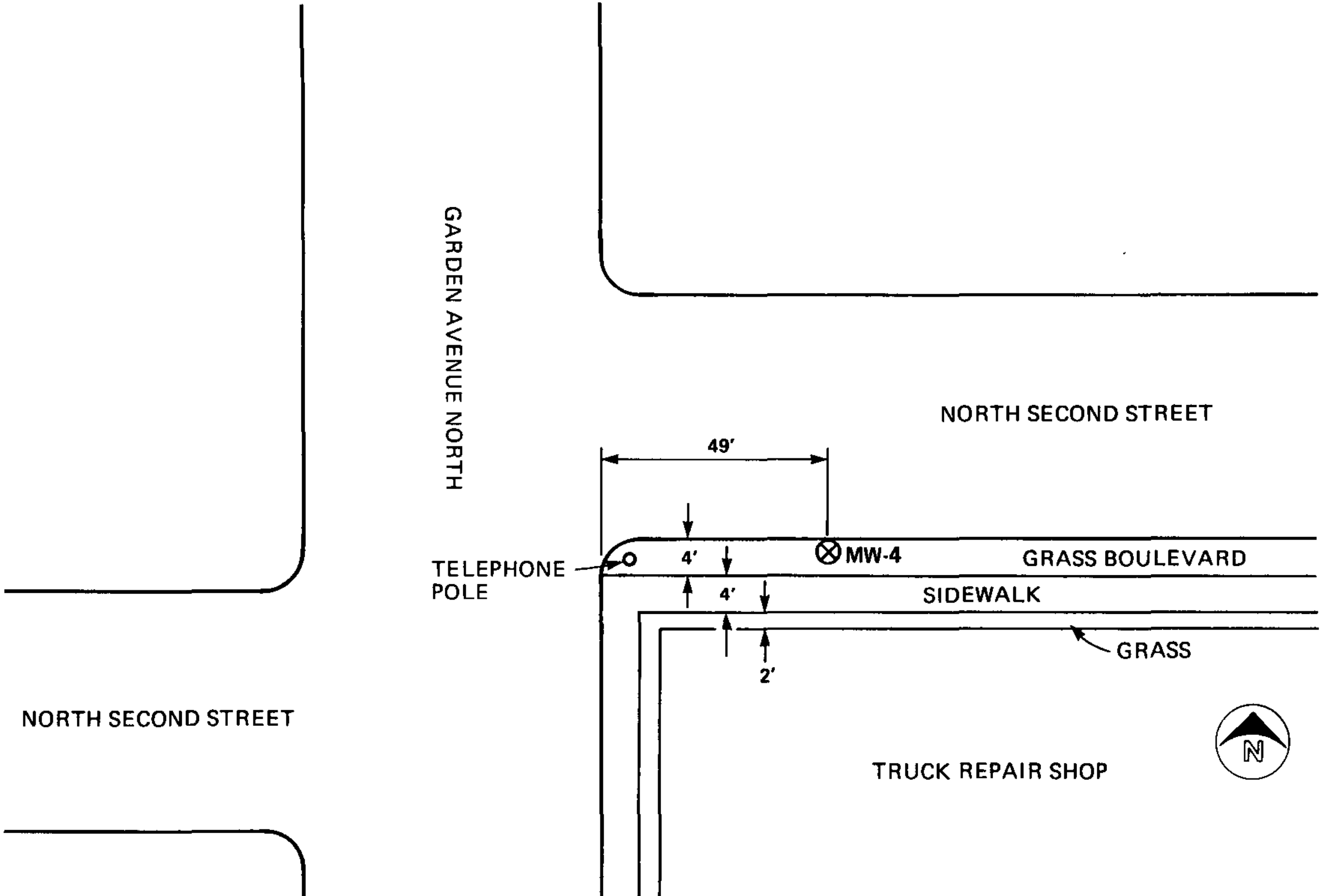


FIGURE A-4
MONITORING WELL MW-4
LOCATION SKETCH
(Not to Scale)
CITY OF RENTON, WA

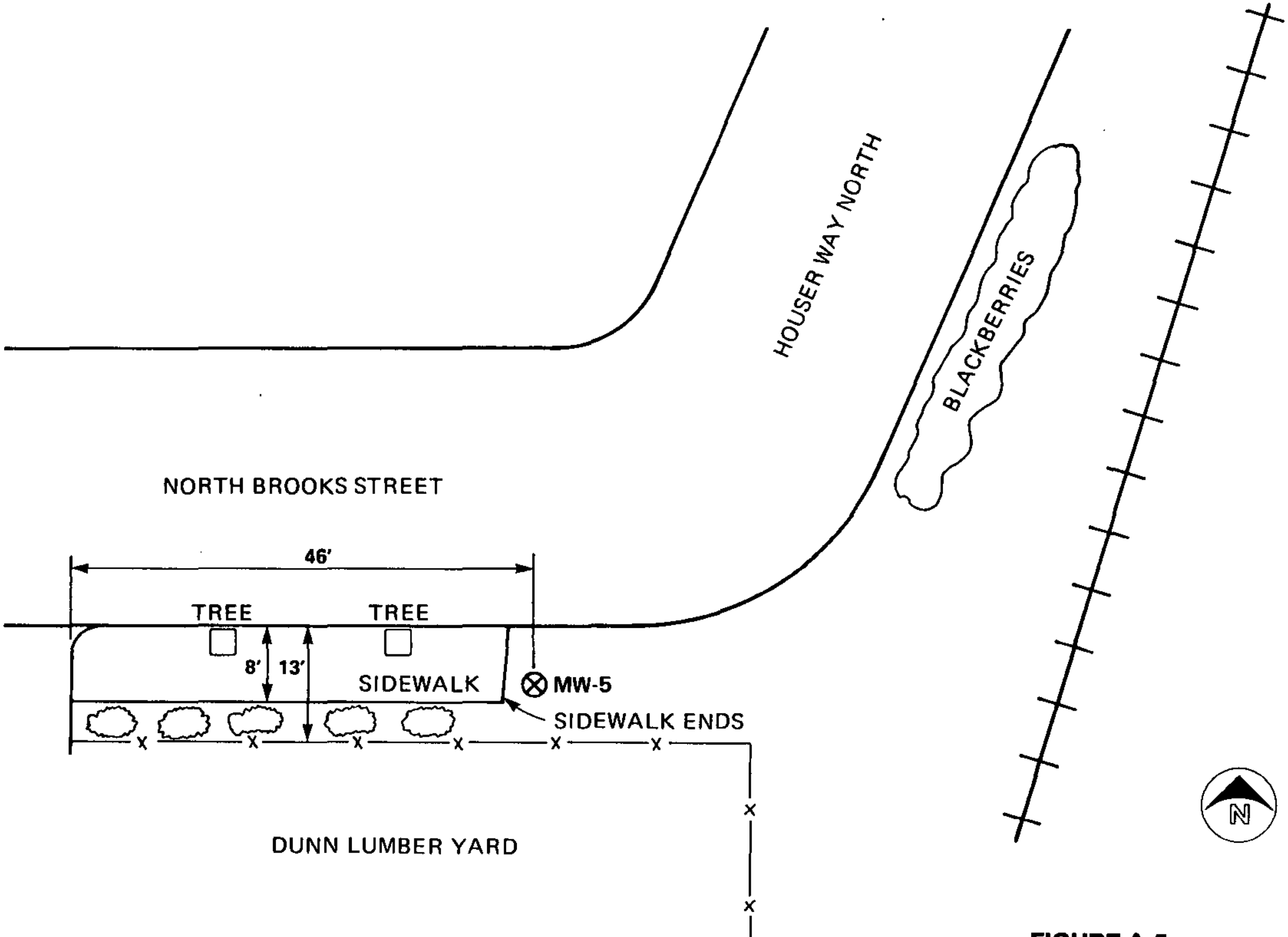


FIGURE A-5
MONITORING WELL MW-5
LOCATION SKETCH
(Not to Scale)
CITY OF RENTON, WA

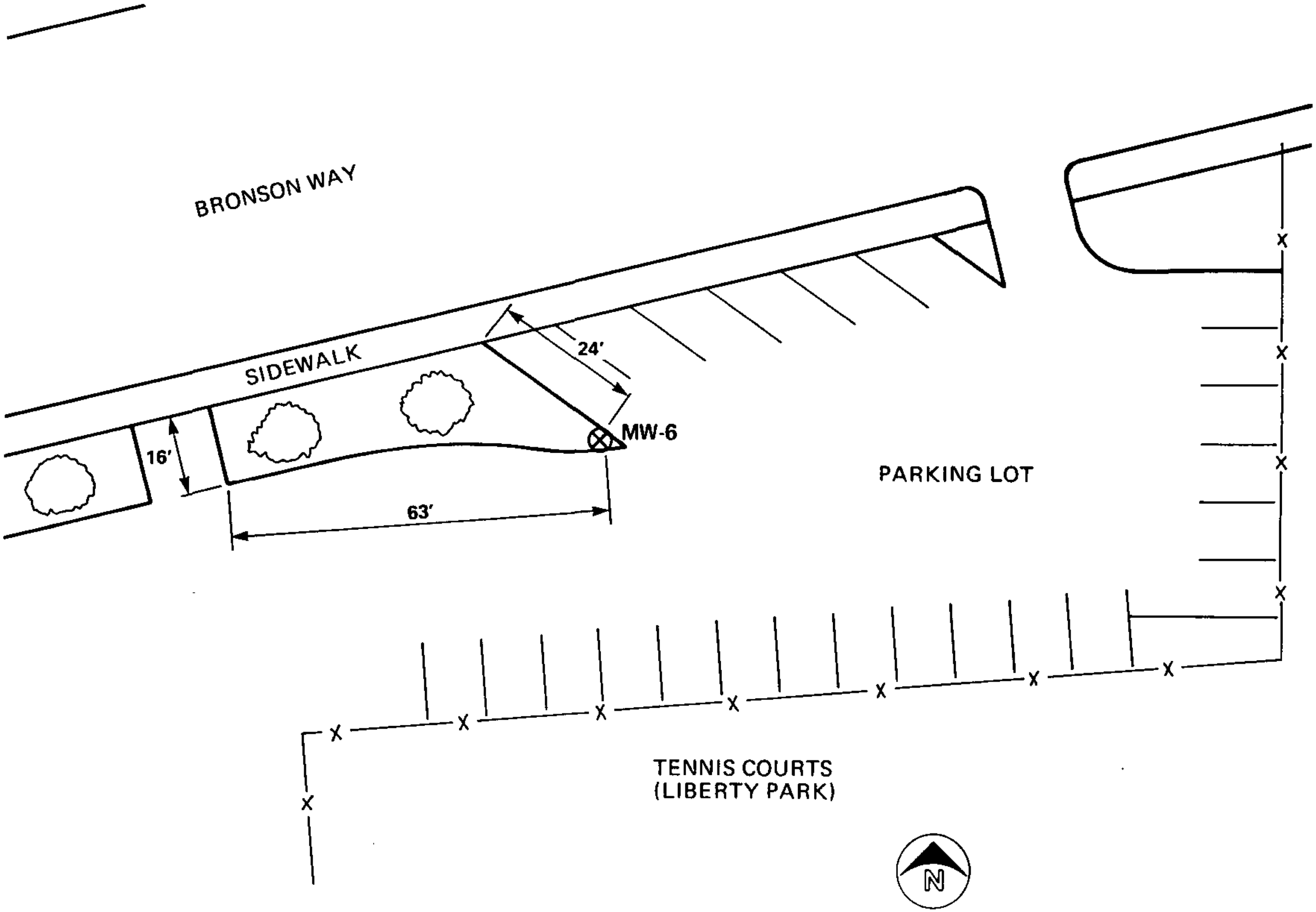


FIGURE A-6
MONITORING WELL MW-6
LOCATION SKETCH
(Not to Scale)
CITY OF RENTON, WA

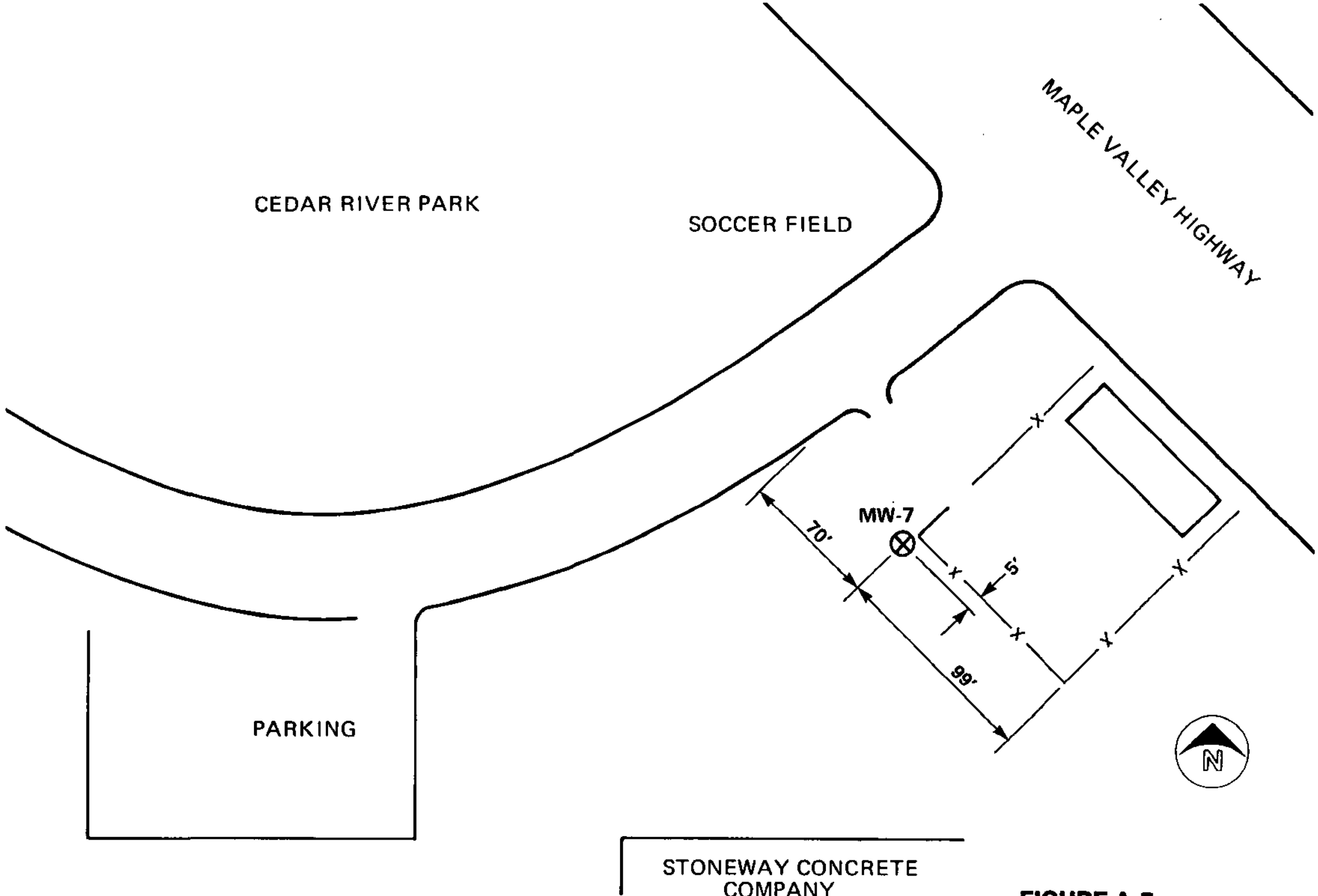


FIGURE A-7
MONITORING WELL MW-7
LOCATION SKETCH
(Not to Scale)
CITY OF RENTON, WA

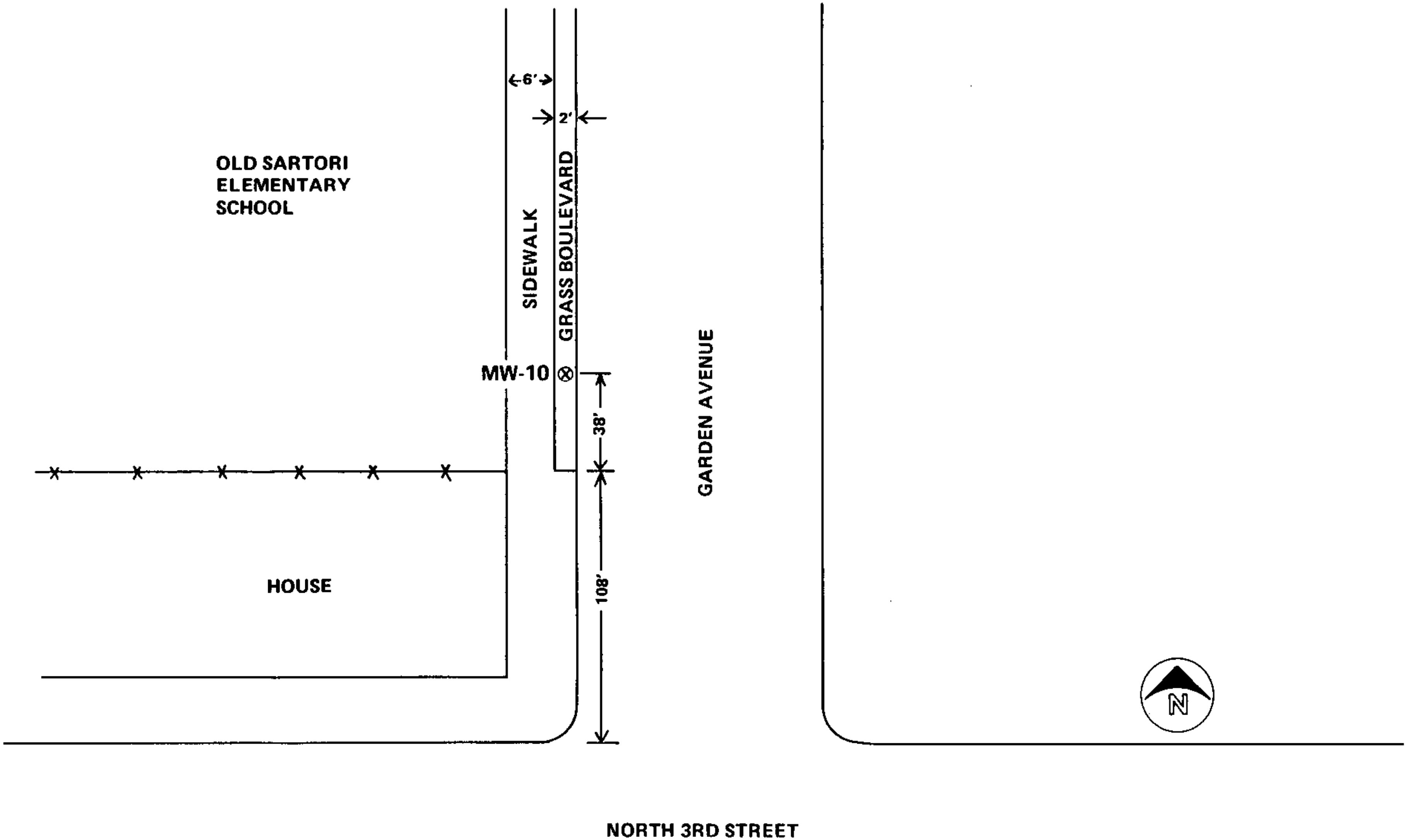


FIGURE A-8
MONITORING WELL MW-106
LOCATION SKETCH
(Not to Scale)
CITY OF RENTON, WA

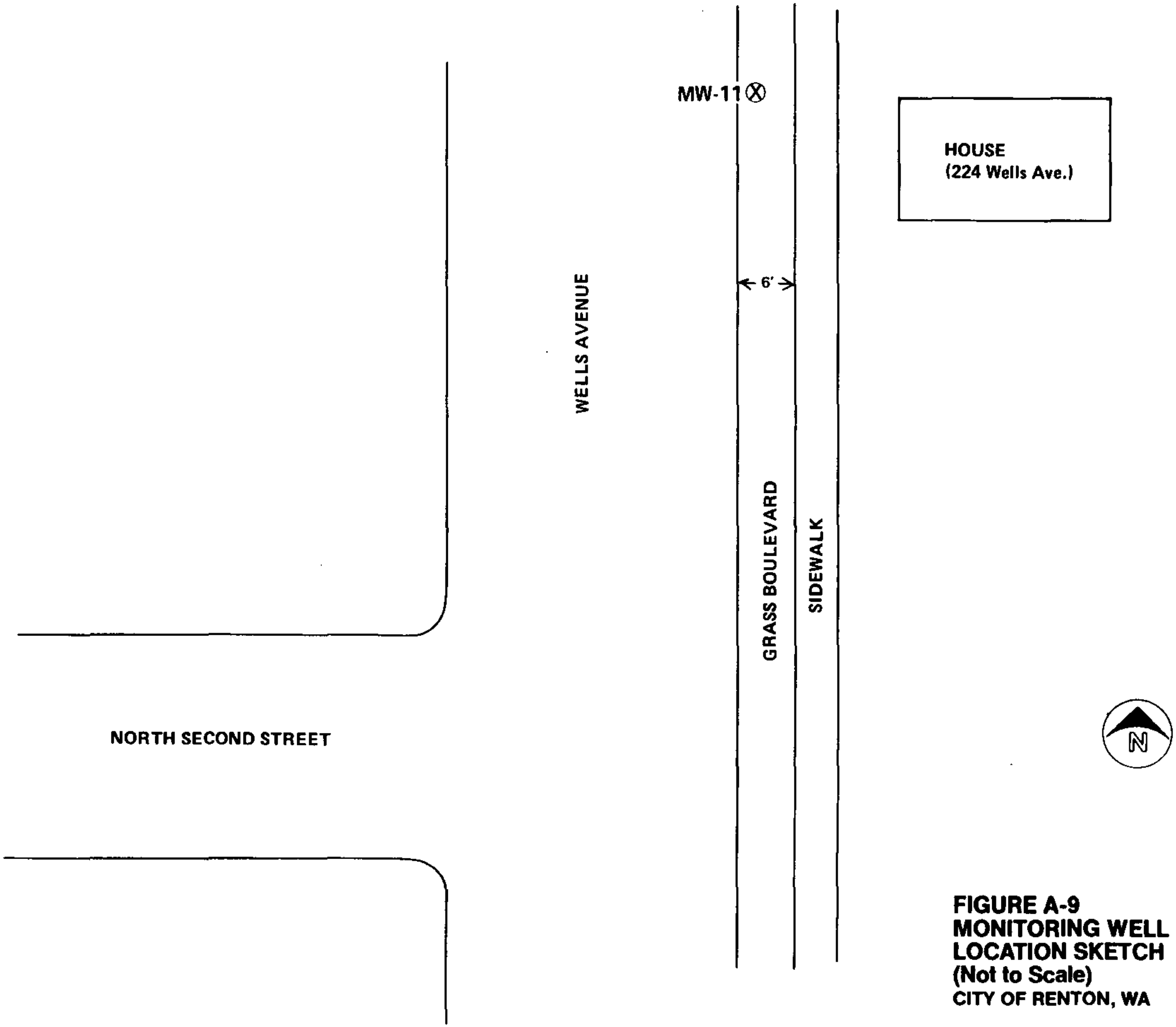


FIGURE A-9
MONITORING WELL MW-11
LOCATION SKETCH
(Not to Scale)
CITY OF RENTON, WA

Appendix B
WELL LOG AND CONSTRUCTION DIAGRAMS

CH2M HILL MONITORING WELL LOG

PROJECT: CITY OF RENTON GROUNDWATER MONITORING WELLS
NUMBER: S20080.A0

COMPLETION DATE: January 23, 1986

LOCATION: RENTON, WASHINGTON

GROUND ELEVATION: 40.9 ft, MSL
PVC CASING ELEVATION: 40.91 ft MSL

DEPTH TO WATER FROM
GROUND & DATE: 21.1 ft., 2-22-86

WELL: MW-1

DRILLING METHOD: CABLE TOOL, 8-INCH CASING

DRILLER: HOKKAIDO DRILLING AND DEVELOPEMENT CO, GRAHAM, WA

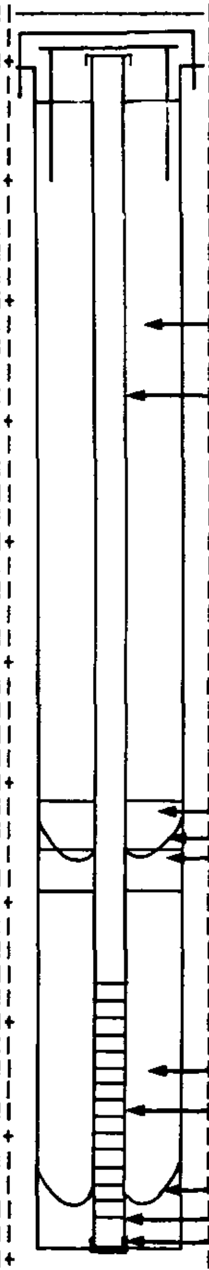
INSPECTOR: SCOTT MCKINLEY / SEA

SAMPLING METHOD: EXAMINATION OF BAILED CUTTINGS

DEPTH BELOW SURFACE (feet)	DESCRIPTION OF MATERIALS
0	SANDY LOAM, brown SAND AND GRAVEL, fine to coarse sand and fine to med gravel
5	GRAVEL, fine to med rounded gravel with some fine to coarse sand
10	
15	GRAVEL, fine to coarse gravel with some coarse sand SAND, med to coarse sand with some fine to coarse gravel
20	SAND AND GRAVEL, coarse sand and fine to med gravel
25	
30	
35	
40	
45	
50	
55	
60	CLAY, grayish-white clay, good plasticity, extremely dense (refusal) End of Boring

RECORD DRAWING

WELL CONSTRUCTION DETAILS



Concrete meter box with lid
8" steel casing with locking cap
(See Generalized Well Construction diagram for detail)

Cement/bentonite seal

2" SCH 40 PVC threaded flush coupled casing

Bentonite pellets
Centering guide
Fine sand

Sand pack (Monterey- Aqua #8)

Machine slotted SCH 40 PVC screen (20 slot size)

Centering guide
Bottom sump
End cap

FIGURE B-1
MW-1 WELL LOG AND CONSTRUCTION DIAGRAM
CITY OF RENTON, WA

CH2M HILL MONITORING WELL LOG

PROJECT: CITY OF RENTON GROUNDWATER MONITORING WELLS
NUMBER: S20080.A0

COMPLETION DATE: April 25, 1986

LOCATION: RENTON, WASHINGTON

GROUND ELEVATION: 51.2 ft. MSL
PVC CASING ELEVATION: 53.32 ft. MSL

DEPTH TO WATER FROM
GROUND & DATE: 26.6 ft, 4-30-86

WELL: MW-2

DRILLING METHOD: CABLE TOOL, 8-INCH CASING

DRILLER: HOKKAIDO DRILLING AND DEVELOPEMENT CO.
GRAHAM, WA

INSPECTOR: J. NINTEMAN / SEA

SAMPLING METHOD: EXAMINATION OF BAILED CUTTINGS

DEPTH BELOW SURFACE (feet)	DESCRIPTION OF MATERIALS
0	SILTY, SANDY LOAM, organic odor, black, soft
	SAND, med to coarse, with some silt
5	
	SAND AND GRAVEL, med to coarse sand and fine to med gravel with a little fine sand and silt, brown, dense
10	
	silt layer
15	
20	SAND AND GRAVEL, poorly sorted, with some silt, gray-brown, dense
25	
30	
35	
	GRAVEL, mostly med to coarse and some med to coarse sand and a little silt, brown, easier drilling, cleaner, hole begins making water
40	
45	
50	END OF BORING

RECORD DRAWING / WELL CONSTRUCTION DETAILS

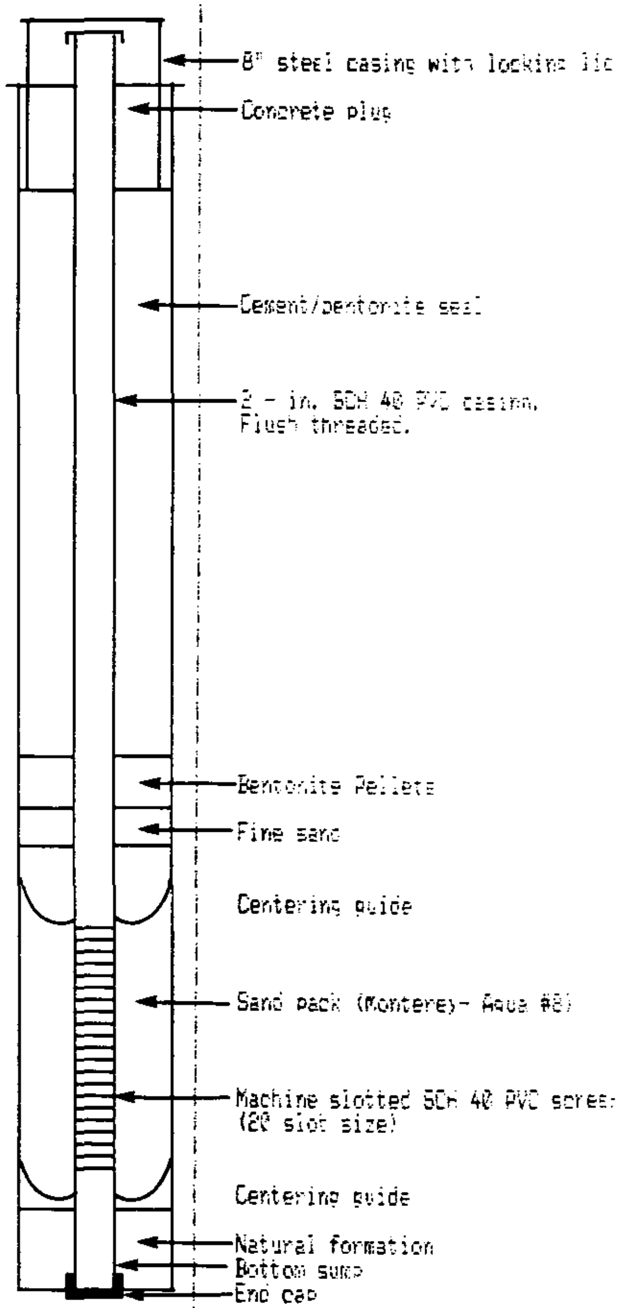


FIGURE B-2
MW-2 WELL LOG AND CONSTRUCTION DIAGRAM
CITY OF RENTON, WA

CH2M HILL MONITORING WELL LOG

PROJECT: CITY OF RENTON GROUNDWATER MONITORING WELLS
NUMBER: S20080.A0

COMPLETION DATE: January 27, 1986

LOCATION: RENTON, WASHINGTON

GROUND ELEVATION: 36.1 ft, MSL
PVC CASING ELEVATION: 35.50 ft, MSL

DEPTH TO WATER FROM
GROUND & DATE: 16.1 ft., 2-22-86

WELL: MW-3

DRILLING METHOD: CABLE TOOL, 8-INCH CASING

DRILLER: HOKKAIDO DRILLING AND DEVELOPEMENT CO, GRAHAM, WA

INSPECTOR: SCOTT MCKINLEY / SEA

SAMPLING METHOD: EXAMINATION OF BAILED CUTTINGS

DEPTH BELOW SURFACE (feet)	DESCRIPTION OF MATERIALS
0	SILTY LOAM, gray-brown, loose
	SILTY LOAM, brown, wet
5	SAND, fine to coarse with some silt and clay, low plasticity
	GRAVEL, fine to coarse, with some fine to coarse sand
10	
15	GRAVEL, fine to coarse, rounded gravel
20	GRAVEL, fine gravel with trace med to coarse sand
	SAND, coarse sand with some fine to med,
25	rounded gravel
	GRAVEL, fine to coarse, rounded gravel with some coarse sand
30	
	SILTY SAND, fine silty sand, brown with some clay, med plasticity
35	
	SAND AND GRAVEL, coarse sand with fine to coarse, rounded gravel
40	
	SAND, coarse sand with some fine gravel
45	
	SAND AND GRAVEL, fine to coarse sand with fine gravel
50	
	End of boring

RECORD DRAWING | WELL CONSTRUCTION DETAILS

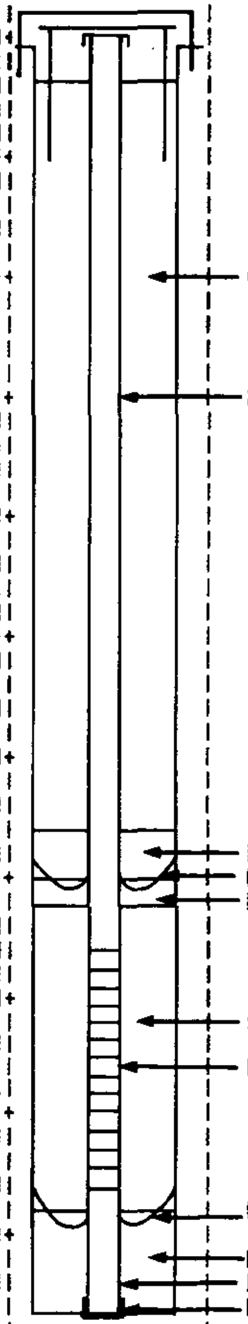


FIGURE B-3
MW-3 WELL LOG AND CONSTRUCTION DIAGRAM
CITY OF RENTON, WA

CH2M HILL MONITORING WELL LOG

PROJECT: CITY OF RENTON GROUNDWATER MONITORING WELLS
NUMBER: S20080.A0

COMPLETION DATE: January 29, 1986

LOCATION: RENTON, WASHINGTON

GROUND ELEVATION: 36.9 ft, MSL
PVC CASING ELEVATION: 36.44 ft, MSL

DEPTH TO WATER FROM
GROUND & DATE: 16.9 ft., 2-22-86

WELL: MW-4

DRILLING METHOD: CABLE TOOL, 8-INCH CASING

DRILLER: HOKKAIDO DRILLING AND DEVELOPEMENT CO, GRAHAM, WA

INSPECTOR: SCOTT MCKINLEY / SEA

SAMPLING METHOD: EXAMINATION OF BAILED CUTTINGS

DEPTH BELOW SURFACE (feet)	DESCRIPTION OF MATERIALS
0	SANDY LOAM, coarse sand, brown and some silty clay
5	SAND AND GRAVEL, coarse sand with fine, rounded gravel
10	SAND, coarse sand and some fine gravel
15	
20	SAND, coarse sand and some fine to coarse, rounded gravel
25	
	SAND, fine to coarse sand and minor fine gravel
30	
	GRAVEL, fine to med rounded gravel and some coarse sand
35	
40	
	SAND AND GRAVEL, coarse sand with fine to med, rounded gravel
45	
	SAND, fine to coarse sand and minor fine gravel
50	END OF BORING

RECORD DRAWING | WELL CONSTRUCTION DETAILS

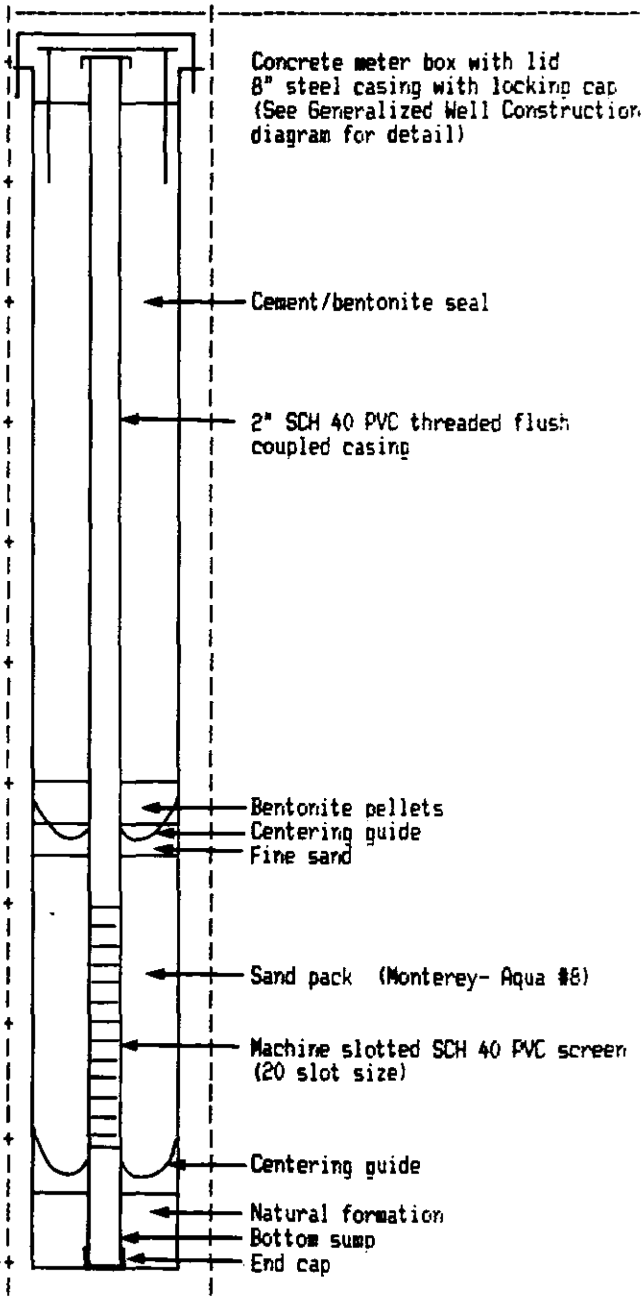


FIGURE B-4
MW-4 WELL LOG AND CONSTRUCTION DIAGRAM
CITY OF RENTON, WA

CH2M HILL MONITORING WELL LOG

PROJECT: CITY OF RENTON GROUNDWATER MONITORING WELLS
NUMBER: S20080.A0

COMPLETION DATE: January 31, 1986

LOCATION: RENTON, WASHINGTON

GROUND ELEVATION: 38.8 ft, MSL
PVC CASING ELEVATION: 38.32 ft, MSL

DEPTH TO WATER FROM
GROUND & DATE: 17.4 ft, 2-22-86

WELL: MW-5

DRILLING METHOD: CABLE TOOL, 8-INCH CASING

DRILLER: HOKKAIDO DRILLING AND DEVELOPEMENT CO, GRAHAM, WA

INSPECTOR: SCOTT MCKINLEY / SEA

SAMPLING METHOD: EXAMINATION OF BAILED CUTTINGS

DEPTH BELOW SURFACE (feet)	DESCRIPTION OF MATERIALS
0	SILTY-CLAY LOAM, brown
5	
	CLAY, approximate 4" layer of gray clay
	SAND, fine to coarse sand and some fine to med, rounded gravel. Trace of brown silt
10	SAND AND GRAVEL, coarse sand with fine gravel
15	
	SAND, coarse sand and some fine to coarse rounded gravel
20	
25	SILTY CLAY, dark gray-brown, plastic and clumpy
30	GRAVEL, fine to med, rounded gravel and some coarse sand, grayish in color
35	
	SAND, med to coarse sand and some fine to med, rounded gravel, brown
40	
45	
50	END OF BORING

RECORD DRAWING | WELL CONSTRUCTION DETAILS

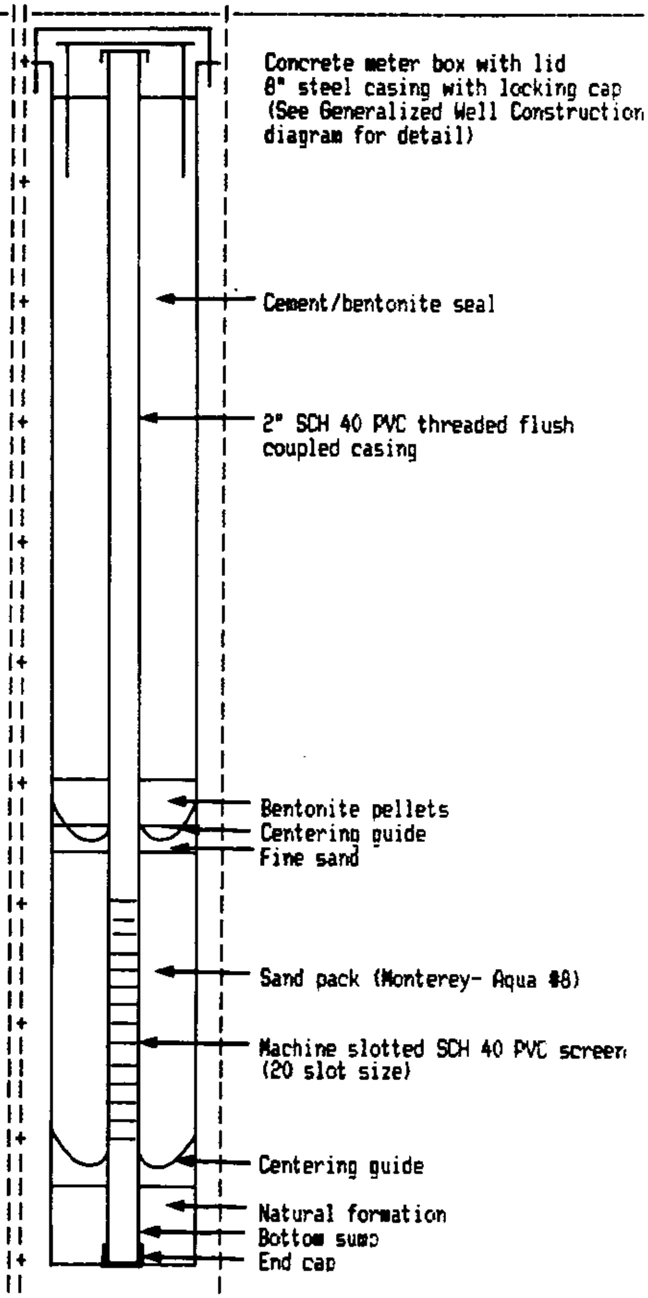


FIGURE B-5
MW-5 WELL LOG AND CONSTRUCTION DIAGRAM
CITY OF RENTON, WA

CH2M HILL MONITORING WELL LOG

PROJECT: CITY OF RENTON GROUNDWATER MONITORING WELLS
NUMBER: S20080.A0

COMPLETION DATE: FEBRUARY 5, 1986

LOCATION: RENTON, WASHINGTON

GROUND ELEVATION: 39.1 ft, MSL
PVC CASING ELEVATION: 38.83 ft, MSL

DEPTH TO WATER FROM
GROUND & DATE: 19.4 ft, 2-22-86

WELL: MW-6

DRILLING METHOD: CABLE TOOL, 8-INCH CASING

DRILLER: HOKKAIDO DRILLING AND DEVELOPEMENT CO, GRAHAM, WA

INSPECTOR: SCOTT MCKINLEY / SEA

SAMPLING METHOD: EXAMINATION OF BAILED CUTTINGS

DEPTH BELOW SURFACE (feet)	DESCRIPTION OF MATERIALS	WELL CONSTRUCTION DETAILS
0	SILTY-CLAY LOAM, brown, moist, clumpy, and trace coarse sand	Concrete meter box with lid 8" steel casing with locking cap (See Generalized Well Construction diagram for detail)
5		
10	SAND, fine to coarse sand and some fine to coarse, rounded gravel, loose	Cement/bentonite seal
15		2" SCH 40 PVC threaded flush coupled casing
	SAND, fine to coarse sand	
20		
25	SAND, med to coarse sand and minor fine gravel	
30		
		Bentonite pellets Centering guide Fine sand
35		
		Sand pack (Monterey-aqua #8)
40		Machine slotted SCH 40 PVC screen (20 slot size)
	SAND, coarse sand and some fine, rounded gravel	
45		
	GRAVEL, fine to coarse rounded gravel and some coarse sand	Centering guide Natural formation
		Bottom sump
50	END OF BORING	End cap

RECORD DRAWING

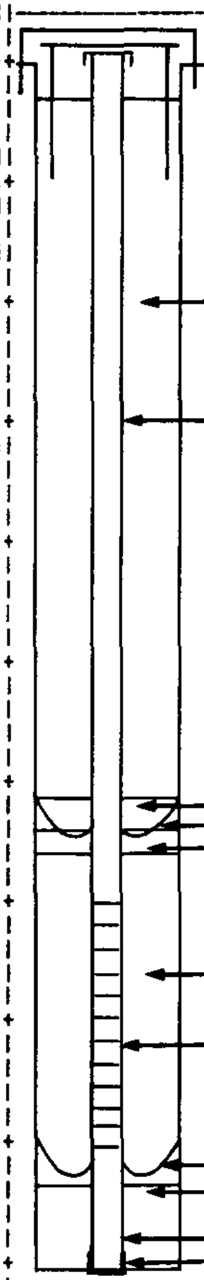


FIGURE B-6
MW-6 WELL LOG AND CONSTRUCTION DIAGRAM
CITY OF RENTON, WA

CH2M HILL MONITORING WELL LOG

PROJECT: CITY OF RENTON GROUNDWATER MONITORING WELLS
NUMBER: S20080.A0

COMPLETION DATE: January 17, 1986

LOCATION: RENTON, WASHINGTON

GROUND ELEVATION: 47.12 ft, MSL
PVC CASING ELEVATION: 47.16 ft, MSL

DEPTH TO WATER FROM
GROUND & DATE: 23.1 ft., 2-22-86

WELL: MW-7

DRILLING METHOD: CABLE TOOL, 8-INCH CASING

DRILLER: HOKKAIDO DRILLING AND DEVELOPEMENT CO, GRAHAM, WA

INSPECTOR: SCOTT MCKINLEY / SEA

SAMPLING METHOD: EXAMINATION OF BAILED CUTTINGS

DEPTH BELOW SURFACE (feet)	DESCRIPTION OF MATERIALS
0	SILTY SAND, fine sand, brown and wet
5	
	SAND AND GRAVEL, coarse sand to fine rounded gravel
	SAND AND GRAVEL, fine to coarse sand and fine
10	rounded gravel
15	
	SAND AND GRAVEL, coarse sand to fine gravel with some fine to med sand
20	
25	
	SAND AND GRAVEL, fine to coarse sand and fine gravel with a little med to coarse gravel
30	
	SAND AND GRAVEL, coarse sand to medium rounded gravel with some fine to med sand and coarse gravel
35	
40	
45	
	SAND AND GRAVEL, coarse sand to coarse rounded gravel with some fine to med sand
50	End of boring

RECORD DRAWING / WELL CONSTRUCTION DETAILS

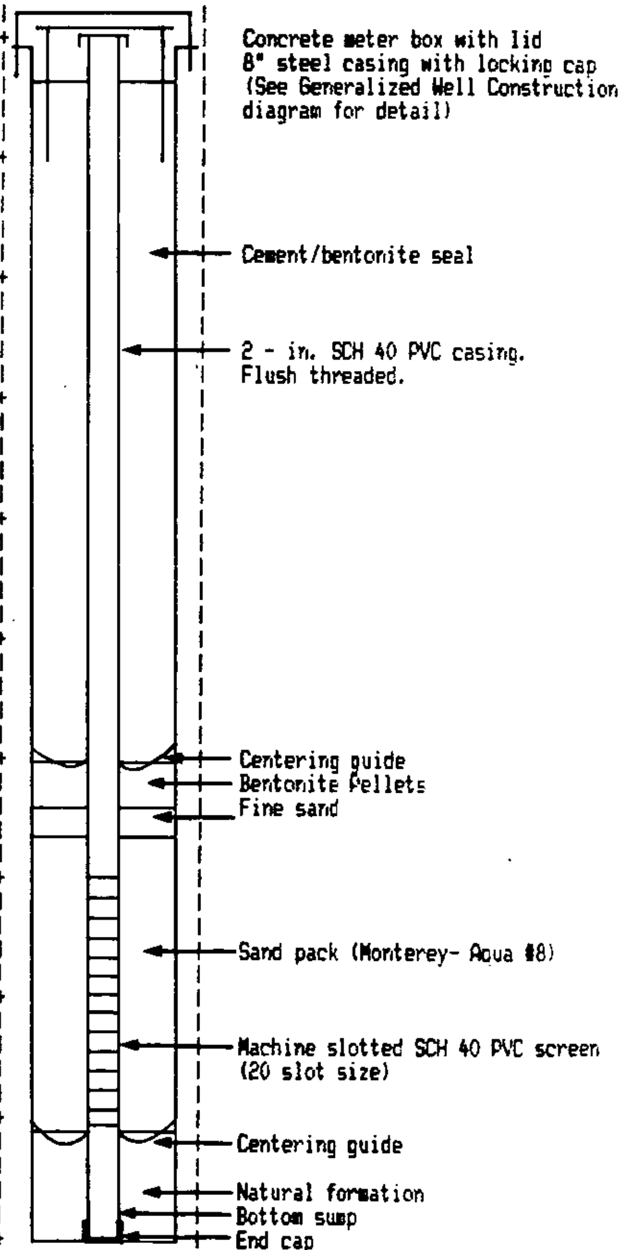


FIGURE B-7
MW-7 WELL LOG AND CONSTRUCTION DIAGRAM
CITY OF RENTON, WA

CH2M HILL MONITORING WELL LOG

PROJECT: CITY OF RENTON GROUNDWATER MONITORING WELLS
NUMBER: S20080.A0

COMPLETION DATE: April 23, 1986

LOCATION: RENTON, WASHINGTON

GROUND ELEVATION: 34.0 ft, MSL
PVC CASING ELEVATION: 34.12 ft, MSL

DEPTH TO WATER FROM
GROUND & DATE: 13.8 ft., 4-30-86

WELL: MW-10

DRILLING METHOD: CABLE TOOL, 8-INCH CASING

DRILLER: HOKKAIDO DRILLING AND DEVELOPEMENT CO.
GRAHAM, WA

INSPECTOR: J. NINTEMAN / SEA

SAMPLING METHOD: EXAMINATION OF BAILED CUTTINGS

DEPTH BELOW SURFACE (feet)	DESCRIPTION OF MATERIALS
0	SILTY LOAM, brown to black
	SANDY SILT, fine sand with some med to coarse sand and fine gravel, brown
5	
	SILTY SAND AND GRAVEL, brown silt, mostly coarse sand to fine gravel
10	
15	SANDY, GRAVELLY SILT, layered zones of silty sand and gravel, and gravelly silt, fine to med gravel, gray silt
20	
25	
30	SILTY CLAY, with some fine to med gravel and a little fine sand, soft, no thread, blue-gray
35	
	END OF BORING
40	

RECORD DRAWING / WELL CONSTRUCTION DETAILS

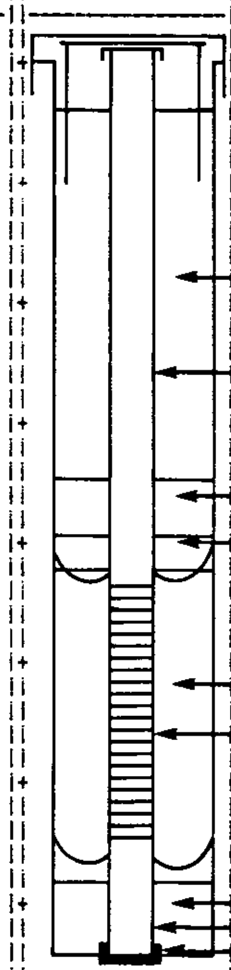


FIGURE B-8
MW-10 WELL LOG AND CONSTRUCTION DIAGRAM
CITY OF RENTON, WA

CH2M HILL MONITORING WELL LOG

PROJECT: CITY OF RENTON GROUNDWATER MONITORING WELLS
NUMBER: S20080.A0

COMPLETION DATE: April 27, 1986

LOCATION: RENTON, WASHINGTON

GROUND ELEVATION: 32.0 ft, MSL
PVC CASING ELEVATION: 32.24 ft, MSL

DEPTH TO WATER FROM
GROUND & DATE: 12.0 ft, 4-30-86

WELL: MW-11

DRILLING METHOD: CABLE TOOL, 8-INCH CASING

DRILLER: HOKKAIDO DRILLING AND DEVELOPEMENT CO.
GRAHAM, WA

INSPECTOR: J. NINTEMAN / SEA

SAMPLING METHOD: EXAMINATION OF BAILED CUTTINGS

DEPTH BELOW SURFACE (feet)	DESCRIPTION OF MATERIALS
0	SANDY SILT, fine sand, with a trace of fine gravel, soft, brown
	increasing sand and gravel content
5	
10	SILTY SAND AND WOOD DEBRIS, fine sand, dark brown to black, soft
15	
	SANDY SILT, with trace of wood debris, dark gray
20	
	SAND AND GRAVEL, mostly coarse sand to fine gravel and some brown silt
25	
	same but with some wood chips
30	
35	SAND AND GRAVEL, coarse sand to med gravel, rounded, hole is making alot of water
40	END OF BORING

RECORD DRAWING

WELL CONSTRUCTION DETAILS

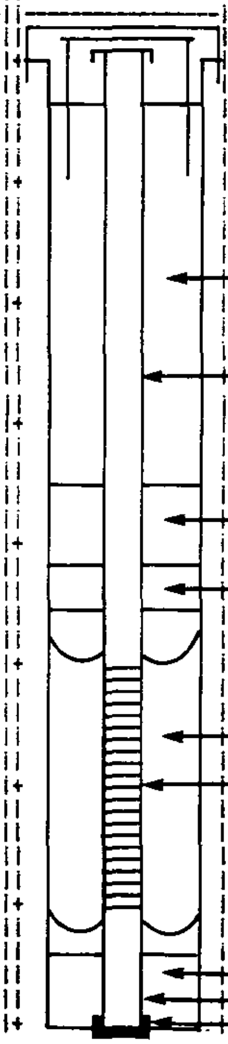


FIGURE B-9
MW-11 WELL LOG AND CONSTRUCTION DIAGRAM
CITY OF RENTON, WA

Appendix C
WELL LOGS FOR EXISTING AND REPLACEMENT PRODUCTION WELLS AND THE MAPLEWOOD GOLF COURSE TEST WELL

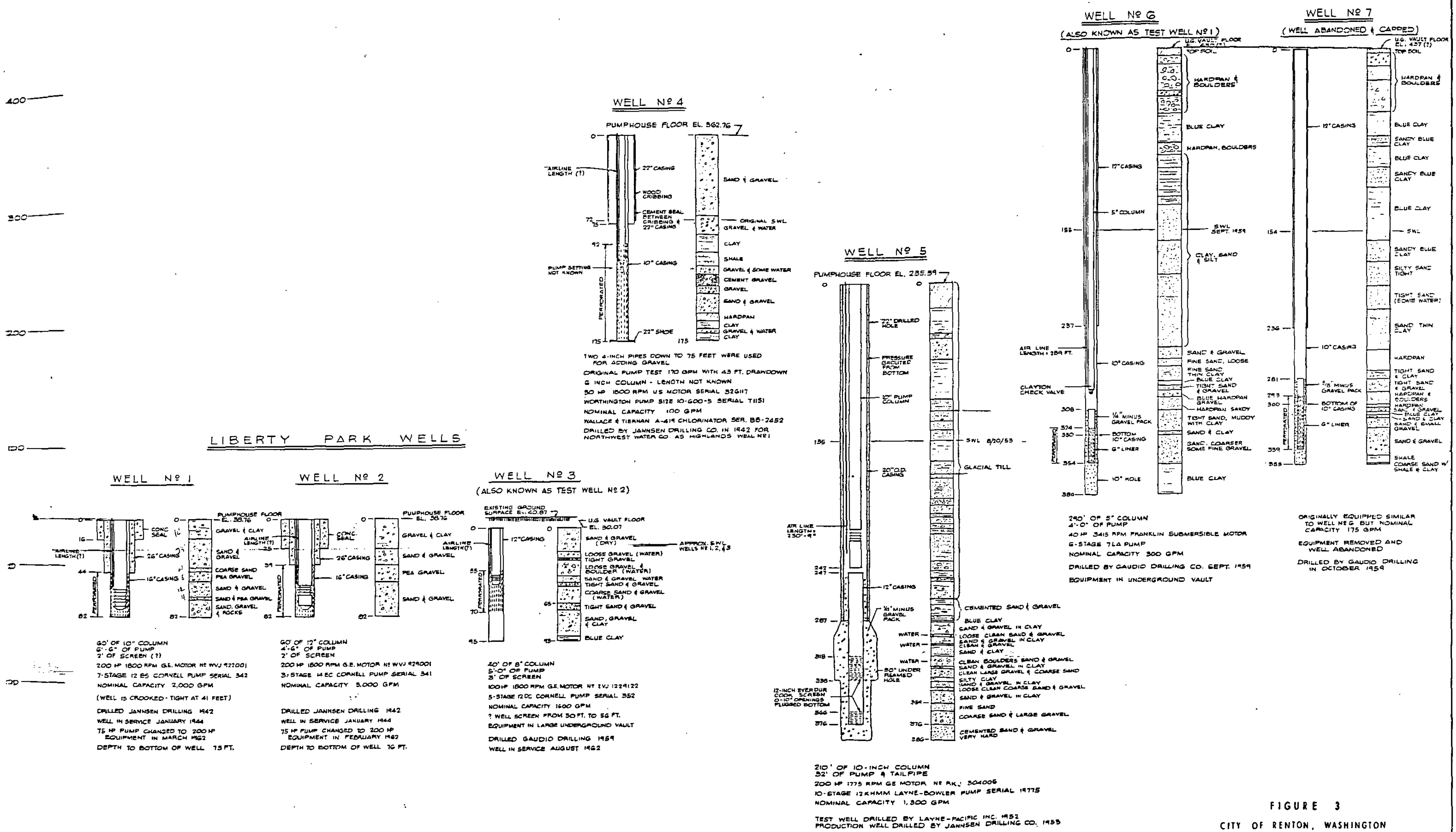


FIGURE 3

CITY OF RENTON, WASHINGTON
WATER SYSTEM INVESTIGATION

WELL LOGS & EQUIPMENT DATA

C-1

CORNELL, HOWLAND, HAYES & MERRYFIELD
SEATTLE PORTLAND CORVALLIS BOISE

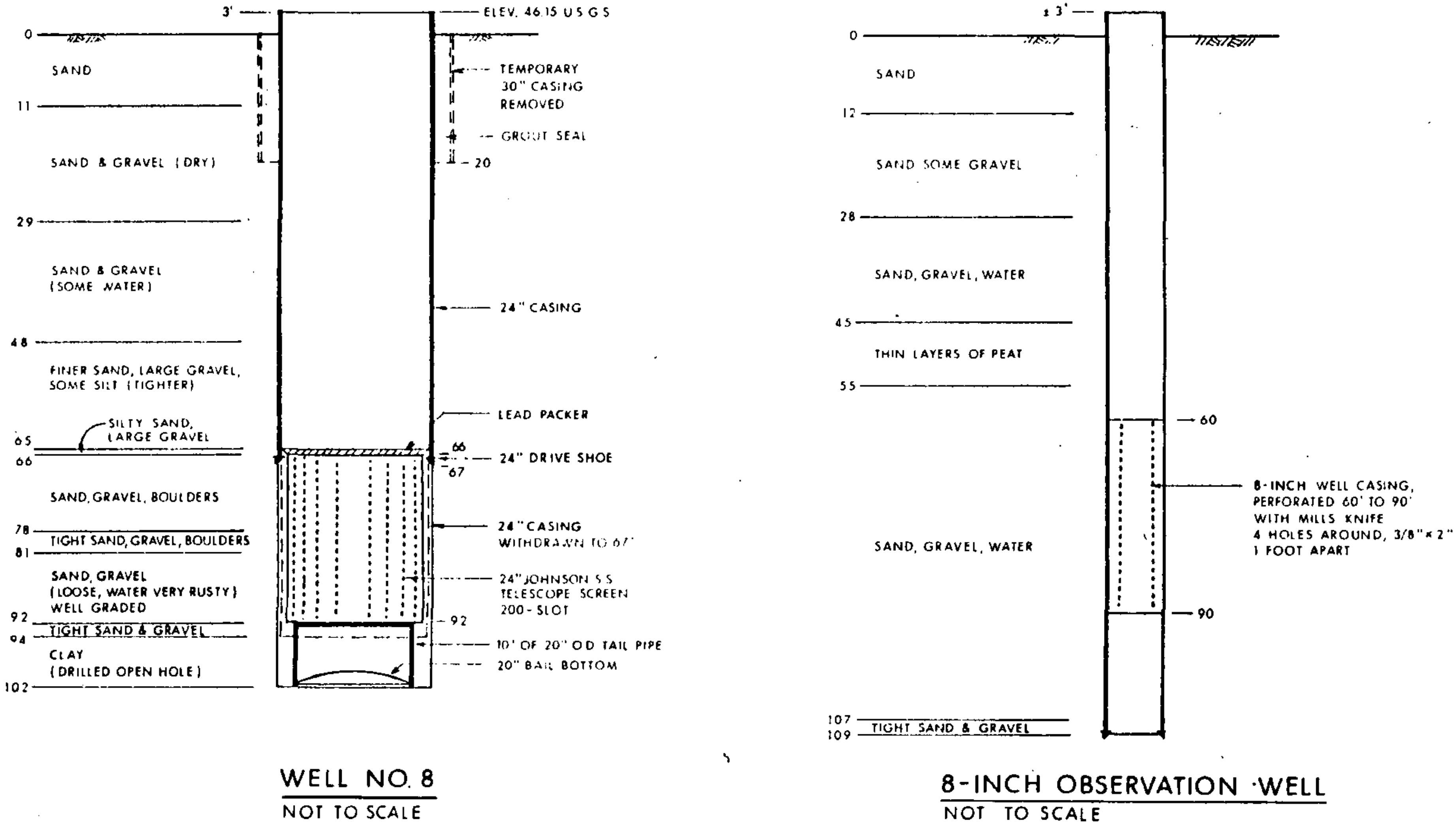


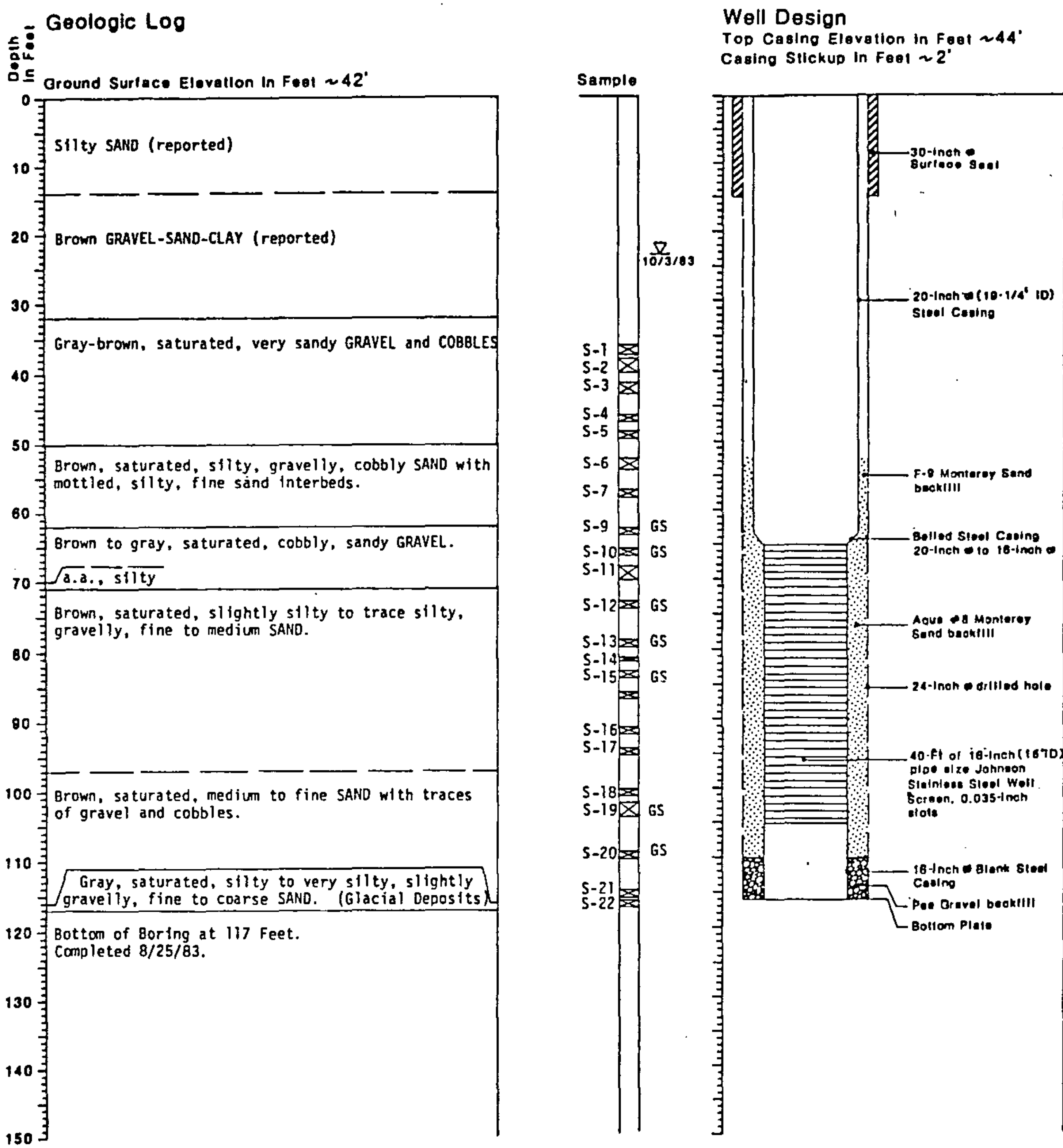
FIGURE 2

CITY OF RENTON, WASHINGTON

WELL LOGS & CONSTRUCTION DETAILS

CORNELL, HOWLAND, HAYES & MERRYFIELD
Engineers and Planners
SEATTLE CORVALLIS BOISE PORTLAND
4790.2 FEBRUARY 1968
CH2M

Boring Log and Construction Data for Well 9



(reported) Refers to material type encountered as reported by driller.

GS Grain Size Analysis

a.a. As Above

NOTES: 1. Soil descriptions are interpretive and actual changes may be gradual.

2. Water Level ∇ is for date indicated and may vary with time of year. ATD: At Time of Drilling

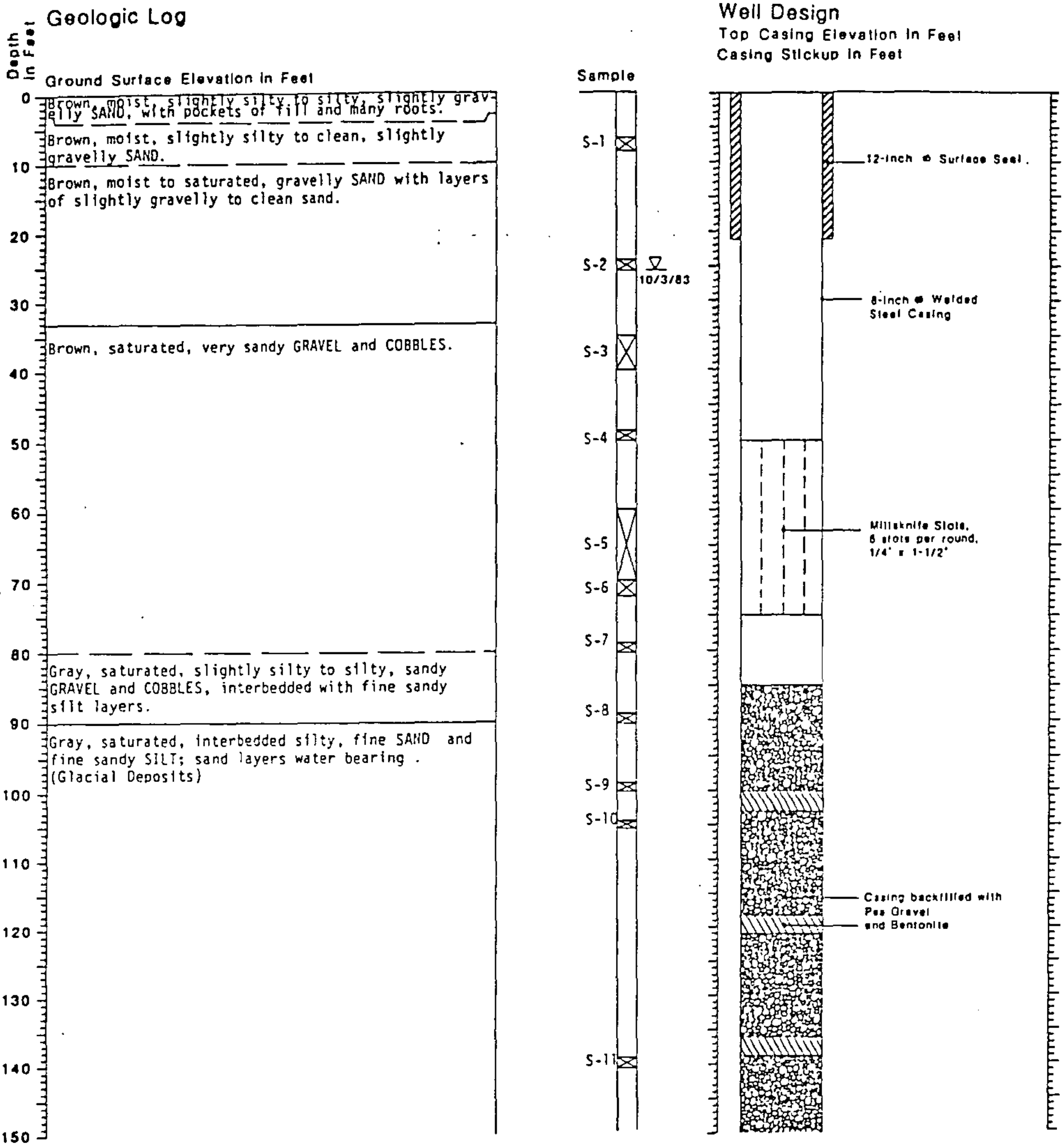
3. Elevation estimated to be same as Observation Well 8 and was obtained from City of Renton Well Location Map W665, Sheet 2 of 2, drawn by RH2 Engineering, 1982.

J-1148 September 1983

HART-CROWSER & associates, inc.

Figure A-1

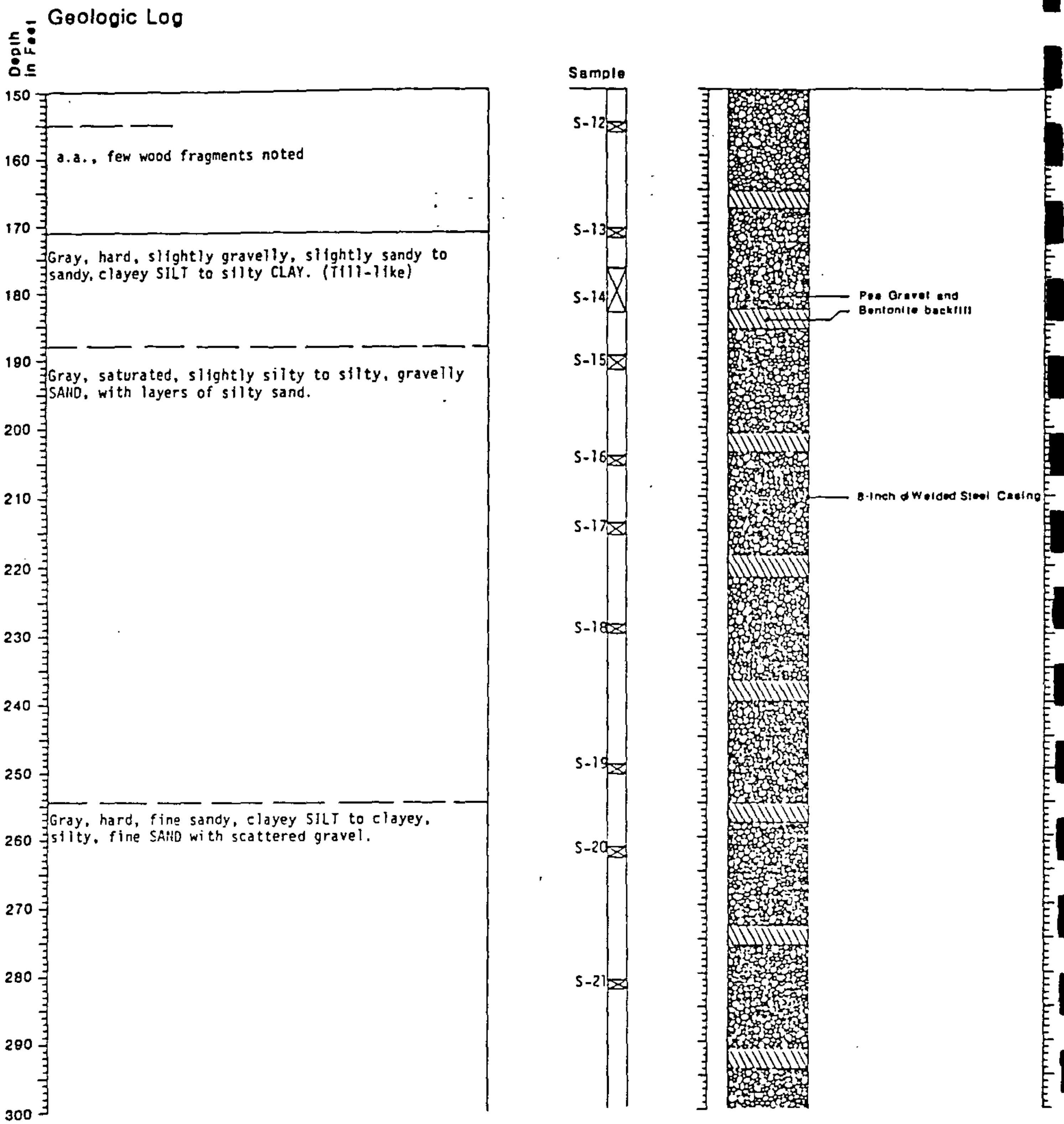
Boring Log and Construction Data for Observation Well 9



NOTES: 1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level ▽ is for date indicated and may vary with time of year.
ATD: At Time of Drilling

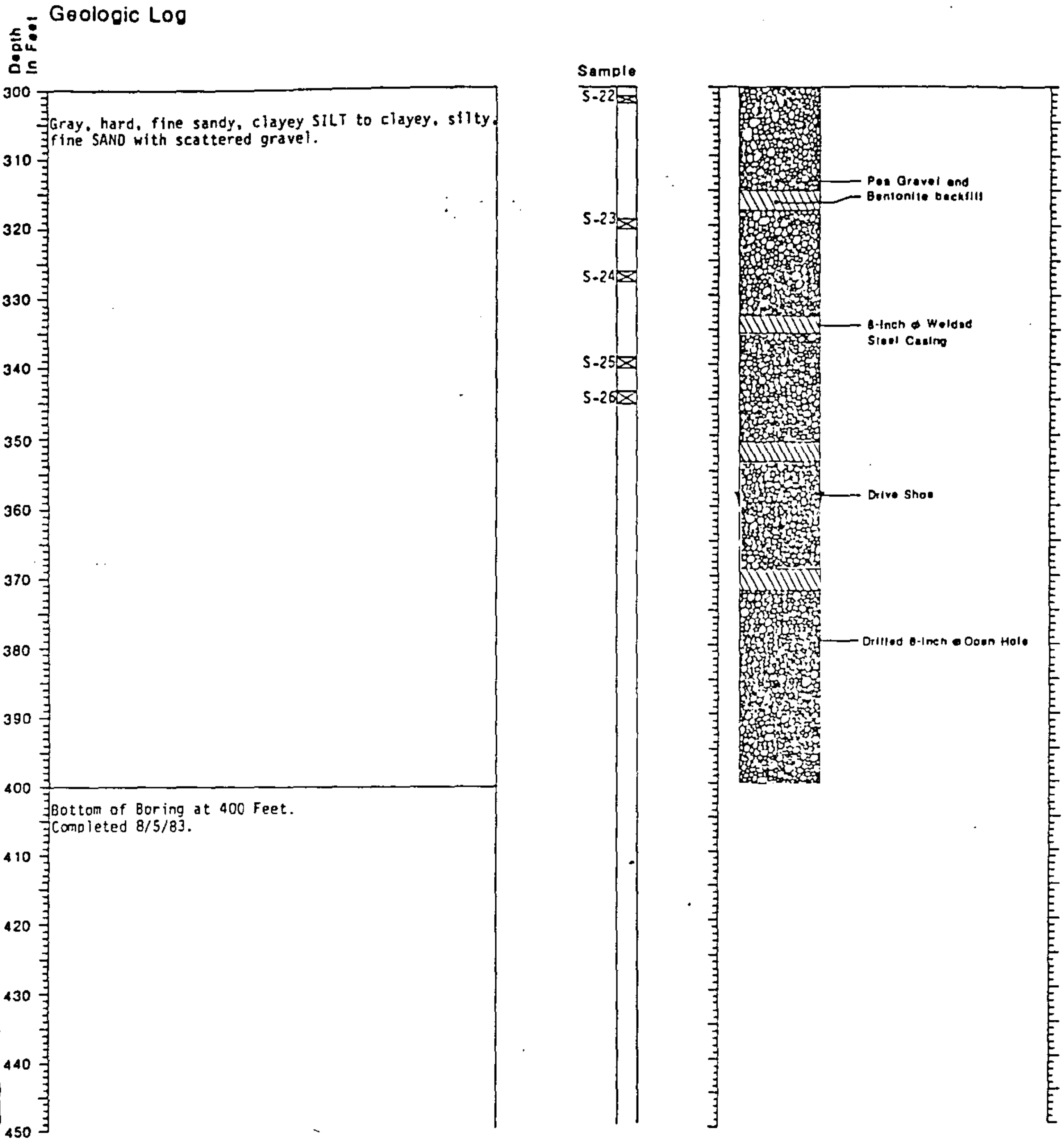
J-1148 September 1983
HART-CROWSER & associates, inc.
Sheet 1 of 3 Figure A-2

Boring Log and Construction Data for Observation Well 9



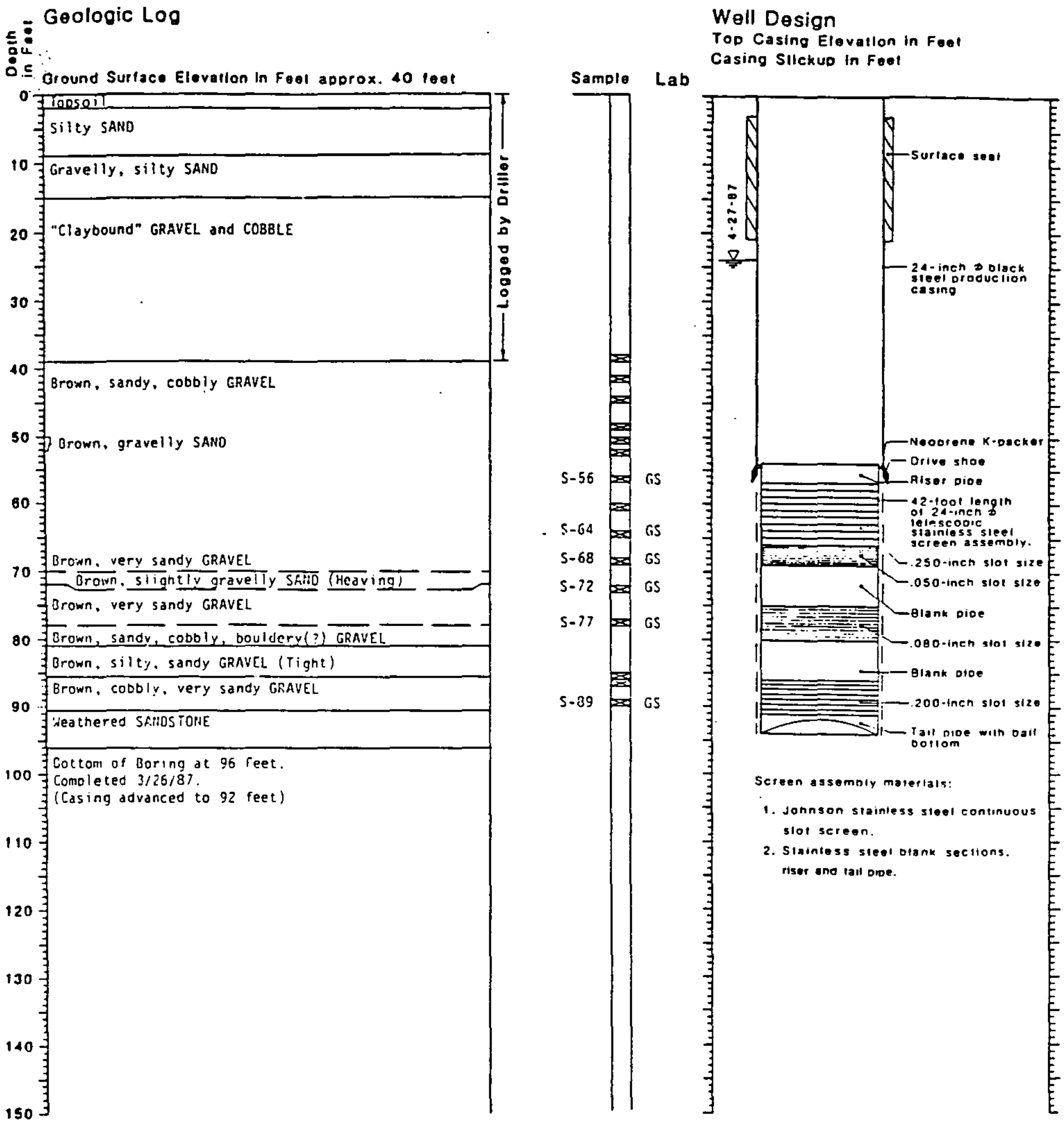
J-1148 September 1983
HART-CROWSER & associates, inc.
Sheet 2 of 3 Figure A-2

Boring Log and Construction Data for Observation Well 9



J-1148 September 1983
HART-CROWSER & associates, inc.
Sheet 3 of 3 Figure A-2

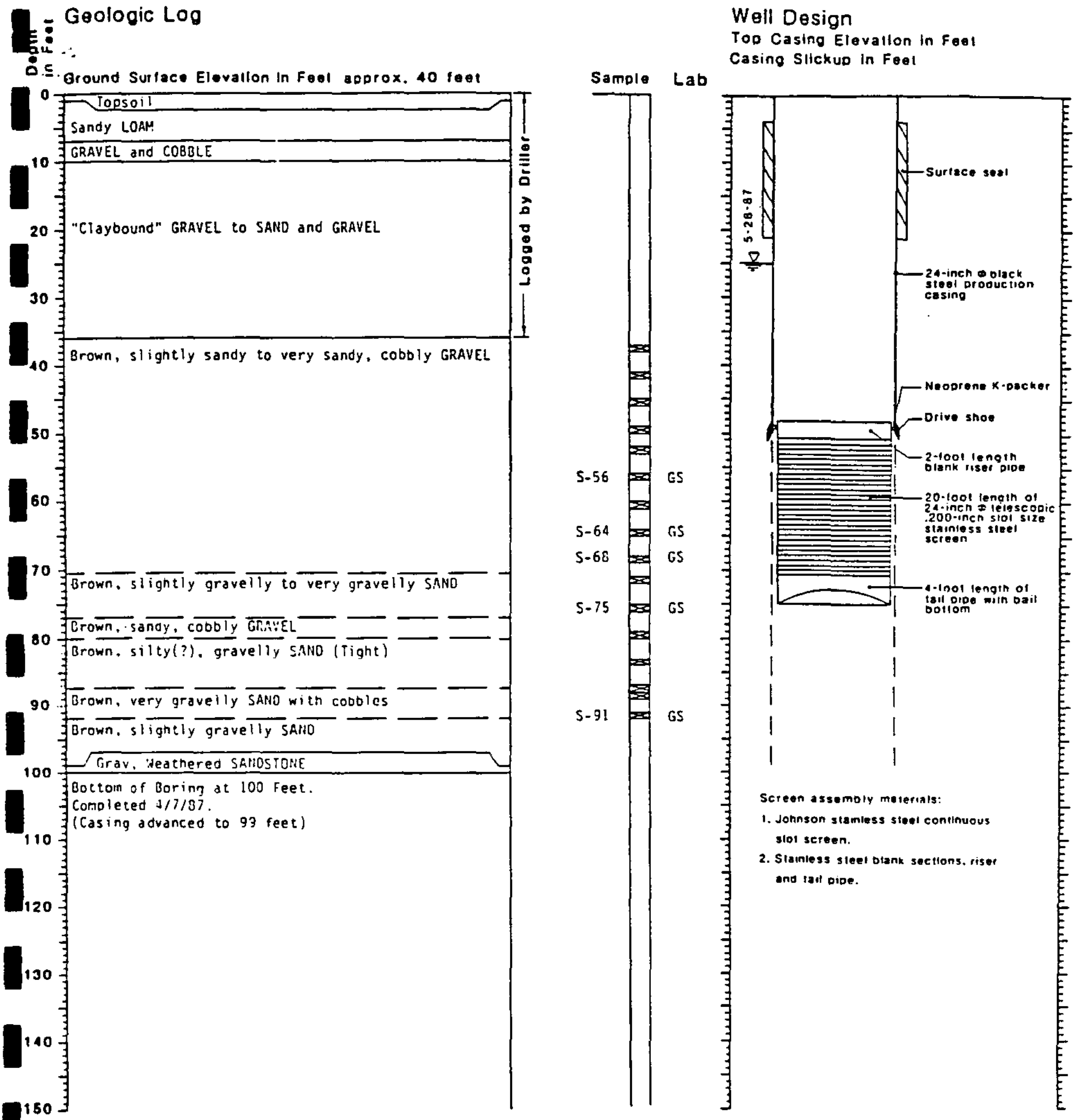
Boring Log and Construction Data for Well RW-1



NOTES: 1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level ∇ is for date indicated and may vary with time of year.
ATD: At Time of Drilling

Hart Crowser, Inc.
J-1667 7/87
Figure 2

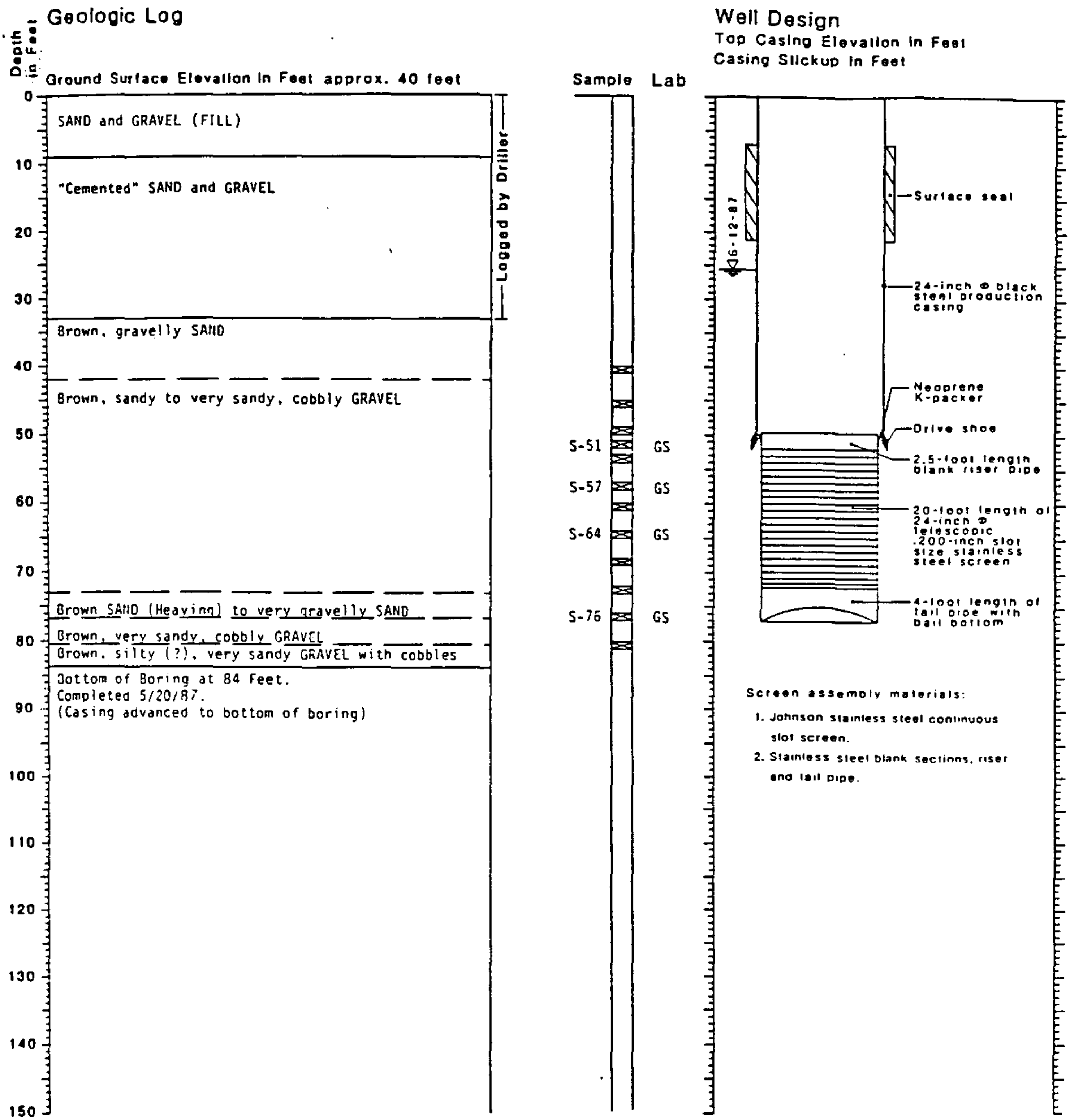
Boring Log and Construction Data for Well RW-2



NOTES: 1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level ▽ is for date indicated and may vary with time of year.
ATD: At Time of Drilling

Hart Crowser, Inc.
J-1667 7/87
Figure 3

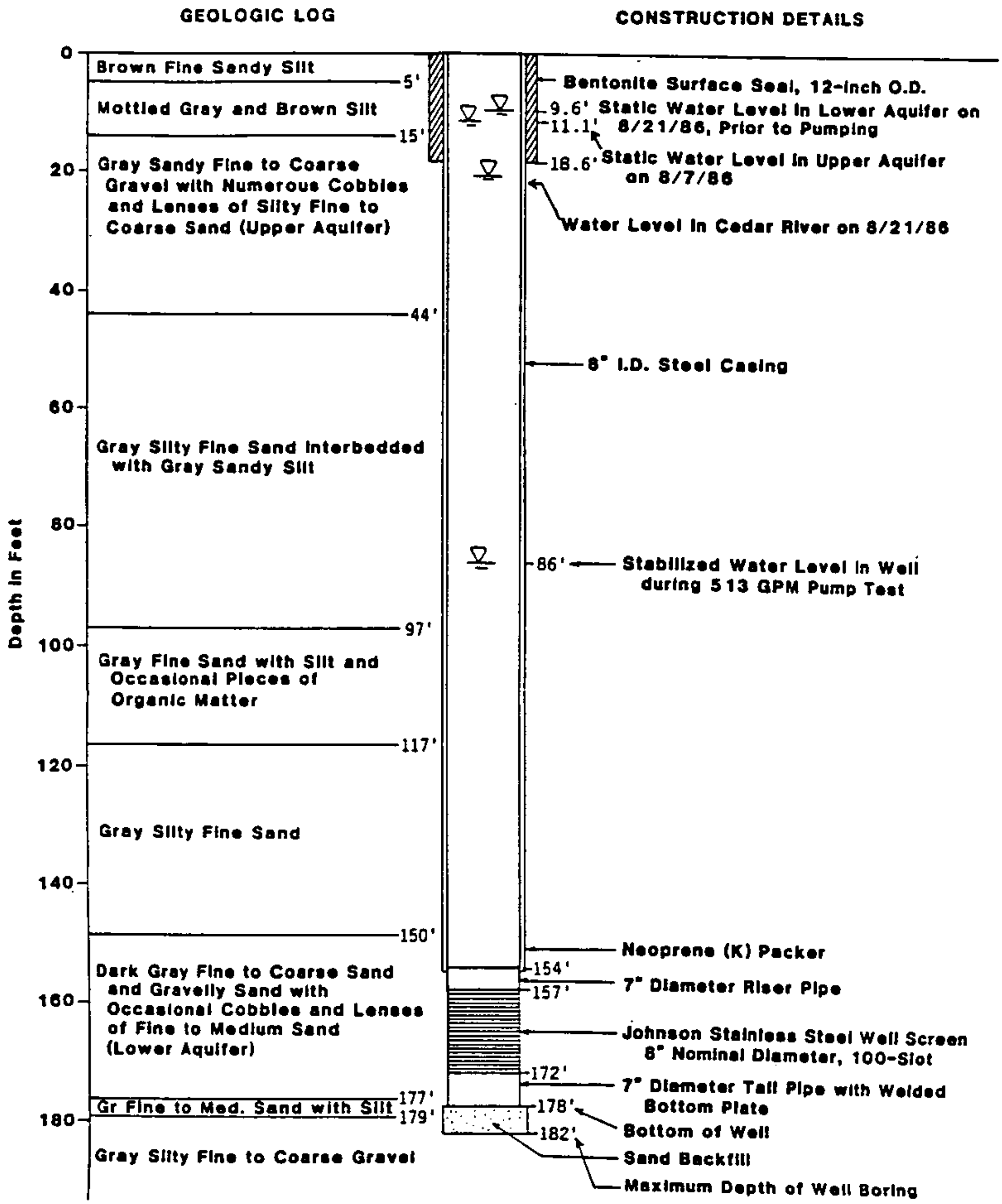
Boring Log and Construction Data for Well RW-3



NOTES: 1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level ▽ is for date indicated and may vary with time of year.
ATD: At Time of Drilling

Hart Crowser, Inc.
J-1667 7/87
Figure 4

CITY OF RENTON TEST WELL
MAPLEWOOD GOLF COURSE



Note: Ground Surface Elevation is 71.1 Feet, City of Renton Datum.

GeoEngineers Incorporated

WELL LOG AND SCHEMATIC

FIGURE 2

Appendix D
GEOLOGIC CROSS-SECTIONS FOR THE CEDAR RIVER AQUIFER
(SOURCE: CH2M HILL, 1988)

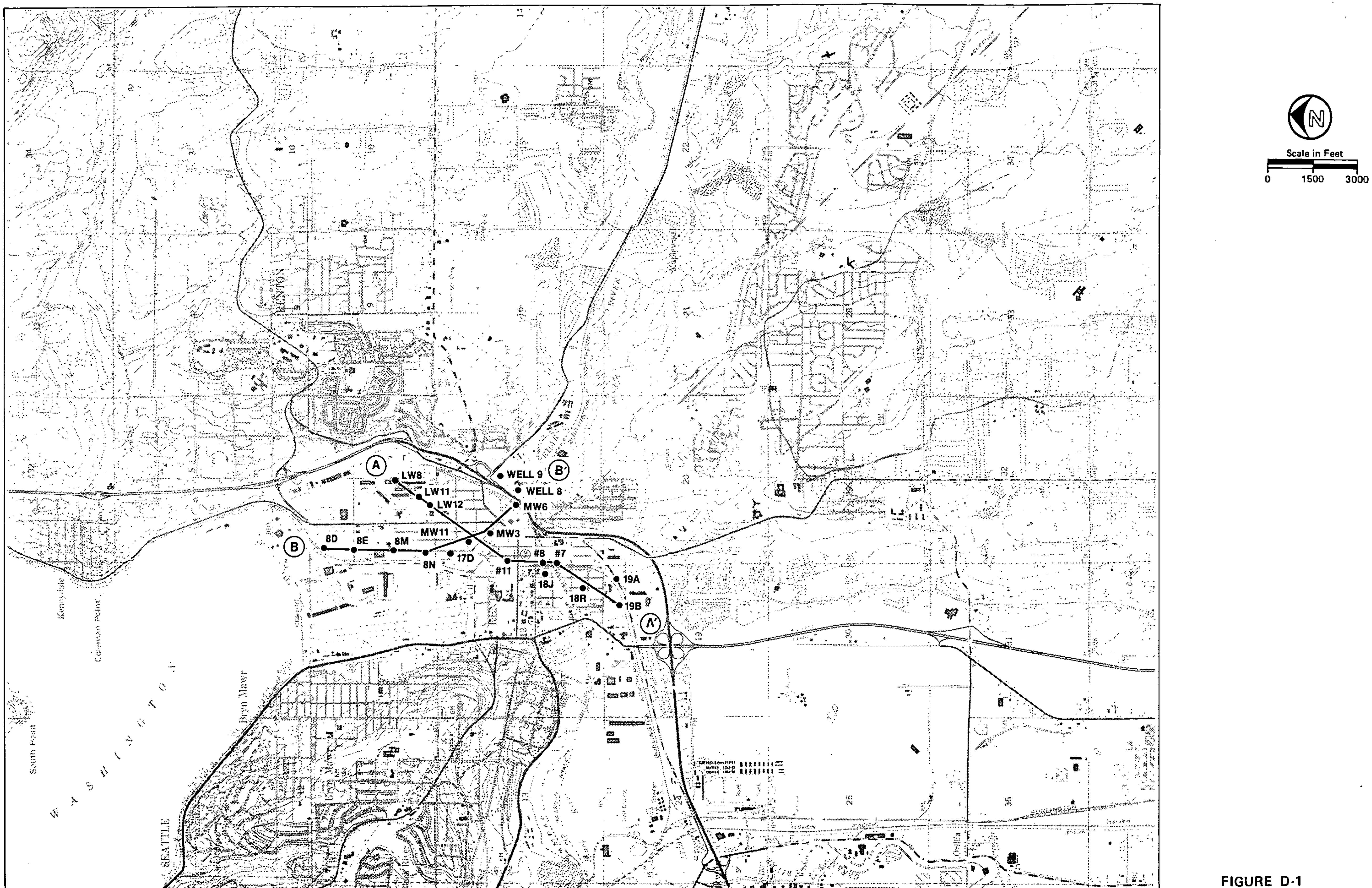


FIGURE D-1
WELLS USED TO CONSTRUCT GEOLOGIC CROSS-SECTIONS
CITY OF RENTON, WA

SECTION A-A'

(See Figure C-1 for Plan View)

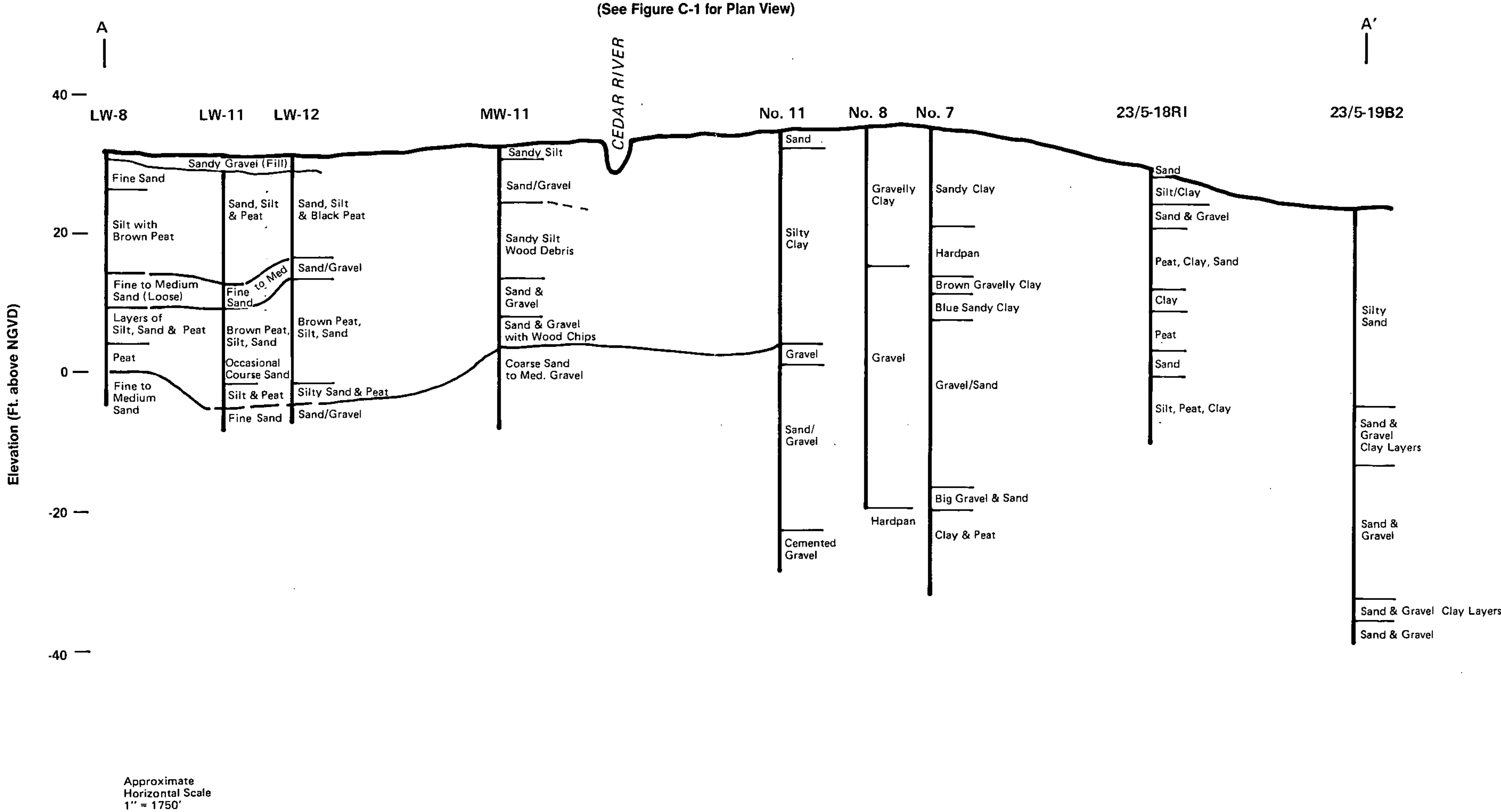


FIGURE D-2
TRANSVERSE GEOLOGICAL CROSS-SECTION
CITY OF RENTON, WA

SECTION B–B'
(See Figure C-1 for Plan View)

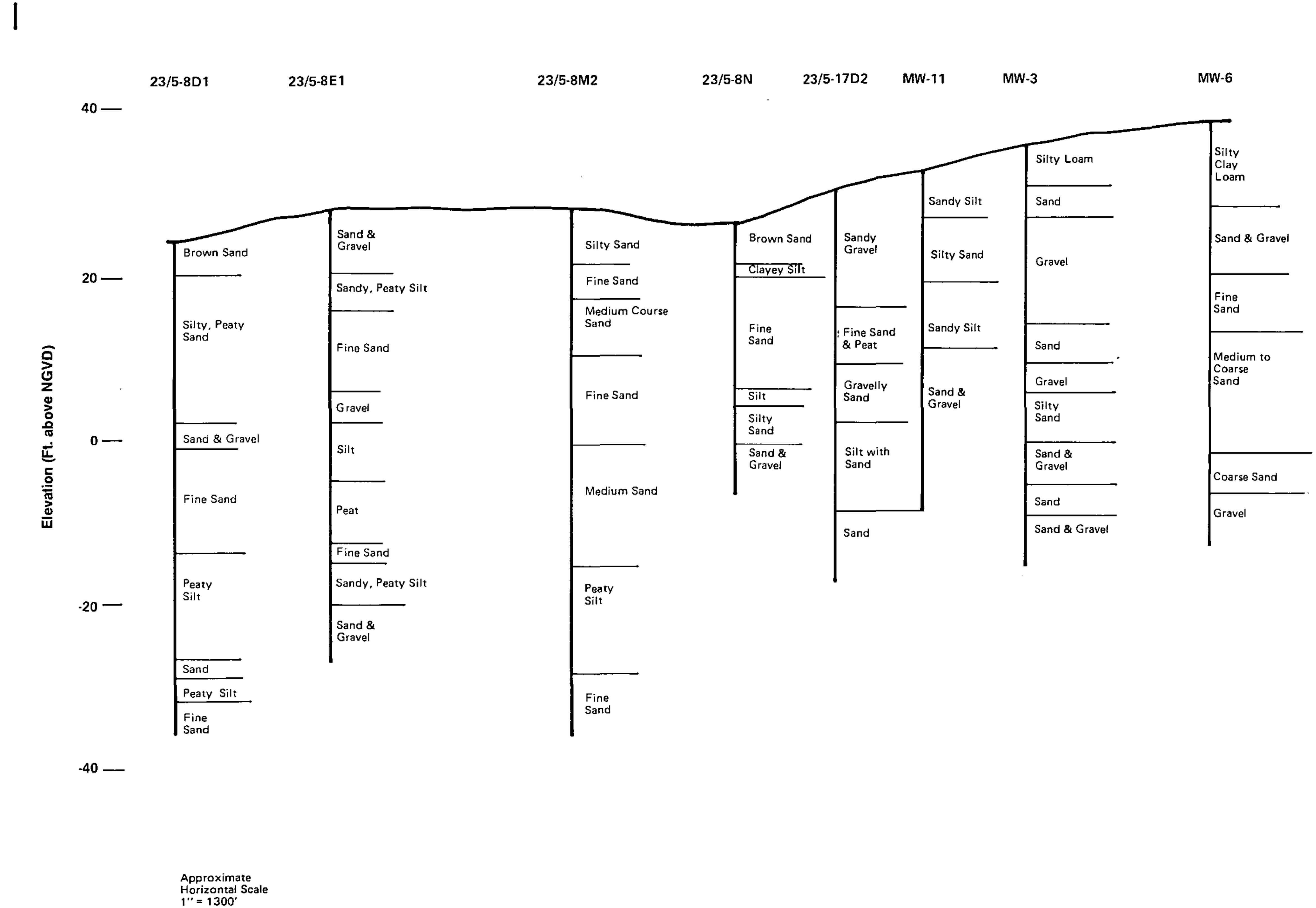


FIGURE D-3
LONGITUDINAL
GEOLOGICAL CROSS-SECTION
CITY OF RENTON, WA

Appendix E
WATER QUALITY SAMPLING RESULTS

Laucks
Testing Laboratories, Inc.
940 South Harney St., Seattle, Washington 98108 (206)767-5060

Certificate

Chemistry, Microbiology, and Technical Services

CLIENT CH2M Hill
P.O. Box 91500
Bellevue, WA 98009-2050
ATTN: Jerry Ninteman

LABORATORY NO. 97207

DATE July 17, 1986

REPORT ON WATER

SAMPLE IDENTIFICATION
Submitted 6/12/86 and identified as shown below:

1) MW1 Rent MW1 6/86
2) MW4 Rent MW4 6/86
3) MW5 Rent MW5 6/86
4) MW7 Rent MW7 6/86

TESTS PERFORMED AND RESULTS:

Samples were analyzed for priority pollutants in accordance with Test Methods for Evaluating Solid Waste, (SW-846), U.S.E.P.A., 1982, Methods 8240 (volatile organics), 8270 (semi-volatile extractables), 8080 (pesticides and PCB's), 9010 (cyanide), 6010 and the 7000 series (metals analysis). Phenol analysis was in accordance with Method 420.2, Methods for Chemical Analysis of Water & Wastes, U.S.E.P.A., March, 1979.

	parts per billion (ug/L)				
Inorganics	1	2	3	4	Method Blank
Dissolved Antimony	L/5.	L/5.	L/5.	L/5.	L/5.
Dissolved Arsenic	L/5.	L/5.	L/5.	L/5.	L/5.
Dissolved Beryllium	L/1.	L/1.	L/1.	L/1.	L/1.
Dissolved Cadmium	L/1.	L/1.	2.	2.	L/1.
Dissolved Chromium	1.	1.	3.	2.	3.
Dissolved Copper	3.	3.	4.	4.	2.
Dissolved Lead	L/10.	L/10.	L/10.	L/10.	L/10.
Dissolved Mercury	L/1.	L/1.	L/1.	L/1.	L/1.
Dissolved Nickel	4.	4.	9.	6.	L/2.
Dissolved Selenium	L/5.	L/5.	L/5.	L/5.	L/5.
Dissolved Silver	2.	2.	3.	5.	L/1.
Dissolved Thallium	L/5.	L/5.	L/5.	L/5.	L/5.
Dissolved Zinc	15.	23.	24.	75.	4.
Total Cyanide	L/5.	L/5.	L/5.	L/5.	L/5.
Total Phenol	L/5.	L/5.	L/5.	L/5.	L/5.

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parts per billion (ug/L)

Volatile Organics (by GC/MS)	1	2	3	4	Field Blank
Chloromethane	L/1.	L/1.	L/1.	L/1.	L/1.
Bromomethane	L/1.	L/1.	L/1.	L/1.	L/1.
Vinyl Chloride	L/1.	L/1.	L/1.	L/1.	L/1.
Chloroethane	L/1.	L/1.	L/1.	L/1.	L/1.
Methylene Chloride	26.	29.	64.	20.	trace
Acrolein	L/5.	L/5.	L/5.	L/5.	L/5.
*Acetone	7.	9.	7.	trace	trace
Acrylonitrile	L/5.	L/5.	L/5.	L/5.	L/5.
*Carbon Disulfide	L/1.	L/1.	L/1.	L/1.	L/1.
1,1-Dichloroethylene	L/1.	L/1.	L/1.	L/1.	L/1.
1,1-Dichloroethane	L/1.	L/1.	L/1.	L/1.	L/1.
trans-1,2-Dichloroethylene	L/1.	L/1.	L/1.	L/1.	L/1.
Chloroform	L/1.	L/1.	L/1.	L/1.	L/1.
*2-Butanone	L/1.	L/1.	L/1.	L/1.	L/1.
1,2-Dichloroethane	L/1.	L/1.	L/1.	L/1.	L/1.
1,1,1-Trichloroethane	L/1.	L/1.	L/1.	L/1.	L/1.
*Vinyl Acetate	L/1.	L/1.	L/1.	L/1.	L/1.
Bromodichloromethane	L/1.	L/1.	L/1.	L/1.	L/1.
Carbon Tetrachloride	L/1.	L/1.	L/1.	L/1.	L/1.
1,2-Dichloropropane	L/1.	L/1.	L/1.	L/1.	L/1.
Trichloroethylene	L/1.	L/1.	L/1.	L/1.	L/1.

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	parts per billion (ug/L)				
Volatile Organics (by GC/MS)	1	2	3	4	Field Blank
Benzene	L/1.	L/1.	L/1.	L/1.	L/1.
Chlorodibromomethane	L/1.	L/1.	L/1.	L/1.	L/1.
1,1,2-Trichloroethane	L/1.	L/1.	L/1.	L/1.	L/1.
2-Chloroethyl vinyl ether	L/1.	L/1.	L/1.	L/1.	L/1.
Bromoform	L/1.	L/1.	L/1.	L/1.	L/1.
*4-Methyl-2-pentanone	L/1.	L/1.	L/1.	L/1.	L/1.
*2-Hexanone	L/1.	L/1.	L/1.	L/1.	L/1.
1,1,2,2-Tetrachloroethane	L/1.	L/1.	L/1.	L/1.	L/1.
Tetrachloroethylene	L/1.	L/1.	L/1.	L/1.	L/1.
Toluene	L/1.	L/1.	L/1.	L/1.	L/1.
Chlorobenzene	L/1.	L/1.	L/1.	L/1.	L/1.
trans-1,3-Dichloropropene	L/1.	L/1.	L/1.	L/1.	L/1.
Ethylbenzene	L/1.	L/1.	L/1.	L/1.	L/1.
cis-1,3-Dichloropropene	L/1.	L/1.	L/1.	L/1.	L/1.
Styrene	L/1.	L/1.	L/1.	L/1.	L/1.
o-Xylene	L/1.	L/1.	L/1.	L/1.	L/1.

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parts per billion (ug/L)

Extractables (by GC/MS)	1	2	3	4	Method Blank
N-nitrosodimethylamine	L/1.	L/1.	L/1.	L/1.	L/1.
Bis(2-chloroethyl)ether	L/1.	L/1.	L/1.	L/1.	L/1.
2-Chlorophenol	L/1.	L/1.	L/1.	L/1.	L/1.
Phenol	L/1.	L/1.	L/1.	L/1.	L/1.
1,3-Dichlorobenzene	L/1.	L/1.	L/1.	L/1.	L/1.
1,4-Dichlorobenzene	L/1.	L/1.	L/1.	L/1.	L/1.
1,2-Dichlorobenzene	L/1.	L/1.	L/1.	L/1.	L/1.
Bis(2-chloroisopropyl)ether	L/1.	L/1.	L/1.	L/1.	L/1.
Hexachloroethane	L/1.	L/1.	L/1.	L/1.	L/1.
N-nitroso-di-n-propylamine	L/1.	L/1.	L/1.	L/1.	L/1.
Nitrobenzene	L/1.	L/1.	L/1.	L/1.	L/1.
Isophorone	L/1.	L/1.	L/1.	L/1.	L/1.
2-Nitrophenol	L/1.	L/1.	L/1.	L/1.	L/1.
2,4-Dimethylphenol	L/1.	L/1.	L/1.	L/1.	L/1.
Bis(2-chloroethoxy)methane	L/1.	L/1.	L/1.	L/1.	L/1.
2,4-Dichlorophenol	L/1.	L/1.	L/1.	L/1.	L/1.
1,2,4-Trichlorobenzene	L/1.	L/1.	L/1.	L/1.	L/1.
Naphthalene	L/1.	L/1.	L/1.	L/1.	L/1.
Hexachlorobutadiene	L/1.	L/1.	L/1.	L/1.	L/1.
4-Chloro-m-cresol	L/1.	L/1.	L/1.	L/1.	L/1.
Hexachlorocyclopentadiene	L/1.	L/1.	L/1.	L/1.	L/1.
2,4,6-Trichlorophenol	L/1.	L/1.	L/1.	L/1.	L/1.
2-Chloronaphthalene	L/1.	L/1.	L/1.	L/1.	L/1.

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Extractables (by GC/MS)	1	2	3	4	Method Blank
Acenaphthylene	L/1.	L/1.	L/1.	L/1.	L/1.
Dimethylphthalate	L/1.	L/1.	L/1.	L/1.	L/1.
2,6-Dinitrotoluene	L/1.	L/1.	L/1.	L/1.	L/1.
Acenaphthene	L/1.	L/1.	L/1.	L/1.	L/1.
2,4-Dinitrophenol	L/1.	L/1.	L/1.	L/1.	L/1.
2,4-Dinitrotoluene	L/1.	L/1.	L/1.	L/1.	L/1.
4-Nitrophenol	L/1.	L/1.	L/1.	L/1.	L/1.
Fluorene	L/1.	L/1.	L/1.	L/1.	L/1.
4-Chlorophenyl phenyl ether	L/1.	L/1.	L/1.	L/1.	L/1.
Diethylphthalate	L/1.	L/1.	L/1.	L/1.	L/1.
4,6-Dinitro-o-cresol	L/1.	L/1.	L/1.	L/1.	L/1.
1,2-Diphenylhydrazine	L/1.	L/1.	L/1.	L/1.	L/1.
4-Bromophenyl phenyl ether	L/1.	L/1.	L/1.	L/1.	L/1.
Hexachlorobenzene	L/1.	L/1.	L/1.	L/1.	L/1.
Pentachlorophenol	L/1.	L/1.	L/1.	L/1.	L/1.
Phenanthrene	L/1.	L/1.	L/1.	L/1.	L/1.
Anthracene	L/1.	L/1.	L/1.	L/1.	L/1.
Dibutylphthalate	L/1.	L/1.	L/1.	L/1.	L/1.
Fluoranthene	L/1.	L/1.	L/1.	L/1.	L/1.
Pyrene	L/1.	L/1.	L/1.	L/1.	L/1.
Benzidine	L/1.	L/1.	L/1.	L/1.	L/1.
Butyl benzyl phthalate	L/1.	L/1.	L/1.	L/1.	L/1.
Benzo(a)anthracene	L/1.	L/1.	L/1.	L/1.	L/1.
Chrysene	L/1.	L/1.	L/1.	L/1.	L/1.
3,3'-Dichlorobenzidine	L/1.	L/1.	L/1.	L/1.	L/1.

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parts per billion (ug/L)

Extractables (by GC/MS)	1	2	3	4	Method Blank
Bis(2-ethylhexyl)phthalate	L/1.	L/1.	L/1.	L/1.	L/1.
N-nitrosodiphenylamine	L/1.	L/1.	L/1.	L/1.	L/1.
Di-n-octyl phthalate	L/1.	L/1.	L/1.	L/1.	L/1.
Benzo(b)fluoranthene	L/1.	L/1.	L/1.	L/1.	L/1.
Benzo(k)fluoranthene	L/1.	L/1.	L/1.	L/1.	L/1.
Benzo(a)pyrene	L/1.	L/1.	L/1.	L/1.	L/1.
Indeno(1,2,3-cd)pyrene	L/1.	L/1.	L/1.	L/1.	L/1.
Dibenzo(ah)anthracene	L/1.	L/1.	L/1.	L/1.	L/1.
Benzo(ghi)perylene	L/1.	L/1.	L/1.	L/1.	L/1.
*Aniline	L/1.	L/1.	L/1.	L/1.	L/1.
*Benzoic Acid	L/1.	L/1.	L/1.	L/1.	L/1.
*Benzyl Alcohol	L/1.	L/1.	L/1.	L/1.	L/1.
*4-Chloroaniline	L/1.	L/1.	L/1.	L/1.	L/1.
*Dibenzofuran	L/1.	L/1.	L/1.	L/1.	L/1.
*2-Methylnaphthalene	L/1.	L/1.	L/1.	L/1.	L/1.
*2-Methylphenol	L/1.	L/1.	L/1.	L/1.	L/1.
*4-Methylphenol	L/1.	L/1.	L/1.	L/1.	L/1.
*2-Nitroaniline	L/1.	L/1.	L/1.	L/1.	L/1.
*3-Nitroaniline	L/1.	L/1.	L/1.	L/1.	L/1.
*4-Nitroaniline	L/1.	L/1.	L/1.	L/1.	L/1.
*2,4,5-Trichlorophenol	L/1.	L/1.	L/1.	L/1.	L/1.

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parts per billion (ug/L)

Pesticides (by GC/ECD)	1	2	3	4	Method Blank
alpha-BHC	L/0.02	L/0.02	L/0.02	L/0.02	L/0.02
beta-BHC	L/0.02	L/0.02	L/0.02	L/0.02	L/0.02
delta-BHC	L/0.02	L/0.02	L/0.02	L/0.02	L/0.02
gamma-BHC (lindane)	L/0.02	L/0.02	L/0.02	L/0.02	L/0.02
heptachlor	L/0.02	L/0.02	L/0.02	L/0.02	L/0.02
aldrin	L/0.02	L/0.02	L/0.02	L/0.02	L/0.02
heptachlor epoxide	L/0.02	L/0.02	L/0.02	L/0.02	L/0.02
dieldrin	L/0.02	L/0.02	L/0.02	L/0.02	L/0.02
4,4'-DDE	L/0.02	L/0.02	L/0.02	L/0.02	L/0.02
4,4'-DDD	L/0.04	L/0.04	L/0.04	L/0.04	L/0.04
endosulfan sulfate	L/0.04	L/0.04	L/0.04	L/0.04	L/0.04
4,4'-DDT	L/0.04	L/0.04	L/0.04	L/0.04	L/0.04
chlordane	L/0.04	L/0.04	L/0.04	L/0.04	L/0.04
alpha endosulfan	L/0.04	L/0.04	L/0.04	L/0.04	L/0.04
beta endosulfan	L/0.04	L/0.04	L/0.04	L/0.04	L/0.04
endrin	L/0.04	L/0.04	L/0.04	L/0.04	L/0.04
endrin aldehyde	L/0.04	L/0.04	L/0.04	L/0.04	L/0.04
toxaphene	L/5.0	L/5.0	L/5.0	L/5.0	L/5.0
PCB 1016	L/1.0	L/1.0	L/1.0	L/1.0	L/1.0
PCB 1221	L/1.0	L/1.0	L/1.0	L/1.0	L/1.0
PCB 1232	L/1.0	L/1.0	L/1.0	L/1.0	L/1.0
PCB 1242	L/1.0	L/1.0	L/1.0	L/1.0	L/1.0
PCB 1248	L/1.0	L/1.0	L/1.0	L/1.0	L/1.0
PCB 1254	L/1.0	L/1.0	L/1.0	L/1.0	L/1.0
PCB 1260	L/1.0	L/1.0	L/1.0	L/1.0	L/1.0
Methoxychlor	L/0.1	L/0.1	L/0.1	L/0.1	L/0.1
Endrin Ketone	L/0.04	L/0.04	L/0.04	L/0.04	L/0.04

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Comment

Methylene Chloride and Acetone were found to be present in the samples. These are common laboratory solvents and it is probable that these values are the result of unavoidable laboratory contamination.

Note:

Samples for dissolved metals analysis were filtered by you in the field prior to submission.

Key

L/ indicates "less than"
* indicates Additional compounds from the EPA's Hazardous Substances List.
trace = an unquantifiable number between 1 and 5 ug/L

Respectfully submitted,

Laucks Testing Laboratories, Inc.

J. M. Owens

J. M. Owens

JMO:laj

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APPENDIX

Surrogate Recovery Quality Control Report

Listed below are surrogate (chemically similar) compounds utilized in the analysis of volatile and organic compounds. The surrogates are added to every sample prior extraction and analysis to monitor for matrix effects, purging efficiency, and sample processing errors. The control limits represent the 95% confidence interval established in our laboratory through repetitive analysis of these sample types.

parts per billion (ug/L)

Sample No.	Surrogate Compound	Spike Level	Spike Found	% Recovery	Control Limit
MB	d4-1,2-Dichloroethane	50.0	45.7	91.4	77-120
MB	d8-Toluene	50.0	51.5	103.	86-119
MB	p-Bromofluorobenzene	50.0	51.5	103.	85-121
1	d4-1,2-Dichloroethane	50.0	47.9	95.8	77-120
1	d8-Toluene	50.0	51.5	103.	86-119
1	p-Bromofluorobenzene	50.0	51.2	102.	85-121
2	d4-1,2-Dichloroethane	50.0	47.5	95.0	77-120
2	d8-Toluene	50.0	50.7	101.	86-119
2	p-Bromofluorobenzene	50.0	50.9	102.	85-121
3	d4-1,2-Dichloroethane	50.0	47.3	94.6	77-120
3	d8-Toluene	50.0	50.6	101.	86-119
3	p-Bromofluorobenzene	50.0	50.6	101.	85-121

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parts per billion (ug/L)

Sample No.	Surrogate Compound	Spike Level	Spike Found	% Recovery	Control Limit
4	d4-1,2-Dichloroethane	50.0	47.7	95.4	77-120
4	d8-Toluene	50.0	50.7	101.	86-119
4	p-Bromofluorobenzene	50.0	51.6	103.	85-121
Blank	2-Fluorophenol	200.	100.	50.0	21-100
Blank	d5-Phenol	200.	80.2	40.1	10-94
Blank	2-Bromophenol	200.	140.	69.8	62-96
Blank	d5-Nitrobenzene	100.	85.6	85.6	35-114
Blank	2-Fluorobiphenyl	100.	78.9	78.9	43-116
Blank	d10-Azobenzene	100.	93.0	93.0	------
Blank	2,4,6-Tribromophenol	200.	181.	90.4	10-123
Blank	d14-Terphenyl	100.	87.4	87.4	33-141
1	2-Fluorophenol	200.	92.6	46.3	21-100
1	d5-Phenol	200.	76.6	38.3	10-94
1	2-Bromophenol	200.	133.	66.4	62-96
1	d5-Nitrobenzene	100.	87.0	87.0	35-114
1	2-Fluorobiphenyl	100.	91.9	91.9	43-116
1	d10-Azobenzene	100.	101.	101.	------
1	2,4,6-Tribromophenol	200.	169.	84.5	10-123
1	d14-Terphenyl	100.	66.5	66.5	33-141
2	2-Fluorophenol	200.	95.2	47.6	21-100
2	d5-Phenol	200.	80.8	40.4	10-94
2	2-Bromophenol	200.	139.	69.7	62-96
2	d5-Nitrobenzene	100.	88.5	88.5	35-114
2	2-Fluorobiphenyl	100.	90.5	90.5	43-116
2	d10-Azobenzene	100.	94.7	94.7	------
2	2,4,6-Tribromophenol	200.	168.	83.8	10-123
2	d14-Terphenyl	100.	77.1	77.1	33-141

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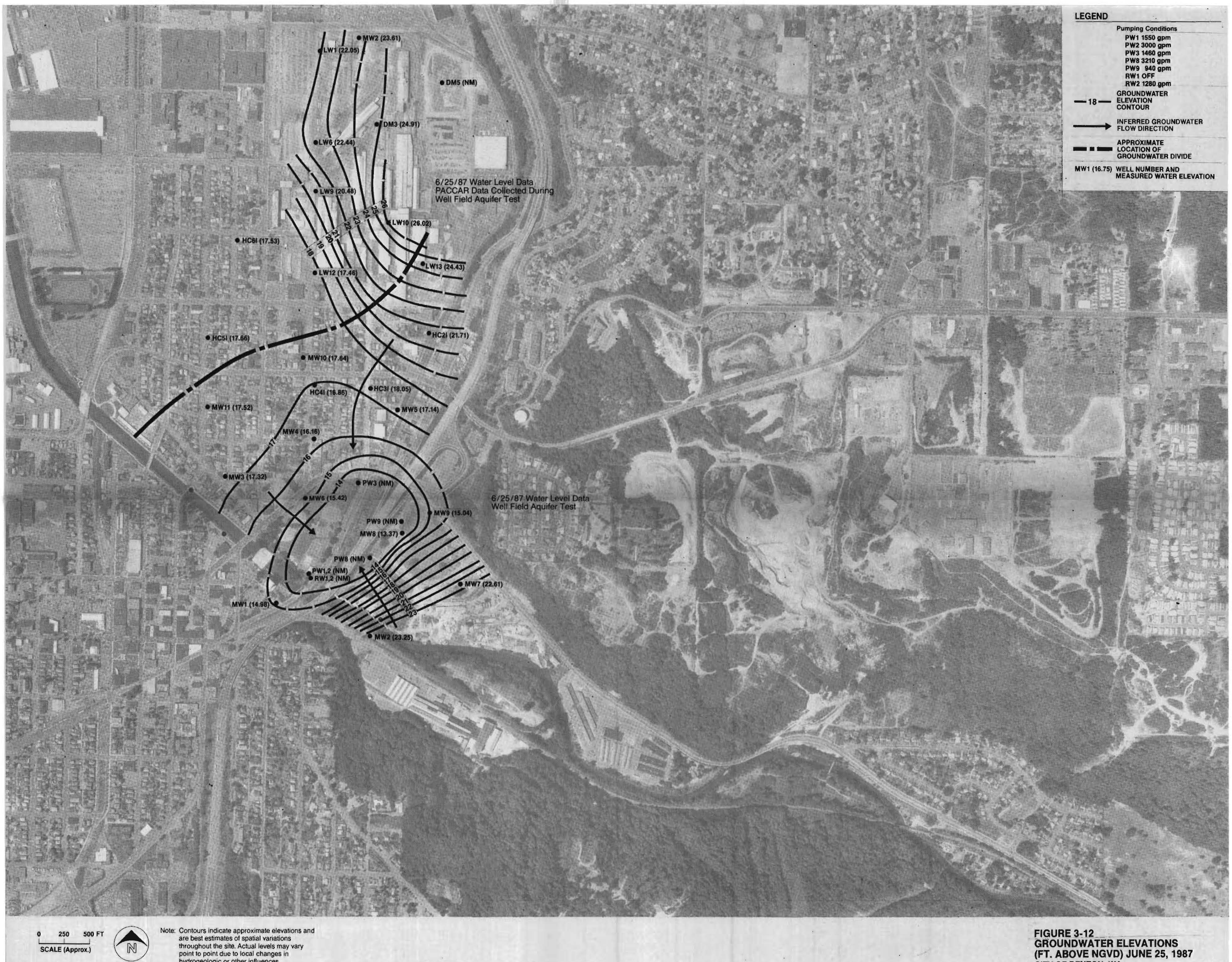
Sample No.	Surrogate Compound	Spike Level	Spike Found	% Recovery	Control Limit
3	2-Fluorophenol	200.	58.6	29.3	21-100
3	d5-Phenol	200.	51.0	25.5	10-94
3	2-Bromophenol	200.	108.	54.1	62-96
3	d5-Nitrobenzene	100.	86.9	86.9	35-114
3	2-Fluorobiphenyl	100.	94.4	94.4	43-116
3	d10-Azobenzene	100.	95.1	95.1	------
3	2,4,6-Tribromophenol	200.	100.	50.2	10-123
3	d14-Terphenyl	100.	65.7	65.7	33-141
4	2-Fluorophenol	200.	100.	50.1	21-100
4	d5-Phenol	200.	85.8	42.9	10-94
4	2-Bromophenol	200.	139.	69.7	62-96
4	d5-Nitrobenzene	100.	84.6	84.6	35-114
4	2-Fluorobiphenyl	100.	92.2	92.2	43-116
4	d10-Azobenzene	100.	95.3	95.3	------
4	2,4,6-Tribromophenol	200.	166.	82.8	10-123
4	d14-Terphenyl	100.	70.9	70.9	33-141
Blank	Isodrin	0.50	0.42	85.0	43-118
1	Isodrin	0.50	0.36	72.0	43-118
2	Isodrin	0.50	0.41	82.4	43-118
3	Isodrin	0.50	0.43	86.6	43-118
4	Isodrin	0.50	0.36	72.6	43-118
Blank	Dibutylchlorendate	1.00	0.84	83.7	24-150
1	Dibutylchlorendate	1.00	0.65	64.8	24-150
2	Dibutylchlorendate	1.00	0.73	73.2	24-150
3	Dibutylchlorendate	1.00	0.89	89.4	24-150
4	Dibutylchlorendate	1.00	0.68	68.2	24-150

MB = Method Blank



Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

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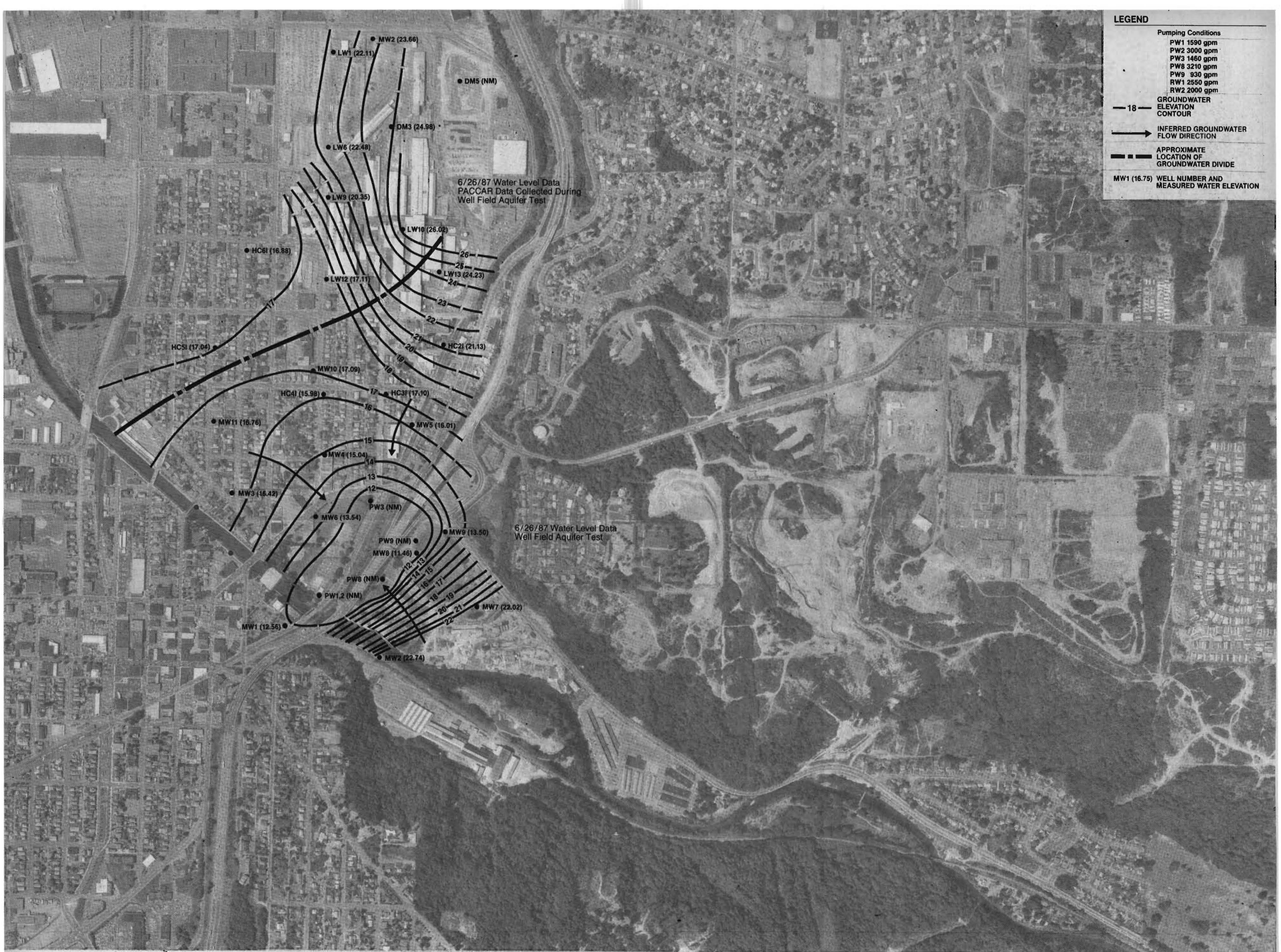
FIGURE 3-12
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) JUNE 25, 1987
CITY OF RENTON, WA



0 250 500 FT
SCALE (Approx.)

N

Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

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FIGURE 3-13
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) JUNE 26, 1987
CITY OF RENTON, WA

0 250 500 FT
SCALE (Approx.)

N

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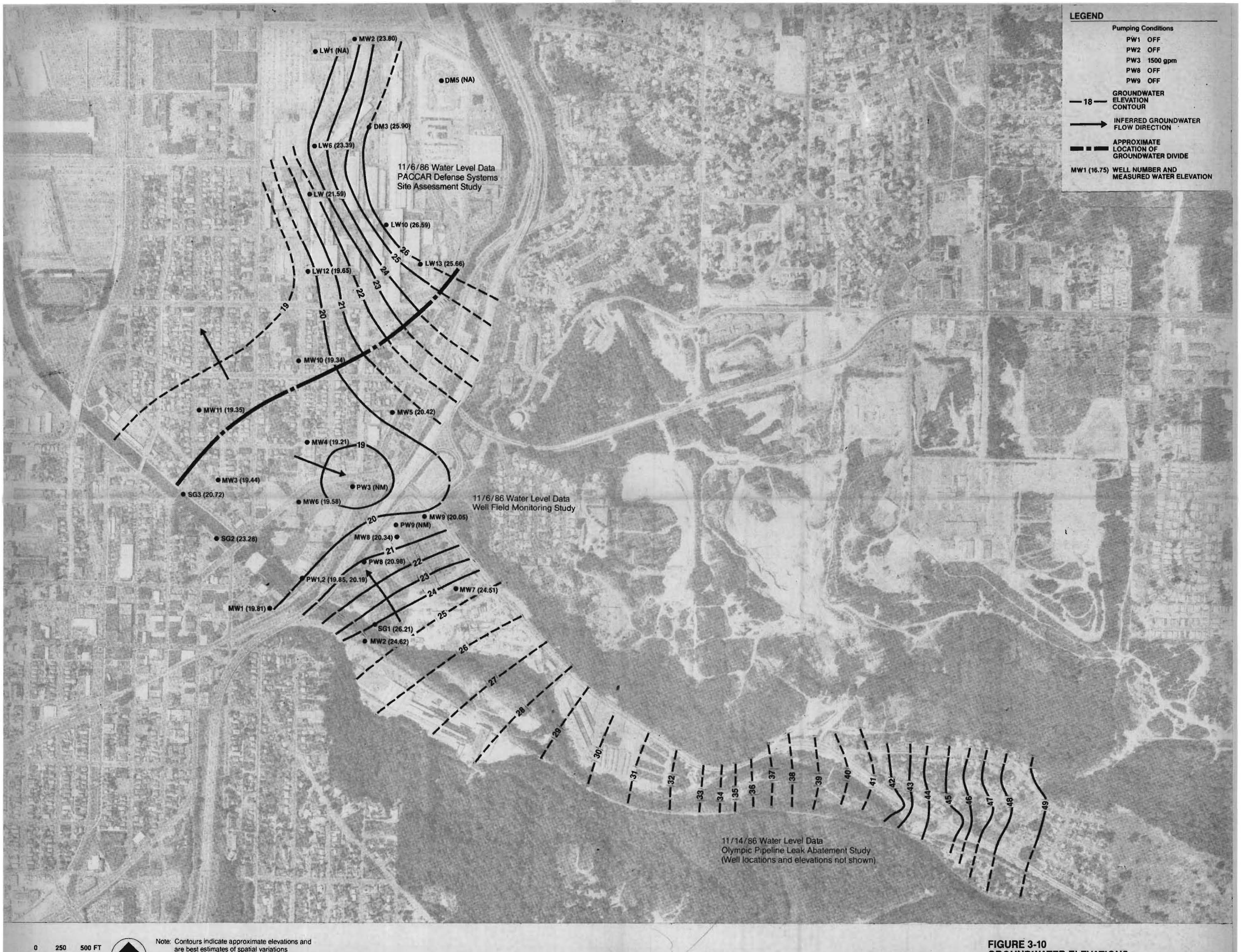
FIGURE 3-21
POTENTIAL ZONE OF CAPTURE
FOR WELL FIELD
CITY OF RENTON, WA



Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

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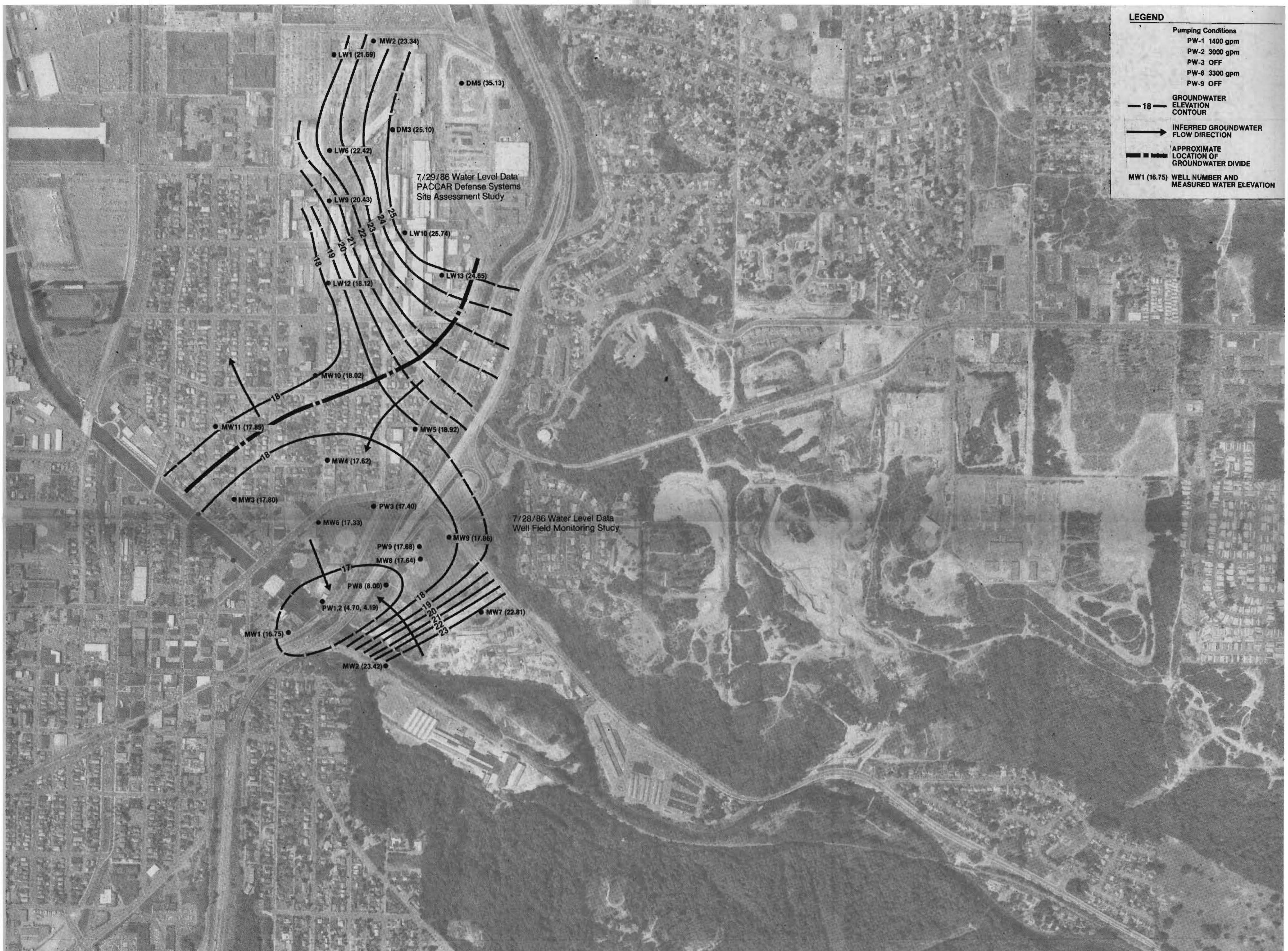
FIGURE 3-10
GROUNDWATER ELEVATIONS
(FT. ABOVE MSL) NOVEMBER 6 and 14, 1986
CITY OF RENTON, WA



Note: Contours indicate approximate elevations and are best estimates of spatial variations throughout the site. Actual levels may vary point to point due to local changes in hydrogeologic or other influences.

FIGURE 3-11
GROUNDWATER ELEVATIONS
(FT. ABOVE NGVD) JULY 28 and 29, 1986
CITY OF RENTON, WA

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