A HYDROGEOLOGIC INVESTIGATION

OF THE SCATTER CREEK/BLACK RIVER AREA, SOUTHERN THURSTON COUNTY, WASHINGTON STATE

BY

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A thesis
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ABSTRACT

In 1981, the Washington State Department of Ecology, (Ecology) Water Resources Program, initiated a hydrogeologic study of the Scatter Creek/Black River Area of southern Thurston County. The study was undertaken in response to public concern about industrial impacts to area ground-water resources. We built upon and expanded the Ecology study in 1989 by conducting an assessment of area ground-water quality and land-use types.

The Scatter Creek/Black River aquifer is contained within highly transmissive sand and gravel drift deposits of Penultimate and Vashon Age. The aquifer is unconfined and is recharged principally from local precipitation and seasonal seepage from area streams and rivers. Water from the aquifer discharges to the Black and Chehalis Rivers and provides a significant portion of the base flows for these rivers. The aquifer saturated thickness varies by location from approximately 41 to 115 feet. Seasonal water-table fluctuations vary by location from approximately 3 to 27 feet. The information gathered to date suggests that current water use has had no long term impacts on area ground-water levels.

To assess the general water quality of the aquifer, thirty-three ground-water samples were analyzed for major cation and anions and forty-five ground-water samples were analyzed for nitrate. In addition, temperature, pH, and specific conductance were measured.

With the exception of nitrate and iron, none of the water quality parameters exceeded Washington Department of Health drinking water standards. Fifteen wells, or approximately 25% of those sampled, had nitrate levels exceeding 5 mg/l. Seven samples exceeded the nitrate drinking water standard of 10 mg/l. A comparison of nitrate analyses for 20 wells that were sampled in 1982 and then resampled in 1983 and 1989 seems to indicate an increase in area ground-water nitrate levels. We were unable to statistically compare the data owing to seasonal data-collection differences.

Land use within the 60 square mile study area was segregated into ten land use classifications. We were unable to correlate those land uses with a high potential to contaminate ground water with high levels of contaminants.

CONVERSION FACTORS AND ABBREVIATIONS

Those readers preferring to use metric (International System) units rather than inch-pound units may do so by using the following conversion factors:

Multiply inch-pound unit	by	To obtain metric unit
	LENGTH	
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	AREA	
acre	4,047	square meter (m2)
acre	0.4047	hectare (ha)
square foot (ft2)	929.4	square centimeter (cm2)
square foot (ft2)	0.09294	square meter (m2)
square mile (mi2)	259.0	hectare (ha)
square mile (mi2)	2.590	square kilometer (km2)
	VOLUME	
cubic foot (ft3)	0.02832	cubic meter (m3)
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m3)
	DISCHARGE	
cubic foot per second (ft3/s)	0.02832	(m3/s)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
	AQUIFER PROPERTIES	
Hydraulic Conductivity		
feet per second (ft/s)	0.3048	meters per second (m/s)
(U.S. gal/day/ft2)	0.000000472	meters per second (m/s)
Transmissivity		
(ft2/s)	0.0929	(m2/s)
(U.S. gal/day/ft)	0.0000001438	(m2/s)

THE GEOLOGIC TIME SCALE

PERIOD	EPOCH	GLACIAL AGES	YEARS BEFORE PRESENT
Quaternary	Holocene		10,000 to present
	Pleistocene		2 million to 10,000
		Wisconsinian	0.1 million
		Sangamonian	
		Illinoisian	
		Yarmouthian	
		Kansan II	
		Kansan I	
		Aftonian	1.5 million
		Nebraskan	1.7 million
Tertiary	Pliocene		12 to 1.7 million
	Miocene		26 to 12 million
	Oligocene		37 to 26 million
	Eocene		53 to 37 million
	Paleocene		65 to 53 million

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CHAPTER I

INTRODUCTION

Since the early to mid 1970's, the Scatter Creek/Black River area of southern Thurston County has undergone tremendous residential and industrial growth. Between 1970 and 1990 the area population, including the towns of Grand Mound, Rochester, Gate, and Oakville, increased by 56% from approximately 3100 to 5500 residents. The area has also seen the establishment of six aquaculture facilities or fish farms, as well as several dairy and poultry farms. These industries use large volumes of ground-water to maintain their operations and each produces waste products which have the potential to degrade the quality of ground-water in local aquifers.

In response to public concern about industrial impacts to area ground-water resources, the Washington State Department of Ecology (Ecology) initiated a hydrogeologic study of the Scatter Creek/Black River area in 1981. The study was designed to assess the probable impacts of proposed industrial water uses and more generally, the ground-water-development potential of the Scatter Creek/Black River area. Between 1981 and 1986, Ecology installed nine triple-completion test wells, conducted aquifer tests, and established an aquifer-wide, water-level-monitoring network.

In 1989, the authors expanded the study to include a baseline assessment of ground-water quality and landuse. Despite the high growth rate in the area, none of the towns in the Scatter Creek valley are currently served by sewers. Human waste is disposed on site through individual septic systems. Because the area is heavily reliant upon high-quality ground-water for domestic and industrial uses, we thought it appropriate to establish a base line, water-quality data base against which future human impacts to area ground-water quality could be judged.

This report presents the findings and conclusions of these studies.

PHYSIOGRAPHIC SETTING

The Scatter Creek/Black River aquifer system encompasses an area of approximately 60 square miles in southwestern Thurston County, Washington State (Figure 1). The aquifer underlies a series of flat to gently rolling, east-west trending grass-covered prairies. The prairies, herein collectively called the Scatter Creek prairies, lie roughly between the towns of Tenino and Oakville. They are contained within Townships 15 and 16 north, and Ranges 2, 3, and 4 west of the Willamette Meridian.

The prairies range in elevation from approximately 300 feet above sea level near Tenino to about 100 feet near Oakville. They are bordered by Tertiary bedrock uplands to the north, east, and south which reach a maximum elevation of 1,454 feet at Northcraft Mountain. Proceeding clockwise from the north, the uplands are called the Maytown upland, the Bald Hills, Michigan Hill, and the Black Hills. The uplands are bisected by the Black and Chehalis Rivers to the north and south, respectively, where these rivers enter the prairie. Scatter Creek originates in the foothills to the north and east of Tenino. It flows west, crossing the prairies, before joining the Chehalis River southwest of Grand Mound.

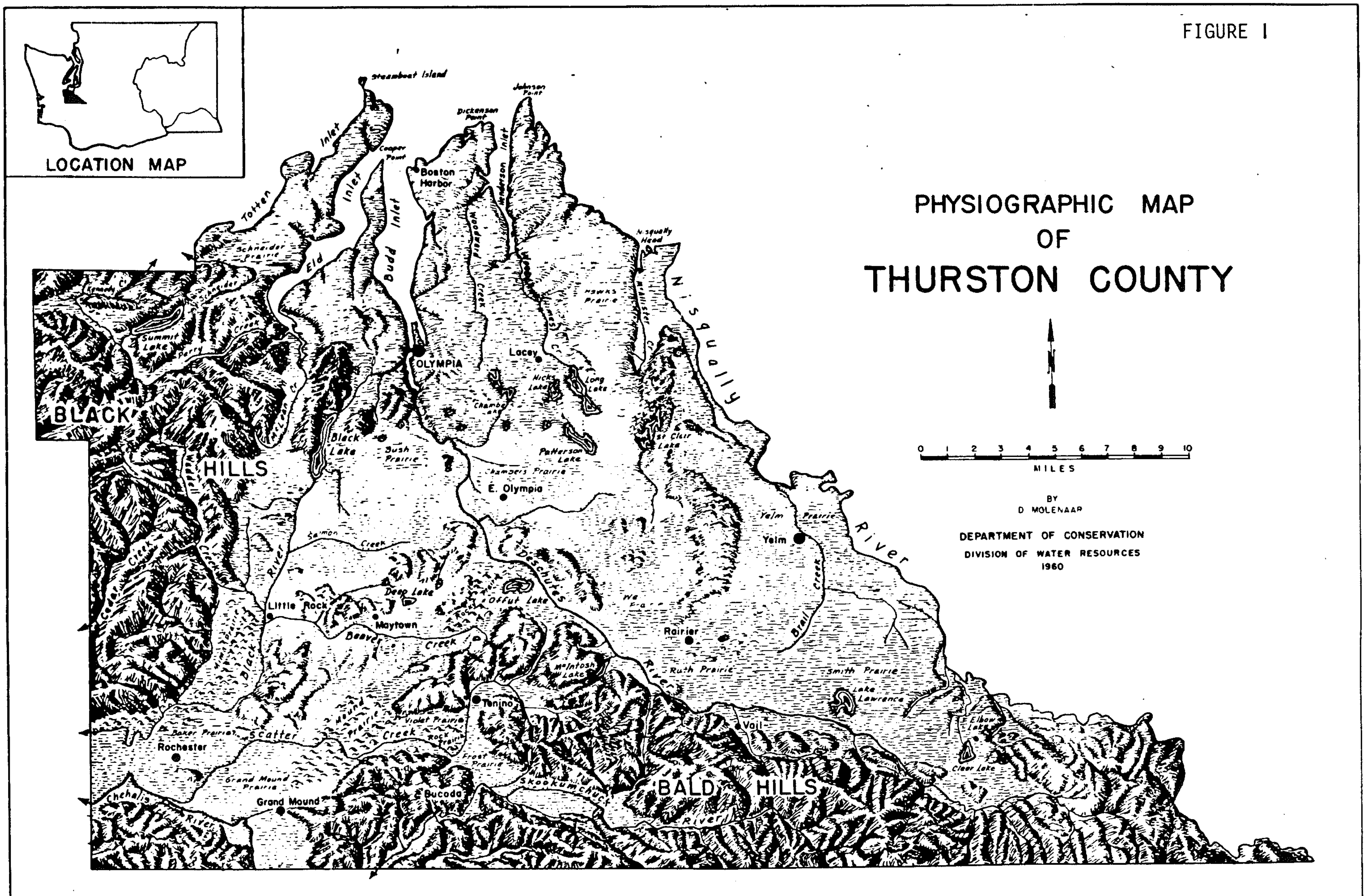


FIGURE I
PHYSIOGRAPHIC MAP
OF
THURSTON COUNTY
0 1 2 3 4 5 6 7 8 9 10
MILES
BY
D. MOLENAAR
DEPARTMENT OF CONSERVATION
DIVISION OF WATER RESOURCES
1960
LOCATION MAP
Steamboat Island
Johnson Point
Dickenson Point
Cooper Point
Boston Harbor
Totten Inlet
Eld Inlet
Budd Inlet
Henderson Inlet
Nisqually Head
Nisqually River
Hawks Prairie
OLYMPIA
Lacey
Hicks Lake
Long Lake
Patterson Lake
Chambers Prairie
E. Olympia
Black Lake
Bush Prairie
Summit Lake
Schneider Prairie
BLACK HILLS
Salmon Creek
Deschutes River
Yelm
Yelm Prairie
Little Rock
Deep Lake
Offutt Lake
Maytown
Beaver Creek
Rairier
Ruth Prairie
Smith Prairie
Lake Lawrence
McIntosh Lake
Tenino
Vail
Violet Prairie
Baker Prairie
Rochester
Scatter Creek
Grand Mound Prairie
Grand Mound
Bucoda
Skookumchuck River
BALD HILLS
Chehalis River
Elbow Lake
Clear Lake
Black River

SOILS

The Scatter Creek/Black River area is predominately underlain by coarse, excessively-drained soils of the Spanaway, Nisqually, and Chehalis Series. Other less abundant soils include the Camas, Mckenna, Maytown, Everett, and Fitch (Ness, 1947).

The Spanaway and Nisqually soil series generally developed from glacial outwash of Vashon origin. They are droughty to very droughty and of low to moderate fertility. The Spanaway series developed under herbaceous and/or grassy cover. It is characterized by 12 to 24 inch deposits of black, sooty, gravelly or stony loam which grades into a loose, porous mixture of dark yellowish-brown, dark grayish-brown, gray, and olive sand and gravel (Ness, 1947). The soil has rapid internal drainage and produces little runoff.

The Nisqually series is typically associated with the Spanaway series but differs from the latter in being gravel free. This soil also originated under an herb and grass cover. It is characterized by 18 to 24 inch deposits of black, sooty, loamy sand that grades into very dark gray or very dark grayish brown, loamy sand. The substratum at a depth of about 28 to 36 inches is an olive, fine sand or sand (Ness, 1947). Like the Spanaway series, this soil has rapid internal drainage and produces little runoff.

Soils of the Chehalis series originated from alluvial deposits of shale, sandstone, basalt, and andesite (Ness 1947). The soil occurs throughout much of the Chehalis river valley. The surface soil to a depth of about 10 inches is a strongly granular, dark-brown, friable, silty-clay loam. From 10 to 15 inches, the soil grades to a lighter brown, granular or subgranular, firm to friable, silty clay. Below a depth of about 36 to 44 inches, "..the soil is yellowish-brown or brown light clay or heavy silty clay loam, faintly mottled with yellow and reddish brown. It has an irregular interlocking structure. The entire profile is moderately permeable to water and plant roots." (Ness, 1947, p. 27).

DRAINAGE

Runoff from the Scatter Creek/Black River prairie system is limited by the high infiltration capacity of the area soils. The surface-water drainage network for the area is poorly developed and runoff from the valley interior is generally restricted to major creeks and rivers. Between Tenino and Rochester, runoff from the prairie is carried by Scatter Creek and Prairie Creek. Between Rochester and Oakville, the Black and Chehalis rivers, with their associated flood channels, receive all runoff from the study area.

CLIMATE

The study area has a maritime climate generally typical of western Washington. The climate is characterized by wet, mild winters and dry summers. Average annual precipitation for the period 1980 to 1991, is approximately 48 inches at the Weyerhaeuser seed orchard near Rochester, with 88 percent occurring between the months of September and April. The average annual temperature at the Weyerhaeuser station is 51.2 ^{0} F.

PREVIOUS INVESTIGATIONS

The geology and ground-water resources of the Scatter Creek area and surrounding uplands has been studied at the regional scale by numerous prior authors. Snavely and others (1958) described the Tertiary volcanic and sedimentary rocks which comprise bedrock throughout much of southern Thurston County. Noble and Wallace (1961) described the geology and ground-water resources of Thurston County in total, with emphasis on the Pleistocene glacial deposits which contain most of the county's important aquifers. Weigle and Foxworthy (1962) evaluated the geology and ground-water resources of West-Central Lewis County which abuts Thurston County to the south. Schlax (1947) and Eddy (1973), described the geology and occurrence of ground water in the central portion of the Chehalis River valley. Pearson and Higgins (1979) evaluated the water resources and flood-damage potential of the Chehalis Indian Reservation, situated near the western end of the study area. Vosse and Rosbach (1979) and the Thurston County Health Department (1984) conducted water quality studies of the Rochester and Grand Mound areas respectively. Lea (1984) described and mapped Pleistocene glacial deposits at the southern margin of the Puget Lobe, within the Bucoda and Tenino quadrangles.

CHAPTER II

PHYSICAL CHARACTERIZATION

The work of Wallace and Molenaar (1961) and Noble and Wallace (1966), provided the first published studies of the water-development potential of the Scatter Creek/Black River Area. These reports provide little quantitative information about the area ground-water system aside from potential well yield estimates.

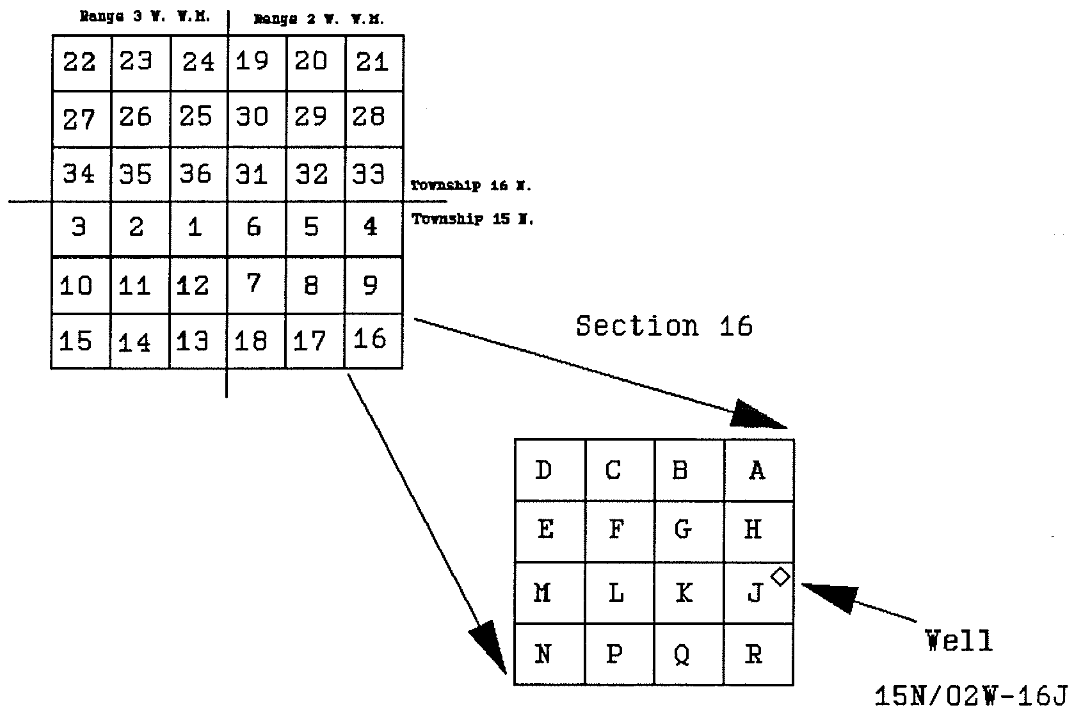
Since publication of the above reports, three multiple-well aquifer tests have been conducted by Robinson, Noble, and Carr (1980), Wildrick (1981), and Wald (1986), in conjunction with production-well installation and testing at local fish farms. These studies were designed to address concerns about local well interference and no attempt was made by the authors to evaluate the aquifer system as a whole.

This chapter builds upon the work of Noble and Wallace (1966) and subsequent authors by providing a quantitative evaluation of the aquifer system in its entirety.

NUMBERING SYSTEM FOR WELL AND STREAM MONITORING SITES

All stream and well sites referenced in this report are assigned a unique identification number. The number consists of a three letter county code followed by a three digit sequential number. The location of each site is defined by township, range, section, and quarter-quarter of the section. Range designations include a "W" to indicate the site lies west of the Willamette meridian. The quarter-quarter section is represented by a single capital letter in accordance with standard United States Geological Survey (USGS) methodology. By example, a site in the northeast quarter of the southeast quarter of Section 16, Township 15 North, Range 02 West, is recorded as 15N/02W-16J. If more than one well or stream site is referenced per quarter-quarter, a number is included after the last letter to assure uniqueness of identification. The location numbering system is illustrated in the following diagram.

Well or Stream Site Numbering System



MEASUREMENT OF GROUND-WATER LEVELS

To assess the rate and direction of movement and seasonal fluctuation of area ground-water levels, we conducted synoptic water-level measurements in 111 wells during August and December 1989 and March and June 1990. In addition, we monitored water levels on a monthly or semimonthly basis in 9 triple-completion piezometer wells installed by Ecology. The location of all wells used for water level monitoring are shown on Plate 1, referenced by site identification number.

We measured ground-water levels in one of two ways. The most common method was to use an Actat Corporation, Model 300 well probe. The instrument consists of a carrying spool with battery, indicator light-buzzer, and a graduated 300-foot length of coaxial cable; one end of which is weighted. When the weighted end of the cable contacts water within a well it completes a circuit and activates the buzzer or indicator light at land surface. We measured the length of cable lowered into the well to the point of water contact to determine depth to water.

We measured wells which were not accessible by well probe with a graduated, 300-foot steel tape and chalk. We coated the bottom ten feet or so of the tape with chalk and then progressively lowered the chalked end of the tape into the well until it contacted water. We determined depth to water by subtracting the wetted portion of the tape from the total length of tape lowered into the well. Regardless of the method used, we measured water levels to a precision of 0.01 feet and rounded to the nearest 0.10 foot for reporting purposes.

STREAM-DISCHARGE MEASUREMENTS

To gain a better understanding of the interaction between Scatter Creek and the local aquifer system, we conducted monthly seepage assessments of Scatter Creek during the period July 1989 to March 1990. To do so, we measured the discharge of Scatter Creek at 10 points along its length and noted the relative gain or loss of water from the creek between adjacent stations. We completed all ten discharge measurements during a single day.

In addition, we compiled and evaluated miscellaneous unpublished discharge measurements made by Ecology, during the period 1981 to 1987, for Scatter Creek, Mima Creek, Beaver Creek, and the Chehalis and Black rivers. The location of all surface water measurement sites discussed in this report are shown on Plate 1, referenced by site identification number.

The stream and well identification system used by Ecology consists of a three letter county code followed by a three digit sequential number. To avoid confusing stream-monitoring sites with like numbered well sites, we assigned all stream-monitoring sites a sequential number starting with 500. Table 1 correlates the stream numbers assigned for this study with those previously published by Eylar and others (1990) for the same gaging stations.

Table 1

Location and/or Correlation of Stream Monitoring Sites With Those Previously Published by Eylar and Others (1990)

Site Location	Water Body	Site Number (This Report)	Site Number Eylar (1990)
15N/03W-22A	Chehalis R.	THR501	THR001
16N/03W-17R	Mima Ck.	THR502	THR002
16N/01W-30D	Scatter Ck.	THR505	THR005
16N/02W-35F	Scatter Ck.	THR506	THR006
16N/02W-32Q02	Scatter Ck.	THR508	THR008
16N/02W-32D	SeaFarm Discharge	THR509	THR009
16N/02W-31G	Scatter Ck.	THR510	THR010
16N/03W-36H	Scatter Ck.	THR511	THR011
16N/03W-34L	Scatter Ck.	THR512	THR012
15N/03W-03D	Scatter Ck.	THR519	THR019
15N/03W-09D	Scatter Ck.	THR520	THR020
15N/03W-08G	Scatter Ck.	THR521	THR021
15N/03W-07C01	Scatter Ck.	THR522	******
15N/03W-07C02	Chehalis R.	THR523	******
16N/03W-02L	Black R.	THR524	******
16N/04W-25Q	Black R.	THR525	******
16N/04W-33H	Black R.	THR526	******
16N/03W-02Q	Beaver Ck.	THR527	******
16N/03W-36L	Domsea Discharge	THR528	******

To measure surface-water discharges, we used a Swoffer Model 2100 horizontal-axis current-meter with wading rod and standard USGS methodology. A detailed description of USGS methodology can be found in Book 3, Chapter A6 of USGS Techniques of Water-Resources Investigations, Carter (1968).

DETERMINATION OF AQUIFER HYDRAULIC PROPERTIES

In order to quantify ground-water velocities and water development potential within the Scatter Creek/Black River area, we estimated aquifer hydraulic characteristics from multiple-well aquifer tests and specific capacity tests. The aquifer tests were conducted at two fish farms and during the installation of piezometers by Ecology in 1986. We obtained specific capacity data from well reports on file with Ecology.

We analyzed the aquifer-test data using the methods of Theis (1935), Cooper-Jacob (1946), and Neuman (1975). These methods enable one to estimate aquifer hydraulic properties from transient (nonsteady, radial flow) aquifer test data. Data analysis was aided through use of a micro-computer program developed by Duffield (1989). We evaluated well specific capacity data using the method of Theis, in Bentall (1963 pp. 331-341). The assumptions and governing equations for each analysis method are presented below in elementary form. Those readers unfamiliar with the terms used in this section should refer to the glossary for term definitions.

THEIS DRAWDOWN METHOD:

In 1935, C. V. Theis with the assistance of C. I. Lubin, presented his now classic equation for quantifying hydraulic properties from transient aquifer test data (equation 1). Theis based his equation on Lubin's work with heat conduction and a continuous point source (Lohman, 1972, p.15).

$$(1) \quad s = \frac{Q}{4\pi T} \int_{r^2S/4Tt}^{\infty} \left(\frac{e^{-u}}{u} \right) du \quad [L]$$

Where

s = drawdown [L]

Q = constant discharge rate for the well $[L^3t^{-1}]$

T = transmissivity $[L^2t^{-1}]$

r = distance from the discharging well to the point where drawdown is measured [L]

S = storage coefficient [dimensionless]

t = time since start of discharge [t]

u = variable of integration [dimensionless]

Where: [L] represents units of length and [t] units of time.

Theis derived his equation based on the following assumptions:

- The potentiometric surface or water table has no slope,
- Flow within the aquifer system and discharging well is laminar,

- Water removed from the aquifer during pumping is derived entirely from aquifer storage,

- The discharging well is 100-percent efficient,

- Water is released instantaneously from storage in response to pumpage induced head declines,

- The well fully penetrates the aquifer and is screened or open throughout its entire saturated thickness,

- The aquifer receives no recharge during the testing period,

- The aquifer is homogeneous, isotropic, and infinite in areal extent, and

- The diameter of the pumping well is small enough that storage within the well can be ignored.

Although equation 1 can not be integrated directly, Theis developed a simple curve matching procedure that allows one to estimate aquifer hydraulic characteristics using equations 2 and 3 below. The procedure is as follows. Logarithmic plots of drawdown (s) with respect to time (t) or (r^2/t) are overlain on identically scaled 'type curves' generated from tabulated values of 1/u and W(u)(see definition below). With the axes of the two plots parallel, the data plot is shifted to achieve a best fit between the type curve and plotted test data. Once a best fit is obtained, a match point is selected and the appropriate values of (s), (t) or (r^2/t), (1/u), and W(u) determined. These valued are then substituted into equations (2) and (3) to solve for T and S.

(2) $$T = \frac{Q}{4\pi s} W(u) \quad [L^2t^{-1}]$$

The aquifer storage coefficient (S) can be estimated as follows:

(3) $$S = \frac{4Ttu}{r^2} \text{ or } \frac{4Tu}{r^2/t} \quad [\text{dimensionless}]$$

Where:

$u = \frac{r^2S}{4Tt}$ [dimensionless]

s = the drawdown at some distance r, from a well discharging at a constant rate Q [L]

Q = the well discharge rate [L^3t^{-1}]

T = aquifer transmissivity [L^2t^{-1}]

W(u) = an exponential integral known as the "well function of u", (see Lohman, 1972, p. 8 and 15) r = the radial distance from the point where drawdown is measured, to the center of the discharging well [L]

S = aquifer storage coefficient [dimensionless]

t = time since discharge started [t]

COOPER-JACOB METHOD:

The Cooper-Jacob method is a modification of the Theis drawdown method and is subject to the same limiting assumptions. Cooper and Jacob (1946) determined that for values of $u \leq 0.01$, aquifer properties could be estimated by plotting drawdown data with respect to time on semilogarithmic paper, with drawdown plotted on the linear axis and time plotted on the logarithmic axis. If the limiting assumptions of the Theis method are valid, the data should plot along a straight line. A best fit line is then drawn through the data and the drawdown per log cycle of time (Δs) is determined. Δs is then substituted into equation 3 along with the pumping rate to solve for aquifer transmissivity.

$$(3) \quad T = \frac{2.30Q}{4\pi\Delta s} \quad [L^2t^{-1}]$$

The storage coefficient is determined by projecting the best fit line back to the point where drawdown equals zero, at corresponding time t_0. The estimated value of t_0, T, and r^2 are then substituted into equation (4) to solve for S.

$$(4) \quad S = \frac{2.25\ Tt_0}{r^2} \quad \text{[dimensionless]}$$

Where:

Δs = the drawdown per log cycle of time [L]

t_0 = the time intercept of the straight line at zero drawdown [t]

T, Q, S, and r are as previously defined.

The Theis and Jacob methods were originally developed for confined-aquifer conditions where transmissivity remains constant, so long as water levels are not drawn down below the bottom of the overlying confining unit. Under water-table conditions, aquifer material contained within the cone of depression of a discharging well, is physically dewatered during pumping. The resultant reduction in saturated thickness causes transmissivity near the discharging well to diminish. Jacob (1963) developed the following correction factor for water table conditions, to enable one to determine the drawdown that would have been measured had aquifer saturated thickness remained constant during pumping. The correction is applicable when measured drawdown is significant relative to the aquifers initial saturated thickness.

(5) $$s' = \frac{s - s^2}{2b}$$

where:

s' = corrected drawdown [L]

s = measured drawdown [L]

b = aquifer initial saturated thickness [L]

NEUMAN METHOD:

During the early stages of well discharge, an unconfined aquifer responds very much like a confined aquifer. Much of the water initially withdrawn through the well is derived from the elastic expansion of water, aquifer compaction, and from aquifer storage in the vicinity of the discharging well. As pumping proceeds, more and more water is withdrawn from aquifer storage within the cone of depression created by the discharging well. Water released by delayed gravity drainage within the expanding cone of depression causes a reduction in the rate of drawdown until such time as delayed gravity response ceases to contribute significantly to well discharge. At that point, drawdown once again increases as the cone of depression expands at a rate equal to the volume of water released from the aquifer by gravity drainage.

The delayed gravity response of water table aquifers causes an apparent increase in aquifer storativity with time. The initial elastic storage coefficient resulting from early pumping stresses gradually increases with pumping time until it equals the specific yield of the aquifer at later pumping times.

S. P. Neuman (1975) presented a method which allows one to quantify both the elastic storage coefficient and specific yield of an unconfined aquifer. The method requires the investigator to match calculated type curves to both the early and late drawdown data. The method is based upon the following simplified equation. Examples of the curve matching procedure are contained in Appendix B.

$$(6) \quad s = \frac{Q}{4\pi T} W(U_A, U_B, \beta)$$

Where:

$W(U_A, U_B, \beta)$ = the well function for a water table aquifer with fully penetrating wells lacking storage capacity [dimensionless]

$U_A = \frac{r^2 S}{4Tt}$ applicable for early (small) time values [dimensionless]

$U_B = \frac{r^2 S_y}{4Tt}$ applicable for late (large) time values [dimensionless]

$\beta = \frac{r^2 P_v}{b^2 P_h}$ [dimensionless]

S_y = aquifer specific yield [fraction]

P_v = aquifer vertical permeability [Lt^{-1}]

P_h = aquifer horizontal permeability $[Lt^{-1}]$

s, Q, T, r, S, t, and b are as previously defined

THEIS RECOVERY METHOD:

Theis (1935) proposed a method for determining transmissivity from aquifer test recovery data. The method is based on the following equation.

$$(7) \quad s' = \frac{Q}{4\pi T}\left[\ln \frac{4Tt}{r^2 S} - \ln \frac{4Tt'}{r^2 S'}\right]$$

Where:

s' = residual drawdown [L]

S = storage coefficient during pumping [dimensionless]

S'= storage coefficient during recovery [dimensionless]

t'= time since pumping stopped [t]

t = time since pumping started [t]

Q, T, and r, are as previously defined

Assuming that S and S′ are constant and equal during the pumping and recovery periods, equation (7) can be simplified as follows:

$$(8) \qquad s' = \frac{Q}{4\pi T} [\ln t/t']$$

Application of the Theis recovery method requires one to prepare semilogarithmic plots of residual drawdown verses t/t′ with residual drawdown on the arithmetic scale and t/t′ on the logarithmic scale. If the assumptions of the Theis drawdown method are true, the data should plot along a straight line through the origin. Draw a best fit line through the data points and estimate the change in residual drawdown per log cycle of time ($\Delta s'$). Knowing Q and $\Delta s'$ one can rearrange equation (8) to solve for T.

THEIS SPECIFIC CAPACITY METHOD:

The transmissivity of an unconfined aquifer can be estimated with reasonable accuracy from well specific capacity data using equation (9) developed by Theis (Bentall 1963, p.333). The equation was developed in accordance with the assumptions previously stated for the Theis drawdown method.

$$(9) \qquad T' = C\,(K - 264 \log_{10} 5S + 264 \log_{10} t)$$

Where:

C = Q/s (1.0 ± 0.3), where the value in parentheses is a correction factor used to account for increased drawdown in the pumping well resulting from well inefficiency, partial penetration impacts, incomplete well development, etc. The factor is adjusted upward for wells of small diameter, poor development, or wells with small or inefficient openings. The factor is adjusted downward for large diameter well-developed wells.

T' = uncorrected transmissivity [gpd/ft]

$K = -66 - 264\log_{10}(3.74r^2 \times 10^{-6})$

Q = well pumping rate [gpm]

s = drawdown in the pumping well at time t [ft]

t = pumping period [days]

S = aquifer storage coefficient [dimensionless]

r = the pumping well effective radius [ft]

Use of equation 9 to estimate aquifer transmissivity is straight forward. Knowing Q, s, r, and t, one can solve for T′ using calculated values of K and known or assumed values of S. Having obtained an estimate of T′, one then uses the chart in Bentall (1963, p. 334), to estimate aquifer transmissivity.

SOIL-WATER BUDGET

We used a mean monthly soil water balance to estimate potential ground-water recharge as soil moisture surplus. A calculation of water surplus, in cubic feet per second, from the soil-water budget was compared to ground water discharge calculations determined from stream seepage assessments, to see if agreement existed between the methods.

The mean monthly climatic water budget for the study area was calculated with WATBUG: A Fortran IV Algorithm For Calculating The Climatic Water Budget (Willmott, 1977). This method is based on precipitation, temperature, and evapotranspiration and is useful to estimate soil-water surplus. No data exists upon which to judge the accuracy of this estimate. Data inputs to the program are estimated soil-water-holding capacity, station latitude, estimated soil-moisture content at the beginning of the computations, estimated heat index, mean-monthly precipitation, and mean-monthly air temperature. Input included the following:

1. We used a soil-water-holding capacity of 2.21 inches based on a mean soil depth of 24 inches and mean values of water-holding capacity for the Spanaway soil profile from the literature (USDA/SCS, 1987, p. 430).

2. Station latitude is 46.8 degrees north.

3. The first month of the calculations was January. We used a soil moisture content of 2.21 inches, with the assumption that in January the soil is saturated and at maximum water-holding capacity.

4. Using the method developed by Thornthwaite and Mather (1957), we calculated an annual heat index of 38.21. The equation, monthly heat index = (mean monthly temperature in $°C/5)^{1.514}$,

was summed for each of the twelve months to determine the annual heat index.

5. We calculated mean-monthly and mean-annual precipitation for the study area using daily records collected at the Weyerhaeuser Seed Orchard (Weyerhaeuser) and the National Weather Service's station in the town of Oakville. We calculated monthly values for only those months with less than 9 days of missing data. Mean-monthly precipitation for the Weyerhaeuser station represents the sum of all available months of data divided by the number of months. The mean-annual precipitation is a summation of the mean-monthly precipitation. The period of record for the Weyerhaeuser station starts in 1980, however, the quality control for the station improved in October 1986. A summary of monthly precipitation from the Weyerhaeuser station is presented in Table 2.

Table 2

Weyerhaeuser Station Precipitation Data

Monthly Total in Inches

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	AVERAGE
JAN	5.41	3.03	8.46	9.09	8.73	0.70	8.39	8.17	5.51	4.29	****	3.75	5.96
FEB	4.50	7.56	8.58	6.53	4.86	3.60	6.54	3.83	2.64	2.93	4.03	4.52	5.01
MAR	5.39	4.16	3.64	4.68	6.05	4.09	3.64	6.55	2.08	4.22	1.03	****	4.14
APR	4.31	6.34	4.91	4.39	4.26	3.66	3.96	2.48	5.52	1.02	****	8.99	4.53
MAY	0.62	3.54	0.95	1.29	4.39	0.98	2.33	2.03	3.02	0.94	1.66	0.78	1.88
JUN	2.24	3.01	2.00	2.45	3.05	2.13	1.38	0.18	1.76	0.72	****	1.28	1.84
JUL	0.52	0.46	0.86	3.36	1.57	0.65	0.66	****	1.21	0.11	0.46	0.19	0.91
AUG	0.72	0.46	0.81	0.45	0.45	0.64	****	****	0.34	0.64	1.93	1.41	0.79
SEP	2.39	2.64	2.11	3.15	****	4.28	2.94	****	1.54	1.01	0.30	0.01	2.04
OCT	0.98	5.36	6.97	1.61	****	9.57	3.48	3.49	1.27	****	3.89	****	4.07
NOV	9.41	7.36	5.73	12.75	11.20	****	11.38	3.52	11.26	3.34	8.30	****	8.43
DEC	7.62	9.97	11.03	4.78	4.38	****	4.44	9.02	5.12	****	3.20	****	6.62

**** Indicates no value for that month.

The monthly and annual precipitation records for Oakville were obtained from Climadata, a computerized database of climate information (Climadata, 1988). The Oakville station has moved several times since record keeping commenced in 1948. Linton Wildrick (personal communication, 1992) performed a double-mass analysis comparing Oakville data with data from the Olympia and Centralia stations. He found that station moves caused only small changes in the catch of the Oakville gage. Therefore, we used all available data for this station and the statistics represent the entire period of record. The mean-monthly and mean-annual precipitation values are calculated the same way as for the Weyerhaeuser data.

The records for the Weyerhaeuser station are incomplete. However, at least eight years of precipitation data are available for each month. The Weyerhaeuser data was compared with the mean monthly and mean annual data from nearby stations in Olympia, Centralia, and Oakville to determine if a precipitation gradient exists in the region.

The Weyerhaeuser station is located in the central part of the study area (15N/03W-10E). The Olympia and Centralia stations are 13 miles north and 8 miles southeast, respectively, and the Oakville station lies to the west about 9 miles. A comparison of the Weyerhaeuser data with data from these stations indicates a strong west-to-east precipitation gradient with a moderate north-to-south gradient. The Weyerhaeuser station's mean-annual precipitation of 46.2 inches falls between the Olympia station, mean-annual of 50.7 inches and Centralia, mean-annual of 45.8 inches. Oakville's mean-annual precipitation is 57.3 inches. Oakville's mean-annual precipitation is twenty-two percent higher than Weyerhaeuser's average mean-annual precipitation. The greater precipitation can be attributed to the orographic effects of the Black Hills. Storms moving in from the Washington Coast move up the Chehalis River valley and drop more moisture over and closer to the Black Hills.

Because of the precipitation gradient, we used Thiessen-weighted polygons, an averaging method, (Dunne and Leopold, 1978) to assess mean areal precipitation for the study area. The study area lies entirely within the Weyerhaeuser and Oakville polygons. Eighty-five percent of the study area is closest to the Weyerhaeuser station, with the remainder closest to Oakville. We calculated the mean-annual and mean-monthly precipitation using a 0.85 weighing for the Weyerhaeuser station data and 0.15 weighing for the Oakville data with the result of 48.27 inches of precipitation for the study area in an average year.

Maximum and minimum daily temperature is also measured at the Weyerhaeuser and Oakville stations. We calculated mean-monthly temperature by summing the maximum and minimum daily temperature values for that month and dividing each by the number of days in the month, then summed the mean-maximum and mean-minimum values and divided by two. We did not calculate a value if a particular month lacked records for more than nine days. Mean-monthly temperature for the Weyerhaeuser station represents the sum of all available months of data divided by the number of months. Each mean-monthly temperature represents at least nine years of data. The mean-annual temperature is a summation of the mean-monthly temperature divided by twelve.

A comparison of Oakville temperature data from Climadata (Climadata, 1988) with the Weyerhaeuser data indicates generally less than one degree differences in mean-monthly temperatures between stations. Therefore, we used the Weyerhaeuser data to represent the study area despite the shorter period of record. A summary of the mean-monthly temperatures from the Weyerhaeuser station is presented in Table 3.

Table 3

Weyerhaeuser Station Temperature Data

Average Monthly Temperature in Degrees Fahrenheit

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	AVERAGE
JAN	31.4	39.0	****	44.1	40.0	35.4	41.9	****	37.8	38.5	****	37.9	38.4
FEB	41.0	40.6	41.2	****	40.3	37.6	40.8	****	42.5	36.5	38.1	45.4	40.4
MAR	42.3	44.3	44.0	46.0	46.2	41.7	48.4	****	44.7	42.7	44.9	****	44.5
APR	49.1	46.0	47.0	48.2	45.8	49.2	46.8	50.0	49.9	51.4	****	47.3	48.6
MAY	52.1	51.2	54.8	55.8	50.5	54.3	54.9	56.2	53.9	55.5	53.4	52.2	53.7
JUN	53.9	54.3	62.3	57.3	57.0	58.2	61.9	59.6	57.8	64.1	****	56.3	58.4
JUL	60.8	58.3	63.3	61.5	61.9	67.0	****	****	63.6	65.4	66.2	63.7	63.2
AUG	59.1	62.1	63.7	63.5	61.7	****	****	****	63.8	67.3	66.2	65.4	63.6
SEP	56.3	56.3	59.8	54.1	****	****	58.5	****	58.4	63.8	67.6	59.9	59.4
OCT	49.0	45.8	52.1	48.1	****	****	52.7	52.6	55.0	****	48.0	****	50.4
NOV	43.5	42.0	41.6	44.5	43.7	****	****	46.2	43.7	49.7	42.7	****	44.2
DEC	40.6	37.8	40.9	30.0	35.2	****	****	37.4	39.8	****	38.2	****	37.5

**** Indicates no value for that month.

GEOLOGIC SETTING

The Puget lowland of western Washington was repeatedly glaciated, during the Pleistocene Epoch, by multiple advances of the Cordilleran Ice Sheet which advanced southward from the coastal mountains of British Columbia (Crandell, 1965). Remnant drift sheets from at least two such advances are preserved within the Scatter Creek/Black River area. The older drift, informally named Penultimate Drift by Lea (1984), unconformably overlies basic igneous and marine sedimentary rocks of the Mcintosh, Skookumchuck, and Lincoln Creek Formations. These formations, which comprise area bedrock, were deposited in Tertiary time during the extensive vulcanism and geosynclinal sedimentation which accompanied formation of the Puget Trough.

During the Penultimate glaciation, the Puget Lobe extended nearly to Centralia and covered much of the Scatter Creek valley. The ice terminated against the bedrock hills which define the valley's southern edge (Lea, 1984). Penultimate Drift is preserved in the uplands bordering Scatter Creek as "thin and discontinuous deposits of moderately weathered drift which lie up to 12 km beyond the inferred limit of Vashon ice" (Lea, 1984, p.34). Within the valley interior, Penultimate Drift is thicker, and is generally buried beneath Vashon outwash gravel.

As the Puget Lobe retreated, meltwater discharge reworked much of the drift deposited during the Penultimate and Vashon glacial advances. Meltwater from the Vashon glaciation reoccupied many of the discharge pathways created during the Penultimate glaciation and the drainage histories for the two events have much in common (Lea, 1984).

At the onset of glacial retreat, meltwater generated during both events is thought to have flowed through Mulqueen Gap, south of the town of Vail, to the Skookumchuck River (Noble and Wallace, 1966). With continued retreat, lower elevation pathways through Johnson Creek, Mcintosh Lake, and the Scatter Creek valley were opened (Lea, 1984). Evidence of major meltwater discharge of Vashon age is well preserved at Rock Prairie west of Tenino. There, east-west trending "longitudinal bars up to 1.6 km long, 490 m wide, and 6 m high..." are superimposed over a "south-southeastward dipping outwash fan constructed by local drainage that escaped complete reworking..." (Lea, 1984, p.57-58).

Most topographic features associated with the Penultimate glaciation have been eroded or are obscured by subsequent Vashon deposits. In many lowland areas well reports provide the only means of differentiating the two drifts.

The following sections contain a brief description of the important geologic formations found within the Scatter Creek/Black River area. The areal distribution of each formation is shown on Plate 3.

Mcintosh Formation, (Eocene)

Within the study area, the Mcintosh Formation consists primarily of dark-gray, indurated, tuffaceous siltstone and claystone interbedded with thin tuff layers and vesicular basalt flows. The basalt commonly contains zeolite amygdules. This formation characteristically weathers to iron-stained chips which are mottled light gray or yellowish orange (Noble and Wallace, 1966). Near Tenino, the upper 250 feet or so of the formation consists of massive arkosic sandstone. To the west and south, the lower, finer-grained members of the formation predominate. Outcrops of Mcintosh Formation can be seen at Tenino and north of Gate. It also outcrops in the Black Hills, the Bald Hills, and the Maytown Upland. This formation yields little water to wells and has limited water development potential.

Northcraft Formation (Late Eocene)

The Northcraft Formation was originally named and described by Snavely and others (1951) at its type locality near Northcraft Mountain. The formation may be as much as 1000 feet thick, and is thought to conformably overly the Mcintosh Formation. It consists chiefly of andesitic and basaltic lava flows and flow breccias. The lower part of the formation consists of basaltic conglomerate, basaltic sandstone, and pyroclastic rocks. Within Thurston County, the Northcraft Formation is found in the Bald hills and at a few outcrops in the Maytown Upland. It can also be seen on the South flank of Lemon Hill west of Tenino. Due to its consolidated nature, the Northcraft Formation does not yield significant volumes of water to wells.

Skookumchuck Formation (Late Eocene)

The Skookumchuck Formation was originally described and named by Snavely and others (1951) from outcrops along the Skookumchuck River. The formation originated as marine, nonmarine, and brackish-water sedimentary deposits and reaches a maximum known thickness of about 3500 feet (Noble and Wallace, 1966). The Skookumchuck Formation consists primarily of siltstone and plagioclase-rich arkosic sandstone, but is often interbedded with coal. Conglomerate beds are found locally near the formation base. Deposits typically weather to a pale orange color and can be found in outcrop at the western end of the Bald Hills, within the Maytown Upland, and about one mile north of Grand Mound. The Skookumchuck formation has little water development potential.

Lincoln Creek Formation (Oligocene)

This formation was originally described and named by Weaver (1912) and subsequently renamed by Snavely and others (1951). It is composed of tuffaceous silty sandstone and siltstone. The upper member is a shallow-water, offshore-marine siltstone containing a large assemblage of marine invertebrate megafossils and microfossils (Noble and Wallace, 1966). The formation is thought to conformably overly the Skookumchuck Formation and reaches a maximum known thickness of about 2,000 feet. The Lincoln Creek Formation is exposed at land surface on Michigan Hill and as a small outcrop south of Rochester. This formation, along with the Skookumchuck formation is thought to underlie the Scatter Creek Prairie at depth. Within the study area, it yields little water to wells.

Logan Hill Formation (Early Pleistocene)

Snavely and others (1951) described and named the Logan Hill Formation from their observations of deeply weathered, poorly sorted sand and gravel on Logan Hill in Lewis County. The upper 50 feet of the formation is typically comprised of clay derived from the weathering of exposed sand and gravel. Pebbles in this zone have deep rinds which, in some cases, can be cut with a knife. When wet, surface exposures are brightly colored, exhibiting various shades of red, yellow, orange, blue, and green (Noble and Wallace 1966). The formation is thought to be of glacial and glaciofluvial origin, resulting from early Pleistocene Cascade Valley glaciation (Weigel and Foxworthy 1962). It is distinguishable from later glacial deposits by its deeply weathered nature and pebble lithology. Pebbles within the Logan Hill Formation are predominately of andesitic or basaltic origin, with lesser amounts of red volcanic, tuffaceous, and dark sandstone pebbles. The pebble lithology of later deposits is largely of granitic and metamorphic origin. The Logan Hill Formation is present in outcrop at the upland surface of Michigan Hill and on the Maytown Upland. Where it occurs within the study area it is not a significant water-bearing unit.

Penultimate Drift (Late Peistocene) (Lea, 1984)
Salmon Springs Drift(?) (Noble and Wallace, 1966)

Salmon Springs Drift was named and described by Crandle and others (1958) during their study of the Pleistocene glacial sequence found near the town of Sumner in Pierce County. The type section contains two drift sheets separated by non-glacial deposits containing peat and ash. Crandle assigned an age of Early Wisconsin time to these deposits, based on radiocarbon analysis of peat from the type locality.

Noble and Wallace (1966), tentatively correlated drift deposits in portions of Thurston County with Salmon Springs Drift of Crandle and others (1958), based on similarities in lithology and stratigraphic position. Subsequent paleomagnetic profiling and fission-track dating of Zircon by Esterbrook and Othberg (1976) and Esterbrook and others (1981) have shown this correlation to be invalid, at least for the lower Salmon Springs Drift member, which is actually early Pleistocene in age, approximately 800,000 years BP.

Following the work of Nobel and Wallace, Lea (1984) reexamined drift deposits within the Tenino and Bucoda quadrangles of Southern Thurston County. By evaluating basalt-clast weathering rind thickness, degree of soil development, and preservation of constructional morphology, Lea mapped a second drift sheet underlying Vashon drift in the Tenino area. Lea informally named these deposits "Penultimate Drift" and suggests that in the Tenino area, they were deposited prior to the last interglaciation (> 125,000 B.P.).

On the basis of lithologic descriptions provided by the authors, we consider Penultimate Drift of Lea (1984) and Salmon Springs Drift(?) of Noble and Wallace (1966) to be the same drift sequence. To avoid further misuse of the name Salmon Springs Drift, we have adopted the preliminary nomenclature of Lea (1984) in this report.

In the Scatter Creek area, Penultimate Drift is characterized by thin, discontinuous till deposits and associated erratics. The till ranges in thickness from 1.5 to 20 feet and is interspersed with poorly sorted, nonstratified outwash sands and gravels which reach thicknesses of 3 to 20 feet (Lea, 1984).

Penultimate till is only lightly weathered and consists of rounded to subrounded pebbles and cobbles in an oxidized, fine-grained matrix of compact sand, silt, and clay. Locally, the matrix consists of uncompacted sand (Lea, 1984). The gravel is often stained reddish brown to yellowish brown and is predominately of mafic volcanic origin, with lesser quantities of metamorphics, silicic plutonics, sandstones, and siltstones.

Penultimate Drift is distinguished from the underlying Logan Hill Formation by its pebble lithology and absence of heavy weathering. Within the Scatter Creek Area, Penultimate Drift underlies much of the prairie where it is capped by more recent deposits of Vashon Drift. In those portions of the study area where it is saturated with water, Penultimate Drift yields large volumes of water to wells.

Vashon Drift (Late Wisconsin)

The name Vashon Drift was first applied by Willis (1898) to describe recent glacial deposits mantling the Tacoma area. Vashon Drift immediately underlies much of the Puget Sound lowland and has been extensively evaluated and described by subsequent authors. In Thurston County, Noble and Wallace (1966) recognized five distinct Vashon units. Two of these, the recessional outwash and subglacial till, are present in appreciable quantities within our study area.

Vashon recessional gravel overlies deposits of Penultimate Drift throughout most of the Scatter Creek prairie. It consists of poorly sorted, coarse-gravel and sand with only minor amounts of silt or clay. The gravel component is predominately basalt, dark sandstone, andesite, and granodiorite, with lesser quantities of siliceous and metamorphic rock.

Vashon till generally consists of poorly sorted deposits of well rounded cobbles and gravel contained within a dense, compact matrix of sandy-silt and clay. The till is usually gray to tan-gray in color. Vashon till is exposed at land surface in the Maytown upland where it is derived from reworked and overridden Vashon advance outwash and Penultimate Drift deposits.

Outcrops of Vashon Drift, unlike Penultimate Drift, are usually bright and fresh in appearance with only minor staining of the gravel component. Bedding is usually poorly defined but some outcrops show horizontal stratification and occasional crossbedding. When saturated, Vashon Drift can yield large volumes of water to wells.

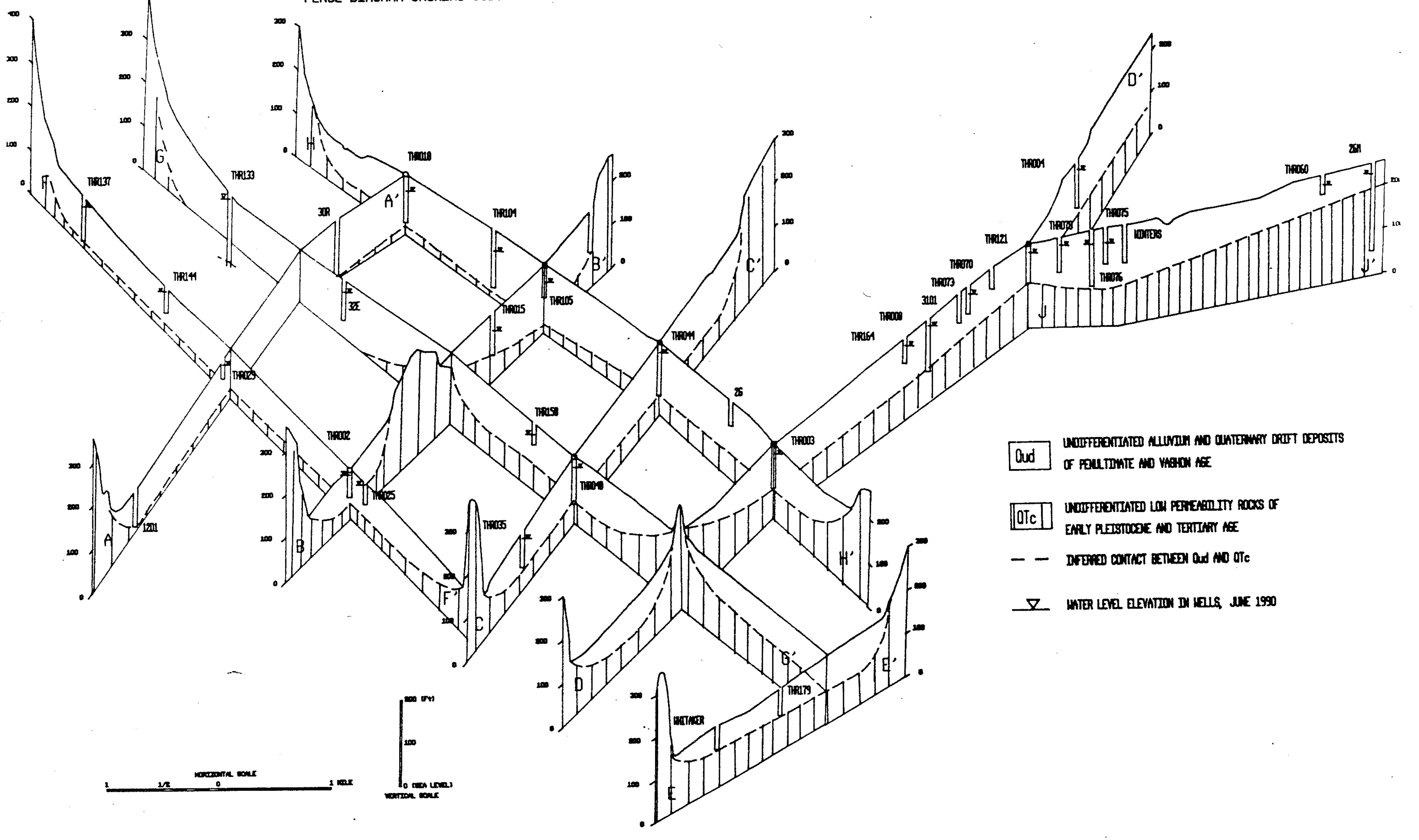
HYDROGEOLOGIC UNITS

The occurrence and movement of water within a ground-water system is largely controlled by the distribution of low permeability materials (confining units) and high permeability materials (aquifers). A convenient means of referencing confining units and aquifers is to group them into hydrogeologic units. A hydrogeologic unit may consist of a single geologic formation, part of a formation, or a group of formations of similar geology and water development potential.

We evaluated data from single and multiple well aquifer tests, ground-water levels, well reports, and surficial geologic information to define hydrogeologic units. Following the lead of Noble and Wallace (1966), we grouped the younger unconsolidated drifts of Penultimate and Vashon age into a single hydrogeologic unit based on their geologic similarity and high water-development potential. Similarly, we grouped the remaining older consolidated or semi-consolidated rocks of low water-development potential into a second hydrogeologic unit. In subsequent discussion, these units are referenced as the unconsolidated valley-fill aquifer, or Qud, and the older consolidated rocks, or QTu. The approximate thickness and distribution of each unit is shown in Figure 2 and Plate 3.

FIGURE 2

FENCE DIAGRAM SHOWING SUBSURFACE GEOLOGY OF THE SCATTER CREEK/BLACK RIVER AREA



Unconsolidated Valley-Fill Aquifer

The unconsolidated, valley-fill aquifer unconformably overlies older consolidated rocks throughout the Scatter Creek Prairie and is the uppermost hydrogeologic unit in the study area. This unit consists of an admixture of reworked outwash and till laid down during the Penultimate and Vashon glacial periods. South and West of Rochester, it also contains recent alluvium and flood deposits of the Black and Chehalis Rivers.

Area water well reports provide a ready means of differentiating these sediments from the underlying older consolidated rocks. Within the valley-fill sediments, Vashon outwash typically consists of poorly sorted, non-to-poorly stratified sand, gravel, and cobbles with interbedded lenses of silt and clay.

In the eastern part of the valley, Vashon Drift overlies outwash and till of penultimate origin. Penultimate till is absent in the western part of the valley and consists of rounded to subrounded pebbles and cobbles in an oxidized fine-grained matrix of compact sand, silt, and clay. Vashon deposits are differentiated from the underlying Penultimate deposits by their fresh appearance and lack of staining.

The unconsolidated, valley-fill sediments attain a maximum known thickness at well THR133, which penetrated 161 feet of silt, sand,

and gravel without encountering bedrock. The minimum known thickness of this unit occurs in well 16N/02W-26M, where basalt was encountered at a depth of 62 feet. Based on the 17 recorded area wells which fully penetrate this unit, the average thickness of the valley-fill sediments is approximately 106 feet.

The unconsolidated, valley-fill aquifer is the source of water for most wells in the Scatter Creek Valley and is capable of supplying large volumes of water to properly constructed wells. Screened irrigation and fish-farm wells are typically capable of sustained withdrawals of 500-2000+ gpm with less than 20 feet of drawdown. Open bottom domestic wells typically yield 20-100 gpm with minimal drawdown.

Older Consolidated Rocks

The stratigraphically lower and older consolidated rock unit is largely composed of sandstones, siltstones, shales, and mafic volcanic rocks of the Mcintosh, Skookumchuck, and Lincoln Creek Formations. The vertical extent of this unit is not known, but two oil and gas exploration wells drilled shortly after the turn of the century, within S.22, T.15N., R.3W., and S.34, T.16N., R.2W., penetrated 1570 and 1942 feet of these rocks, respectively, before drilling was terminated.

Within the valley interior, the upper surface of this unit generally dips to the west from a maximum known elevation of approximately 190 feet above sea level at well 16N/02W-26M, to at least 50 feet below sea level at well THR133. Notable exceptions to this occur near the towns of Grand Mound and Rochester. There older rocks form an elongated east-west tending hill south of Rochester, and the knoll west of Grand Mound from which the town was named.

In addition to defining the basal confining unit for the valley-fill aquifer, this unit forms the uplands which border the Scatter Creek Valley. Except where truncated by the Chehalis and Black rivers, these uplands effectively serve as no-flow boundaries by restricting lateral ground-water movement into and out of the Scatter Creek valley.

Within the Maytown upland, the older consolidated rocks are mantled by glacial drift of Penultimate and Vashon age. Patterns of ground-water movement in this area are ill defined, but ground-water movement from the Maytown upland into the study area is suspected based on contoured water levels for selected wells, which show a definite southern component of flow. The relative importance of this contribution is unclear, but is not thought to significantly contribute to aquifer recharge.

The water-development potential of the older consolidated rocks is generally poor. Some domestic wells obtain water from this unit near the valley perimeter, where the unconsolidated sediments are not saturated or are absent. When sufficient secondary porosity is present, the unit is capable of yielding enough water for domestic use.

HYDRAULIC CHARACTERISTICS OF THE VALLEY-FILL AQUIFER

The ability of a hydrogeologic unit to produce water is largely a function of the hydraulic conductivity and storage properties of the unit matrix. To define the range and distribution of hydraulic characteristics for the valley-fill aquifer, we relied on well specific-capacity information and data from multiple- and single-well aquifer tests. We used the methods of Theis (1935), Cooper-Jacob (1946), and Neuman (1975) to evaluate the multiple-well test data.

Information from multiple-well aquifer tests provide the best estimates of aquifer hydraulic properties. We used the average storage coefficient determined from the multiple-well tests to estimate transmissivity from the specific capacities of wells. We converted the estimated transmissivity values to units of hydraulic conductivity by dividing the transmissivity by the saturated thickness of the aquifer.

The results of these analyses are shown in Tables 4 and 5 referenced by well number and location. Data plots with the corresponding best-fit type curve for the aquifer tests are provided in Appendix B.

Table 4

Estimated Hydraulic Properties of the Unconsolidated Valley-Fill Aquifer, Derived From Multiple Well Aquifer Test Data

Test Site	Method	Radius to Obs. Well (ft)	$(T)_1$	$(S)_2$	$(Sy)_3$	$(K)_4$
Domsea at Gate	Jacobs	1200	127656	0.002	*****	939
16N/04W-25Q01	Theis	1200	116395	0.002	*****	856
	Neuman	1108	76190	0.0002	0.006	560
	Jacob	1108	169920	0.000006	*****	1249
	Theis	1100	118498	0.006	*****	871
	Jacob	1100	131962	0.005	*****	970
	Neuman	995	139910	0.0001	0.003	1030
	Jacob	588	205200	0.00003	*****	1510
	Neuman	588	93960	0.0002	0.006	690
	Neuman	300	102125	0.0003	0.01	750
Seafarm of Wa.	Neuman	127	56232	0.00003	0.03	750
16N/02W-32E	Neuman	470	117360	0.0002	0.01	1565
	Neuman	966	194256	0.006	0.11	2590
THR015	Jacobs	0.5	179568	*****	*****	3325
16N/03W-33P01	Theis	280	173232	0.001	*****	3208
Summary Statistics		Minimum	56323	0.000006	0.003	560
		Maximum	205200	0.006	0.11	3325
		Mean	133500	0.002	0.025	1390
		Median	127656	0.0003	0.01	970

1-Aquifer transmissivity, Ft^2/day
2-Aquifer storage coefficient, dimensionless
3-Aquifer specific yield, dimensionless
4-Aquifer hydraulic conductivity, Ft/day

Table 5

Hydraulic Properties of the Unconsolidated Valley-Fill Aquifer, Estimated From the Specific Capacity of Wells Using the Method of Theis (1935)

Well Number	Location	Well Yield[1]	Specific Capacity[2]	Est. T[3]	B[4]	Est. K[5]
THR164	15N/02W-06E01	50	5.0	1584		
THR011	15N/02W-06N01	20	6.7	1938		
THR173	15N/03W-03R01	350	23.3	7953		
THR175	15N/03W-06A02	265	132.5	42280		
THR035	15N/03W-09F03	90	45.0	11888		
THR058	16N/02W-19R01	200	6.7	1863		
THR066	16N/02W-29L01	400	100.0	29182		
THR004	16N/02W-29L02	249	23.0	7285	105	69
THR073	16N/02W-31L01	150	75.0	20851		
THR075	16N/02W-32A01	750	42.0	12143		
THR076	16N/02W-32B01	850	60.7	17692		
THR121	16N/02W-33E01	370	28.5	8307		
THR102	16N/03W-32E01	600	33.3	9630		
THR105	16N/03W-33G03	125	8.9	2721		
THR119	16N/03W-36J02	584	64.8	19434	76	256
THR120	16N/03W-36J03	1440	37.9	10168	74	137
THR122	16N/03W-36K01	1420	47.3	13515	90	150
THR137	16N/04W-26K01	90	90.0	25021	67	373
Summary Statistics		Minimum	5.0	1584	**	69
		Maximum	132.5	42280	**	373
		Mean	46.1	13525	**	197
		Median	40.0	12016	**	137

(1) Well yield [gpm]
(2) Well specific capacity: equal to well yield/feet of drawdown [gpm/ft of dd]
(3) Aquifer Transmissivity [Ft2/day]
(4) Aquifer saturated thickness [Ft]
(5) Aquifer horizontal hydraulic conductivity [Ft/day]

For this study, the hydraulic conductivity and transmissivity estimates obtained from the specific capacity of wells are about an order of magnitude less than those obtained from the multiple-well test data. This can be explained in part by the additional drawdown that occurs in a pumping well due to partial penetration impacts, poor well development, and turbulent flow within the well. These factors tend to reduce the specific capacity of a well, hence the transmissivity estimated from this data. Still, the analysis results seem reasonable and are within the error range of this method.

Using the entire data set from Tables 4 and 5, we calculated a mean storage coefficient of 0.002 and a specific yield of 0.025 for the valley-fill aquifer. The median hydraulic conductivity for the aquifer is 864 ft/day with values ranging from 69 to 3325 ft/day.

GROUND-WATER MOVEMENT

Ground-water within the valley-fill aquifer generally moves from the upland recharge area near Tenino toward points of natural ground-water discharge along the Chehalis and Black Rivers. The direction of ground-water movement can be inferred from plates 4 through 7, which show the general head distribution for the valley-fill aquifer for the period 1989 to 1990. The head data was derived from synoptic water-level measurements made on consecutive days in August and December 1989, and March and June, 1990. The contoured head values represent lines of equal hydraulic potential and are called equipotential lines. Lateral ground-water movement is generally perpendicular to the equipotential lines in the direction of decreasing head.

Ground-water movement within the valley is principally from east to west. Deviations from the general trend occur locally, near streams, and west of Tenino where there is an apparent southern component of flow resulting from ground-water movement into the study area from the Maytown upland (see Plate 5). Additionally, north/south components of flow are evident between Grand Mound and the Chehalis Indian reservation where ground-water moves toward natural points of discharge along the Black and Chehalis Rivers.

Within the Scatter Creek valley, natural ground-water discharge is restricted to narrow zones along the major rivers and streams. The Chehalis and Black Rivers receive most of the aquifer discharge during summer baseflow conditions. Scatter Creek also receives ground-water discharge in its lower reach and in the Mima Prairie area west of Tenino.

Table 6 shows the saturated thickness and seasonal variation in vertical head distribution for four piezometer nests completed in the valley-fill aquifer. Hydrographs for selected area wells are contained in appendix C.

Table 6

1987-1988 Water Level Elevations in Feet Above Mean Sea Level, for Selected Nested Piezometers

Well Location	Well Number	Screen Interval	Water Table Elevation Dec. 87	Water Table Elevation Apr. 88
16N/02W-29	THR004	103-108	178.37	195.85
	THR005	74-82	178.23	195.74
	THR006	41-48	178.25	195.79
15N/03W-02	THR044	120-125	134.39	149.70
	THR045	80-85	134.67	150.12
	THR046	49-52	134.82	150.44
16N/03W-33	THR015	88-93	112.38	121.67
	THR016	64-70	112.45	121.75
	THR017	43-46	114.71	121.89
15N/04W-01	THR026	104	99.90	101.08
	THR027	65	100.99	102.15
	THR028	< 65	101.24	102.35

As seen in table 6, vertical head gradients in the study area are relatively small and varied from 0.06 to 2.33 feet across the saturated thickness of the aquifer. All nested piezometers listed in table 6 had decreasing head with depth, indicating downward components of flow, or recharge conditions. The exceptions to this occurred in piezometers THR004, THR005, and THR006 where heads indicate both upward and downward components of flow, possibly indicating an area of local confinement or aquifer stratification. The well report for this well shows a layer of tight silty sand and gravel between piezometers THR004 and THR005 which may account for the observed head distribution.

We estimated the mean, horizontal hydraulic gradient for the aquifer from the June 1990 head measurements for wells 16N/02W-25E1 and THR054. These wells are located at the eastern and western end of the study area respectively. The mean hydraulic gradient of approximately 0.002, or 10.6 feet per mile, was obtained by dividing the difference in head at each well site by the linear distance separating them. In the absence of pumpage induced drawdowns, local gradients in the study area vary from approximately 0.001 to 0.003, or 5.3 to 15.8 feet per mile.

We used Darcy's law to estimate ground water seepage-velocities within the valley-fill aquifer. Assuming a mean regional gradient of 0.002, a median hydraulic conductivity of 864 Ft/day, and a specific yield of 0.11, the mean ground water seepage-velocity for the aquifer is estimated to be approximately 16 feet per day with values ranging from approximately 1.3 to 60 feet per day.

The water-saturated portion (saturated thickness) of unit Qud varies by season and location. Table 7 is a summary of the maximum variation in saturated thickness for the valley-fill aquifer as measured in selected wells during the period 1975 to 1991.

Table 7

Variation in Aquifer Saturated Thickness as Measured in Selected Wells During the Period 1975-1991

Well Number	Location	Saturated Thickness (ft) Maximum	Minimum	Maximum Historic Fluctuation
THR003	15N/03W-02R1	91	72	19
THR044	15N/03W-03A1	114	87	27
THR002	15N/03W-05N1	77	69	8
THR048	15N/03W-10D1	91	78	13
THR026	15N/04W-01D01	110	101	9
THR004	16N/02W-29L2	115	94	21
THR008	16N/02W-31N1	101	81	20
THR018	16N/03W-29L2	84	81	3
THR015	16N/03W-33P1	67	47	20
THR119	16N/03W-36J02	95	81	14
THR137	16N/04W-26K01	78	72	6

Seasonal variations in water-table elevation are greatest in the central and eastern portion of the study area, where historic water levels have varied by as much as 27 feet. In the western portion of the study area where ground water discharges to the Chehalis and Black rivers, the water table fluctuates seasonally by about three to eight feet. This pattern of water-level fluctuation is typical for ground water systems with relatively large areas of ground-water recharge and smaller areas of discharge.

NATURAL GROUND-WATER EXCHANGE WITH STREAMS

In western Washington, the base flow of most lowland, perennial streams is derived from ground-water discharge. The exchange of water between a stream and the local ground-water system is driven by the difference in head between them. When the head in a stream is greater than that in a hydraulically contiguous aquifer, water moves from the stream to the aquifer. When head in the aquifer exceeds that of the stream, ground water flows from the aquifer into the stream.

Surface-water seepage assessments provide a means of determining where and when a stream is gaining from or losing water to ground-water storage. To conduct a seepage assessment, one establishes a series of gaging sites at various points along a stream and then measures the discharge at all sites over a short period of time. The relative increase or decrease in discharge between stations, that is not accounted for through physical diversion or tributary input, is the volume of water exchanged between the stream and ground-water storage.

In order to assess stream seepage rates for this study, we conducted and or evaluated 155 discharge measurements of Scatter Creek, the Chehalis and Black rivers, major tributaries of these rivers, and fish farm discharges. Table 8 provides the date, stream course, measured discharge, and river mile of each gaging site. The location of each gaging site is shown on Plate 1 referenced by station number.

Table 8

Miscellaneous Discharge Measurements For Selected Streams in the Scatter Creek/Black River Area

Station Number	Stream Course	River Mile	Measurement Date	Discharge (cfs)
THR501	Chehalis River	60.1	07/13/87	197
			08/24/87	154
			09/22/87	224
THR502	Mima Creek	1.0	04/07/82	27
			05/04/82	17
			06/15/82	6.7
			07/15/82	2.9
			08/18/82	1.6
			10/01/82	2.0
			11/12/82	9.8
			12/29/82	33
			02/07/83	31
			05/04/83	13
			08/26/87	1.2
THR505	Scatter Creek	16.4	06/15/82	5.3
			07/15/82	1.4
			08/18/82	0.82
			11/12/82	0.75
			07/26/89	DRY
			08/18/89	DRY
			10/11/89	DRY
			11/29/89	TOO HIGH
			03/28/90	14
THR506	Scatter Creek	13.1	07/26/89	0.85
			08/18/89	0.45
			10/11/89	TOO LOW
			11/29/89	18
			03/28/90	22
THR508	Scatter Creek	9.9	07/26/89	DRY
			08/18/89	DRY
			10/11/89	DRY
			11/29/89	TOO LOW
			03/28/90	37

Table 8 (continued)

Miscellaneous Discharge Measurements For Selected Streams in the Scatter Creek/Black River Area

Station Number	Stream Course	River Mile	Measurement Date	Discharge (cfs)
THR509	Sea Farm @ Scatter Ck. (Discharge)	9.1*	07/15/87	8.1
			08/25/87	7.9
			09/22/87	6.9
			07/26/89	7.4
			08/18/89	6.9
			10/11/89	6.1
			11/29/89	5.4
			03/28/90	8.9
THR510	Scatter Creek	8.5	08/13/81	3.1
			09/16/81	1.8
			07/16/87	7.7
			07/26/89	6.5
			08/18/89	6.4
			10/11/89	6.4
			11/29/89	4.0
			03/28/90	43
THR511	Scatter Creek	7.8	12/21/81	190
			02/10/82	76
			04/09/82	89
			05/06/82	33
			06/15/82	5.4
			07/15/82	2.1
			08/08/82	1.0
			11/12/82	DRY
			12/29/82	104
			02/07/83	67
			05/04/83	22
			08/25/87	4.0
			09/22/87	3.8
			07/26/89	7.4
			08/18/89	6.0
			10/11/89	5.8
			11/29/89	3.5
			03/28/90	40

Table 8 (continued)

Miscellaneous Discharge Measurements For Selected Streams
in the Scatter Creek/Black River Area

Station Number	Stream Course	River Mile	Measurement Date	Discharge (cfs)
THR512	Scatter Creek	4.6	07/16/87	16
			08/25/87	15
			09/22/87	11
			07/26/89	20
			08/18/89	15
			10/11/89	13
			11/29/89	9.0
			03/28/90	73
THR519	Scatter Creek	4.1	05/19/81	31
			05/20/81	34
			08/13/81	12
			09/16/81	9.1
			07/26/89	18
			08/18/89	17
			10/11/89	12
			11/29/89	TOO HIGH
			03/28/90	77
THR520	Scatter Creek	2.3	05/20/81	43
			08/13/81	8.0
			09/16/81	7.6
			07/26/89	14
			08/18/89	16
			10/11/89	12
			11/29/89	8.0
			03/28/90	74
THR521	Scatter Creek	1.5	12/22/81	162
			02/10/82	83
			04/09/82	96
			05/06/82	48
			07/16/87	13
			08/24/87	12
			09/22/87	9.8
			08/18/89	18
			10/11/89	12
			11/29/89	8.7
			03/28/90	77
THR522	Scatter Creek	0.0	07/17/87	13
			08/24/87	12
			09/22/87	10

Table 8 (continued)

Miscellaneous Discharge Measurements For Selected Streams in the Scatter Creek/Black River Area

Station Number	Stream Course	River Mile	Measurement Date	Discharge (cfs)
THR523	Chehalis River	54.7	07/17/87	280
			08/24/87	196
			09/22/87	260
THR524	Black River	17.2	05/06/82	103
			06/15/82	29
			07/15/82	24
			08/18/82	14
			10/01/82	13
			11/12/82	52
			02/07/83	181
			05/04/83	76
			07/14/87	17
			08/26/87	8.7
			09/22/87	9.3
THR525	Black River	9.1	08/26/87	35
			09/22/87	38
THR526	Black River	4.1	06/15/82	114
			07/15/82	80
			08/18/82	59
			10/04/82	61
			11/12/82	164
			05/04/83	223
			07/14/87	69
			08/26/87	44
			09/22/87	47
THR527	Beaver Creek	0.2	04/07/82	84
			05/06/82	38
			06/15/82	11
			07/15/82	7.7
			08/18/82	5.2
			10/01/82	5.2
			11/12/82	17
			12/29/82	82
			02/07/83	80
			05/04/83	28
			07/14/83	5.5
			08/26/87	2.6
			09/22/87	1.9

Table 8 (continued)

Miscellaneous Discharge Measurements For Selected Streams in the Scatter Creek/Black River Area

Station Number	Stream Course	River Mile	Measurement Date	Discharge (cfs)
THR528	Domsea @ Scatter Ck (Discharge)	7.1*	05/20/81	20
			02/10/82	17
			04/09/82	17
			05/06/82	17
			07/15/87	18
			08/25/87	17
			09/22/87	15
			10/11/89	11
			11/29/89	8.9
			03/28/89	13
			06/18/89	11

* Indicates the point of discharge to Scatter Creek

Table 9 shows the seepage gain or loss from Scatter Creek for five monitoring events during the period July 1989 to March 1990. The seepage gain or loss, in cubic feet per second per river mile, is determined by dividing the difference in discharge between adjacent stations by the distance in river miles between stations. A negative seepage value indicates the creek lost water to ground-water storage between stations. A positive seepage value indicates the creek gained water from ground-water storage between gaging stations.

The indicated seepage values have not been corrected to account for physical diversion of water from the creek for irrigation or other beneficial uses. Locating and quantifying such uses was beyond the scope of this study. If large consumptive diversions did occur during the monitoring events, they would tend to cause over estimation of seepage losses in losing reaches and under estimation of seepage gains in gaining reaches of the stream.

Table 9

Seepage Gain or Loss from Scatter Creek in Cubic Feet per Second per River Mile (cfs/river mi)

Measurement Date	Station Number	River Mile	Discharge (cfs)	Seepage Gain (+) or Loss (-) in (cfs/mi)
07/26/89	THR505	16.4	DRY	
	THR506	13.1	0.85	+ 0.26
	THR508	9.9	DRY	- 0.26
	THR509	9.1[A]	7.4[B]	
	THR510	8.5	6.5	- 1.5
	THR511	7.8	7.4	+ 1.3
	THR528	7.1[A]	***	
	THR512	4.6	20	
	THR519	4.1	18	- 4.0
	THR520	2.3	14	- 2.2
	THR521	1.5	***	
08/18/89	THR505	16.4	DRY	
	THR506	13.1	0.45	+ 0.14
	THR508	9.9	DRY	- 0.14
	THR509	9.1[A]	6.9[B]	
	THR510	8.5	6.4	- 0.83
	THR511	7.8	6.0	- 0.57
	THR528	7.1[A]	***	
	THR512	4.6	15	
	THR519	4.1	17	+ 4.0
	THR520	2.3	16	- 0.56
	THR521	1.5	18	+ 2.5

Table 9 (Continued)

Seepage Gain or Loss from Scatter Creek
in Cubic Feet per Second per River Mile (cfs/river mile)

Measurement Date	Station Number	River Mile	Discharge (cfs)	Seepage Gain (+) or Loss (-) in (cfs/mi)
10/11/89	THR505	16.4	DRY	
	THR506	13.1	LOW	
	THR508	9.9	DRY	
	THR509	9.1[A]	6.1[B]	
	THR510	8.5	6.4	+ 0.50
	THR511	7.8	5.8	- 0.85
	THR528	7.1[A]	11[B]	
	THR512	4.6	13	- 1.2
	THR519	4.1	12	- 2.0
	THR520	2.3	12	
	THR521	1.5	12	
11/29/89	THR505	16.4	HIGH	
	THR506	13.1	18	
	THR508	9.9	LOW	- 5.6
	THR509	9.1[A]	5.4[B]	
	THR510	8.5	4.0	- 2.3
	THR511	7.8	3.5	- 0.71
	THR528	7.1[A]	8.9[B]	
	THR512	4.6	9.0	-1.1
	THR519	4.1	HIGH	
	THR520	2.3	8.0	
	THR521	1.5	8.7	+ 0.87
03/28/90	THR505	16.4	14	
	THR506	13.1	22	+ 2.4
	THR508	9.9	37	+ 4.7
	THR509	9.1[A]	8.9[B]	
	THR510	8.5	43	- 2.1
	THR511	7.8	40	- 4.3
	THR528	7.1[A]	13[B]	
	THR512	4.6	73	+ 6.3
	THR519	4.1	77	+ 8.0
	THR520	2.3	74	- 1.7
	THR521	1.5	77	+ 3.8

(A) Point of fish farm discharge to Scatter Creek, river mile
(B) Volume of fish farm discharge to Scatter Creek (cfs)

Evaluation of Table 9 indicates that for the period studied, Scatter Creek is predominately an effluent or losing stream through its central portion and is an influent or gaining stream at the upper and lower ends. Between stations THR505 (mile 16.4) and THR506 (mile 13.1) the creek gained water from ground-water during all 5 sampling events. Between stations THR506 (mile 13.1) and THR520 (mile 2.2) the creek generally lost water to ground-water storage. Between stations THR520 (mile 2.2) and THR521 (mile 1.1) the creek either gained water from ground-water storage or the flow between stations was the same.

Table 10 is a seepage assessment for the Chehalis and Black Rivers for the period August 24-26, 1987. As with Table 9, the seepage estimates have not been corrected to account for physical diversion of water from the rivers.

Table 10

Seepage Gain or Loss From the Chehalis and Black Rivers for the Period August 24-26, 1987, in Cubic Feet per Second per River Mile (cfs/river mile)

Station	River	River Mile	Disch. (cfs)	Date	Seepage Gain (cfs/riv. mi.)
12027500[A]	Chehalis	59.9	168	08/24	
THR522	Scatter	****	12[B]	08/24	
THR523	Chehalis	54.7	196	08/24	+ 3.1[E]
THR524	Black	17.2	8.7	08/26	
THR527	Beaver	****	2.6[C]	08/26	
THR502	Mima	****	1.2[D]	08/26	
THR525	Black	9.1	35	08/26	+ 2.8[F]
THR526	Black	4.1	44	08/26	+ 1.8[G]

[A] USGS gage at Grand Mound, reported discharge is daily mean
[B] Tributary input to the Chehalis River from Scatter Creek
[C] Tributary input to the Black River from Beaver Creek
[D] Tributary input to the Black River from Mima Creek
[E] Seepage gain between stations 12027500 and THR523
[F] Seepage gain between stations THR524 and THR525
[G] Seepage gain between stations THR525 and THR526

Table 10 indicates that ground-water discharge from the valley-fill aquifer contributes significantly to the base flows of the Chehalis and Black Rivers. From the USGS gage at Grand Mound to station THR523, a distance of approximately 5.2 river miles, the Chehalis river gained 16 cfs from the aquifer. This constitutes 8% of the discharge measured at the lower gaging site and equates to a seepage gain of 3.1 cfs per river mile. Similarly, the Black River gained approximately 9 cfs from the aquifer between stations THR525 and THR526, a distance of approximately 5 river miles. This constitutes approximately 20% of the discharge measured at the lower gaging site and equates to a seepage gain of 1.8 cfs per river mile.

WATER BUDGET OF THE STUDY AREA

Figure 4 shows the general soil-water budget for the study area. The values for monthly potential and actual evapotranspiration were calculated with the program WATBUG (Willmott, 1977). The program output from WATBUG is shown in Table 11. The water budget indicates soil-moisture deficits in the months of May through September, with surplus water available during the remaining months. The annual moisture surplus is estimated to be 31.2 inches of water over the study area. This water is available as surface runoff to area streams or as ground-water recharge. 31.2 inches of water over an area of approximately 38,765 acres would yield about 100,789 acre-feet of water per year, or a water flow of 139 cfs continuously.

We compared the estimated soil moisture surplus derived from the WATBUG program, with the ground water discharges determined from seapage assessments of the Chehalis and Black rivers. Using the measured seepage gains of 3.1 and 1.8 cfs per river mile for the Chehalis and Black Rivers respectively, estimated ground-water discharge to the streams would amount to approximately 53 and 27 cfs respectively. These estimates are based on stream reaches of 17 miles for the Chehalis river and 15 miles for the Black River. Although these estimates are rough, the values seem reasonable and indicate that most of the available moisture surplus recharges the ground water system and ultimately discharges to the Chehalis and Black rivers.

FIGURE 3

AVERAGE MONTHLY WATER BUDGET FOR THE

SCATTER CREEK/BLACK RIVER STUDY AREA

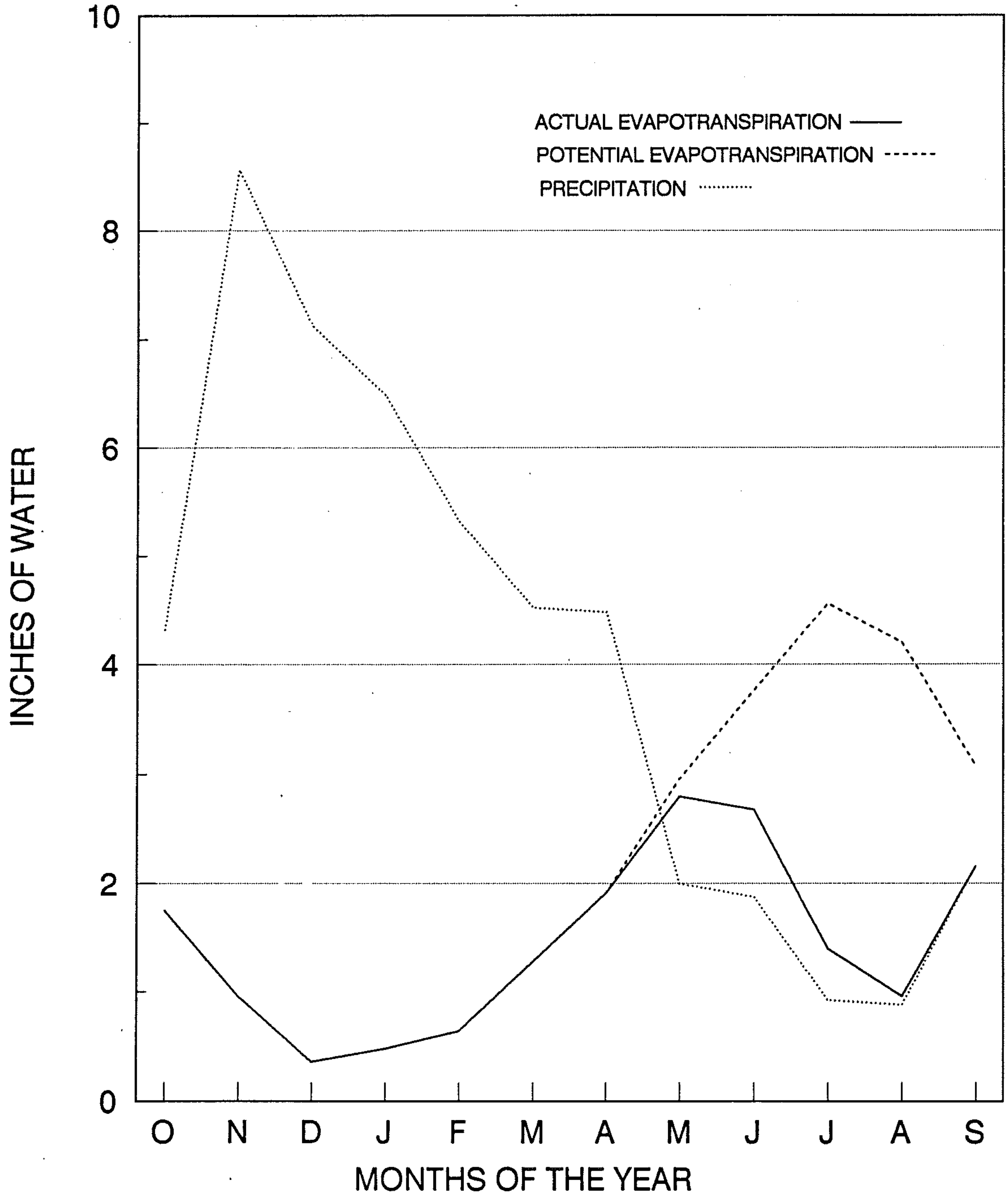


Table 11

Scatter Creek/Black River Area Annual Water Budget

NO. OF MONTHS OVER WHICH BALANCING OCCURS IS 1

TOTAL NO. OF MONTHS EVALUATED IS 12

SOIL MOISTURE CAPACITY IS 2.21 inches

LATITUDE IS 46.8

MO	TEMP	UPE	APE	PREC	DIFF	ST	DST	AE	DEF	SURP
1	38.48	0.60	0.48	6.48	6.04	2.20	0.00	0.48	0.00	6.04
2	40.46	0.80	0.64	5.32	4.68	2.20	0.00	0.64	0.00	4.68
3	44.42	1.24	1.28	4.52	3.24	2.20	0.00	1.28	0.00	3.24
4	48.56	1.68	1.92	4.48	2.56	2.20	0.00	1.92	0.00	2.56
5	53.78	2.28	2.96	2.00	-1.00	1.40	-0.80	2.80	0.20	0.00
6	58.46	2.80	3.76	1.88	-1.88	0.60	-0.80	2.68	1.08	0.00
7	63.14	3.36	4.56	0.92	-3.64	0.12	-0.48	1.40	3.16	0.00
8	63.68	3.44	4.20	0.88	-3.32	0.04	-0.08	0.96	3.28	0.00
9	59.36	2.92	3.08	2.16	-0.92	0.04	0.00	2.16	0.92	0.00
10	50.36	1.88	1.76	4.32	2.52	2.20	2.16	1.76	0.00	0.36
11	44.24	1.20	0.96	8.56	7.60	2.20	0.00	0.96	0.00	7.60
12	37.58	0.51	0.36	7.12	6.76	2.20	0.00	0.36	0.00	6.76
YEARLY TOTAL										31.2

Where:

MO is the month of the year.
TEMP is the mean monthly temperature.
UPE is the unadjusted potential evapotranspiration.
APE is the potential evapotranspiration which is UPE multiplied by a correction factor for latitude.
PREC is the precipitation in millimeters.
DIFF is the PREC minus APE.
ST is the amount of water in storage.
DST is the change in storage.
AE is the actual evapotranspiration. AE is equal to APE when precipitation is greater than APE. AE is equal to precipitation plus change is storage (regardless of sign) when precipitation is less than APE.
DEF is the moisture deficit, APE minus AE.
SURP is the surplus. Surplus is equal to PREC minus APE when the soil is saturated. Surplus is zero if storage is decreasing, because all the water goes to storage or AE. Any water above AE satisfies storage first, then is surplus.

GROUND-WATER RECHARGE

The most commonly used method for qualitatively estimating ground-water recharge is to evaluate water inflow and outflow from the basin. The inflow of water to a basin is derived from precipitation, surface water inflow, ground water inflow, storage changes in surface or ground water bodies, and water imported to the basin by humans. The outflow of water from a basin is comprised of evapotranspiration, natural surface and ground water discharge, storage changes in ground or surface water bodies, and consumptive water use by humans. For basins in relative equilibrium, where long term ground and surface water storage changes are minimal, this relationship can be represented by the following equation.

$$GR = (P + Si + Gi + I) - (E + So + Go + Cg + Cs)$$

Where: GR = ground water recharge

P = average annual precipitation within the basin

Si = average annual volume of surface water inflow to the basin

Gi = average annual volume of ground water inflow to the basin

I = average annual volume of water imported to the basin by humans

E = annual evapotranspiration for the basin

So = average annual volume of surface water outflow from the basin

Go = average annual volume of ground water outflow from the basin

Cg = average annual consumptive ground water use by humans

Cs = average annual consumptive surface water use by humans

Unqualified application of this method to the Scatter Creek area is hindered by a lack of continuous discharge data for Scatter Creek, the Chehalis, and the Black River. The discharge data that is available suggests that Scatter Creek provides a significant volume of recharge to the Rock Prairie area west of Tenino during the early fall. Neglecting this contribution would result in underestimating ground water recharge to the aquifer.

An alternate method for estimating ground-water recharge is to quantify ground water flux across an imaginary vertical plane which separates aquifer recharge areas from areas of ground-water discharge. For aquifers in dynamic equilibrium, the volume of flow across this boundary is equal to the average annual volume of ground-water recharge.

Within the Scatter Creek valley ground-water discharge is restricted to narrow zones along the Chehalis and Black Rivers and the lower reaches of Scatter Creek. If we assume that ground water exchange occurs throughout the length of the Chehalis and Black Rivers as they cross the Scatter Creek valley, then we can use Darcy's law to estimate ground water discharge from the aquifer. Based on river reaches of 17 and 15 miles respectively for the Chehalis and Black rivers, a hydraulic gradient of 0.001, a median hydraulic conductivity of 864 ft/day, and an average saturated thickness of 85 feet, the total annual discharge to both rivers is estimated to be approximately 143 ft^3/sec, with 76 ft^3/sec discharging to the Chehalis River and 67 ft^3/sec discharging to the Black River. This value is approximately equal to the estimated soil moisture surplus calculated for the study area, as discussed in the preceding section.

While this estimate is rough, it is generally consistent with the recharge rate determined from surface water seepage assessments of the Chehalis and Black Rivers, and indicates that most of the available moisture surplus enters the ground water system as recharge.

CHAPTER III

AQUIFER WATER QUALITY

We collected and analyzed ground-water samples to determine if ground water pollution was occurring and to characterize the quality of ground water in the study area. This chapter presents our methods for water sample collection, analytical methods used to determine the concentration of constituents, a review of laboratory accuracy, a detailed discussion of the nitrate analysis, and water typing of the samples based on the major cation and anion present.

STUDY METHODS

We analyzed water samples at three laboratories: The Evergreen State College (Evergreen), Manchester Laboratory (Manchester), or Laucks Testing Laboratory Inc. (Laucks). Analyses for alkalinity, orthophosphate, sulfate, nitrate, chloride, sodium, potassium, calcium, magnesium, iron, and silica, were conducted at Evergreen and Manchester, where 16 and 20 samples were processed respectively. Forty-five nitrate analyses were done by Laucks.

All of the wells we sampled, save three, are currently used for either domestic or industrial water supply. The three remaining wells are test wells installed by Ecology. For the nitrate assessment, we chose wells which previously had been sampled for nitrates or wells in close proximity to potential nitrate sources, such as dairies or fish farms.

Four of the wells sampled contain three piezometers set and open at different depths within the six-inch diameter borehole. The data for these wells are listed as separate analyses, because the water samples come from different elevations in the aquifer. The following groups of well numbers designate the triple completion wells: THR004, THR005, and THR006; THR026, THR027, and THR028; THR003, THR042, and THR043; and THR044, THR045, and THR046.

Samples processed at Evergreen for orthophosphate, silica, and metal cation analysis were filtered the same day as collected. The filtering apparatus was acid washed with 1:1 HNO_3 and triple rinsed with ultra-pure water prior to filtering each sample. Samples were filtered through a 0.45 micron millipore filter which had been presoaked according to recommended procedures in <u>Standard Methods for the Examination and Treatment of Water and Wastewater</u> (APHA, AWWA, WPCF, 1985). The samples for metal ion and silica analysis were acidified with concentrated HNO_3 equal to two percent of sample volume.

All sample analyses were completed within recommended holding times with the exception of cation analyses conducted at Evergreen, where sample holding times were exceeded by one week.

FIELD CHEMICAL ANALYSIS, TEMPERATURE MEASUREMENT AND COLLECTION OF GROUND-WATER SAMPLES

In preparation for sampling we purged the wells until temperature, specific conductance, and pH stabilized. Stabilization of these parameters indicates the well is discharging water which just entered the well and not water which has been in the well for some time. We measured temperature and specific conductance with a YSI Model 3000 combination meter, and pH with a Piccolo model HI 1280 meter. The combination meter's accuracy is +/- 0.3^0 C for temperature and +/- 4% of meter scale for conductance. The Piccolo meter's accuracy is to +/- 0.01 pH unit. We calibrated all field-monitoring equipment in accordance with the manufacturers' recommendations at the beginning of each sampling period and periodically throughout the day to assure meter accuracy. Equipment problems prevented us from making pH determinations for some samples.

Following stabilization and recording of temperature, pH, and conductance, we triple rinsed the sample bottles (except those used for nutrient analyses) with well water prior to sample collection. We tagged and placed the water samples in an ice chest for delivery to the laboratory. Where possible, we obtained the samples from hose bibs that by-passed the distribution system's pressure tank. Where this was not possible, we purged the well long enough to cycle at least one tank volume of water through the pressure tank prior to sampling.

ANALYTICAL METHODS

We selected analytical methods for dissolved species concentration determinations from Standard Methods for the Examination and Treatment of Water and Wastewater (APHA, AWWA, WPCF, 1985). A brief description of each method is presented below. For each method, the quantitation or detection limit is given.

The quantitation limit is dependent on the standard curve constructed for sample determination. The laboratory is 95 percent certain that the analyte exists if a value is reported within the quantitation limits.

Detection limit is given for those methods without a quantitation limit. The detection limit refers to the lowest level of analyte that can be detected by the method. At the detection limit, no confidence can be expressed in the accuracy of the determination.

Alkalinity

We determined alkalinity via a potentiometric titration to a preselected end point,(APHA, AWWA, WPCF, 1985, p. 269). In our determination, we quickly acidified the samples to a pH of 4.5 with 0.00876 N HCl. Alkalinity as $CaCO_3$ was calculated by the following formula:

$$\text{Alkalinity, milligrams (mg) } CaCO_3\text{/liter (L)} = \frac{A * N * 50{,}000}{B}$$

where A = milliliter (mL) standard acid used
B = mL of sample
N = normality of standard acid

The standard deviation for this method is 5 milligrams per liter (mg/l) with an average bias (lower than true value) of 9 mg/l (APHA, AWWA, WPCF, 1985).

Manchester Laboratory used a similar method, EPA Method 310.1. (EPA, 1984) with a practical quantitation limit of 1 mg/l (values expressed as $CaCO_3$). The standard deviation equals 1 mg/l in the range of 10 to 500 mg $CaCO_3$/L when alkalinity is due to carbonate or bicarbonate.

Chloride

We used a colormetric test, the Mercuric Nitrate Method, (APHA, AWWA, WPCF, 1985 p. 288), to determine the chloride-ion concentration in samples. The principle is that "...chloride can be titrated with mercuric nitrate, $Hg(NO_3)_2$, because of the formation of soluble, slightly dissociated mercuric chloride. In the pH range of 2.3 to 2.8, diphenylcarbanzone indicates the titration end point by formation of a purple complex with the excess mercuric ions" (APHA, AWWA, WPCF, 1985, p. 288).

With 100 ml of sample we adjusted the pH to 2.5 with 0.1 N nitric acid. We added color indicator-acidifier reagent A to the sample, and then titrated with mercuric nitrate until the sample changed color from blue-green to purple. We filtered the titrant after make-up because it formed a white precipitate. Our previous experimentation indicated that the precipitate did not influence the performance of the titrant. We calculated chloride by determining how much mercuric nitrate was used to achieve the purple endpoint. The calculation is:

$$mg\ Cl^-/L = \frac{(A-B) * N * 35.450}{mL\ sample}$$

Where A = mL titrant for sample
B = mL titrant for blank
N = normality of $Hg(NO_3)_2$

The relative standard deviation for this test is 3.3 percent and relative error is 2.9 percent (APHA, AWWA, WPCF, 1985). Sample values are reported to 0.1 mg/l chloride.

Manchester Laboratory use "Determination of Anions by Ion Chromatography with Conductivity Measurement" (APHA, AWWA, WPCF, 1985, p. 483). The quantitation limit is 0.1 mg Cl^-/L, with an error range of 2 percent. (personal communication, Dave Thompson, 1992)

Metal Cations and Silica

We used Atomic Absorption Spectrometry to determine the sample concentration of the following dissolved species; calcium, magnesium, sodium, potassium, iron, and silica. The principle is that "when a beam of radiant energy is passed through a cloud of atomic vapor, certain very specific wavelengths characteristic of the element in the vapor are absorbed." (Fishman et. al., 1989, p. 17) By measuring the absorbance of the radiant energy as it passes through the vapor cloud, the concentration of the element in the vapor cloud can be determined using Beer's law.

To 20 ml of the sample we added 5 ml of concentrated nitric acid, 5 ml of 20,000 parts per million (ppm) cesium chloride, 5 ml of 40,000 ppm lanthanum chloride and then diluted to 100 ml total volume using ultra-pure water. We then ran the samples and standards according to standard procedures (Perkin Elmer, 1982) to determine absorbance values for the standards and the samples. We then calculated the concentration of each ion in each sample using Beer's law and multiplied by any dilution factor to determine original sample concentrations.

Sample values are reported to 0.1 mg/l with a relative level of precision of 2 percent (Personal communication, Dr. Jim Stroh 1990).

Manchester Laboratory used the Inductively Coupled Plasma technique to determine metal ions, EPA 600/4-79-020, 4.1.1. (EPA, 1984) Lower quantitation limits are as follows: Calcium, 0.01 mg/l; Iron, 0.02 mg/l; Magnesium, 0.01 mg/l; Potassium, 1 mg/l; Silica, 0.07 mg/l; and Sodium, 0.07 mg/l. (Huntamer and Hyre, 1991)

Nitrate

We used the Nitrate Electrode Screening Method,(APHA, AWWA, WPCF, 1985) to determine the concentration of nitrate in our samples. The principle is that a nitrate ion-specific electrode, when placed in a sample, develops a potential across a thin, porous, inert membrane that holds in place a water-immiscible, liquid ion exchanger. The electrical potential is then read from the log scale on an Orion 407A pH meter.

To 10 ml of sample we added 10 ml of buffer solution. We placed the ion-specific electrode in the sample and used the direct-read scale on a calibrated pH meter to determine the mg/l of nitrate in the sample.

Orion states that sample values can be reproduced within 2 percent with a minimum detection range of 0.14 mg/l nitrate (Orion). Based on the sensitivity of the instrument, nitrate values are reported to 0.1 mg/l with an error range of 2 percent.

The Manchester and Laucks laboratories used Automated Cadmium Reduction (APHA, AWWA, WPCF, 1985, p. 400) for analyzing dissolved nitrate + nitrite. Values are reported in terms of milligrams Nitrate + Nitrite per liter, and the practical quantitation limit is 0.01 mg/l.

Phosphorous

We used a colormetric test, Ascorbic Acid Method, to determine filtrable phosphorus as orthophosphate. The principle is "...ammonium molybdate and potassium antimonyl tartrate react in an acid medium with orthophosphate to form a heterpoly acid, phosphomolybdic acid, that is reduced to intensely colored molybdenum blue by ascorbic acid." (APHA, AWWA, WPCF, 1985, p. 448)

We filtered 50 mL of sample through a 0.45 micron millipore membrane to separate out filtrable phosphorus and then combined the sample with 8.0 mL of reagent. We used a Bausch and Lomb Spectronic 88 spectrophotometer set at a wavelength of 880 nm to determine the absorbency of the sample.

We constructed a concentration versus absorbency curve by linear regression of standard concentrations (4 total) with their respective absorbencies ($R^2 = 0.99$). Substituting sample absorbency into the linear equation yielded the concentration of orthophosphate.

Sample values are reported to two decimal places (0.01 mg/l), based on the sensitivity of the test to discern a difference in absorbence values in standards which contained 0.0125 mg/l and 0.0255 mg/l orthophosphate, respectively. The APHA, AWWA, and WPCF (1985) state a relative standard deviation of 9.1 percent and a relative error of 10.0 percent on sample determination using this method.

Manchester Laboratory conducted a total phosphorus analysis. Ammonium persulfate and sulfuric acid were added to the sample to convert the phosphorus to dissolved orthophosphorus. The dissolved orthophosphorus of the digestate is determined colorimetrically by observing the formation of a molybdenum blue complex at 880 nm. The Automated Ascorbic Acid Reduction Method (APHA, AWWA, WPCF, 1985, p. 450) has a detection limit of 0.02 mg/l, and values are reported as total phosphorus in mg/l.

Sulfate

We used the Turbidimetric Method (APHA, AWWA, WPCF, 1985, p. 467) to determine sulfate ion concentration. The principle is that sulfate is precipitated in an acid medium with barium chloride to form barium sulfate. The light scattered by the sample's barium sulfate is then measured in a turbidimeter. A set of standards is prepared to produce a standard curve of turbidity versus concentration of sulfate. The sample sulfate concentration was determined by calculation using the linear equation for the standard curve (R^2 = 0.95).

To each sample we added buffer solution B and 0.2 grams of barium chloride crystal (screened to 20 mesh size), and then determined the sample's turbidity in a Hach Model 2100A turbidimeter. We made standards at the following concentrations: 0.5 ppm, 2.0 ppm, 4.0 ppm, 6.0 ppm, 8.0 ppm, and 10 ppm. We treated standards the same as a sample and determined their corresponding turbidity.

Manchester Laboratory used "Determination of Anions by Ion Chromatography with Conductivity Measurement" (APHA, AWWA, WPCF, 1985, p. 483) to determine sulfate as the anion SO_4^{2-}. The quantitation limit is 0.5 mg SO_4^{2-}/L with an error range of 2 to 5 percent. (personal communication, Dave Thompson, 1992)

LABORATORY ACCURACY

We conducted two checks on the quality of the general chemistry work done at the Evergreen Laboratory. Duplicate samples were analyzed by Manchester Laboratory for three of the samples analyzed at Evergreen and a summation of the total milliequivalents (meq) of cations and anions was done for each sample to determine the relative difference (i.e ion balance) between cation and anion analyses. In addition to the checks on general chemistry, 21 duplicate samples for nitrate were analyzed among the three laboratories. Manchester and Laucks Laboratories also did internal laboratory duplicate sample analysis.

Naturally occurring water has a neutral electrical change. Hence, in an accurately done water analysis, the sum of cation and anion milliequivalents per liter (meq/l) should be the same. This comparison can indicate if the chemical analyses have large errors. The USGS states that for a sample concentration of seven meq/l (cations + anions) the percent error should be less than 3 percent, while a sample with 0.9 meq/l may have up to a 12 percent error and still be a useful determination (Fishman, et. al. 1989). Milligrams per liter of dissolved species were converted to meq/l with conversion factors listed in Hem (1985).

We calculated percent error as follows:

$$\frac{[\text{Sum cations (meq/l)} - \text{Sum anions (meq/l)}]}{[\text{Sum cations (meq/l)} + \text{Sum anions (meq/l)}]} \times 100$$

Our samples generally had ion concentrations of 1.5 to 3 meq/l, so errors of less than ten percent are reasonable. Eleven of the samples had errors of less than seven percent, while three of the samples, had errors near twenty percent. The errors for samples in wells THR029, THR098, and THR164 were 16.7, 22.4, and 17.8 percent respectively.

Water samples obtained in December 1989 from wells THR047, THR175, and THR181 were analyzed at both Evergreen and Manchester Laboratories. A comparison of the chemical analysis, Table 12, indicates the determinations of milliequivalents, alkalinity as $CaCO_3$, and metal anions (except potassium) agree within acceptable limits. The determinations of potassium and chloride disagree consistently; our determinations at Evergreen are higher than Manchester for potassium and lower for chloride.

The Evergreen potassium determinations are one-half the amount determined by Manchester. The Atomic Absorption method used at Evergreen is ten times more sensitive for potassium detection than the Inductively Coupled Plasma technique used by Manchester. Because of the difference in the testing methods, we feel the Evergreen work is more accurate for potassium.

The chloride determinations made at Evergreen are significantly different from those made at Manchester. Error ranges for sample determination do not overlap. We are unable to explain the differences.

The sulfate determinations at both laboratories agree except for the sample from well THR181 for which the Manchester Laboratory value is less than the Evergreen value.

The Manchester Laboratory analyzed nitrate/nitrite and total phosphorus. Whereas, at Evergreen Laboratory we analyzed nitrate and orthophosphate. In the nitrate comparison, we disregard the nitrite because, generally, nitrite in ground water is an insignificant constituent. While there are many forms for phosphorus, generally, the orthophosphate dominates and is the major constituent. The nitrate values agree well; differences are within the expected error range for these analytical methods. The orthophosphate values determined by Manchester are 50 percent of values determined at Evergreen.

While there are differences in the results from the two laboratories, overall the comparisons agree very well.

Table 12

Comparison Of Sample Splits
Between Evergreen (EVE) and Manchester (MAN)

	Well Numbers					
	THR047		THR175		THR181	
Laboratory	EVE	MAN	EVE	MAN	EVE	MAN
Sum of Meq/l.	2.0	2.08	1.98	2.02	2.76	2.83
Percent Error	3.0	5.1	4.3	4.4	1.2	9.5
TDS	80.5	80.9	78.8	80.6	109.7	107.6
	Analyte Concentration in mg/l					
SO_4^{2-}	3.0	3.7	3.0	3.7	8.0	5.7
PO_4^{3-}	0.04	0.02	0.07	0.02	0.05	0.02
NO_3^-	2.7	1.92	3.7	2.59	4.2	3.36
Cl^-	2.0	4.5	3.1	5.7	2.8	5.2
Ca^{2+}	10.5	10.9	10.5	11.0	13.5	15.5
Fe	(u)	(u)	(u)	(u)	(u)	(u)
Mg^{2+}	3.2	3.48	2.7	3.04	5.0	5.20
K^+	0.44	0.9	0.43	1.1	0.49	0.9
SiO_2	13.2	13.2	12.3	12.6	16.6	15.8
Na^+	5.3	5.5	6.2	6.5	6.8	7.0
ALK. as $CaCO_3$	40.2	37.7	36.8	34.2	52.3	48.4

(u) indicates no analyte was detected at the reported quantitation limit of 0.02 mg/l.

Table 13 is a summary of the laboratory analytical work conducted on nitrate samples. Twenty-one sample splits were shared among the Manchester, Evergreen and Laucks laboratories; none of the samples were analyzed by all three laboratories. An inspection of the data indicates that there is some agreement, but also wide variation in sample determination. Samples analyzed by Evergreen and Laucks agree very well, and with the exception of THR184 good agreement exists between the Evergreen and Manchester determinations. Within the duplicate nitrate samples analyzed at Manchester and Laucks, three analyses stand out. Samples analyzed at Manchester for wells THR067, THR207, and THR216 had values of 15.1, 14.8, and 17.3 respectively. Samples from the same well analyzed by Laucks gave the following, THR067 was 2.3, THR207 was 2.3, and THR216 was also 2.3. Both laboratories conducted internal audits of procedures and data reported and the reviews did not reveal any errors in sample determinations. We are unable to reconcile the variability between laboratories.

Table 13

Comparison of Nitrate Sample Splits
Between Manchester, Evergreen, and Laucks

Laboratory Sample #	MAN	EVE	Laucks
THR011	1.64	1.9	***
THR084	2.86	3.2	***
THR041	2.78	***	2.6
THR057	3.16	***	2.2
THR064	1.79	***	1.5
THR067	15.1	***	2.3
THR077	17.3	***	2.3
THR085	****	2.0	1.8
THR098	****	2.5	2.7
THR109	1.11	1.4	***
THR141	****	4.3	4.0
THR164	1.85	2.3	***
THR165	5.33	***	3.4
THR180	****	7.1	6.2
THR184	0.25	2.6	***
THR187	1.52	***	1.5
THR192	1.3	***	1.2
THR202	1.36	1.5	***
THR206	****	1.7	1.5
THR207	14.8	***	2.3
THR221	****	4.3	4.0

*** indicates no sample analysis by that laboratory

In addition to the sample split analyses conducted, each laboratory analyzed sample duplicates. For the Manchester laboratory two duplicate samples from well THR025 resulted in determinations of 2.37 and 2.54 mg/l nitrate. The three duplicate sample analyses conducted by Laucks resulted in the following: THR035 2.5 and 2.4 mg/l; THR060 1.9 and 2.3 mg/l; and THR212 1.7 and 1.4 mg/l. The sample splits within laboratories indicate good precision.

Due to the interlaboratory discrepancies, we resampled several of the wells in March of 1990 to see if the high nitrate readings could be confirmed. Table 14 is a list of the wells that were resampled and the nitrate/nitrite values determined in December of 1989 and March of 1990.

Table 14

Comparison of Wells Sampled In December of 1989 And Resampled in March of 1990 For Nitrate

WELL	12/89	3/90
THR077	17.3	2.5
THR125	16.2	2.1
THR141	5.8	6.3
THR165	5.3	8.0
THR207	14.5	2.5
THR208	2.3	6.1

An inspection of the data in Table 14 indicates that the wells which previously tested high showed a significant drop, while the other wells showed an increase. The increase in nitrate concentration was not expected in March of 1989 at higher ground-water levels. The difference within this data again points to the variability in nitrate levels in the ground water at any given time.

WATER CHEMISTRY

Results

Table 15 lists all wells used for the study. The table contains information on the well number, site location, sampling date, land use code, well purpose, water temperature, conductivity, pH (either field or laboratory), and total dissolved solids. For the 1989 samples, the total dissolved solids are calculated values. For the

1982 or 1983 samples, we do not know if the total dissolved solids were measured or calculated. Under "well purpose", an asterisk indicates a complete cation/anion analysis for that sample, Q designates a water quality sample, and WSE represents a well used for water surface elevation determinations.

Table 15
Well Information

Well Number	Well Location	Sample Date	Land Code	Well Purpose	Temp	Cond	pH	TDS
THR001	16N/02W-27R03	12/11/89	60	Q	9.8	69	6.4	-
THR002	15N/03W-05N01		-	WSE	-	-	-	-
THR003	15N/03W-02R01	3/01/89	60	Q	10.0	129	6.5	-
THR004	16N/02W-29L02	3/01/89	30	Q	10.4	139	6.4	-
THR005	16N/02W-29L03	3/01/89	30	Q	10.4	144	6.5	-
THR006	16N/02W-29L04	3/01/89	30	Q	11.0	208	6.1	-
THR007	16N/02W-29D01		-	WSE	-	-	-	-
THR008	16N/02W-31N01		-	WSE	-	-	-	-
THR011	15N/02W-06N01	12/15/89	10	BOTH *	10.5	132	6.2	96.8
THR013	15N/03W-10E02	12/14/89	80	BOTH *	7.7	125	-	86.9
THR014	16N/03W-33M01	8/23/82	52	Q	-	-	-	59
THR014	16N/03W-33M01	3/15/83	52	Q	-	-	-	60
THR014	16N/03W-33M01	12/14/89	52	Q *	8.8	105	-	77.6
THR015	16N/03W-33P01		-	WSE	-	-	-	-
THR018	16N/03W-29L02		-	WSE	-	-	-	-
THR021	16N/03W-29L01	8/23/82	51	Q	-	-	-	61
THR021	16N/03W-29L01	3/16/83	51	Q	-	-	-	70
THR021	16N/03W-29L01	12/13/89	51	Q *	9.9	103	-	68.5
THR025	15N/03W-05P01	8/23/82	10	Q	-	-	-	43
THR025	15N/03W-05P01	3/14/83	10	Q	-	-	-	70
THR025	15N/03W-05P01	12/14/89	10	Q *	-	-	-	86.8
THR026	15N/04W-01D01	3/01/89	30	Q	11.3	132	6.3	
THR027	15N/04W-01D02	3/01/89	30	Q	11.1	136	6.2	-
THR028	15N/04W-01D03	3/01/89	30	Q	9.8	120	6.1	-
THR029	15N/04W-01A01	8/23/82	30	Q	-	-	-	89
THR029	15N/04W-01A01	3/14/83	30	Q	-	-	-	90
THR029	15N/04W-01A01	12/13/89	30	Q *	10.4	148	-	86.5
THR031	15N/03W-06P01	12/15/89	30	Q *	11.6	203	6.0	131.9
THR032	15N/03W-08A01	8/23/82	10	Q	-	-	-	47
THR032	15N/03W-08A01	3/15/83	10	Q	-	-	-	70
THR033	15N/03W-08F01		-	WSE	-	-	-	-
THR035	15N/03W-09F03	8/23/82	10	Q	-	-	-	67
THR035	15N/03W-09F03	3/15/83	10	Q	-	-	-	80

Table 15 (Continued)
Well Information

Well Number	Well Location	Sample Date	Land Code	Well Purpose	Temp	Cond	pH	TDS
THR035	15N/03W-09F03	12/12/89	10	Q	10.8	138	-	-
THR039	15N/03W-10P01	8/23/82	30	Q	-	-	-	92
THR040	15N/03W-11F01	8/23/82	30	Q	-	-	-	53
THR040	15N/03W-11F01	3/14/83	30	Q	-	-	-	70
THR041	16N/03W-36J01	8/24/82	-	-	-	-	-	86
THR041	16N/03W-36J01	3/15/83	-	-	-	-	-	110
THR041	16N/03W-36J01	12/12/89	20	Q *	9.4	137	-	95.0
THR042	15N/03W-02R02	3/01/89	60	Q	9.9	136	6.5	-
THR043	15N/03W-02R03	3/01/89	60	Q	10.4	147	6.7	-
THR044	15N/03W-03A01	3/01/89	60	Q	10.9	119	6.7	-
THR045	15N/03W-03A02	3/01/89	60	Q	10.5	112	6.7	-
THR046	15N/03W-03A03	3/01/89	60	Q	12.6	116	6.1	-
THR047	15N/03W-03F01	12/14/89	10	Q *	10.5	115	6.8	80.5
THR050	15N/04W-02A01		-	WSE	-	-	-	-
THR053	15N/04W-02P01	8/23/82	51	Q	-	-	-	50
THR053	15N/04W-02P01	3/16/83	51	Q	-	-	-	80
THR053	15N/04W-02P01	12/12/89	51	Q	10.3	111	-	-
THR054	15N/04W-03G01	8/23/82	10	Q	-	-	-	52
THR054	15N/04W-03G01	3/16/83	10	Q	-	-	-	60
THR057	15N/04W-10G02	12/12/89	20	Q *	11.4	120	-	84.5
THR058	16N/02W-19R01		-	WSE	-	-	-	-
THR060	16N/02W-27G02	12/11/89	30	Q	9.9	88	6.3	-
THR062	16N/02W-27M01		-	WSE	-	-	-	-
THR063	16N/02W-27Q01		-	WSE	-	-	-	-
THR064	16N/02W-28J01	8/24/82	10	Q	-	-	-	48
THR064	16N/02W-28J01	3/16/83	10	Q	-	-	-	50
THR064	16N/02W-28J01	12/11/89	10	Q *	10.5	87	6.6	62.6
THR065	16N/04W-35P01		-	WSE	-	-	-	-
THR066	16N/02W-29L01	8/24/82	30	Q	-	-	-	169
THR066	16N/02W-29L01	3/14/83	30	Q	-	-	-	120
THR066	16N/02W-29L01	12/11/89	30	Q	9.8	144	6.6	-
THR067	16N/02W-30F01	12/12/89	30	Q *	9.4	132	-	106.6
THR068	16N/02W-30K01		-	WSE	-	-	-	-
THR070	16N/02W-31B01	8/24/82	-	-	-	-	-	100
THR070	16N/02W-31B01	4/04/83	-	-	-	-	-	120
THR071	16N/02W-31J01	8/24/82	51	Q	-	-	-	85
THR071	16N/02W-31J01	3/14/83	51	Q	-	-	-	80
THR071	16N/02W-31J01	12/11/89	51	Q	10.3	150	-	-
THR073	16N/02W-31L01		-	WSE	-	-	-	-
THR074	16N/02W-31Q01		-	WSE	-	-	-	-
THR075	16N/02W-32A01		-	WSE	-	-	-	-
THR076	16N/02W-32B01		-	WSE	-	-	-	-
THR077	16N/02W-32E01	8/24/82	10	Q	-	-	-	93
THR077	16N/02W-32E01	3/14/83	10	Q	-	-	-	60
THR077	16N/02W-32E01	12/11/89	10	Q *	10.2	133	6.7	115.2
THR077	16N/02W-32E01	3/20/90	10	Q	10.3	129	-	-

Table 15 (Continued)
Well Information

Well Number	Well Location	Sample Date	Land Code	Well Purpose	Temp	Cond	pH	TDS
THR078	16N/02W-32F01		-	WSE	-	-	-	-
THR079	16N/02W-32L02		-	WSE	-	-	-	-
THR080	15N/03W-11P02		-	WSE	-	-	-	-
THR081	15N/03W-12B01	8/24/82	10	Q	-	-	-	70
THR081	15N/03W-12B01	3/14/83	10	Q	-	-	-	80
THR082	16N/03W-36J04		-	WSE	-	-	-	-
THR083	15N/03W-13P01		-	WSE	-	-	-	-
THR084	15N/03W-14P01	8/23/82	10	Q	-	-	-	88
THR084	15N/03W-14P01	12/15/89	10	Q *	11.6	176	6.2	110.9
THR085	16N/03W-36L03	8/24/82	20	Q	-	-	-	62
THR085	16N/03W-36L03	3/15/83	20	Q	-	-	-	60
THR085	16N/03W-36L03	12/12/89	20	Q *	10.0	106	6.6	-
THR086	15N/04W-01H01		-	WSE	-	-	-	-
THR089	16N/03W-16K03	8/23/82	-	Q	-	-	-	77
THR089	16N/03W-16K03	3/14/83	-	Q	-	-	-	70
THR091	16N/03W-21F01	8/23/82	-	Q	-	-	-	87
THR091	16N/03W-21F01	3/16/83	-	Q	-	-	-	90
THR092	16N/03W-27D01	12/15/89	30	Q	9.8	127	-	-
THR093	16N/03W-27M02		-	WSE	-	-	-	-
THR094	16N/03W-28F01	8/23/82	30	Q	-	-	-	67
THR094	16N/03W-28F01	3/16/83	30	Q	-	-	-	70
THR094	16N/03W-28F01	12/14/89	30	Q *	9.9	115	-	84.3
THR095	16N/03W-29M01	12/13/89	51	Q	8.4	128	-	-
THR098	16N/03W-31B01	8/23/82	70	Q	-	-	-	72
THR098	16N/03W-31B01	3/16/83	70	Q	-	-	-	70
THR098	16N/03W-31B01	12/13/89	70	Q *	10.2	126	6.0	82.0
THR099	16N/03W-31B02		-	WSE	-	-	-	-
THR100	16N/03W-31G02	12/13/89	70	Q	10.7	138	-	-
THR102	16N/03W-32E01		-	WSE	-	-	-	-
THR103	16N/03W-32G01	8/23/82	-	Q	-	-	-	45
THR103	16N/03W-32G01	3/15/83	-	Q	-	-	-	90
THR104	16N/03W-33C01	12/15/89	10	Q	10.0	108	-	-
THR105	16N/03W-33G03	8/23/82	10	Q	-	-	-	53
THR105	16N/03W-33G03	3/15/83	10	Q	-	-	-	70
THR106	16N/03W-34D01	8/23/82	10	Q	-	-	-	50
THR106	16N/03W-34D01	3/15/83	10	Q	-	-	-	80
THR107	16N/03W-34M01	12/15/89	30	Q	9.7	100	-	-
THR109	16N/03W-35N01	8/23/82	30	Q	-	-	-	55
THR109	16N/03W-35N01	3/15/83	30	Q	-	-	-	60
THR109	16N/03W-35N01	12/15/89	30	Q *	9.8	114	6.1	81.9
THR112	16N/03W-36G02		-	WSE	-	-	-	-
THR114	16N/03W-36H02		-	WSE	-	-	-	-
THR115	16N/03W-36H03		-	WSE	-	-	-	-
THR116	16N/03W-36H04		-	WSE	-	-	-	-
THR117	16N/03W-36H05		-	WSE	-	-	-	-
THR119	16N/03W-36J02		-	WSE	-	-	-	-

Table 15 (Continued)
Well Information

Well Number	Well Location	Sample Date	Land Code	Well Purpose	Temp	Cond	pH	TDS
THR120	16N/03W-36J03		-	WSE	-	-	-	-
THR121	16N/02W-33E01		-	WSE	-	-	-	-
THR122	16N/03W-36K01		-	WSE	-	-	-	-
THR123	16N/03W-09B01	8/23/82	-	Q	-	-	-	34
THR123	16N/03W-09B01	3/14/83	-	Q	-	-	-	50
THR124	16N/03W-10L01	8/23/82	-	Q	-	-	-	38
THR124	16N/03W-10L01	3/14/83	-	Q	-	-	-	30
THR125	16N/03W-36P01	12/15/89	30	Q	10.2	130	-	-
THR125	16N/03W-36P01	3/20/90	30	Q	10.8	113	-	-
THR127	16N/04W-25G01		-	WSE	-	-	-	-
THR129	16N/04W-25K01		-	WSE	-	-	-	-
THR130	16N/04W-25K02		-	WSE	-	-	-	-
THR131	16N/04W-25L01		-	WSE	-	-	-	-
THR133	16N/04W-25Q01		-	WSE	-	-	-	-
THR134	16N/04W-25Q02		-	WSE	-	-	-	-
THR135	16N/04W-25R01		-	WSE	-	-	-	-
THR136	16N/04W-25R02		-	WSE	-	-	-	-
THR137	16N/04W-26K01	12/13/89	51	Q	10.2	106	-	-
THR140	16N/04W-34K01	8/23/82	-	Q	-	-	-	87
THR140	16N/04W-34K01	3/14/83	-	Q	-	-	-	90
THR140	16N/04W-34K01	12/13/89	-	Q *	10.6	106	-	81.3
THR141	16N/04W-35C01	12/13/89	10	Q *	11.1	154	5.8	99.7
THR141	16N/04W-35C01	3/20/90	10	Q	11.1	-	-	-
THR142	15N/03W-05C01		-	WSE	-	-	-	-
THR143	16N/04W-36G01	8/23/82	20	Q	-	-	-	102
THR143	16N/04W-36G01	3/14/83	20	Q	-	-	-	90
THR143	16N/04W-36G01	12/14/89	20	Q	10.1	126	-	-
THR144	16N/04W-36M01	8/23/82	51	Q	-	-	-	156
THR144	16N/04W-36M01	3/14/83	51	Q	-	-	-	185
THR144	16N/04W-36M01	12/14/89	51	Q	11.6	146	-	-
THR157	16N/02W-32P01		-	WSE	-	-	-	-
THR158	15N/03W-04Q01		-	WSE	-	-	-	-
THR160	16N/02W-34D01		-	WSE	-	-	-	-
THR162	15N/03W-02G01	8/24/82	-	Q	-	-	-	108
THR163	16N/03W-11D01	8/23/82	-	Q	-	-	-	55
THR163	16N/03W-11D01	3/14/83	-	Q	-	-	-	60
THR164	15N/02W-06E01	12/15/89	30	Q *	10.1	102	6.0	60.7
THR165	15N/02W-06H01	8/24/82	30	Q	-	-	-	71
THR165	15N/02W-06H01	3/14/83	30	Q	-	-	-	90
THR165	15N/02W-06H01	12/11/89	30	Q *	10.2	155	-	105.2
THR165	15N/02W-06H01	3/20/90	30	Q	10.8	175	-	-
THR166	15N/03W-01A01		-	WSE	-	-	-	-
THR167	15N/03W-01K01	8/24/82	-	Q	-	-	-	65
THR167	15N/03W-01K01	3/14/83	-	Q	-	-	-	70
THR169	15N/03W-01N01		-	WSE	-	-	-	-
THR170	15N/03W-05A02		-	WSE	-	-	-	-

Table 15 (Continued)
Well Information

Well Number	Well Location	Sample Date	Land Code	Well Purpose	Temp	Cond	pH	TDS
THR171	15N/03W-06G01	8/23/82	-	Q	-	-	-	71
THR171	15N/03W-06G01	3/14/83	-	Q	-	-	-	90
THR173	15N/03W-03R01	8/23/82	10	Q	-	-	-	63
THR173	15N/03W-03R01	3/15/83	10	Q	-	-	-	80
THR173	15N/03W-03R01	12/15/89	10	Q	11.2	122	-	-
THR174	15N/03W-04B01	8/23/82	-	Q	-	-	-	73
THR174	15N/03W-04B01	3/15/83	-	Q	-	-	-	60
THR175	15N/03W-06A02	3/15/83	10	Q	-	-	-	80
THR175	15N/03W-06A02	12/14/89	10	Q *	9.0	120	6.7	78.8
THR176	15N/03W-04K01	8/23/82	40	Q	-	-	-	70
THR176	15N/03W-04K01	3/16/83	40	Q	-	-	-	70
THR176	15N/03W-04K01	12/14/89	40	Q	9.8	109	-	-
THR178	16N/03W-06A01		-	WSE	-	-	-	-
THR180	16N/02W-29A01	8/24/82	10	Q	-	-	-	51
THR180	16N/02W-29A01	3/14/83	10	Q	-	-	-	80
THR180	16N/02W-29A01	12/11/89	10	Q *	10.4	152	6.4	81.0
THR181	15N/03W-01M01	12/14/89	10	Q *	10.3	155	6.9	107.6
THR184	15N/03W-11H01	12/15/89	10	Q *	10.9	144	-	96.7
THR186	16N/02W-32Q02		-	WSE	-	-	-	-
THR187	16N/02W-35H01	12/11/89	10	Q *	10.7	114	6.5	84.8
THR192	16N/02W-26A01	12/11/89	53	Q *	10.5	75	5.8	51.6
THR200	16N/04W-36P01	12/14/89	10	Q	10.5	126	-	-
THR201	16N/02W-34D02	12/15/89	10	Q	11.5	109	-	-
THR202	15N/03W-06A02	12/15/89	10	Q *	9.0	104	6.1	72.0
THR203	16N/04W-25L02	12/13/89	30	Q *	10.7	139	-	94.3
THR204	16N/03W-30R03	12/13/89	70	Q	10.8	140	-	-
THR205	15N/03W-14K01	12/12/89	10	Q	10.9	148	-	-
THR206	15N/03W-13N01	12/12/89	10	Q *	10.2	115	-	79.3
THR207	15N/03W-15A01	12/12/89	30	Q *	10.9	152	-	120.0
THR207	15N/03W-15A01	3/20/90	30	Q	11.1	164	-	120.0
THR208	15N/03W-11N01	12/12/89	10	Q	10.3	128	-	-
THR208	15N/03W-11N01	3/20/90	10	Q	11.1	148	-	-
THR209	15N/03W-09F02	12/12/89	10	Q	10.1	129	-	-
THR210	15N/03W-08B01	12/12/89	30	Q	10.7	122	-	-
THR211	15N/03W-08G01	12/12/89	10	Q	10.1	129	-	-
THR212	15N/04W-03G02	12/12/89	10	Q	10.5	109	-	-
THR213	16N/02W-32H01	12/11/89	52	Q	10.7	126	6.5	-
THR215	16N/02W-36B01	12/11/89	20	Q	10.1	126	-	-
THR219	16N/02W-32M01	12/11/89	80	Q	9.7	129	6.4	-
THR220	16N/02W-32F02	12/11/89	10	Q	10.4	124	6.5	-
THR221	16N/04W-25J01	12/14/89	20	Q *	10.3	146	7.3	111.3

Table 16 is a summary of the water quality data gathered during this study. It contains the well number, date sampled, dissolved species concentrations, and a remarks column. The remarks column provides information on which laboratory did the sample analysis. Sample numbers which begin with an EG-89 were analyzed in a water quality class at Evergreen in March of 1989. Sample numbers with an EG in the beginning of the number were analyzed at Evergreen. Sample numbers which start out 508 were analyzed at Manchester and sample numbers starting with a GM were analyzed at Laucks. Water quality samples for this study were collected in March and December of 1989 and March of 1990. The table also contains data collected by Thurston County in 1982 and 1983.

Table 16
Water Chemistry Data
Constituents in mg/L

Well #	Date	SO_4^{2-}	PO_4^{3-}	NO_3^-	$NO_3^-+NO_2^-$	Cl^-	$CaCO_3$	Ca^{2+}	Fe	Mg^{2+}	K^+	SiO_2	Na^+	Remarks
THR001	12/11/89	-	-	-	0.97	-	-	-	-	-	-	-	-	GM-4
THR003	3/01/89	4.7	-	-	-	4.7	46.0	10.70	-	4.0	1.3	-	6.3	EG89-1
THR004	3/01/89	4.9	-	-	-	4.3	42.3	12.56	-	4.6	1.6	-	6.0	EG89-7
THR005	3/01/89	6.2	-	-	-	4.6	42.9	12.96	-	4.8	1.8	-	6.3	EG89-8
THR006	3/01/89	7.3	-	-	-	7.2	44.4	19.60	-	5.2	1.5	-	7.6	EG89-9
THR011	12/15/89	5.0	0.07	1.9	-	2.5	46.9	11.29	0.02(U)	4.2	1.0	17.2	6.7	EG13
THR011	12/15/89	-	-	-	1.64	-	-	-	-	-	-	-	-	508251
THR013	12/14/89	3.8	0.02	-	2.51	4.6	39.3	11.10	0.02(U)	3.97	1.4	14.2	6.0	508245
THR014	8/23/82	-	-	1.2	-	-	-	-	-	-	-	-	-	
THR014	3/15/83	-	-	1.3	-	5(U)	-	-	-	-	-	-	-	
THR014	12/14/89	4.2	0.02	-	1.48	4.0	34.5	9.17	0.02(U)	3.12	1.1	14.4	5.6	508250
THR021	8/23/82	-	-	1.6	-	-	-	-	-	-	-	-	-	
THR021	3/16/83	-	-	1.6	-	5(U)	-	-	-	-	-	-	-	
THR021	12/13/89	3.1	0.02	-	-	3.5	32.6	9.26	0.02(U)	3.04	1.1	13.8	-	508239
THR021	12/13/89	-	-	-	2.10	-	-	-	-	-	-	-	-	GM36
THR025	8/23/82	-	-	1.7	-	-	-	-	-	-	-	-	-	
THR025	3/14/83	-	-	1.9	-	5.0	-	-	-	-	-	-	-	
THR025	12/14/89	4.8	0.02	-	2.54	5.4	37.6	11.30	0.02(U)	3.80	1.3	13.4	6.6	508247 DUP
THR025	12/14/89	4.8	0.02	-	2.37	5.3	37.6	11.30	0.02(U)	3.79	1.1	13.4	6.5	508247
THR026	3/01/89	4.5	-	-	-	6.1	42.4	11.43	-	4.1	1.6	-	7.2	EG89-4
THR027	3/01/89	5.2	0.01(U)	-	-	11.4	42.0	11.50	-	3.9	1.0	-	6.6	EG89-5
THR028	3/01/89	7.3	0.02	-	-	5.1	32.4	10.40	-	3.5	0.9	-	6.1	EG89-6
THR029	8/23/82	-	-	4.3	-	-	-	-	-	-	-	-	-	
THR029	3/14/83	-	-	3.7	-	5(U)	-	-	-	-	-	-	-	
THR029	12/13/89	-	-	-	6.70	-	-	-	-	-	-	-	-	GM37
THR029	12/13/89	5.3	0.02	-	-	4.9	29.9	13.10	0.02(U)	4.12	1(U)	15.1	7.4	508240
THR031	12/15/89	-	-	-	4.66	-	-	-	-	-	-	-	-	508255
THR031	12/15/89	1.0(U)	0.09	5.0	-	17.7	55.4	18.42	0.02(U)	6.5	0.7	19.5	8.6	EG16
THR032	8/23/82	-	-	1.5	-	-	-	-	-	-	-	-	-	
THR032	3/15/83	-	-	1.5	-	5(U)	-	-	-	-	-	-	-	
THR035	8/23/82	-	-	2.0	-	-	-	-	-	-	-	-	-	
THR035	3/15/83	-	-	2.7	-	8.0	-	-	-	-	-	-	-	
THR035	12/12/89	-	-	-	2.40	-	-	-	-	-	-	-	-	GM24 DUP
THR035	12/12/89	-	-	-	2.50	-	-	-	-	-	-	-	-	GM24
THR039	8/23/82	-	-	1.7	-	-	-	-	-	-	-	-	-	
THR040	8/23/82	-	-	1.5	-	-	-	-	-	-	-	-	-	
THR040	3/14/83	-	-	0.2(U)	-	5(U)	-	-	-	-	-	-	-	
THR041	8/24/82	-	-	4.0	-	-	-	-	-	-	-	-	-	
THR041	3/15/83	-	-	4.0	-	5(U)	-	-	-	-	-	-	-	

Table 16 Continued
Water Chemistry Data
Constituents in mg/L

Well #	Date	SO_4^{2-}	PO_4^{3-}	NO_3^-	$NO_3^-+NO_2^-$	Cl^-	$CaCO_3$	Ca^{2+}	Fe	Mg^{2+}	K^+	SiO_2	Na^+	Remarks
THR041	12/12/89	5.7	0.02	-	2.78	4.8	42.0	12.50	0.02(U)	4.62	1.5	14.6	6.5	508235
THR041	12/12/89	-	-	-	2.60	-	-	-	-	-	-	-	-	GM17
THR042	3/01/89	5.4	-	-	-	5.3	43.8	11.48	-	4.0	1.2	-	6.2	EG89-2
THR043	3/01/89	6.2	-	-	-	5.3	41.3	13.01	-	3.9	1.6	-	6.4	EG89-3
THR044	3/01/89	5.2	-	-	-	4.2	47.0	8.05	-	4.4	2.8	-	6.6	EG89-11
THR045	3/01/89	4.7	-	-	-	4.4	41.1	10.60	-	3.6	1.3	-	5.6	EG89-12
THR046	3/01/89	5.4	-	-	-	4.3	51.2	13.50	-	3.4	1.3	-	5.9	EG89-13
THR047	12/14/89	3.0	0.04	2.7	-	2.0	40.2	10.47	0.02(U)	3.2	0.4	13.2	5.3	EG9
THR047	12/14/89	3.7	0.02	-	1.92	4.5	37.7	10.90	0.02(U)	3.48	1(U)	13.2	5.5	508244
THR049	8/23/82	-	-	0.2(U)	-	-	-	-	-	-	-	-	-	
THR049	3/14/83	-	-	0.2(U)	-	5.0	-	-	-	-	-	-	-	
THR053	8/23/82	-	-	1.2	-	-	-	-	-	-	-	-	-	
THR053	3/16/83	-	-	1.4	-	5.0	-	-	-	-	-	-	-	
THR053	12/12/89	-	-	-	1.90	-	-	-	-	-	-	-	-	GM30
THR054	8/23/82	-	-	1.6	-	-	-	-	-	-	-	-	-	
THR054	3/16/83	-	-	1.1	-	5(U)	-	-	-	-	-	-	-	
THR057	12/12/89	-	-	-	2.20	-	-	-	-	-	-	-	-	GM29
THR057	12/12/89	6.3	0.05	-	3.16	4.4	35.0	11.20	0.02(U)	3.33	1.2	13.3	6.6	508238
THR060	12/11/89	-	-	-	2.30	-	-	-	-	-	-	-	-	GM5
THR060	12/11/89	-	-	-	1.90	-	-	-	-	-	-	-	-	GM5 DUP
THR064	8/24/82	-	-	1.0	-	-	-	-	-	-	-	-	-	
THR064	3/16/83	-	-	0.7	-	5.0	-	-	-	-	-	-	-	
THR064	12/11/89	-	-	-	1.50	-	-	-	-	-	-	-	-	GM7
THR064	12/11/89	4.0	0.02	-	1.79	3.6	27.0	8.44	0.02(U)	2.10	1(U)	10.7	5.2	508232
THR066	8/24/82	-	-	8.5	-	-	-	-	-	-	-	-	-	
THR066	3/14/83	-	-	8.5	-	6.0	-	-	-	-	-	-	-	
THR066	12/11/89	-	-	-	3.10	-	-	-	-	-	-	-	-	GM9
THR067	12/12/89	3.7	0.03	-	15.10	4.6	44.0	10.80	0.02(U)	5.22	1.5	15.0	6.6	508236
THR067	12/12/89	-	-	-	2.30	-	-	-	-	-	-	-	-	GM18
THR070	8/24/82	-	-	5.2	-	-	-	-	-	-	-	-	-	
THR070	4/04/83	-	-	5.2	-	6.0	-	-	-	-	-	-	-	
THR071	8/24/82	-	-	2.4	-	-	-	-	-	-	-	-	-	
THR071	3/14/83	-	-	3.4	-	5.0	-	-	-	-	-	-	-	
THR071	12/11/89	-	-	-	2.60	-	-	-	-	-	-	-	-	GM15
THR077	8/24/82	-	-	2.3	-	-	-	-	-	-	-	-	-	
THR077	3/14/83	-	-	3.2	-	5.0	-	-	-	-	-	-	-	
THR077	12/11/89	-	-	-	2.30	-	-	-	-	-	-	-	-	GM12
THR077	12/11/89	5.0	0.03	-	17.30	4.3	44.1	15.50	0.02(U)	4.54	1.5	16.4	6.6	508233
THR077	3/20/90	-	-	-	2.50	-	-	-	-	-	-	-	-	

Table 16 Continued
Water Chemistry Data
Constituents in mg/L

Well #	Date	SO_4^{2-}	PO_4^{3-}	NO_3^-	$NO_3^-+NO_2^-$	Cl^-	$CaCO_3$	Ca^{2+}	Fe	Mg^{2+}	K^+	SiO_2	Na^+	Remarks
THR081	8/24/82	-	-	1.5	-	-	-	-	-	-	-	-	-	
THR081	3/14/83	-	-	1.4	-	5(U)	-	-	-	-	-	-	-	
THR084	8/23/82	-	-	3.9	-	-	-	-	-	-	-	-	-	
THR084	12/15/89	7.0	0.1	3.2	-	10.7	44.5	13.64	0.02(U)	6.8	0.6	16.6	7.8	EG15
THR084	12/15/89	-	-	-	2.86	-	-	-	-	-	-	-	-	508254
THR085	8/24/82	-	-	0.8	-	-	-	-	-	-	-	-	-	
THR085	3/15/83	-	-	1.2	-	5(U)	-	-	-	-	-	-	-	
THR085	12/12/89	-	-	-	1.80	-	-	-	-	-	-	-	-	GM19
THR085	12/12/89	4.0	0.04	2.0	-	3.4	28.2	8.76	0.02(U)	3.0	0.8	11.2	5.6	EG2
THR089	8/23/82	-	-	2.1	-	-	-	-	-	-	-	-	-	
THR089	3/14/83	-	-	2.4	-	7.0	-	-	-	-	-	-	-	
THR091	8/23/82	-	-	3.3	-	-	-	-	-	-	-	-	-	
THR091	3/16/83	-	-	3.1	-	5(U)	-	-	-	-	-	-	-	
THR092	12/15/89	-	-	-	1.63	-	-	-	-	-	-	-	-	508258
THR094	8/23/82	-	-	1.0	-	-	-	-	-	-	-	-	-	
THR094	3/16/83	-	-	1.7	-	13.0	-	-	-	-	-	-	-	
THR094	12/14/89	4.4	0.02	-	1.44	4.6	38.9	10.80	0.02(U)	3.26	1.1	13.7	6.1	508249
THR095	12/13/89	-	-	-	2.90	-	-	-	-	-	-	-	-	GM35
THR098	8/23/82	-	-	1.9	-	-	-	-	-	-	-	-	-	
THR098	3/16/83	-	-	1.8	-	5(U)	-	-	-	-	-	-	-	
THR098	12/13/89	5.0	0.05	2.5	-	2.0	35.3	11.05	0.02(U)	3.9	1.1	15.0	6.1	EG5
THR098	12/13/89	-	-	-	2.70	-	-	-	-	-	-	-	-	GM33
THR100	12/13/89	-	-	-	3.80	-	-	-	-	-	-	-	-	GM34
THR103	8/23/82	-	-	1.7	-	-	-	-	-	-	-	-	-	
THR103	3/15/83	-	-	3.0	-	15.0	-	-	-	-	-	-	-	
THR104	12/15/89	-	-	-	1.40	-	-	-	-	-	-	-	-	508257
THR105	8/23/82	-	-	0.9	-	-	-	-	-	-	-	-	-	
THR105	3/15/83	-	-	1.1	-	5(U)	-	-	-	-	-	-	-	
THR106	8/23/82	-	-	0.4	-	-	-	-	-	-	-	-	-	
THR106	3/15/83	-	-	0.7	-	5.0	-	-	-	-	-	-	-	
THR107	12/15/89	-	-	-	1.57	-	-	-	-	-	-	-	-	508259
THR109	8/23/82	-	-	0.6	-	-	-	-	-	-	-	-	-	
THR109	3/15/83	-	-	0.7	-	5(U)	-	-	-	-	-	-	-	
THR109	12/15/89	5.0	0.05	1.4	-	3.7	38.1	9.44	0.02(U)	4.2	0.8	13.7	5.5	EG18
THR109	12/15/89	-	-	-	1.11	-	-	-	-	-	-	-	-	508260
THR123	8/23/82	-	-	0.5	-	-	-	-	-	-	-	-	-	
THR123	3/14/83	-	-	0.6	-	5(U)	-	-	-	-	-	-	-	
THR124	8/23/82	-	-	0.2(U)	-	-	-	-	-	-	-	-	-	
THR124	3/14/83	-	-	0.3	-	5(U)	-	-	-	-	-	-	-	

Table 16 Continued
Water Chemistry Data
Constituents in mg/L

Well #	Date	SO_4^{2-}	PO_4^{3-}	NO_3^-	$NO_3^-+NO_2^-$	Cl^-	$CaCO_3$	Ca^{2+}	Fe	Mg^{2+}	K^+	SiO_2	Na^+	Remarks
THR125	12/15/89	-	-	-	16.20	-	-	-	-	-	-	-	-	508261
THR125	3/20/90	-	-	-	2.10	-	-	-	-	-	-	-	-	
THR137	12/13/89	-	-	-	0.97	-	-	-	-	-	-	-	-	GM42
THR140	8/23/82	-	-	0.3	-	-	-	-	-	-	-	-	-	
THR140	3/14/83	-	-	1.6	-	5.0	-	-	-	-	-	-	-	
THR140	12/13/89	-	-	-	1.90	-	-	-	-	-	-	-	-	GM38
THR140	12/13/89	3.9	0.02	-	-	4.3	35.8	9.49	0.02(U)	3.47	1(U)	16.5	5.9	508241
THR141	12/13/89	-	-	-	4.0	-	-	-	-	-	-	-	-	GM41
THR141	12/13/89	5.0	0.06	4.3	-	5.8	39.6	14.09	0.02(U)	4.4	0.9	18.1	7.5	EG6
THR141	3/20/90	-	-	-	6.30	-	-	-	-	-	-	-	-	
THR143	8/23/82	-	-	0.8	-	-	-	-	-	-	-	-	-	
THR143	3/14/83	-	-	1.1	-	5.0	-	-	-	-	-	-	-	
THR143	12/14/89	-	-	-	0.65	-	-	-	-	-	-	-	-	GM48
THR144	8/23/82	-	-	7.3	-	-	-	-	-	-	-	-	-	
THR144	3/14/83	-	-	10.0	-	6.0	-	-	-	-	-	-	-	
THR144	12/14/89	-	-	-	6.0	-	-	-	-	-	-	-	-	GM45
THR162	8/24/82	-	-	1.2	-	-	-	-	-	-	-	-	-	
THR163	8/23/82	-	-	0.3	-	-	-	-	-	-	-	-	-	
THR163	3/14/83	-	-	0.3	-	5(U)	-	-	-	-	-	-	-	
THR164	12/15/89	-	-	-	1.85	-	-	-	-	-	-	-	-	508253
THR164	12/15/89	3.0	0.05	2.3	-	1.8	23.9	9.00	0.02(U)	2.6	0.6	12.3	5.1	EG14
THR165	8/24/82	-	-	3.5	-	-	-	-	-	-	-	-	-	
THR165	3/14/83	-	-	2.9	-	7.0	-	-	-	-	-	-	-	
THR165	12/11/89	5.0	0.02	-	5.33	6.2	44.0	15.30	0.02(U)	4.38	1.3	16.1	7.6	508234
THR165	12/11/89	-	-	-	3.40	-	-	-	-	-	-	-	-	GM14
THR165	3/20/90	-	-	-	8.0	-	-	-	-	-	-	-	-	
THR167	8/24/82	-	-	1.5	-	-	-	-	-	-	-	-	-	
THR167	3/14/83	-	-	1.5	-	5(U)	-	-	-	-	-	-	-	
THR171	8/23/82	-	-	2.3	-	-	-	-	-	-	-	-	-	
THR171	3/14/83	-	-	3.0	-	5.0	-	-	-	-	-	-	-	
THR173	8/23/82	-	-	1.1	-	-	-	-	-	-	-	-	-	
THR173	3/15/83	-	-	1.6	-	5(U)	-	-	-	-	-	-	-	
THR173	12/15/89	-	-	-	6.82	-	-	-	-	-	-	-	-	508263
THR174	8/23/82	-	-	0.9	-	-	-	-	-	-	-	-	-	
THR174	3/15/83	-	-	1.5	-	5(U)	-	-	-	-	-	-	-	
THR175	3/15/83	-	-	3.1	-	6.0	-	-	-	-	-	-	-	
THR175	12/14/89	3.8	0.02	-	2.59	5.7	34.2	11.00	0.02(U)	3.04	1.1	12.6	6.5	508246
THR175	12/14/89	3.0	0.07	3.7	-	3.1	36.8	10.54	0.02(U)	2.7	0.4	12.3	6.2	EG10
THR176	8/23/82	-	-	0.8	-	-	-	-	-	-	-	-	-	

Table 16 Continued
Water Chemistry Data
Constituents in mg/L

Well #	Date	SO_4^{2-}	PO_4^{3-}	NO_3^-	$NO_3^-+NO_2^-$	Cl^-	$CaCO_3$	Ca^{2+}	Fe	Mg^{2+}	K^+	SiO_2	Na^+	Remarks
THR176	3/16/83	-	-	0.8	-	5(U)	-	-	-	-	-	-	-	
THR176	12/14/89	-	-	-	1.10	-	-	-	-	-	-	-	-	GM43
THR180	8/24/82	-	-	3.3	-	-	-	-	-	-	-	-	-	
THR180	3/14/83	-	-	3.4	-	10.0	-	-	-	-	-	-	-	
THR180	12/11/89	3.0	0.03	7.1	-	5.5	28.2	15.01	0.02(U)	3.5	0.5	12.3	5.9	EG1
THR180	12/11/89	-	-	-	6.20	-	-	-	-	-	-	-	-	GM-8
THR181	12/14/89	5.4	0.02	-	3.36	5.2	48.4	15.50	0.02(U)	5.20	1.7	15.8	7.0	508243
THR181	12/14/89	8.0	0.05	4.2	-	2.8	52.3	13.46	0.02(U)	5.0	0.5	16.6	6.8	EG8
THR184	12/15/89	-	-	-	0.25	-	-	-	-	-	-	-	-	508262
THR184	12/15/89	6.0	0.05	2.6	-	2.0	46.4	12.67	0.02(U)	4.2	1.0	15.2	6.6	EG19
THR187	12/11/89	6.5	0.02	-	1.52	4.5	36.7	11.00	0.02(U)	3.50	1.1	14.1	5.9	508231
THR187	12/11/89	-	-	-	1.50	-	-	-	-	-	-	-	-	GM3
THR192	12/11/89	-	-	-	1.20	-	-	-	-	-	-	-	-	GM2
THR192	12/11/89	9.0	0.02	-	1.30	3.8	15.0	6.06	0.02(U)	1.66	1.2	8.6	5.0	508230
THR200	12/14/89	-	-	-	2.40	-	-	-	-	-	-	-	-	GM44
THR201	12/15/89	-	-	-	1.21	-	-	-	-	-	-	-	-	508252
THR202	12/15/89	-	-	-	1.36	-	-	-	-	-	-	-	-	508256
THR202	12/15/89	6.0	0.04	1.5	-	1.8	33.1	9.00	0.02(U)	2.6	0.7	11.8	5.5	EG17
THR203	12/13/89	-	-	-	1.20	-	-	-	-	-	-	-	-	GM39
THR203	12/13/89	3.3	0.01	-	-	12.0	41.7	12.10	0.02(U)	5.07	1(U)	12.7	6.2	508242
THR204	12/13/89	-	-	-	3.70	-	-	-	-	-	-	-	-	GM32
THR205	12/12/89	-	-	-	2.80	-	-	-	-	-	-	-	-	GM21
THR206	12/12/89	-	-	-	1.50	-	-	-	-	-	-	-	-	GM20
THR206	12/12/89	6.0	0.01(U)	1.7	-	2.1	35.9	8.54	0.02(U)	4.0	1.1	14.2	5.8	EG3
THR207	12/12/89	-	-	-	2.30	-	-	-	-	-	-	-	-	GM23
THR207	12/12/89	4.6	0.02	-	14.80	5.5	50.9	13.90	0.02(U)	4.80	1.2	15.9	8.4	508237
THR207	3/20/90	-	-	-	2.50	-	-	-	-	-	-	-	-	
THR208	12/12/89	-	-	-	2.30	-	-	-	-	-	-	-	-	GM22
THR208	3/20/90	-	-	-	6.10	-	-	-	-	-	-	-	-	
THR208	3/20/90	-	-	-	6.10	-	-	-	-	-	-	-	-	
THR209	12/12/89	-	-	-	2.10	-	-	-	-	-	-	-	-	GM26
THR210	12/12/89	-	-	-	2.80	-	-	-	-	-	-	-	-	GM27
THR211	12/12/89	-	-	-	1.90	-	-	-	-	-	-	-	-	GM28
THR212	12/12/89	-	-	-	1.40	-	-	-	-	-	-	-	-	GM31 DUP
THR212	12/12/89	-	-	-	1.70	-	-	-	-	-	-	-	-	GM31
THR213	12/11/89	-	-	-	1.80	-	-	-	-	-	-	-	-	GM11
THR214	12/11/89	-	-	-	3.40	-	-	-	-	-	-	-	-	GM16
THR215	12/11/89	-	-	-	1.50	-	-	-	-	-	-	-	-	GM1
THR219	12/11/89	-	-	-	2.80	-	-	-	-	-	-	-	-	GM13

Table 16 Continued
Water Chemistry Data
Constituents in mg/L

Well #	Date	SO_4^{2-}	PO_4^{3-}	NO_3^-	$NO_3^-+NO_2^-$	Cl^-	$CaCO_3$	Ca^{2+}	Fe	Mg^{2+}	K^+	SiO_2	Na^+	Remarks
THR220	12/11/89	-	-	-	3.10	-	-	-	-	-	-	-	-	GM10
THR221	12/14/89	-	-	-	1.30	-	-	-	-	-	-	-	-	GM46
THR221	12/14/89	5.0	0.06	1.4	-	3.7	58.9	12.43	0.02(U)	5.2	1.4	16.6	6.6	EG11

FINDINGS

With few exceptions the water quality is very good in the Scatter Creek/Black River aquifer. We used the State drinking water standards as the threshold to determine if a particular constituent exceeded recommended maximum contaminant levels (MCL) in a water sample. Table 17 lists the primary and secondary drinking-water standards from Washington Administrative Code 246-290-310.

Table 17

Primary & Secondary Drinking Water Standards

Substance	Primary MCLs (mg/l)
Arsenic	0.05
Barium	1.00
Cadmium	0.01
Chromium	0.05
Fluoride	4.0
Lead	0.05
Mercury	0.002
Nitrate (as Nitrogen)	10.0
Selenium	0.01
Substance	**Secondary MCLs (mg/l)**
Chloride	250.0
Copper	1.0
Iron	0.3
Manganese	0.05
Silver	0.1
Sulfate	250.0
Zinc	5.0

For the physical characteristics of specific conductance and total dissolved solids, the State has established secondary MCL of 700 microhms/cm and 500 mg/l respectively.

All of the sample constituents determined were less than the adopted MCL, except for nitrate. In four of the wells sampled in 1989, nitrate levels equaled or exceeded the MCL of 10 ppm. Table 18 lists the wells which had nitrate readings which equaled or exceeded the MCLs.

Table 18

Wells With Nitrate Values Exceeding the MCL

Well Number	PPM Nitrate
THR125	16.2
THR144	10.0
THR207	14.8
THR216	17.3

The hardness of the water ranged from a high of 58.9 mg/l $CaCO_3$ to a low of 15 mg/l $CaCO_3$. The calculated total dissolved solids of the samples range from 51.5 mg/l to 131 mg/l. The calculated values for total dissolved solids are consistent with the measured specific conductance and hardness determinations.

WATER TYPING

Water typing is a method of classifying a water sample based on the predominate cation and anion in the sample. "Waters in which no one cation or anion constitutes as much as 50 percent of the totals should be recognized as a mixed type and should be identified by the names of all the important cations and anions." (Hem, 1985 p. 166) Sample constituents expressed as milligrams per liter were converted to meq/l using conversion factors listed in Hem (1985).

The thirty-three complete cation/anion analyses show the water to be mostly a mixed type with the dominate cations being Calcium and Magnesium. Bicarbonate is the dominant anion. Our work agrees with work conducted by the U.S. Geologic Survey (Turney, 1986) and the Washington State, Department of Conservation (Noble & Wallace, 1966). Thirteen complete water samples and thirty-one partial analysis were found in the literature. Those analyses indicate the water is of calcium bicarbonate type, with one exception. Table 19 contains a list of the well water samples for December 1989 and the percentage composition of the sample, when the sample constituents are expressed in milliequivalents.

Table 19

Ion Concentration Expressed as a Percentage of Cations or Anions in Milliequivalents

Well	K^+	Ca^{2+}	Mg^{2+}	Na^+	Cl^-	SO_4^{2-}	PO_4^{3-}	NO_3^-	ALK.
THR011	2.3	46.0	28.1	23.8	6.2	9.1	<0.1	2.7	81.9
THR013	3.2	44.5	29.2	23.2	12.6	7.6	<0.1	3.9	75.9
THR014	2.9	46.4	26.0	24.7	12.4	9.6	<0.1	2.6	75.3
THR021	2.9	47.2	25.6	24.4	11.7	7.5	<0.1	4.0	76.8
THR025	2.4	47.5	26.3	23.9	14.4	9.7	<0.1	3.7	72.0
THR029	1.9	48.7	25.3	24.1	14.6	11.5	<0.1	11.3	62.5
THR031	0.9	49.8	29.0	20.2	29.5	<0.1	<0.1	4.8	65.5
THR041	2.9	47.1	28.7	21.3	11.8	10.4	<0.1	3.9	73.8
THR047	1.0	50.8	25.6	22.4	5.8	6.5	<0.1	4.5	83.1
THR057	2.7	48.5	23.8	25.1	12.3	13.0	<0.1	5.1	69.5
THR064	1.8	50.3	20.6	27.3	13.5	11.0	<0.1	3.8	71.6
THR067	3.0	41.6	33.2	22.3	9.7	5.7	<0.1	18.3	66.2
THR077	2.7	49.8	26.7	20.7	8.7	7.4	<0.1	20.1	63.7
THR084	1.0	42.7	35.1	21.2	21.7	10.5	<0.1	3.7	63.9
THR085	2.0	46.2	26.0	25.6	12.3	10.7	<0.1	4.1	73.0
THR094	2.6	49.0	24.4	24.0	12.7	9.0	<0.1	2.3	76.0
THR098	20.3	38.5	22.6	18.5	6.2	11.5	<0.1	4.4	77.7

Table 19 (Continued)

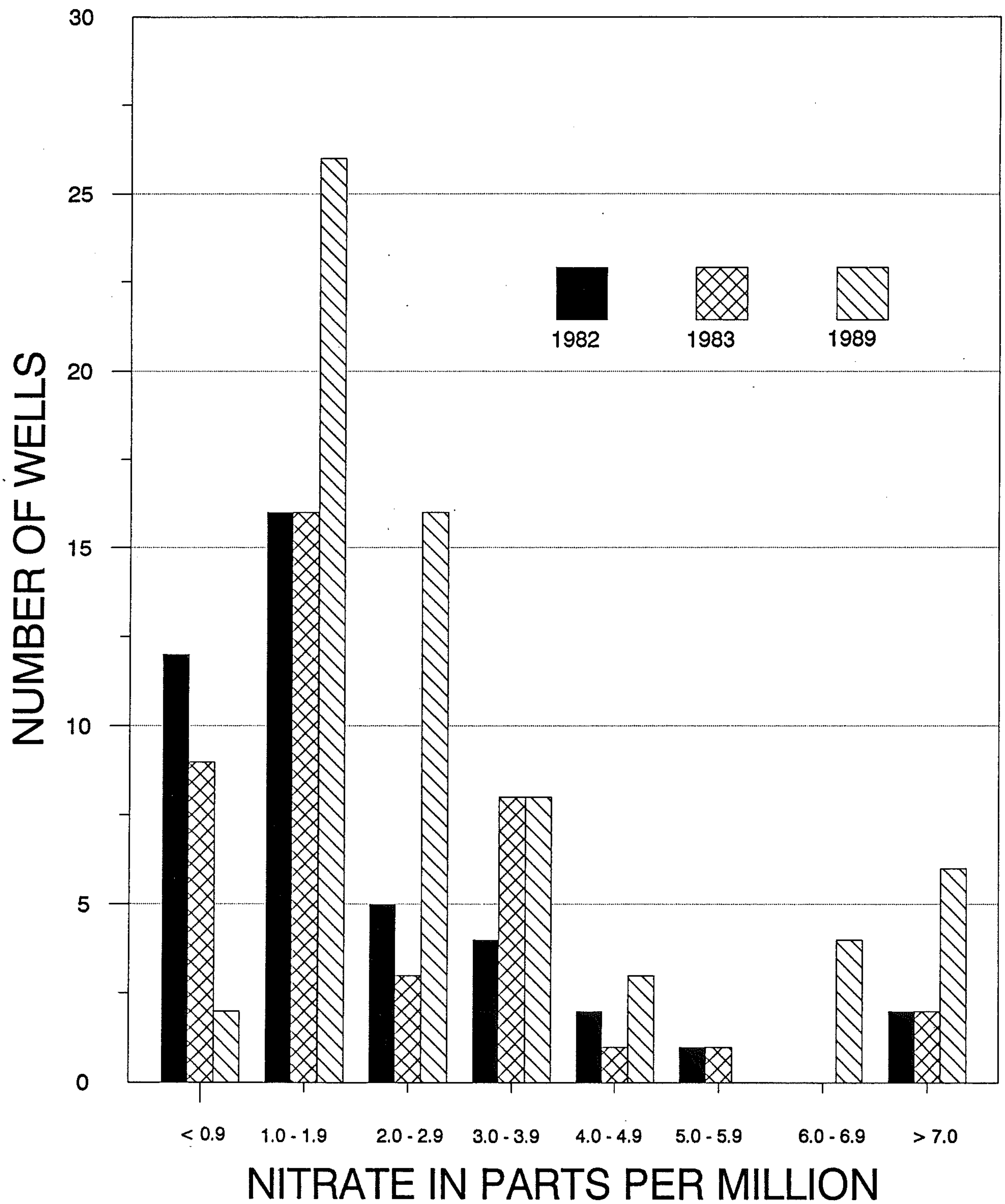
Ion Concentration Expressed as a Percentage of Cations or Anions in Milliequivalents

Well	K^+	Ca^{2+}	Mg^{2+}	Na^+	Cl^-	SO_4^{2-}	PO_4^{3-}	NO_3^-	ALK.
THR109	2.0	43.8	31.8	22.4	10.5	10.5	<0.1	2.3	76.6
THR140	2.3	43.0	28.8	25.9	12.7	8.5	<0.1	3.2	75.5
THR141	1.6	49.8	25.5	23.2	14.5	9.2	<0.1	6.1	70.0
THR164	1.6	49.8	24.1	24.5	8.0	9.9	<0.1	5.9	75.9
THR165	2.2	51.3	24.2	22.3	14.1	8.4	<0.1	6.9	70.5
THR175	1.0	51.0	21.8	26.1	9.2	6.6	<0.1	6.3	77.6
THR180	1.2	51.9	24.7	22.2	17.3	7.0	<0.1	12.8	63.0
THR181	0.9	48.2	29.7	21.2	5.8	12.2	<0.1	5.0	76.9
THR184	2.0	49.0	26.7	22.3	4.9	10.8	0.1	3.6	80.5
THR187	2.6	46.4	27.0	23.9	12.3	13.3	<0.1	2.4	71.9
THR192	4.5	44.0	19.9	31.6	17.5	30.0	<0.1	3.4	48.7
THR202	1.9	48.9	23.0	26.2	5.9	14.5	<0.1	2.8	76.7
THR203	1.8	45.9	31.7	20.6	26.8	5.4	<0.1	1.5	66.0
THR206	2.7	41.2	31.8	24.2	6.4	13.4	<0.1	3.0	77.2
THR221	2.5	45.2	31.3	21.0	7.4	7.4	<0.1	1.6	83.5

NITRATE

Four of the wells sampled in December 1989 contained elevated nitrate levels. The nitrate data collected in our study were compared with historical data to determine if there has been a significant increase in the background nitrate levels in the aquifer with time. The mean nitrate value for all wells sampled was 3.9 in 1989 (65 wells), 2.3 in 1983 (40 wells) and 2.0 in 1982 (42 wells). Figure 5 indicates the number of water samples collected in the study area for the years 1982, 1983, and 1989 with sample nitrate values clustered in parts per million.

FIGURE 4
NITRATE DATA
DISTRIBUTION BY CLUSTERS



Twenty-one of the wells have been sampled for nitrates in 1982, 1983, and 1989. Table 20 is a list of the wells, and the nitrate values for the three different years. The nitrate data from the different years can not be directly compared, because the samples were collected at different times of the year. Samples in 1989 were collected in December, those of 1983 in March, and 1982's in August.

Table 20

Nitrate Values for Wells Sampled in 1982, 1983, And 1989

Well No.	1982	1983	1989
THR014	1.2	1.3	1.5
THR021	1.6	1.6	2.1
THR025	1.7	1.9	2.5
THR029	4.3	3.7	6.7
THR035	2.0	2.7	2.4
THR041	4.0	4.0	2.6
THR053	1.2	1.4	1.9
THR064	1.0	0.7	1.7
THR066	8.5	8.5	3.1
THR071	2.4	3.4	2.6
THR085	0.8	1.2	1.9
THR094	1.0	1.7	1.4
THR098	1.9	1.8	2.6
THR109	0.6	0.7	1.3
THR140	0.3	1.6	1.9
THR143	0.8	1.1	0.7
THR144	7.3	10.0	6.0
THR165	3.5	2.9	4.4
THR173	1.1	1.6	6.8
THR176	0.8	0.8	1.1
THR180	3.3	3.4	6.7

While no statistically valid inferences can be drawn from these data, we did evaluate the data to see if it appeared that nitrates were increasing over time. The nitrate data used in this comparison did not include any of the 1989 nitrate samples which are suspect because of laboratory discrepancies. In 14 cases the 1989 nitrate level was higher than in the previous years. Three of the 1989 nitrate levels were between the 1982 and 1983 levels and in four cases the 1989 level was less than the previous years. Of the 14 wells which showed an increase in nitrate for 1989, 8 increased less than 50 percent, 5 increased between 50 and 100 percent, and one increased over 100 percent.

DEPARTMENT OF HEALTH'S WATER-QUALITY DATA

We reviewed Washington State Department of Health's water-quality records for 33 public systems within the study area. The 33 public systems have a total of eighty-seven water-quality analyses on record. The public systems are required to conduct periodic water-quality assessments. The requirements vary depending on the size of the system and population served. In general, an assessment of the primary drinking-water constituents is required every three years for the larger systems. For smaller systems, testing for these constituents is required when the system is developed.

In two analyses the iron exceeded the MCL. The conductivity of the samples ranged from 30 to 320 microhms per centimeter, with conductivity above 150 microhms per centimeter in eleven samples and greater than 200 microhms per centimeter in three samples. Hardness, expressed as $CaCO_3$, exceeded 75 mg $CaCO_3$/L in only three of the samples. This indicates soft water, low in calcium and magnesium.

Nitrate values for the 87 samples ranged from undetectable to 7.1 mg/l. The mean nitrate value was 2.5 mg/l with a standard deviation of 1.51 and a variance of 2.28.

The public water system chemical analyses indicate general agreement with our work for species determination, conductivity, and hardness.

CHAPTER IV

LAND USE

We conducted an assessment of the land uses within the study area in an attempt to link land use with water quality. This was done because the geology in the region renders the aquifer susceptible to contamination.

STUDY METHODS

In 1989, Mr. Robert Bergquist mapped the land uses in the study area while under contract as an administrative intern with Ecology. Mr. Bergquist subdivided the study area into ten land-use classifications based on information obtained from aerial photographs and on-the-ground field inspections.

The land-use classifications within this report are not directly comparable to the land-use classifications within the Rochester Sub-Area Plan (Thurston County,1977). Within the Sub-area plan, Thurston County mapped areas of forestry, agriculture, aquaculture, residential, and business within the study area. In general, these designations agreed with the land-use classifications defined in our study, but are less detailed. The distribution of land uses within the study area is shown on Plate 2 and described below by classification.

Residential/high density: This classification includes house densities of two or more dwelling units per acre.

Undeveloped/natural: This classification is for areas which have not been recently disturbed. They may never have been altered or may have reverted to native vegetation.

Agriculture/rangeland: This classification is for areas that are used for pasture or production of grass type crops.

Fruits and vegetables: This classification is for land where only fruits or vegetables are grown.

Livestock-poultry: This classification refers to areas immediately affected by poultry operations.

Livestock-cattle/dairy: This classification refers to land used to support dairy operations.

Livestock-horses: This classification refers to areas where horses are raised commercially.

Industrial: This classification is for both industrial areas such as a gravel pit and roads such as Interstate 5.

Fish hatchery: This classification includes the land immediately affected by the operation of an aquaculture facility. However, it does not include land beyond the discharge point.

Tree farms/lumber: This classification includes land used for Christmas tree production, seed production, and telephone pole production.

Table 21 is a summary of the land use categories, percent of the study area within each land use, and the number of water quality samples analyzed for each land use.

Table 21

Summary of Land Use Categories

Land Use Type	Area in Acres	Percentage of Area	Number of Water Samples
Residential	4198	10.8	14
Undeveloped/Natural	12519	32.3	4
Agriculture/Range Land	17043	44.0	5
Agriculture/Fruit	461	1.2	0
Livestock-Poultry	486	1.3	1
Livestock-Cattle/Dairy	425	3.7	3
Livestock-Horses	357	0.9	1
Industrial	1351	3.5	0
Fish Hatchery	325	0.8	4
Tree Farm or Lumber	600	1.6	1

LAND USE AND WATER QUALITY

We reviewed the water-quality information for each sample in relationship to the land use surrounding the water well. The high density residential and fish farm land uses have the potential to contaminate the ground water. We used the constituent nitrate to determine if contamination is occurring. Plate 8 is a map of the high density land use, fish farms, ground-water contours for December 1989, and all nitrate values collected within this study. An inspection of this plate shows no pattern of high nitrate correlation with land uses having the greatest potential to generate nitrate. The three nitrate values from Manchester Laboratory which we can not confirm, because of laboratory differences, were plotted. However we are not sure that they represent accurate determinations.

Because of the nature of their operation, fish farms have the potential to degrade ground-water quality. An assessment of one fish farm and ground-water quality (Erickson, 1990) indicated some ground-water contamination. Three of the wells we sampled, THR077, THR085, and THR098 were associated with fish farms. These samples indicate that, for the constituents determined, these fish farms are not contaminating ground water.

We were not able to associate a particular land use with detrimental impacts to water quality. However, it does appear nitrate levels are increasing. We suspect that septic systems and agriculture practices are the most likely sources. The land-application sites of animal manure are continually changing, depending on the farmers involved and who owns the property. Because of this, it is very hard to correlate land application sites and associated water quality. In addition, the rapid movement of the ground water in the system makes it problematic to tie any of the land uses to water quality. The rapid movement of ground water would transport the contaminates from their source and dilute them.

CHAPTER V

WATER ALLOCATION

Water use in Washington is regulated through a permitting system administered by the State Department of Ecology. A water-use permit is required for any use of surface water. A permit is required for ground-water use in excess of five thousand gallons per day, or for non-commercial irrigation of more than one-half acre. The intent of the permitting system is to establish a priority hierarchy of water users based on the date water is first put to permitted use. In times of shortage, water use by junior appropriators can be regulated to protect the rights of senior appropriators.

Water-right permits specify the intended use of the water while limiting the maximum instantaneous and annual quantity of water withdrawn. By examining water-right records on file with Ecology, we estimated the maximum permitted water use in the study area. Table 22 is a summary of permitted water use by principal types and annual quantity. Appendix D contains a listing of the surface and ground-water rights issued for the Scatter Creek area by water right number, purpose of use, and annual and instantaneous quantity.

Table 22

Permitted Water Use by Type and Annual Quantity

	Annual Water Use in (AF)[1]	
Use Type	Ground-Water	Surface-Water
Aquaculture	24,278.0	1.0
Irrigation	9,659.0	2804.5
Public Water	891.4	***
Poultry	207.5	***
Domestic Supply	103.2	3.0
Stock Water	83.7	14.3
Dairy Operations	55.5	***

[1] Acre Feet: One acre foot is equal to 325,858 gallons.

Total permitted ground-water use for the study area is 35,278.3 AF per year, while permitted surface-water use is 2,822.8 Acre Feet per year. The total permitted instantaneous ground-water use is 63,878 gallons per minute, or 140.7 cubic feet per second. The total permitted instantaneous surface-water use is 27.28 cubic feet per second.

The volume of water permitted for use within the Scatter Creek area, probably exceeds actual use by a much as 30-50 percent, depending on the use. This occurs because water rights, once issued, remain in effect until formally relinquished whether they are used or not. Areas which were formerly irrigated and later subdivided for housing tend to have more allocated water rights than actual water use. In addition, water rights for public water supply are generally issued for the ultimate buildout of the system, which may not occur for several years.

Despite the large volume of water pumped from the Scatter Creek/Black River aquifer, consumptive water use represents only a small part of the total volume pumped. Consumptive use refers to that water which is pumped and permanently removed from the aquifer by evaporation, transpiration, sewerage, or other means. In the Scatter Creek area, sewerage is absent. Thus, some portion, perhaps 70-90 percent, of water withdrawn for domestic supply is returned to the aquifer through septic drainfields and settling ponds.

Aquaculture, a largely nonconsumptive use, accounts for 69 percent of the total annual permitted ground-water use. Water from these facilities is discharged to unlined settling ponds or nearby streams, where it quickly returns to the aquifer. Taking all this into account, consumptive water use within the Scatter Creek valley is probably less than 34 percent of the total volume pumped, or 13,000 AF/year.

In order to estimate the discrepancy between permitted and actual water use for public-water systems, we evaluated information from the Department of Health's data base for public-water-supply systems. There are approximately 890 public water service connections within the Scatter Creek area, serving an estimated 2574 residential units. An average daily water use of 450 gallons per connection equates to an annual total use of 449 acre feet, roughly half of the permitted annual quantity of 891 AF.

CHAPTER VI

ANALYSIS AND CONCLUSIONS

The Scatter Creek/Black River Area of Southwestern Thurston County is underlain by unconsolidated drift deposits of sand, gravel, and cobbles of Penultimate and Vashon origin. These deposits form the matrix for the highly productive valley-fill aquifer that supplies water to most area residents and other water users. The aquifer is unconfined and varies in thickness from approximately 60 feet to 160 feet. The average thickness of the valley-fill sediments is approximately 106 feet.

The aquifer has a median hydraulic conductivity of 864 ft/day with values ranging from 69 to 3325 ft/day. The average storage coefficient and specific yield of the aquifer are 0.002 and 0.025 respectively. The aquifer is capable of yielding 2500 gpm or more to properly developed wells with approximately 20 feet of drawdown. Due to ease with which the aquifer transmits water, well interference is generally not a problem.

Evaluation of hydrographs for selected wells indicates that no appreciable water-level declines have occurred in the Scatter Creek area since initial monitoring began in 1977. There has in fact been a marked rise of water levels in some wells in response to ground-water recharge following the drought of 1976-77. The information gathered to date suggests that current water use has not unduly impacted aquifer water levels or seasonal water-level fluctuations.

Water Quality

The water-quality data collected during this study indicates no ground-water-quality problems in the aquifer at this time. The data collected provide a broad assessment of current conditions upon which to compare future work.

The definition of a ground-water-quality problem necessarily depends on the criteria used to define the term "problem". Using the State drinking water standards, there is not a problem with the water quality within the Scatter Creek/Black River aquifer. An exception is for the constituent nitrate. Disregarding nitrate, water from two public water system wells contained iron concentrations which exceeded the established MCL. The samples were from wells distant from each other and resampling by the public water systems did not confirm the high levels of iron.

Nitrate can enter the ground-water by the natural reduction of ammonium, nitrogen, or from disposal of sewage or organic waste. "Anionic species such as nitrate are readily transported in water and are stable over a considerable range of conditions. The nitrate and organic species .... are generally considered to be indicators of pollution through disposal of sewage or organic waste." (Hem, 1985, p. 124). Generally, nitrates associated with septic tanks also have elevated chloride levels. However, we did not find elevated chlorides associated with samples high in nitrates.

The Thurston County Environmental Health Department is concerned about both the elevated nitrate levels found in this study and the potential for nitrate contamination because the soils drain very rapidly and the area relies on septic systems for waste disposal. Rapid draining and aerobic conditions do not allow soil microorganisms time to decompose the nitrate. In the 1970's, the water supplies for Bucoda and Oakville were contaminated by septic-tank effluent and these towns have soils and underlying geology similar to our study area.

While no inferential statistics could be drawn from the data, it appears that nitrate levels have increased over time. Of the 15 wells with nitrates in excess of 5 mg/l, four were located in high-density residential sections (100+ units/section) and three were located in moderate-density-residential sections (50-100 units/section). The remainder were located in low-density-residential sections where agricultural land use predominates. These data are not sufficient to draw specific conclusions about the sources of nitrates. None of the nitrate values in excess of 5 mg/l were associated with elevated chlorides, which suggests the nitrate did not originate from septic systems.

A comparison of data collected during this study with historical data indicates agreement as to water type, pH, specific conductance, temperature, and general levels of chemical constituents.

Needs for Additional Study

This study was hindered by the lack of continuous discharge data for the Black River and Scatter Creek. Continuous gaging of these sources would enable us to better estimate ground-water recharge rates and estimate the contribution of ground-water discharge to the base flows of Scatter Creek and the Chehalis and Black rivers. Proper management of Chehalis and Black River instream flows requires a better understanding of how base flows in these streams are affected by water use from the aquifer. To reconcile this problem, we recommend that continuous recording gages be installed and maintained on Scatter Creek at Stations THR505 and THR521. In addition, the USGS gage at station 12029000 on the Black River at Little Rock should be reactivated and supplemented with an additional gage near the confluence of the Black with the Chehalis.

The apparent increase in nitrate levels in the aquifer from 1982 to 1989 is reason to suspect contamination by human and animal wastes. The Scatter Creek area is home to a number of dairies and poultry-rearing facilities which produce a substantial quantity of waste each year. Liquid dairy waste is generally stored in lagoons or other temporary holding facilities and applied to the land during favorable conditions. Chicken manure is readily available to area vegetable farmers who use it to fertilize their fields.

Land application of animal manure has the potential to impact ground-water quality if best management practices are not followed. Over application of dairy waste within the Mound Prairie area is suspected to have caused elevated nitrates in ground-water sampled from down-gradient domestic wells, and is cause for ongoing studies by Thurston County Environmental Health (Davis, 1992). To prove a cause and effect relationship between dairy-waste handling and ground-water contamination, we need better accounting of land used for dairy waste disposal. To correlate animal-waste-handling practices with ground-water contamination, we recommend monitoring up and down gradient of the application sites. A monthly sampling regimen is recommended to quantify the seasonality of contaminant distribution.

The data we compiled and gathered during this study provide a benchmark upon which to base future work. Monitoring of ground water quality in the study area should be conducted periodically to determine if future development causes an increase in ground-water contamination.

CHAPTER VII

REFERENCES CITED

APHA, AWWA, WPCF. (1985). Standard methods for the examination and treatment of water and wastewater. Washington, D.C.: American Public Health Association.

Bentall, R. (1963). Methods of determining permeability, transmissibility and drawdown. United States Geological Survey Water Supply Paper 1536-I.

Carter, R. W., and Davidian, J. (1968). General procedure for gaging streams, U.S. Geological Survey techniques of water-resources investigations, Book 3, Chapter A6.

Climadata User's Manual. (1988). TD 3200 Summary of the Day - Cooperative Observer Network, U.S. West Optical Publishing, 90 Madison Street, Suite 200, Denver, CO, 80206..

Cooper, H. H., Jr., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Am. Geophys. Union Trans., v. 27, no. 4, p.526-534.

Crandell and others. (1958). Pleistocene sequence in southeastern part of the Puget Sound Lowland, Washington. American Journal of Science, 256, 384-397.

Crandell, D. R., 1965, The glacial geology of western Washington and Oregon, in Weight, H. E., Jr., and Frey, D. G., eds., The Quaternary of the United States: Princeton University Press, Princeton, p. 341-353.

Davis, S., (1992) Thurston County Environmental Health, personal communication.

Duffield, G. M., and Rumbaugh, J. O. III. (1989). Aqtesolv. Geraghty and Miller Modeling Group, computer software.

Dunne, T., and Leopold, L. B., (1978). Water in Environmental Planning. 818 p.

Eddy, P. A. (1973). Geohydrology of the Chehalis River valley, Grays Harbor County, Washington. Geohydrology Monograph. Washington Department of Ecology.

Erickson, D. (1990). Rochester Ground-Water Quality Investigation, Wa. State Department of Ecology, Environmental Investigations and Laboratory Services Program. 23 p.

Esterbrook, D. J., Briggs, N. D., Westgate, J. A., Gorton, M. (1981). Age of Salmon Springs glaciation in Washington. Geology, 9 (2), 87-93.

Esterbrook, D. J., Othberg, K. L. (1976). Paleomagnetism of Pleistocene sediments in the Puget lowland, Washington. International Geological Correlation Programme [Prague], Vladimir, S. editor, Project 73/1/24, 189-207.

Eylar, T., Anderson, C., and Blair, M. (1990). Streamflow and ground-water level records for Southwest Washington 1976 to 1989. Washington State Department of Ecology, Water Resources Program, 90-57. 463 p.

Fishman, M. J. and Friedman,L. C., Editors. (1989). Techniques of water-resources investigations of the United States Geological Survey, Book 5, Chapter A1. Methods For Determination of Inorganic Substances in Water and Fluvial Sediments. Third Edition. 545 p.

Garling, M. E., Molenaar, D., et. al. (1965). Water resources and geology of the Kitsap peninsula and certain adjacent islands. Washington Division of Water Resources, Water Supply Bulletin number 18.

Hem, John D. (1985). Study and interpretation of the chemical characteristics of natural water. Third edition, U. S. Geological Survey Water-Supply Paper 2254.

Huntamer, D., and Hyre, J. (1991). Manchester environmental laboratory users manual, Third Edition.

Lea, Peter D. (1984). Pleistocene Glaciation at the Southern Margin of the Puget Lobe, Western Washington. Unpublished Master of Science Thesis, University of Washington. 96 p.

Logan, R. L., (compiler) (1987), Geologic map of the Chehalis river and Westport Quadrangles, Washington: Wa. Division of Geology and Earth Resources, Open-file report 87-8. 18 p.

Lohman, S. W. (1979). Ground-water hydraulics. United States Geological Survey, professional paper 708.

Ness, A. O. (1947). Soil survey of Thurston County, Washington. United States Department of Agriculture in Cooperation With Washington Agricultural Experiment Station, Series 1947, 6.

Neuman, S. P. (1975). Analysis of pumping test data from anisotropic unconfined aquifers considering delayed yield. Water Resources Research, 11 (2), 329-342.

Noble, J. B., and Wallace, E. F. (1966). Geology and ground-water resources of Thurston County, Washington. Washington Division Water Resources, Water Supply Bulletin 10 (2).

Orion Research Incorporated. Orion model 93-07 nitrate electrode instruction manual.

Pearson, H. E., and Higgins, G. T. (1979). Water resources of the Chehalis Indian reservation, Washington. United States Geological Survey, open-file report 77-704.

Perkin Elmer. (1982). Analytical methods for atomic absorption spectrophotometry.

Robinson, Noble, and Carr, (1981). Drilling and Testing of Black River Production Well 4, 16N/04W-25K, Letter Report, 8 p.

Schasse, H. W., (compiler) (1987), Geologic map of the Centralia Quadrangle, Washington: Wa. Division of Geology and Earth Resources, Open-file report 87-11. 27 p.

Schlax, W. N., Jr. (1947). Preliminary report on ground-water resources of the central Chehalis valley, Washington. United States Geological Survey, open-file report.

Snavely, P. D., Jr., et. al. (1951). Geology of the eastern part of the Centralia-Chehalis district, Washington. United States Geological Survey Bulletin 1053.

Theis, C. V., (1935). The relation between the lowering of the piezometric surface and the rate and duration of discharging of a well using ground-water storage: Am. Geophys. Union trans., v. 16, p. 519-524.

Thornthwaite, C. W., and Mather J. R. (1957). Instructions and tables for computing potential evapotranspiration and the water balance. Publications in Climatology, X (3). Centerton, New Jersey: Drexel Institute of Technology, Laboratory of Climatology.

Thurston County Health Department. (1984). Grand Mound/Rochester aquifer survey-final review. draft.

Turney, G. L. (1986). Quality of ground-water in the Puget sound region, Washington, 1981. United States Geological Survey, Water-Resources Investigations Report 84-4258.

U.S. Department of Agriculture, Soil Conservation Service. (1987). Soil survey of Lewis County area, Washington.

U.S. Environmental Protection Agency. (1984). Methods for chemical analysis of water and waste. EPA 600/4-79-020.

Wald, A., (1986). Aquifer test of December 30, 1985, Sea Farm of Norway Well No.5, T.16N., R.2W., S.32E05 W.M., near Grand Mound, Wa. Letter Report, 5 p.

Walters, K. L., and Kimmel, G. E. (1968). Ground-water occurrence and stratigraphy of unconsolidated deposits, central Pierce County, Washington. Washington Department of Water Resources, 22.

Weaver, C. E. (1912). A preliminary report on the Tertiary paleontology of western Washington. Washington Geological Survey Bulletin 15.

Weigle, J. M., and Foxworthy, B. L. (1962). Geology and ground-water resources of west-central Lewis County, Washington. Washington Division of Water Resources Water Supply Bulletin No. 17.

Wildrick, L. E., (1981). Testing of Black River Production Well 3, 16N/04W-25, Letter Report, 5 p.

Willmott, C. J. (1977). WATBUG: A fortran IV algorithm for calculating the climatic water budget. Water Resources Center, University of Delaware. OWRT Project No. A-040-DEL.

Vosse, P. and Rosbach M. (1979). Determination of the pollution potential of ground-water in the vicinity of Rochester, Washington. Vosse, Rosbach & Associates, Environmental Consultants.

Wallace, E. F., and Molenaar, D. (1961). Geology and ground-water resources of Thurston County, Washington, Water Supply Bulletin No. 10,1. State of Washington Department of Conservation and the United States Geological Survey.

CHAPTER VIII

OTHER REFERENCES

Bretz, J. H, (1913). Glaciation of the Puget sound region. Washington Geological Survey Bulletin 8.

Cummans, J. E., and Nassar, E. G. (1975). Low flow characteristics of streams in the Grays Harbor drainages, Washington. United States Geological Survey open-file report.

Driscoll, F. G. (1986). Groundwater and Wells, second edition. 1089 p.

EsterBrook, D. J. (1986). Stratigraphy and chronology of quaternary deposits of the Puget lowland and Olympic mountains of Washington and the Cascade mountains of Washington and Oregon. Quaternary Science Reviews, 5, 145-159.

Noble, J. B. (1990). Proposed revision of nomenclature for the Pleistocene stratigraphy of coastal Pierce County, Washington. Washington Division of Geology and Earth Resources, open file report 90-4.

Phillips, E. L. (1964). Washington climate for these counties: Clark, Cowlitz, Lewis, Skamania and Thurston. Washington State University (Pullman) Agriculture Extension Service.

Ramsahoye, L.E., and Lang, S. M. (1961). A simple method for determining specific yield from pumping tests. United States Geological Survey Water Supply Paper 1536-C.

Schuster, E. J. (1987). Selected papers on the geology of Washington. Washington Division of Geology and Earth Resources, Bulletin 77.

United States Department of Agriculture. (1962). Soil survey of Thurston County, Washington.

U.S. Department of Commerce. (1973). Monthly normals of temperature, precipitation, and heating and cooling degree days, 1941-70: Washington. National Oceanic and Atmospheric Administration, Environmental Data Service.

U.S. Weather Bureau. (1965). Climatological summary, Oakville, Washington. Climatography of the United States, 20-45.

CHAPTER IX

GLOSSARY

Aquifer: The water saturated portions of a formation or group of formations that are capable of yielding water to a well in useful quantities.

Aquifer, confined: An aquifer contained between two aquitards. The water level in wells completed in confined aquifers, usually raises above the top of the aquifer.

Aquifer, unconfined: An aquifer that is not separated from land surface by an intervening aquitard.

Aquifer test: A test designed to determine the hydraulic characteristics of a aquifer. This is accomplished by pumping a well and monitoring the resultant drawdown with respect to time, in nearby observation wells.

Aquitard: A formation, group of formations, or part of a formation of lower hydraulic conductivity than surrounding aquifers. Aquitards may or may not be saturated and tend to inhibit the movement of water between aquifers.

Baseflow: That component of stream flow derived from ground-water discharge.

Cone of depression: The decline in total head around a well resulting from withdrawal of water from an aquifer.

Current meter: An instrument used to measure stream velocity.

Discharge area: Those areas of an aquifer where there are vertical components of hydraulic head in an upward direction.

Drawdown: Pumpage induced water level decline in a well.

Effective porosity: The interconnected spaces between particles in a porous medium through which water can move. Effective porosity is expressed as a percentage of total bulk volume.

Formation: An assemblage of earth materials that is grouped together into a unit that is convenient for description or mapping.

Hydraulic conductivity: An aquifers ability to transmit water. Hydraulic conductivity is expressed as the volume of water at the prevailing kinematic viscosity, that will move through a unit area of aquifer at right angles to the flow direction per unit hydraulic gradient per unit time.

Hydraulic gradient: The change in total head in an aquifer with respect to horizontal distance. Expressed as h/l where h is the difference in total measured head between two points in an aquifer that are separated by horizontal distance l.

Hydrograph: A plot of stream discharge or ground-water levels in a well with respect to time.

Hydrostatic pressure: The total pressure exerted by water at any given point within a non-moving water body.

Hydrostratigraphic unit: A formation, group of formations, or part of a formation which can be grouped into aquifers or confining layers based on similarities in hydrologic characteristics.

Observation well: A nonpumping well used to measure elevation changes in the water table or potentiometric surface resulting from ground-water withdrawal at a near by pumping well.

Piezometer: A short screened well installed to measure total hydrostatic pressure at a specific location and depth.

Porosity: The percentage of void space in a porous medium relative to the total volume of porous medium.

Potentiometric surface: An imaginary surface defined by plotting the measured water level elevations of wells completed in a confined aquifer. This concept is valid only for those aquifers that do not have large vertical gradients.

Recharge area: Those areas of an aquifer where there are vertical components of hydraulic head in a downward direction.

Recovery: The rise of water levels in a pumping or observation well that occurs after pumping ceases.

Saturated zone: That portion of the subsurface where all interconnected voids are filled with water.

Seepage velocity: The actual rate that water or other fluids move through a porous media.

Specific capacity: A measure of a wells production capacity defined as the yield rate per unit of drawdown. Specific capacity is usually expressed as gallons per minute per foot of drawdown.

Specific yield: The ratio of the volume of water that will drain from a porous medium under the influence of gravity, relative to the total volume of material.

Storativity: The volume of water released from or taken up by an aquifer, per unit area of aquifer per unit change in head.

Stream, gaining: A stream or stream reach which receives inflow from ground-water discharge.

Stream, losing: A stream or stream reach which discharges flow to ground-water.

Transmissivity: The rate that water of prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient. Transmissivity is equal to the aquifer hydraulic conductivity multiplied by aquifer thickness.

Transpiration: Water vapor transferred to the air through plants.

Unsaturated zone: That portion of the subsurface which contains both air and water.

Water budget: A conceptual evaluation of water movement in an aquifer or drainage basin with respect to water input vs water discharged from the system.

Water table: That level in the saturated zone where pressure is equal to atmospheric pressure.

Well, fully penetrating: A well that is screened or perforated across the full saturated thickness of an aquifer.

Well, partially penetrating: A well that is not screened or perforated across the full saturated thickness of an aquifer.

Well interference: The unacceptable decline in a wells water level resulting from pumpage of another well.

APPENDIX A

Well Driller Reports of

Materials Penetrated by Representative Wells

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)

Well 15N/02W-06E01 (THR164)

Dean Burkholder, Domestic supply, Altitude 196.85' MSL

Top soil and gravel	0	3
Gravel and Boulders	3	18
Hardpan	18	28
Clay and gravel, some water	28	48
Gravel and water	48	60

Casing 6-inch to 60 feet. Yields 50 gpm with 10 feet of drawdown after 4 hours. Static water level 15 feet on 02/18/75.

Well 15N/02W-06H01 (THR165)

John Mondor, Domestic supply, Altitude 208.97' MSL

Top soil	0	1
Sand and gravel	1	12
Cemented gravel	12	35
Sand	35	40
Cemented gravel	40	55
Sand and gravel	55	64

Casing 6-inch to 64 feet. Yields 16 gpm, little drawdown. Static water level 39 feet on 08/13/79. Drilled by A. A. Hoffman.

Well 15N/02W-06N01 (THR011)

Jack Scheuermann, Domestic supply, Altitude 194' MSL

Cobbles and gravel	0	22
Sand and gravel	22	31
Packed gravel	31	38
Gravel	38	67

Casing 6-inch to 67 feet. Yield 20 gpm with 3 feet of drawdown after 1 hour. Static water level 39 feet in 11/10/79. Drilled by William Anderson, Rochester.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 15N/03W-02G01 (THR162)		
Kalnoski, Domestic supply, Altitude 179' MSL		
Top soil	0	8
Cemented gravel	8	44
Yellow sand	44	48
Pea gravel	48	51
Gravel	51	57

Casing 6-inch to 57 feet. Drilled by Keto Drilling Co.

Materials	Thickness (Feet) (From)	(To)
Well 15N/03W-02R1 (THR003)		
Wa. State Department of Ecology, test well, Altitude 173.19' MSL		
Black top soil and sandy gravel	0	4
Tan silty coarse sand, gravel, and cobbles	4	8
Silty coarse sand, tight	8	9
Tan coarse sand and gravel, 3-inch minus	9	23
Tan coarse sand and gravel with cobbles	23	34
Clayey silt, sand and gravel, tight	34	37
Tan coarse sand and gravel	37	68
Tan-gray medium sand and gravel	68	76
Medium sand gravel and cobbles	76	85
Brown medium sand and gravel	85	92
Coarse sand gravel and cobbles	92	103
Claystone, soft with sandstone layers	103	145

Casing 6-inch to 106 feet. Two inch piezometers installed from 30-34', 64-68', and 94-99'.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 15N/03W-03A1 (THR044)		
Wa. State Department of Ecology, test well, Altitude 171.41′ MSL		
Black top soil	0	12
Brown -gray sandy gravel 3-inch minus	12	17
Tan-gray silty/sandy gravel	17	20
Tan silty sand and gravel, tight	20	33
Sandy medium to coarse gravel, with water	33	35
Silty/sandy large gravel and cobbles	35	49
Sandy medium to coarse gravel	49	63
Tan fine sand and gravel 1.5-inch minus	63	65
Sandy/silty coarse gravel	65	69
Sandy gravel 1-inch minus	69	73
Medium sand and large gravel	73	87
Fine sand and some gravel 1-inch minus	87	101
Red-brown fine sand with some gravel and coal fragments	101	112
Fine sand with clay binder and gravel	112	119
Coarse gravel with fine to medium sand	119	126
Brown siltstone	126	132

Casing 6-inch to 129 feet. Two inch piezometers installed from 49-52′, 80-85′, and 120-125′.

Well 15N/03W-03R01 (THR173)

Rochester water, Community domestic supply, Altitude 168′ MSL

Materials	From	To
Top soil	0	1
Black sand and gravel	1	4
Boulders, sand, and gravel	4	22
Coarse gravel and sand	22	40
Very fine pea gravel, with water	40	43
Coarse to fine gravel	43	48
Fine gravel and sand	48	50
Coarse to fine gravel, some sand	50	60
Hardpan	60	62
Coarse to fine gravel, some sand	62	73

Casing 8-inch to 73 feet. Perforated from 40-60 and 62-71 feet. Yields 350 gpm with 15 feet of drawdown after 24 hours. Static water level 33 feet on 08/26/72. Drilled by Jake Smith, Tenino.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 15N/03W-04B01 (THR174)		
Jim Smiley, Domestic supply, Altitude 158.56' MSL		
Top soil	0	2
Gravel and rocks	2	22
Sand	22	27
Consolidated conglomerate	27	36
Sand and silt	36	42
Gravel and sand	42	54
Fine to coarse gravel, water bearing	54	57

Casing 6-inch to 56 feet. Yields 20 gpm with little drawdown after 1 hour. Static water level 34 feet on 11/11/75. Drilled by A. A. Hoffman, Oakville.

Well 15N/03W-04Q01 (THR158)

De'Aquiar, Domestic supply, Altitude 150.44' MSL

Materials	Thickness (Feet) (From)	(To)
Top soil	0	2
Yellow and brown sand and gravel	2	28
Yellow and gray sand	28	44
Gravel, water bearing	44	47
Gravel and sand	47	50

Casing 6-inch to 50 feet. Yield 100 gpm. Static water level 28 feet on 09/11/49. Drilled by C. F. King

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)

Well 15N/03W-05N1 (THR002)

Wa. State Department of Ecology, test well, Altitude 117.54' MSL

Black top soil	0	2
Red-black topsoil with clay	2	4
Brown till	4	6
Tan till	6	13
Sand and gravel with cobbles, loose, water at 17 feet	13	28
Silty sand, gravel, and cobbles	28	37
Coarse sand and gravel, loose	37	54
Silty sand and gravel, tight	54	76
Medium coarse sand and some gravel	76	79
Gray siltstone with sandstone streaks	79	86

Casing 6-inch to 67 feet.

Well 15N/03W-05P01 (THR025)

George Holm, Domestic supply, Altitude 140.80' MSL

Top soil	0	4
Rock and gravel	4	15
Sand gravel and water	15	48
Gravel and water	48	51

Casing 6-inch to 51 feet. Yield 20 gpm with 4 feet of drawdown after 2 hours. Static water level 20 feet on 02/23/77. Drilled by Anderson Drilling, Rochester.

Well 15N/03W-06A02 (THR175)

Rochester water, Community domestic supply, Altitude 135.39' MSL

Sand and gravel	0	7
Yellow cemented gravel with clay	7	47
Sand and gravel, some water	47	54
Sand, coarse gravel with water	54	70

Casing 10-inch to 71 feet. Screened slot size 60 from 55-70 feet. Yields 265 gpm with 2 feet of drawdown after 12.5 hours. Drilled by Williams drilling Co., Toledo.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 15N/03W-09F03 (THR035)		
Gene White, Dairy operation, Altitude 147.33' MSL		
Sand and gravel	0	30
Sandy gravel	30	52
Gravel and sand	52	63
Sandy gravel	63	74
Gravel and sand	74	80+

Casing 8-inch to 81 feet. Perforated from 55-60 and 75-78. Yield 90 gpm with 2 feet of drawdown after 0.5 hours. Static water level 25.5 feet on 06/01/70. Drilled by King Drilling Co. Centralia.

Well 15N/03W-10D1 (THR048)

Wa. State Department of Ecology, test well, Altitude 158' MSL

Materials	From	To
Top soil with gravel and boulders	0	4
Tan silty sand, gravel, boulders, tight	4	13
Silty sand and gravel 2-inch minus, tight	13	27
Sandy gravel 2-inch minus	27	31
Clayey silt, sand, and gravel	31	37
Coarse sand, gravel, and cobbles water at 37 feet	37	68
Medium sand, coarse gravel and cobbles	68	80
Medium sand and gravel coarse	80	100
Brown-gray clay with coal seams	100	112
Tan-gray soft shale	112	120

Casing 6-inch to 115 feet.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 15N/03W-14R01 (THR179)		
Ralph Strong, Irrigation, Altitude 155' MSL		
Top soil, sandy gravelly silt	0	16
Cemented gravel	16	42
Sandy gravel and water	46	56
Sand and water	56	59
Gravel	59	62

Casing 6-inch to 62 feet. Yields 50 gpm with 10 feet of drawdown after 2 hours. Static water level 22 feet on 07/27/65. Drilled by Lymon Mowrey.

Well 15N/04W-01A01 (THR029)

Marvin Isaacson, Domestic supply, Altitude 115.93' MSL

Top soil	0	7
Sandy gravel	7	22
Fine sand	22	35
Sandy gravel	35	42

Casing 6-inch to 42 feet. Yields 24 gpm with little drawdown. Static water level 17 feet on 08/10/76. Drilled by A. A. Hoffman.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 15N/04W-01D01 (THR026)		
Wa. State Department of Ecology, test well, Altitude 110.71' MSL		
Fill dirt and logs	0	6
Dark brown clay	6	9
Tan clay bound sand, gravel, and cobbles	9	13
Tan sand, gravel and some cobbles	13	20
Tan sand and gravel, loose	20	25
Tan silty sand and gravel	25	29
Reddish brown sandy gravel, water at 31'	29	36
Medium sandy gravel, tight	36	57
Coarse sandy gravel w/cobbles, loose	57	69
Very tight sandy gravel and cobbles	69	84
Medium coarse sand and large gravel	84	93
Coarse sand and large gravel	93	117
Dark gray shale, soft	117	136

Casing 6-inch to 106 feet. Two inch piezometers installed from 25-30', 60-65', and 99-104'.

Materials	Thickness (Feet) (From)	(To)
Well 15N/04W-10G02 (THR057)		
Emil Carlson, Irrigation, Altitude 102.61' MSL		
Top soil	0	6
Hardpan	6	17
Water bearing gravel	17	26

Casing 8-inch to 26 feet. Yields 216 gpm with 1 foot of drawdown. Static water level 8 feet on 06/10/58.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 15N/04W-12D01		
Pat Moore, irrigation, Altitude 100' MSL		
Brown clay	0	2
Brown gravel and clay	2	40
Brown silty sand, some gravel, water	40	42
Green clay, with gravel and sand, seepage	42	50
Gray gravel and sand, water	50	52
Green clay, with gravel and sand, seepage	52	58
Green clay, dry	58	83
Gray sand and silt with clam shells	83	85
Gravel, water	85	86
Clay and sand, dry	86	88
Shale	88	?

Casing 8-inch to 52 feet. Yield 75 gallons per minute with 7 feet of drawdown.

Well 16N/02W-19R01 (THR058)

Monte Visa Poultry, Poultry production, Altitude 220.32' MSL

Top soil and gravel	0	3
Cemented gravel with yellow clay	3	39
Gravel and sand, water bearing	39	41
Yellow clay with gravel	41	54
Gravel and sand, water bearing	54	65
Coarse gray sand	65	67
Large gravel and coarse sand	67	78

Casing 8-inch to 68 feet. Screened slot size 25 from 68-78 feet. Yield 200 gpm with 30 feet of drawdown after 1 hour. Static water level 32 feet on 07/25/79. Drilled by Williams well drilling, Toledo.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/02W-26M		
Dandar Farms, irrigation well		
Top soil	0	2
Cemented gravel and boulders	2	10
Cemented gravel, some water at 55'	10	58
Sand and gravel, water bearing	58	62
Gray basalt	62	143
Gray-blue sandy clay	143	195
Gray shale	195	202

Casing 10-inch to 62 feet. Perforated from 56 to 61 feet. Yield: 25 gpm with 35 feet of drawdown after 1 hour.

Well 16N/02W-27G01 (THR059)

Mark Butler, Domestic supply, Altitude 260' MSL

Materials	From	To
Top soil and cobbles	0	3
Cobbles and gravel	3	22
Gravel	22	43

Casing 6-inch to 43 feet. Yields 20 gpm with 1 foot of drawdown after 2 hours. Static water level 19 feet on 03/14/80. Drilled by Anderson Drilling, Rochester.

Well 16N/02W-29L01 (THR066)

John P. Sweeney, Domestic supply, Altitude 218' MSL

Materials	From	To
Top soil	0	2
Cobbles and dirty gravel	2	39
Sandy gravel	39	50
Gravel, water bearing	50	80

Casing 8-inch to 80 feet. Perforated from 50-70 feet. Yields 400 gpm with 4 feet of drawdown after 2 hours. Static water level 28 feet in 05/77. Constructed by Grady Strawn, Tenino.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/02W-29L2 (THR004)		
Wa. State Department of Ecology, test well, Altitude 217.65′ MSL		
Brown top soil and gravel	0	4
Brown gravel	4	7
Tan coarse sandy gravel with cobbles and boulders	7	26
Tan sandy coarse gravel, loose	26	32
Tan sandy gravel and cobbles, tight	32	43
Reddish brown sandy gravel, loose	43	45
Tan silty sandy coarse gravel	45	56
Brown-gray coarse sand with large gravel	56	66
Medium to coarse sand	66	74
Sandy large gravel with cobbles	74	88
Silty coarse sand with gravel, tight	88	99
Medium to coarse sand	99	104
Silty medium to coarse sand, tight	104	118
Medium sand	118	124
Gray graveley clay	124	127
Tan-gray siltstone	127	134
Gravel, water bearing	134	135
Gray siltstone	135	148

Casing 6-inch to 107 feet. Yield 249 gpm with 10.8 feet of drawdown after 4 hours. Two inch piezometers installed from 41-48′, 74-82′, and 103-108′.

Well 16N/02W-30F01 (THR177)

Ernest Perkins, Domestic supply, Altitude 210′ MSL

Top soil	0	2
Black clay and gravel, very hard	2	33
Gravel and sand, water bearing	33	39
Gravel and clay, hard	39	50
Gravel and sand, water bearing	50	57

Casing 6 inch to 57 feet. Yields 80 gpm with 25 feet of drawdown after 1 hour. Static water level 23 feet on 06/22/76. Drilled by Art Merzonian.

Materials Penetrated by Representative Wells

Materials	Thickness (From)	(Feet) (To)
Well 16N/02W-31B01 (THR070)		
Bob Workman, Domestic supply, Altitude 205' MSL		
Top soil and rocks	0	2
Tan/yellow sand and gravel lightly cemented	2	49

Casing 6-inch to 49 feet. Yields 20 gpm with 3 feet of drawdown after 1 hour. Static water level 29 feet on 09/04/73.

Materials	Thickness (From)	(Feet) (To)
Well 16N/02W-31L01 (THR073)		
H. D. Maze, Domestic supply, Altitude 203.93' MSL		
Top soil	0	5
Gravel	5	25
Hardpan	25	35
Sand and gravel	35	66

Casing 8-inch to 66 feet. Perforated from 50-62. Yields 150 gpm with 2 feet of drawdown. Static water level 25 feet on 05/22/50. Drilled by Oliver Erdman, Elma.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/02W-31N1 (THR008)		
Wa. State Department of Ecology, test well, Altitude 191.17′ MSL		
Dark brown sandy coarse gravel	0	3
Brown sandy coarse gravel and cobbles	3	6
Tan silty, sandy coarse gravel with cobbles and boulders	6	26
Tan silty gravel to 3 inch	26	39
Tan medium sand with gravel and cobbles	39	68
Coarse sand and gravel with cobbles	68	82
Coarse sand	82	84
Red brown gravelly coarse sand	84	98
Red brown silty medium sand with gravel and orange clay	98	103
Coarse sandy gravel, 2 inch minus	103	113
Gray claystone with shale layers	113	122

Casing 6-inch to 119 feet. Two inch piezometers installed from 31-35′, 71-75′, and 107-110′.

Materials	Thickness (Feet) (From)	(To)
Well 16N/02W-31Q01 (THR074)		
E. F. Parkhurst, Domestic supply, Altitude 198.36′ MSL		
Previous well unknown construction	0	45
Sand and gravel lightly cemented, water	45	72

Casing 8-inch to 72 feet. Perforated from 49-69 feet. Yields 240 gpm. Drilled by K & M Drilling Co., Centralia.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/02W-32A01 (THR075)		
Jay Agnew, Irrigation, Altitude 226.31' MSL		
Boulders and gravel	0	15
Brown sand	15	29
Sand with some gravel	29	32
Cemented gravel	32	48
Sand, water bearing	48	51
Sand with some gravel, water bearing	51	64
Coarse sand and gravel, water bearing	64	78
Gravel and sand, water bearing	78	81
Sand with some gravel	81	83

Casing 12-inch to 83 feet. Perforated from 64-77 feet. Yields 750 gpm with 18 feet of drawdown. Static water level 38 feet on 11/28/56. Drilled by C. D. Roberts, Chehalis.

Well 16N/02W-32A02

Winters Dairy, Domestic supply , Altitude 228' MSL

Materials	From	To
Top soil and gravel	0	2
Boulders and gravel	2	12
Hardpan and boulders	12	58
Sand and gravel, some water	58	61
Gravel, clay and boulders	61	78
Gravel and water	78	85
Gravel and clay	85	88

Casing 6-inch to 80 feet. Yield 60 gpm. Static water level 42 feet on 09/18/89.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/02W-32B01 (THR076)		
Jay Agnew, Irrigation, Altitude 228.43' MSL		
Top soil and boulders	0	2
Cemented gravel and boulders	2	33
Cemented gravel	33	38
Cemented sand and gravel, water bearing	38	55
Sand and gravel, water bearing	55	66
Sand, water bearing	66	85
Sand and gravel, water bearing	85	129

Casing 12-inch to 129 feet. Perforated from 90-126. Yields 850 gpm with 14 feet of drawdown after 4.5 hours. Static water level 33 feet on 04/28/77. Drilled by Kenneth Witham.

Well 16N/02W-32E

Seafarm of Washington, aquaculture, Altitude 203' MSL

Materials	From	To
Black top soil and gravel	0	2
Brown gravel and boulders, some clay	2	28
Sand, gravel and water	28	39
Sand, gravel and clay	39	43
Sand and gravel	43	48
Sand, gravel and clay	48	52
Sand, gravel and water	52	89
Gray sandstone	89	90

Casing 16-inch to 52 feet. Screened slot size 150 from 52 to 89 feet. Yield 2150 gpm with 15 feet of drawdown after 24 hours.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/02W-32F01 (THR078)		
Robert Thomson, Irrigation, Altitude 213.62' MSL		
Top soil	0	6
Clay, gravel and boulders	6	19
Gravel and clay	19	31
Gravel, sand and clay, water bearing	31	48
Dirty clay and gravel	48	58
Sand and gravel, some water	58	61
Sand, gravel and clay	61	78
Sand and gravel, water bearing	78	80

Casing 8-inch to 80 feet. Perforated from 30-40 feet. Yields 155 feet with little drawdown. Static water level 28 feet on 09/17/52. Drilled by L. B. Richardson, Tacoma.

Well 16N/02W-32Q01 (THR186)

Oramel Wilkins, Domestic supply, Altitude 209.19' MSL

Materials	From	To
Top soil	0	3
Cobbles and gravel	3	17
Sand and gravel	17	45
Blue clay	45	68

Casing 6 inch to 62 feet. Perforated from 38-42 feet. Yields 20 gpm with 17 feet of drawdown after 2 hours. Static water level 19 feet on 09/30/77. Drilled by William Anderson, Rochester.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)

Well 16N/02W-33E01 (THR121)

S. J. Agnew, Irrigation, Altitude 231.48' MSL

Top soil and large gravel	0	3
Clay and boulders	3	20
Hardpan	20	32
Coarse gravel, with sand and clay	32	40
Coarse sand, loose gravel	40	43
Coarse sand, with gravel and clay	43	58
Sand and gravel	58	62
Coarse sand and gravel, some clay	62	70
Coarse sand and gravel	70	73
Sand and gravel, with some clay	73	75
Clay and gravel	75	85

Casing 12-inch to 85 feet. Perforated from 30-37 and 45-55 feet. Yields 370 gpm with 13 feet of drawdown. Static water level 25 feet on 01/06/51. Drilled by L. B. Richardson, Tacoma.

Well 16N/03W-16K03 (THR089)

Weyerhaeuser Co., Domestic supply, Altitude 140' MSL

Sand	0	27
Sand and gravel	27	60
Coarse sand and gravel	60	78

Casing 6-inch to 74 feet. Screened slot size 40 from 73-78 feet. Yields 33 gpm with little drawdown. Static water level 47 feet on 10/03/72. Drilled by M. B. Patterson.

Well 16N/03W-27D01 (THR092)

Frank Lemmon, Domestic supply, Altitude 160.78' MSL

Cobbles and gravel	0	23
Gravel and sand	23	47
Hardpan	47	54
Gravel	54	92

Casing 6-inch to 92 feet. Yields 20 gpm with 6 feet of drawdown after 1 hour. Static water level 65 feet on 12/22/79. Drilled by William Anderson, Rochester.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/03W-29L2 (THR018)		
Wa. State Department of Ecology, test well, Altitude 135.99′ MSL		
Black top soil and gravel	0	4
Dark brown soil and sandy gravel	4	6
Tan clay bound sand and gravel	6	9
Tan silty sand and gravel, loose	9	11
Tan silty sand and gravel, tight	11	15
Tan sand and gravel	15	18
Tan silty sand and gravel, tight	18	24
Tan silty sand, some gravel, very tight	24	28
Tan sand and gravel, loose	28	47
Fine sand and gravel, water at 47′	47	53
Medium sand and gravel	53	62
Coarse sand and gravel with cobbles	62	73
Medium sand and gravel - 2" minus	73	89
Coarse sand and gravel - 2" minus	89	113
Medium sand and gravel	113	118
Dark gray shale, hard	118	126

Casing 6-inch to 111 feet. Two inch piezometers installed from 45-49′, 72-76′, and 98-103′.

Materials	Thickness (Feet) (From)	(To)
Well 16N/03W-30R03 (THR096)		
Daniel Swecker, Aquaculture, Altitude 134.05′ MSL		
Top soil	0	2
Cemented gravel	2	37
Cemented coarse sand and gravel, water	37	46
Coarse sand and gravel, water bearing	46	72
Packed sand	72	76
Coarse sand and gravel	76	100

Casing 12-inch to 100 feet. Perforated from 78-98 feet. Yields 600 gpm. Static water level 31 feet in 12/75. Drilled by Roberts Well Drilling, Chehalis.

Materials Penetrated by Representative Wells

Materials	Thickness (From)	(Feet) (To)
Well 16N/03W-32E01 (THR102)		
Robert L. Nichols, Irrigation, Altitude 144.22' MSL		
Top soil	0	5
Cemented gravel	5	45
Cemented gravel and sand	45	62
Coarse gravel and sand, water bearing	62	64
Fine sand and small boulders	64	75
Coarse sand with some gravel	75	80
Brown sand	80	87
Sand with some gravel	87	90
Coarse gravel, water bearing	90	93

Casing 12-inch to 93 feet. Perforated from 60-65 and 75-78. Yields 600 gpm with 18 feet of drawdown after 4 hours. Static water level 42 feet on 05/18/62. Drilled by C. D. Roberts, Chehalis.

Materials	Thickness (From)	(Feet) (To)
Well 16N/03W-33C01 (THR104)		
Adolph Rotter, Irrigation, Altitude 158.11' MSL		
Clay, sand and Boulders	0	18
Cemented gravel	18	41
Sand and gravel	41	51
Cemented gravel	51	82
Sand, heaving	82	104
Sand and gravel, water bearing	104	128
Gravel, water bearing	128	133

Casing 8-inch to 133 feet. Yields 50 gpm with 20 feet of drawdown after 2 hours. Drilled by Lyman Mowrey, Chehalis.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/03W-33G03 (THR105)		
Rochester Water, Community Domestic supply, Altitude 163' MSL		
Top soil	0	2
Boulders with clay binder	2	16
Gravel with clay binder	16	51
Yellow sand	51	52
Gravel and sand, water bearing	52	61
Gravel with yellow clay binder	61	70
Black sand, water bearing	70	72
Gravel and coarse sand, water bearing	72	77

Casing 8-inch to 73 feet. Screened slot size 25 from 73-77 feet. Yields 125 gpm with 14 feet of drawdown after 4 hours. Static water level 34 feet on 03/24/75. Well drilled by Willie Williams, Toledo.

Well 16N/03W-33M01 (THR014)

Rochester water, Community domestic supply, Altitude 154' MSL

Top soil	0	3
Sand and gravel	3	25
Cemented sand and gravel	25	59
Sand and gravel, water bearing	59	65
Gravel, water bearing	65	70

Casing 8-inch to 70 feet. Yields 50 gpm with little drawdown. Drilled by Terry Gavin, Chehalis.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/03W-33P1 (THR015)		
Wa. State Department of Ecology, test well, Altitude 158.84' MSL		
Black gravel and top soil	0	4
Tan silty to graveley cobbles	4	6
Tan-gray silty to graveley cobbles	6	9
Tan silty to sandy gravel	9	13
Tan-gray silty to sandy gravel with cobbles, tight	13	17
Gravel, loose	17	19
Silty gravel with cobbles, very tight	19	24
Silty-sandy gravel	24	29
Silty-sandy gravel and cobbles, tight	29	41
Sandy graveley silt, very tight	41	46
Silty sand and coarse gravel, loose	46	58
Brown sand and gravel 4-inch minus	58	75
Beige silty clay and large gravel	75	79
Red oxidized sand coarse, with gravel and cobbles	79	84
Tan-gray sandy coarse gravel	84	91
Graveley 3-inch minus, very fine sand	91	94
Mudstone, dark gray shale, soft	94	105

Casing 6-inch to 98 feet. Two inch piezometers installed from 43-46', 64-70', and 88-93'.

Well 16N/03W-36

Domsea Farms, Aquaculture,

Black top soil	0	2
Brown sand and gravel with cobbles	2	36
Brown sand and gravel	36	56
Sand and large gravel, water bearing	56	101

Casing 16-inch to 101 feet. Yield 2,460 gpm with 15.6 feet of drawdown after 24 hours. Screened, slot size 125 from 67-101 feet.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/03W-36G02 (THR112)		
Domsea Farms, Inc., Aquaculture, Altitude 191.98′ MSL		
Top soil	0	2
Compact gravel	2	35
Sand and gravel	35	73
Compact sand and gravel	73	75
Sand and gravel, medium to large	75	99

Casing 16-inch to 69 feet. Screened slot size 150 from 69-99 feet. Drilled by George Burt, Poulsbo.

Materials	From	To
Well 16N/03W-36H05 (THR117)		
Mike Carlson, Domestic supply, Altitude 193.48′ MSL		
Top soil	0	2
Gravel and sand	2	49

Casing 6-inch to 49 feet. Yields 40 gpm with 15 feet of drawdown after 1 hour. Static water level 9 feet on 04/18/78. Drilled by Edwin C. King.

Materials	From	To
Well 16N/03W-36J02 (THR119)		
Domsea farms Inc., Aquaculture, Altitude 199.82′ MSL		
Brown top soil	0	4
Brown silt	4	8
Sand and gravel with clay	8	24
Sand and gravel, to 2 inch	24	42
Compact sand and gravel	42	51
Brown sand and gravel, with silt and clay	51	99
Loose brown sand and gravel	99	108
Blue gray clay bound sand and gravel	108	118
Brown silty shale	118	138

Casing 8-inch to 138 feet. Perforated from 60-108 feet. Yields 584 gpm with 9 feet of drawdown after 3 hours. Static water level 33 feet on 12/15/76. Drilled by Storey-Armstrong Drilling, Puyallup.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/03W-36J03 (THR120)		
Domsea farms Inc., Aquaculture, Altitude 200.54' MSL		
Dark clay bound sand, gravel, and cobbles	0	20
Gravel and sand	20	43
Clay bound gravel, layered with loose sand and gravel	43	63
Large gravel with some sand	63	94
Large gravel with some sand, lose	94	105
Silty shale	105	108

Casing 16-inch to 68 feet. Screened slot size 150 from 68-99 feet. Yields 1440 gpm with 38 feet of drawdown after 2.5 hours. Static water level 31 feet on 01/07/77. Drilled by Storey-Armstrong Drilling Co., Puyallup.

Well 16N/03W-36K01 (THR122)

Domsea farms, Inc., Aquaculture, Altitude 197.51' MSL

Top soil	0	3
Boulders	3	9
Sandy hardpan	9	20
Sand and gravel	20	36
Gravel and boulders	36	62
Sand and gravel, water bearing	62	107
Blue hardpan	107	108
Blue clay	108	109

Casing 16-inch to 60 feet. Screened slot size 250 from 60-109. Yields 1420 gpm with 30 feet of drawdown after 6 hours. Static water level 17 feet on 11/29/77. Drilled by George Burt.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/04W-25J		
Global Aqua, aquaculture, Altitude 105′ MSL		
Soil	0	2
Brown sand and gravel	2	25
Gray sand and gravel	25	90
Sand and gravel with gray clay chunks	90	155
Blue siltstone	155	157

Casing 16-inch to 114 feet. Screened with slot size 150 from 114 to 154 feet. Yield 3,000 gpm.

Materials	Thickness (Feet) (From)	(To)
Well 16N/04W-25K01 (THR129)		
Domsea farms Inc., Aquaculture, Altitude 120.87′ MSL		
Gravel	0	3
Gravel, hardpan	3	7
Gravel	7	12
Brown hardpan	12	38
Medium gravel, water bearing	38	52
Sand and gravel	52	83
Fine sand and gravel	83	89
Cobbles and gravel	89	93
Large gravel	93	105
Compact sand and gravel	105	106
Medium sand and gravel	106	110
Fine sand and gravel	110	116
Clay and cobbles	116	122
Medium gravel and sand	122	128
Medium to large gravel	128	152

Casing 16-inch to 107 feet. Screened slot size 150 from 106 to 152. Static water level 25.4 feet on 06/26/78. Drilled by George D. Burt.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/04W-25K02 (THR130)		
Domsea farms Inc., Aquaculture, Altitude 119.96′ MSL		
Brown coarse gravel with fine to medium sand, silty matrix	0	39
Gravel, water bearing	39	57
Sandy gravel, silty	57	100
Poorly sorted sand and gravel	100	127
Small gravel with coarse to medium sand	127	142
Medium coarse clean sand	142	146

Casing 16-inch to 109. Screened slot size 30 from 111-129 and slot size 100 from 129-142. Drilled by George D. Burt, Poulsbo.

Well 16N/04W-25L01 (THR131)

Ben Owen, Domestic supply, Altitude 120.38′ MSL

Materials	Thickness (Feet) (From)	(To)
Mixed gravel	0	35
Sand	35	49
Cemented sand	49	51
Mixed gravel	51	53

Casing 6-inch to 53 feet. Yield 16 gpm with little drawdown. Static water level 23 feet on 02/23/80. Drilled by A. A. Hoffman, Oakville.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/04W-25Q01 (THR133)		
Domsea farms Inc., Aquaculture, Altitude 119.88' MSL		
Brown cemented gravel, fine to medium sand with silt	0	16
Brown sand and gravel	16	18
Brown sand and gravel, with clay	18	25
Brown compact sand and gravel	25	36
Brown sand and gravel	36	74
Redish brown sand and gravel	74	80
Gray sand and gravel	80	90
Poorly sorted brown sand and gravel	90	119
Gravel with medium to coarse brown sand	119	160
Sand and gravel with clay	160	161

Casing 16-inch to 115 feet. Screened slot size 100 from 115-130 and slot size 150 from 135-150. Drilled by George D. Burt, Poulsbo.

Well 16N/04W-25Q02 (THR134)

Domsea farms Inc., Aquaculture, Altitude 117.91' MSL

Brown sand and gravel	0	10
Silty sand and gravel	10	16
Orange-brown sand and gravel	16	100
Brown silty sand and gravel	100	101
Brown coarse sand and gravel	101	150
Brown medium sand and gravel	150	153
Brown coarse sand and gravel	153	156
Brown poorly sorted silty fine sand and gravel	156	160

Casing 16-inch to 110 feet. Screened from 110-146 feet.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/04W-26K01 (THR137)		
Briarwood farms, Poultry production, Altitude 119.48' MSL		
Gravel, lose, fine to coarse	0	30
Sand and gravel	30	40
Sand and cobbles	40	63
Gravel and sand	63	65
Sand with some cobbles	65	92
Sand and Gravel, clean	92	102
Blue clay	102	?

Casing 8-inch to 102 feet. Perforated from 94-101 feet. Yield 90 gpm with 1 foot of drawdown after 1 hour. Static water level 35 feet in 06/71. Drilled by Edwin C. King, Centralia.

Well 16N/04W-34R01

Black River Turf Farm, irrigation, Altitude 100'MSL

Materials	From	To
Yellow silty top soil	0	16
Yellow silty sand and gravel	16	80
Gray sand and gravel	80	133
Gray siltstone, hard	133	?

Casing 10-inch to 107 feet. Screened slot size 50 from 107 to 133. Yield 1000 gpm. Static water level 19 feet on 06/13/89.

Materials Penetrated by Representative Wells

Materials	Thickness (Feet) (From)	(To)
Well 16N/04W-35P01 (THR065)		
Earl H. Voekel, Irrigation, Altitude 100.37' MSL		
Clay	0	6
Gravelly clay	6	15
Cemented gravel	15	28
Sand and gravel, water bearing	28	47
Compact sand, water bearing	47	73
Sand and gravel	73	79
Sandy gravel, water bearing	79	88
Sand, water bearing	88	93
Cemented gravel	93	104
Sand and gravel, heaving	104	112

Casing 10-inch to 112 feet. Perforated from 105-112. Static water level 18 feet in 02/69. Drilled by Lyman Mowrey, Chehalis.

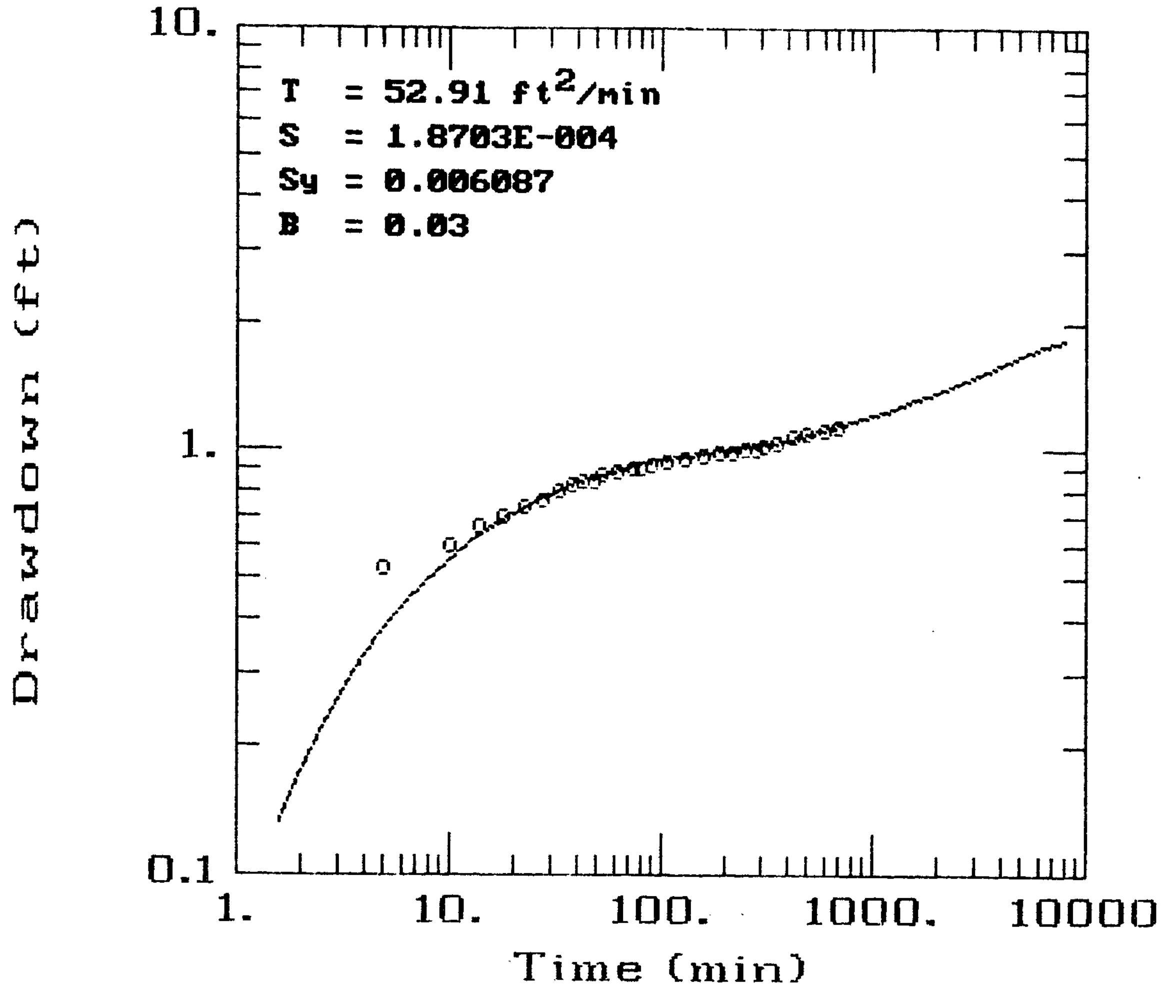
Materials	Thickness (Feet) (From)	(To)
Well 16N/04W-36M01 (THR144)		
Briarwood farms, Poultry production, Altitude 107.53' MSL		
Top soil and clay	0	4
Sand and gravel with boulders	4	45
Gravel and sand	45	62

Casing 8-inch to 62 feet. Perforated from 38-46 and 52-61 feet. Static water level 15 feet on 09/13/69. Drilled by Edwin C. King, Centralia.

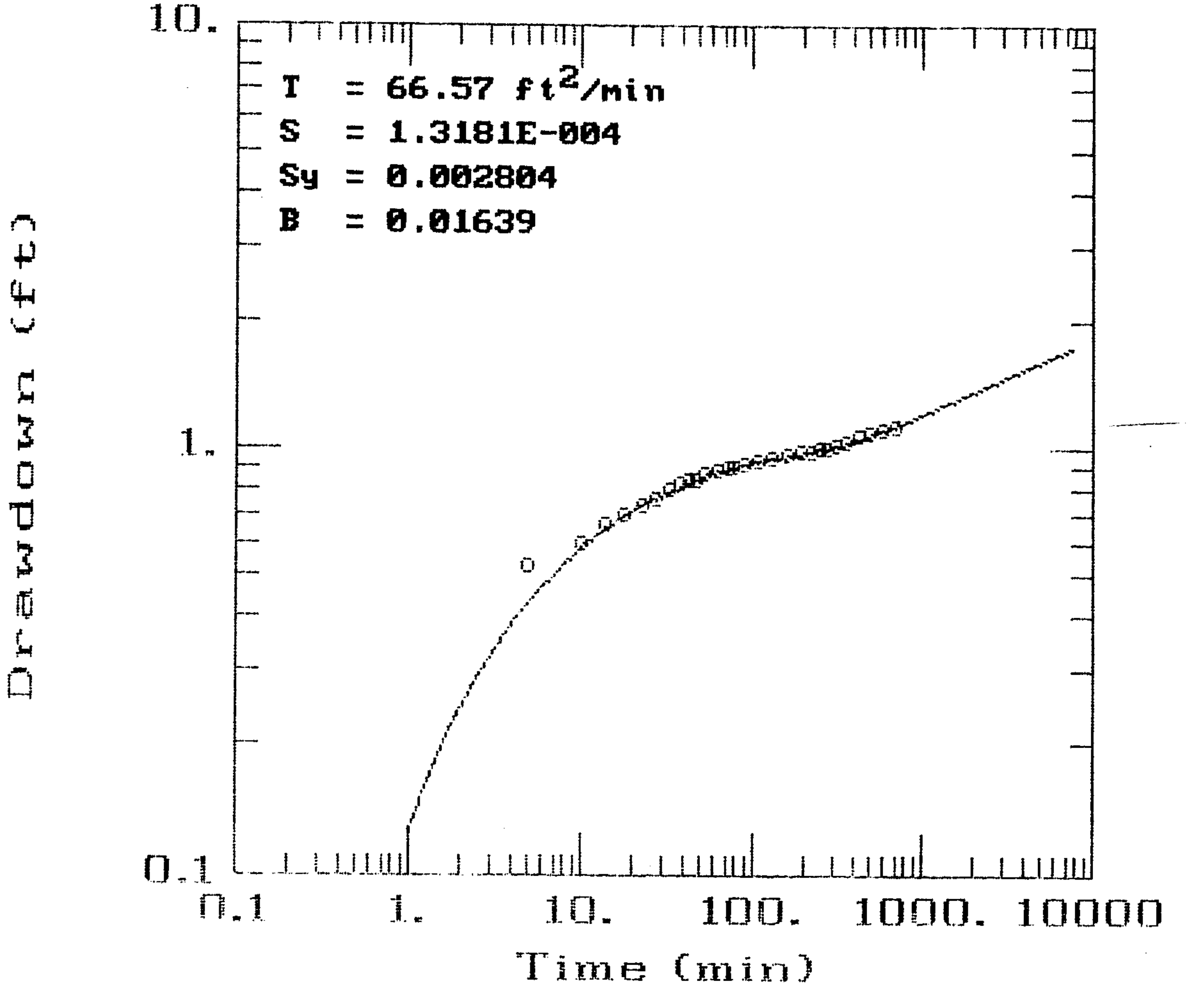
APPENDIX B

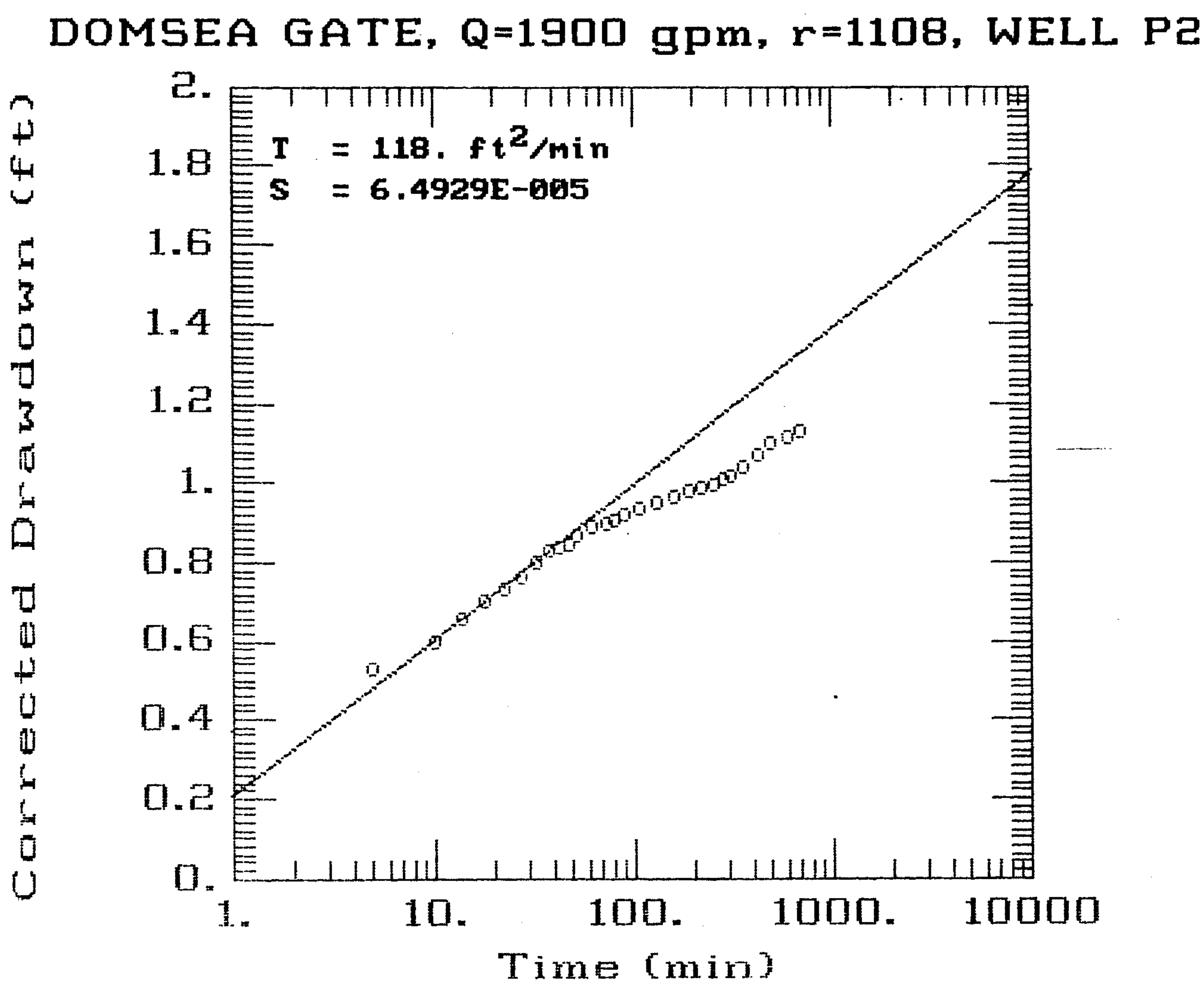
Aquifer Test Data Plots

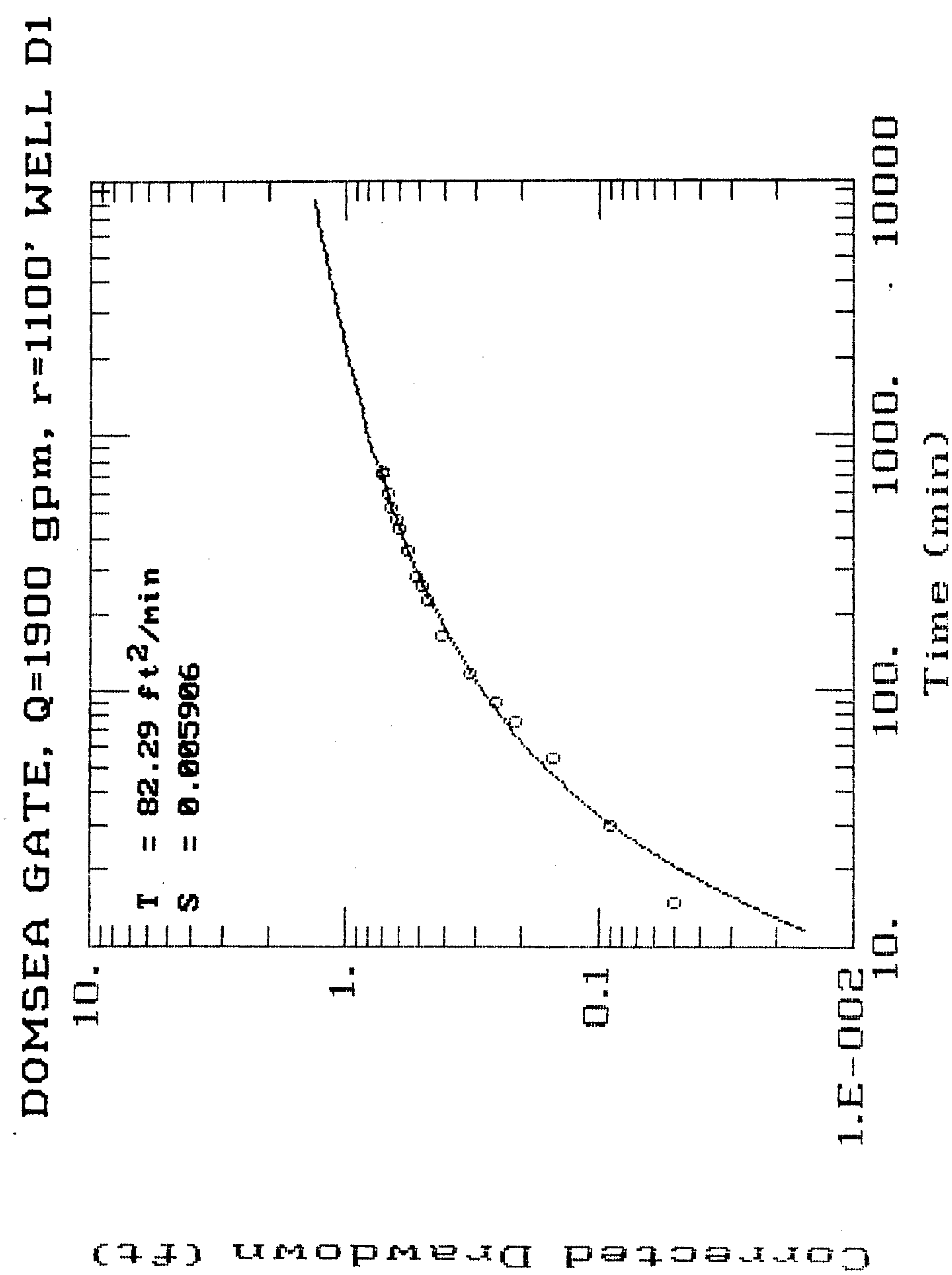
DOMSEA GATE, Q=1900 gpm, r=1108, WELL P2

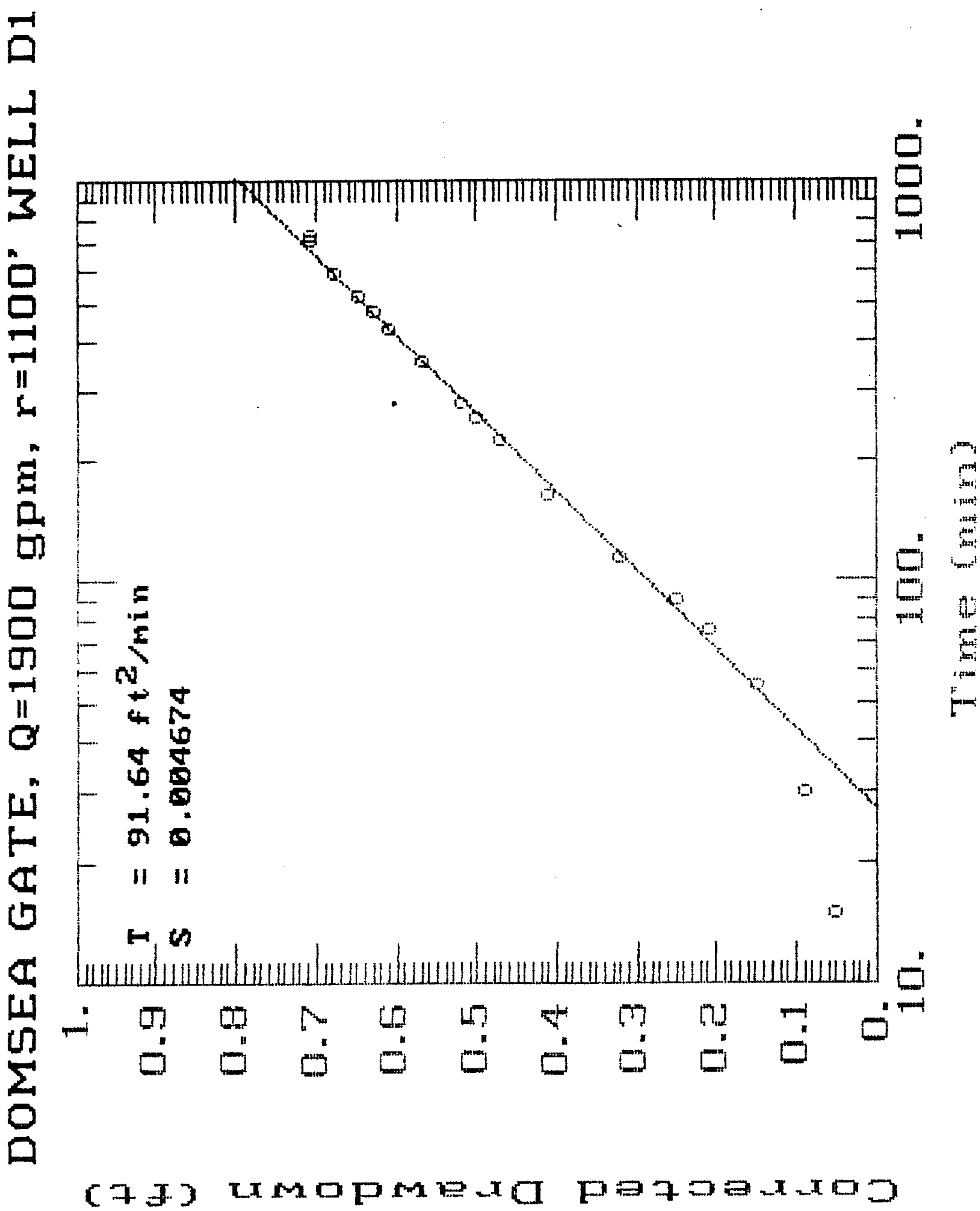


DOMSEA GATE, Q=1900 gpm, r=1108, WELL P2



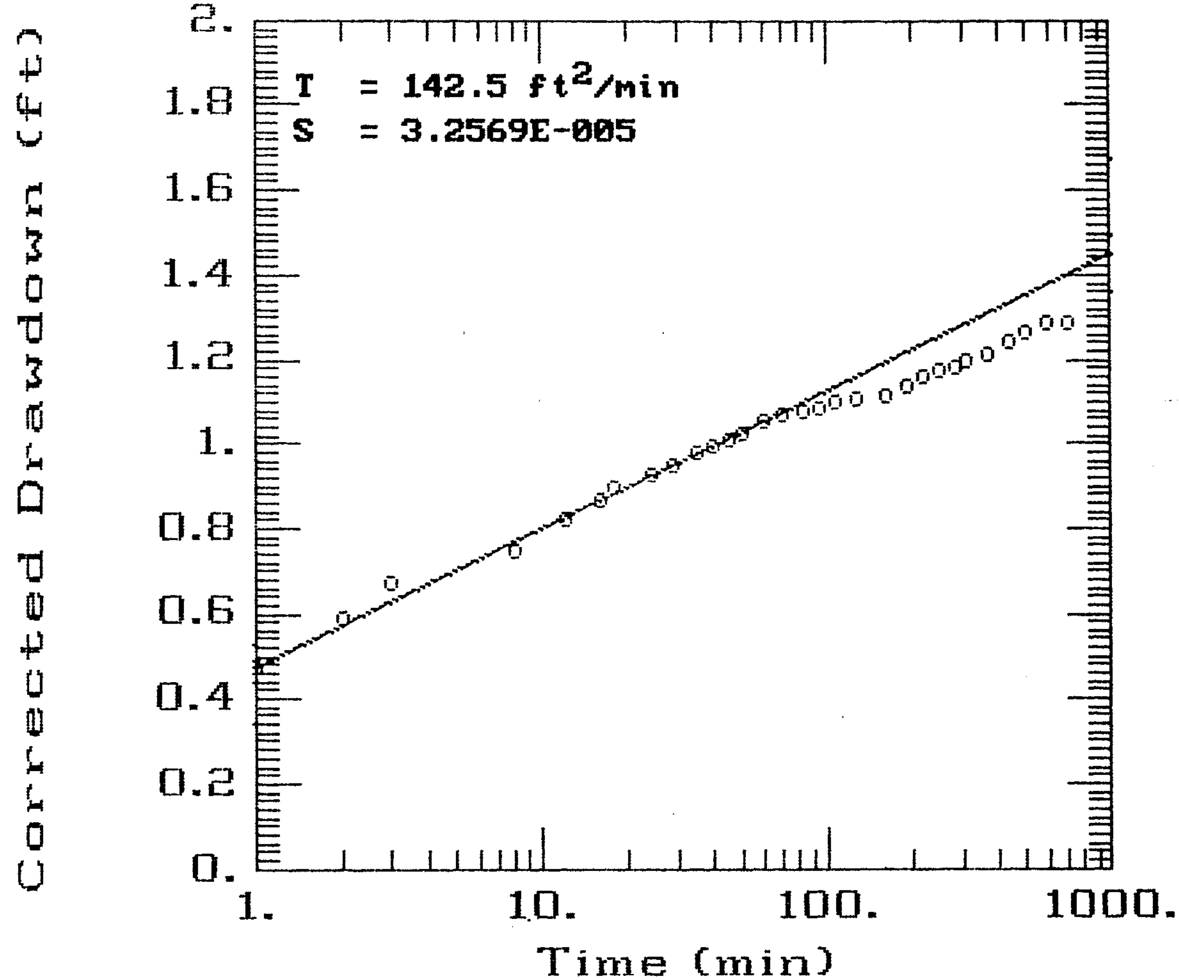

DOMSEA GATE, Q=1900 gpm, r=1108, WELL P2
T = 118. ft2/min
S = 6.4929E-005
2.
1.8
1.6
1.4
1.2
1.
0.8
0.6
0.4
0.2
0.
1.
10.
100.
1000.
10000
Time (min)
Corrected Drawdown (ft)

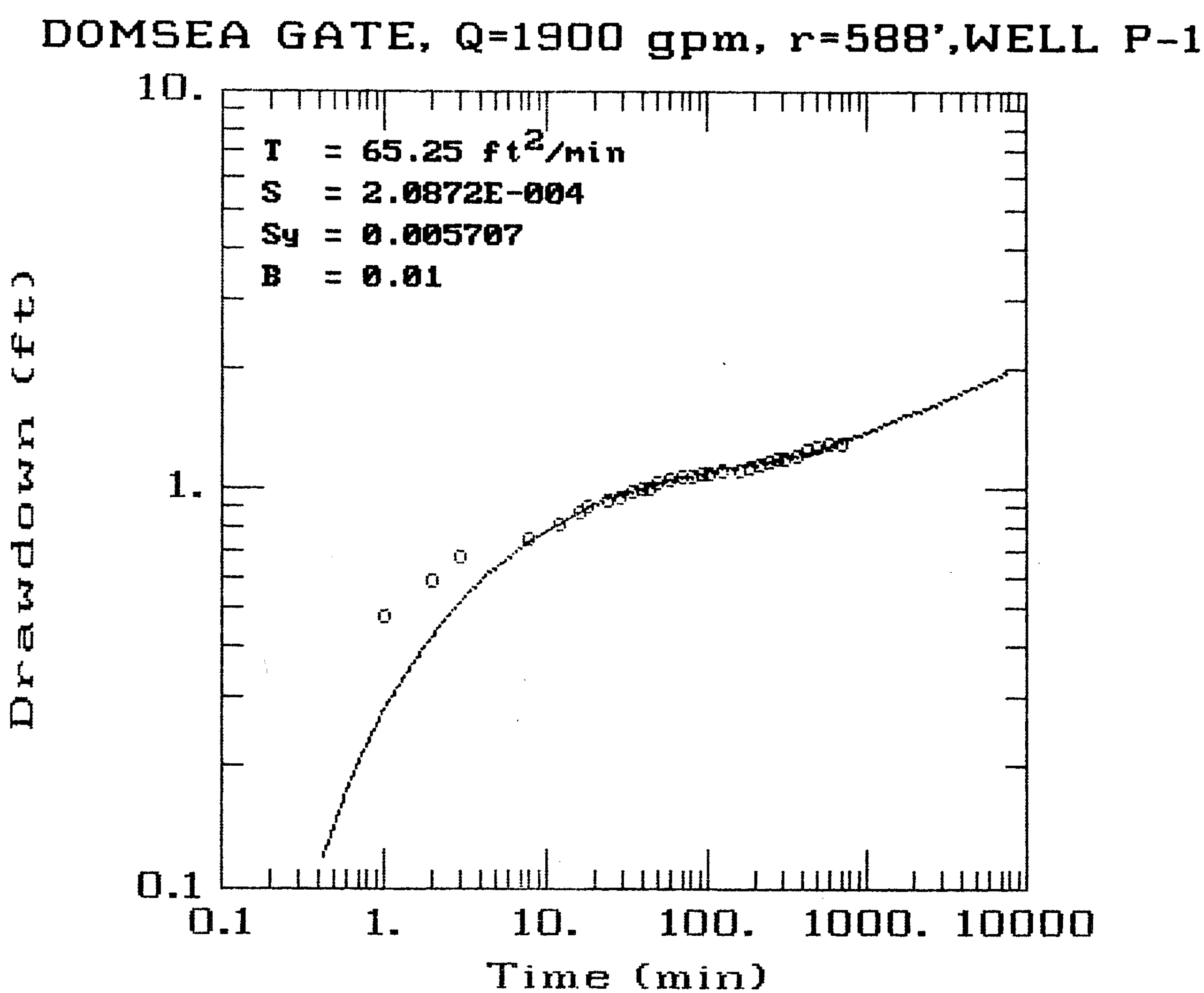

DOMSEA GATE, Q=1900 gpm, r=1100' WELL D1
T = 82.29 ft²/min
S = 0.005906
Corrected Drawdown (ft)
10.
1.
0.1
1.E-002
10.
100.
1000.
10000.
Time (min)



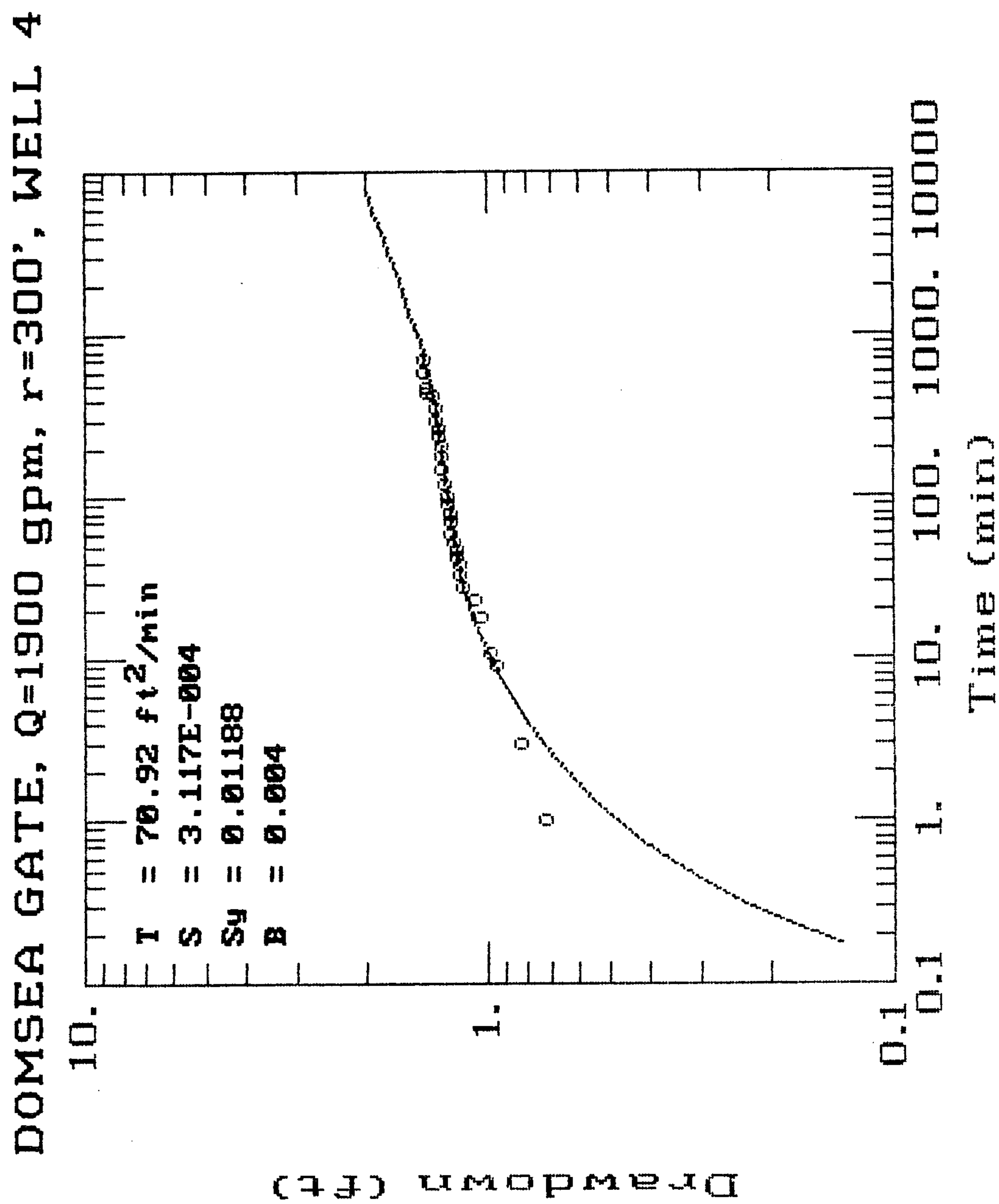
DOMSEA GATE, Q=1900 gpm, r=1100' WELL D1
T = 91.64 ft²/min
S = 0.004674
1.
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.
10.
100.
1000.
Time (min)
Corrected Drawdown (ft)

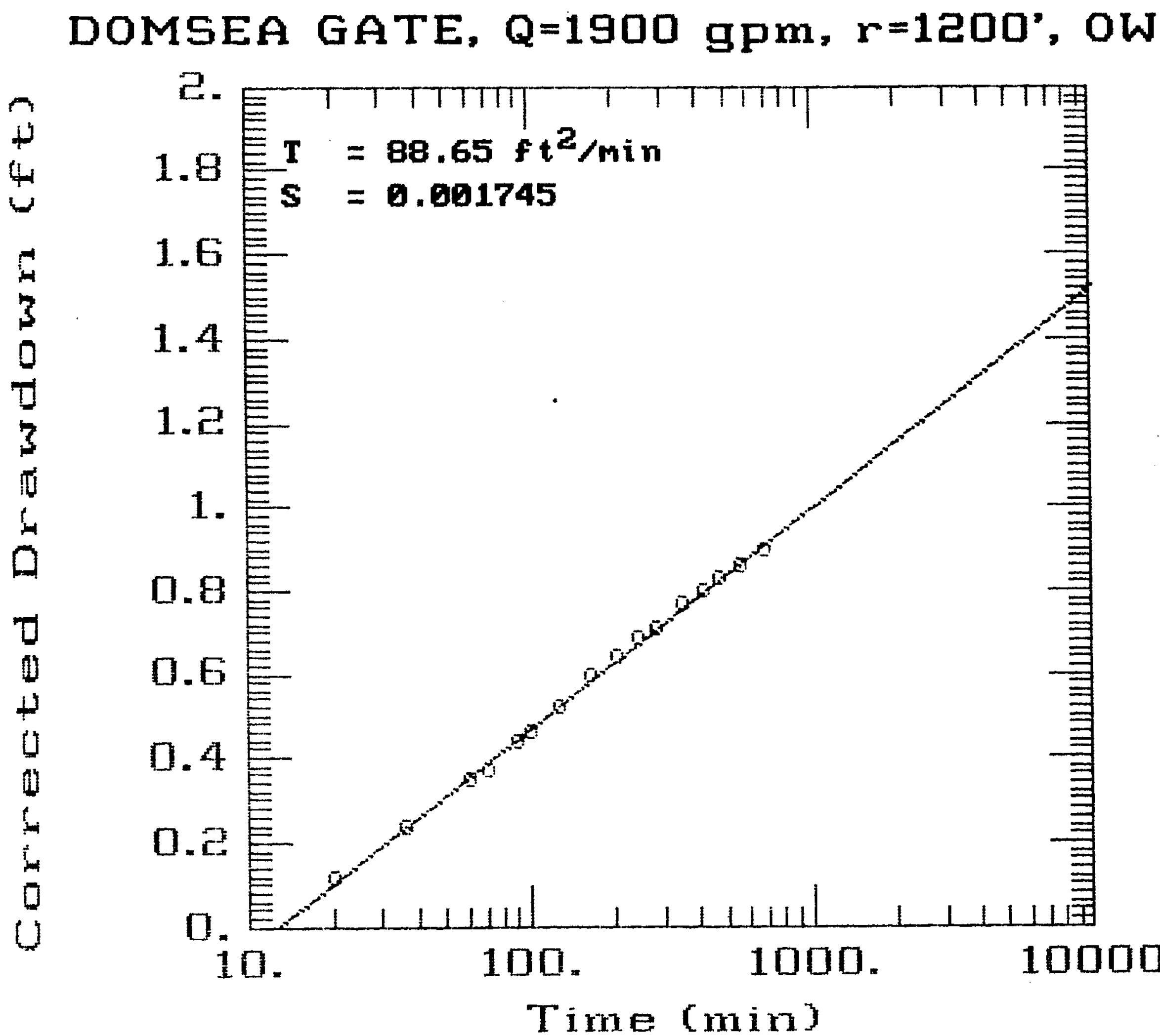
DOMSEA GATE, Q=1900 gpm, r=588',WELL P-1



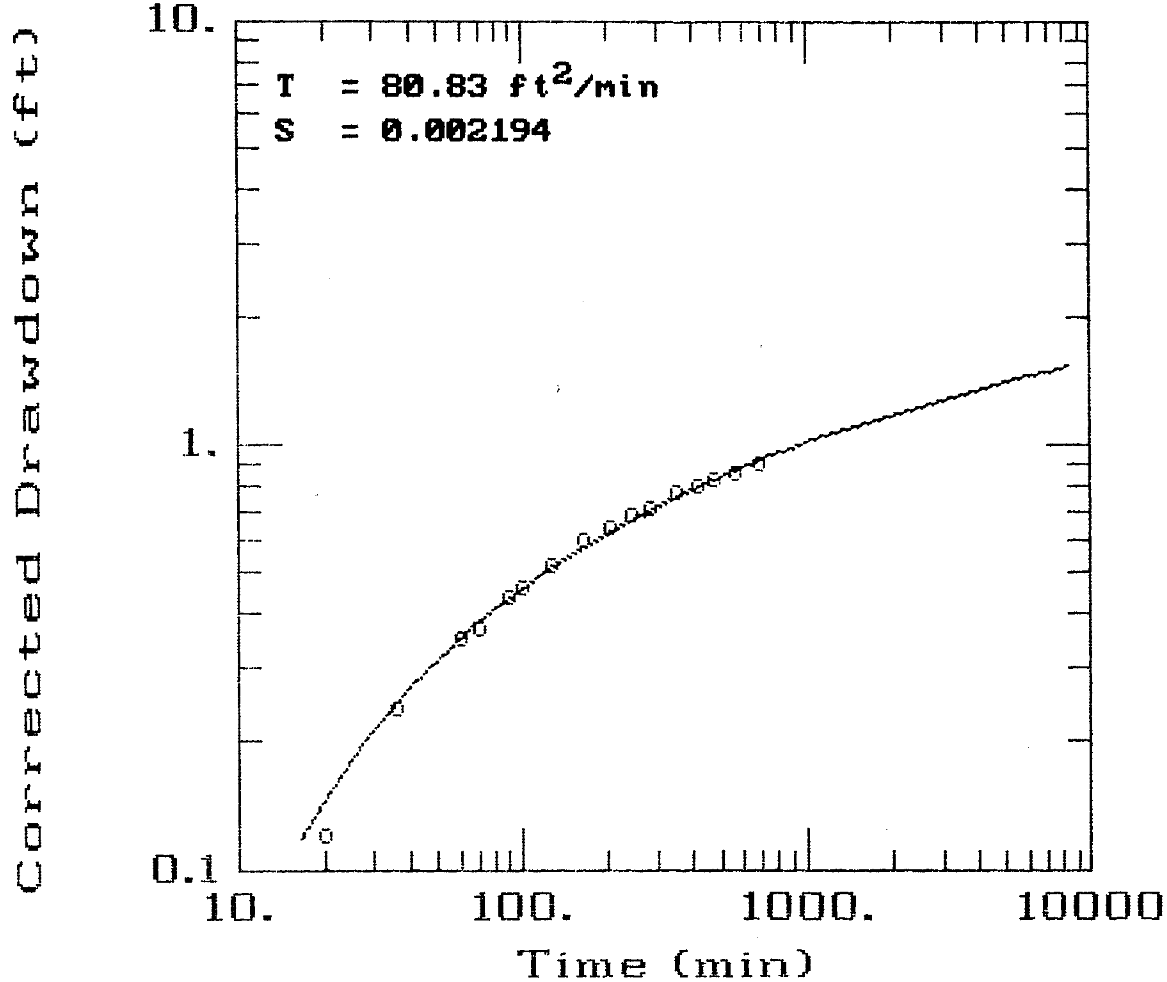


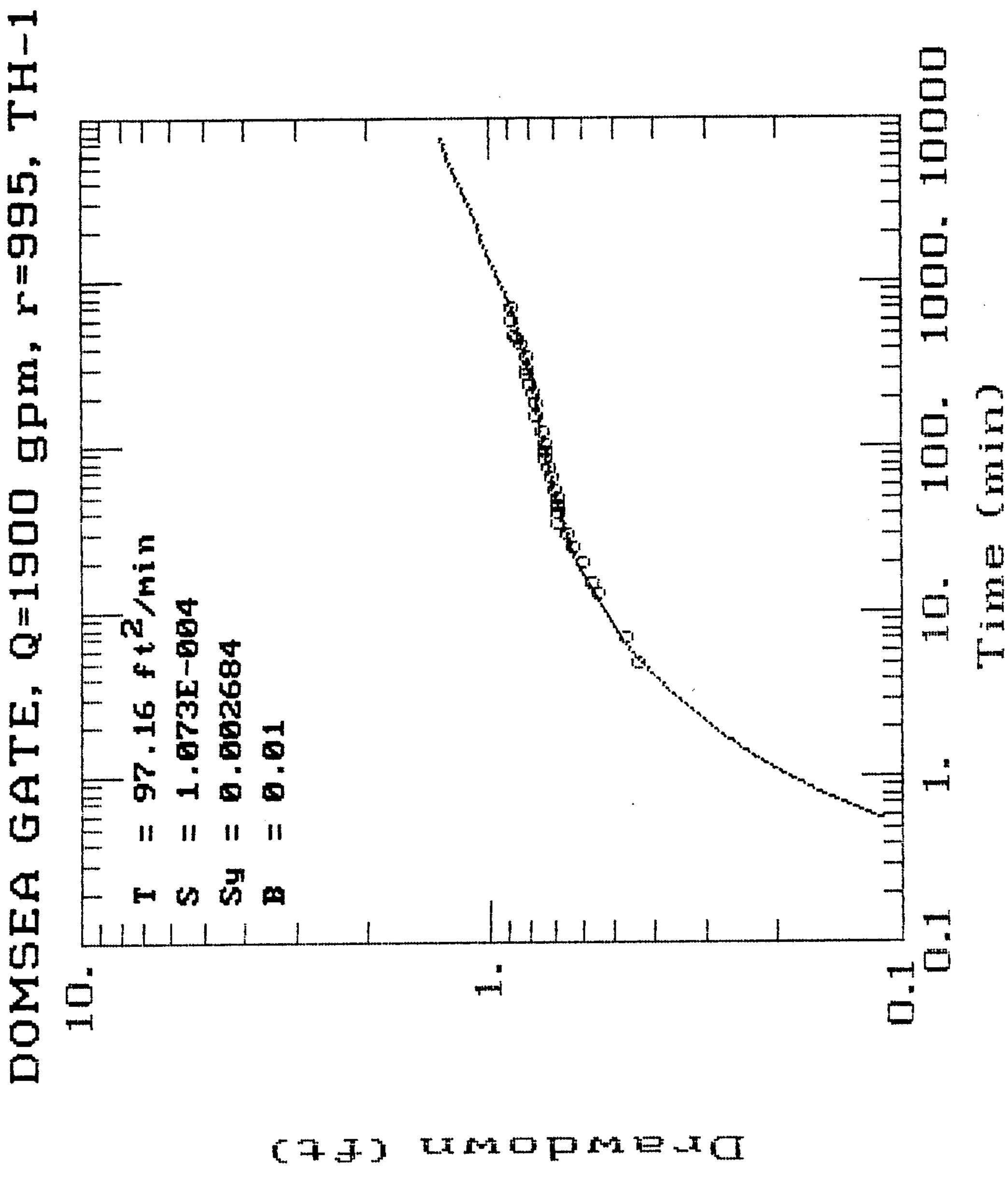
DOMSEA GATE, Q=1900 gpm, r=588',WELL P-1
T = 65.25 ft²/min
S = 2.0872E-004
Sy = 0.005707
B = 0.01
Drawdown (ft)
10.
1.
0.1
0.1
1.
10.
100.
1000.
10000
Time (min)

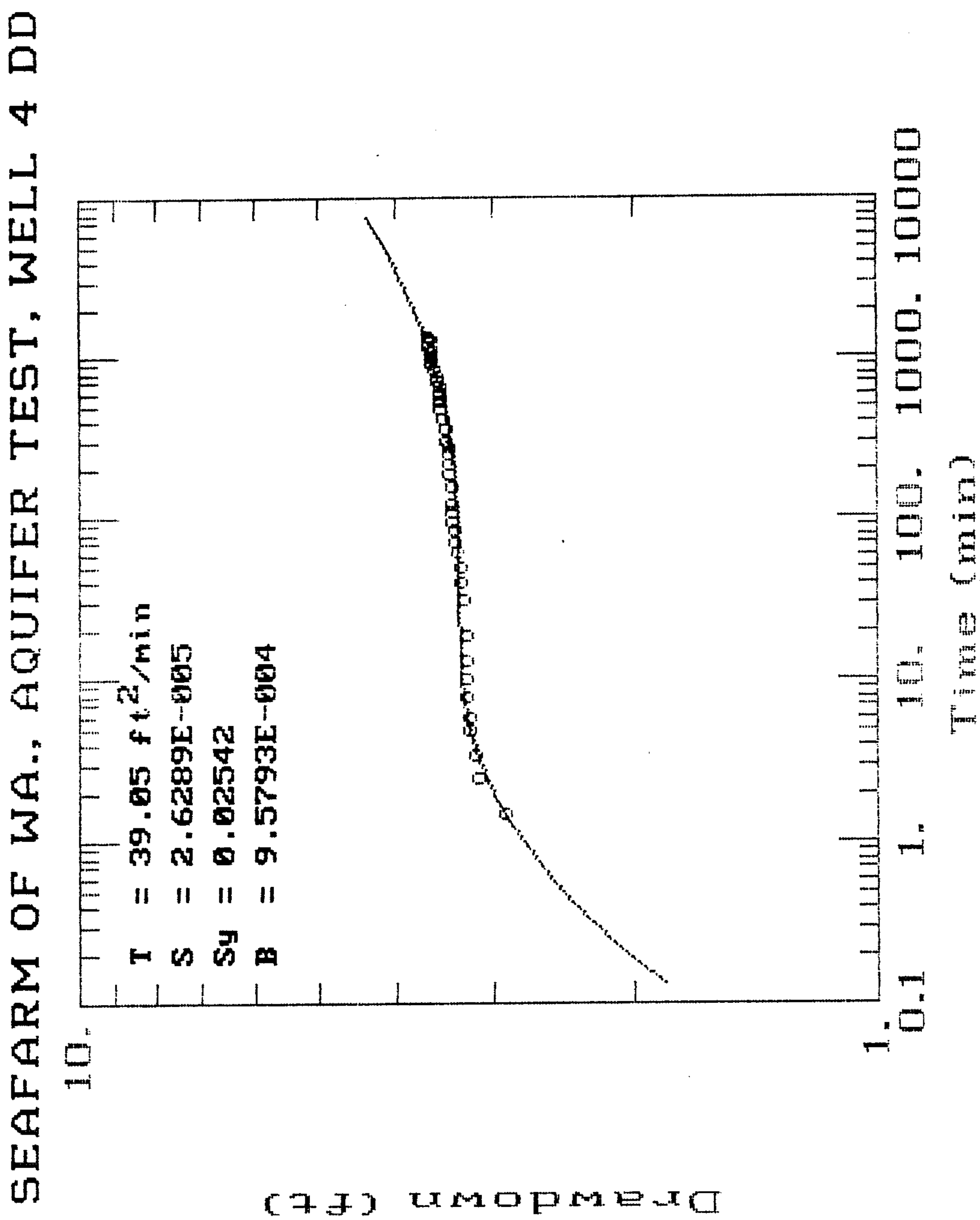

DOMSEA GATE, Q=1900 gpm, r=300', WELL 4
T = 70.92 ft2/min
S = 3.117E-004
Sy = 0.01188
B = 0.004
10.
1.
0.1
0.1
1.
10.
100.
1000.
10000.
Time (min)
Drawdown (ft)

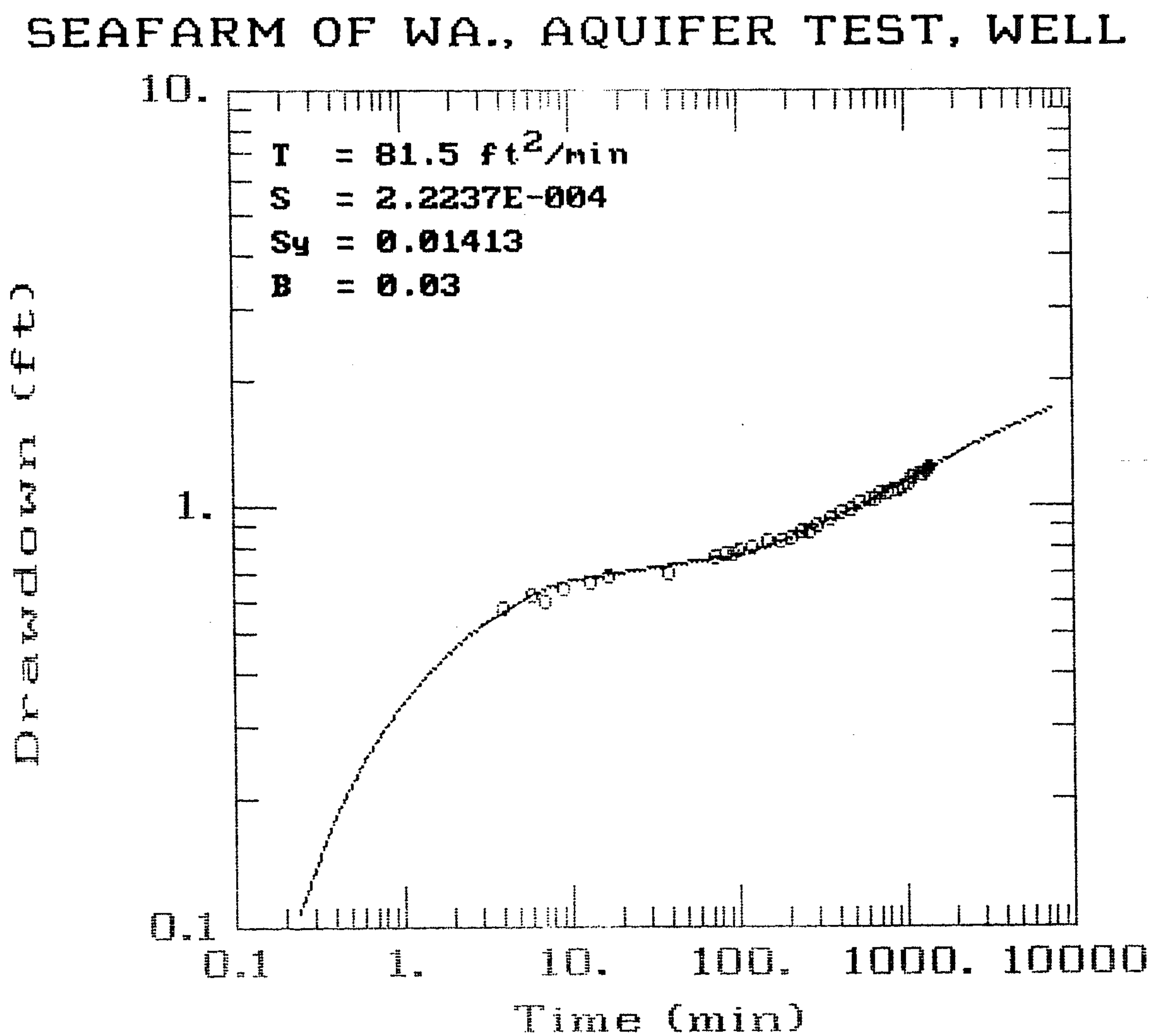

DOMSEA GATE, Q=1900 gpm, r=1200', OWEN
T = 88.65 ft2/min
S = 0.001745
Corrected Drawdown (ft)
2.
1.8
1.6
1.4
1.2
1.
0.8
0.6
0.4
0.2
0.
10.
100.
1000.
10000
Time (min)

DOMSEA GATE, Q=1900 gpm, r=1200', OWEN

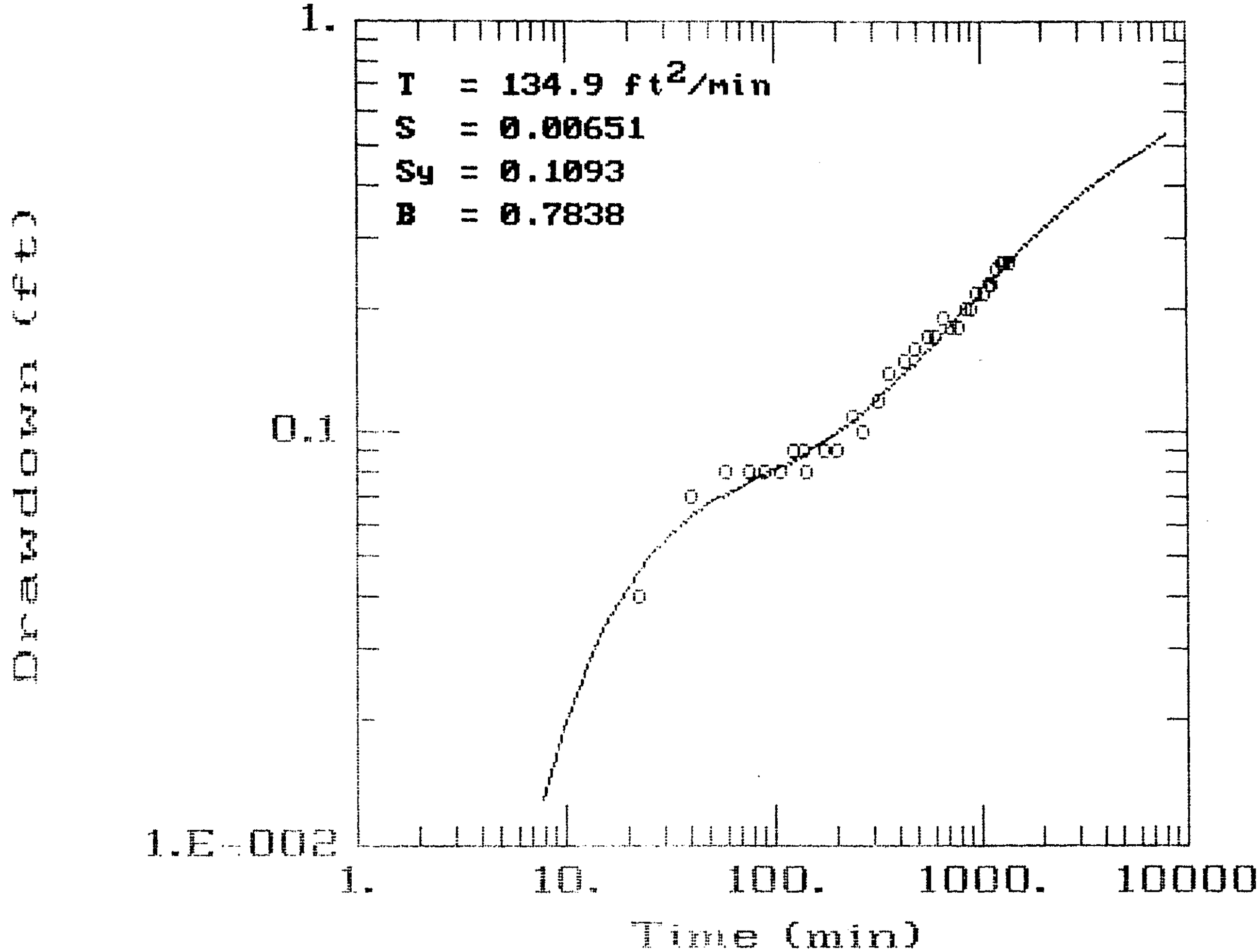


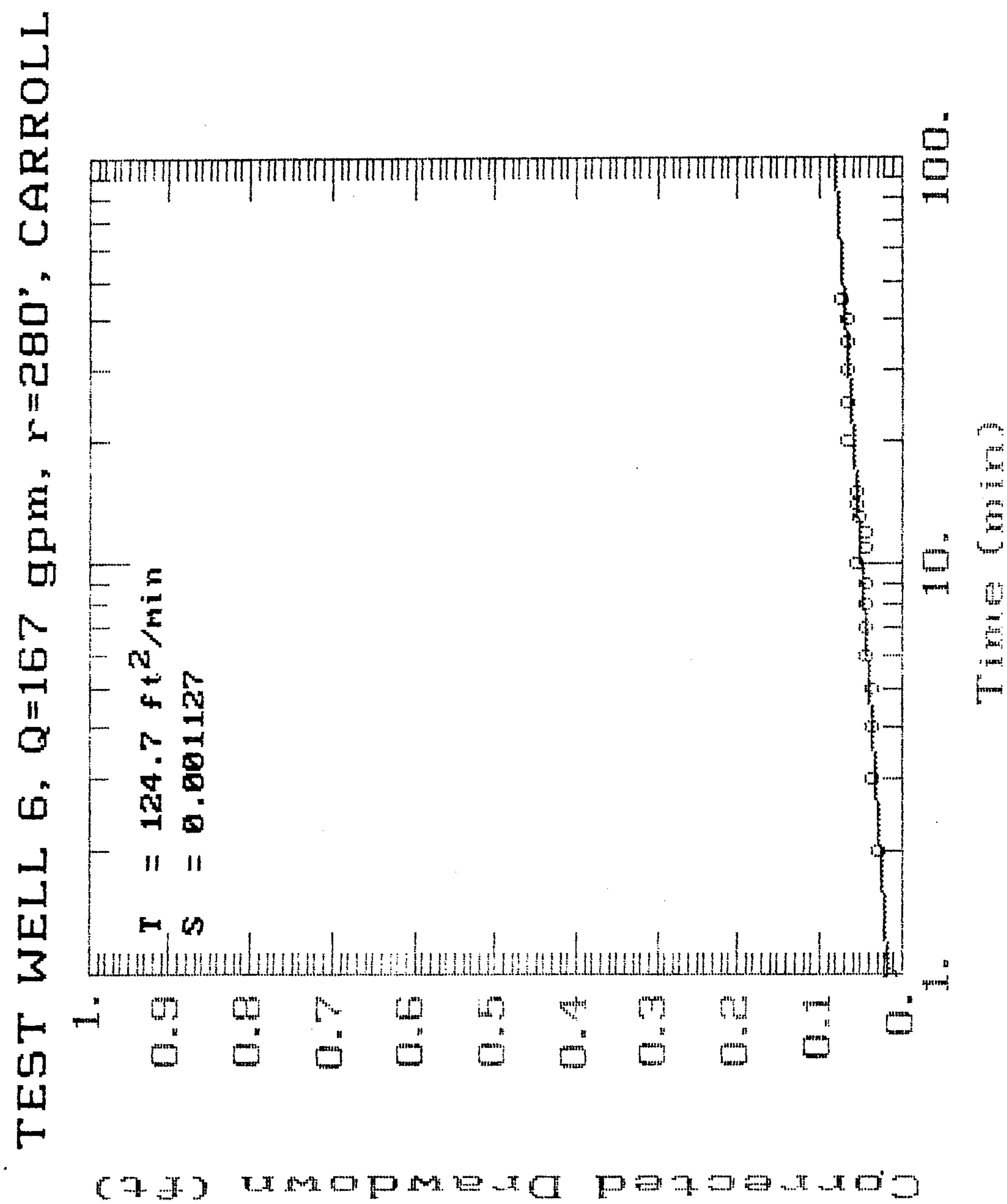

DOMSEA GATE, Q=1900 gpm, r=995, TH-1
T = 97.16 ft2/min
S = 1.073E-004
Sy = 0.002684
B = 0.01
Drawdown (ft)
10.
1.
0.1
Time (min)
0.1
1.
10.
100.
1000.
10000.

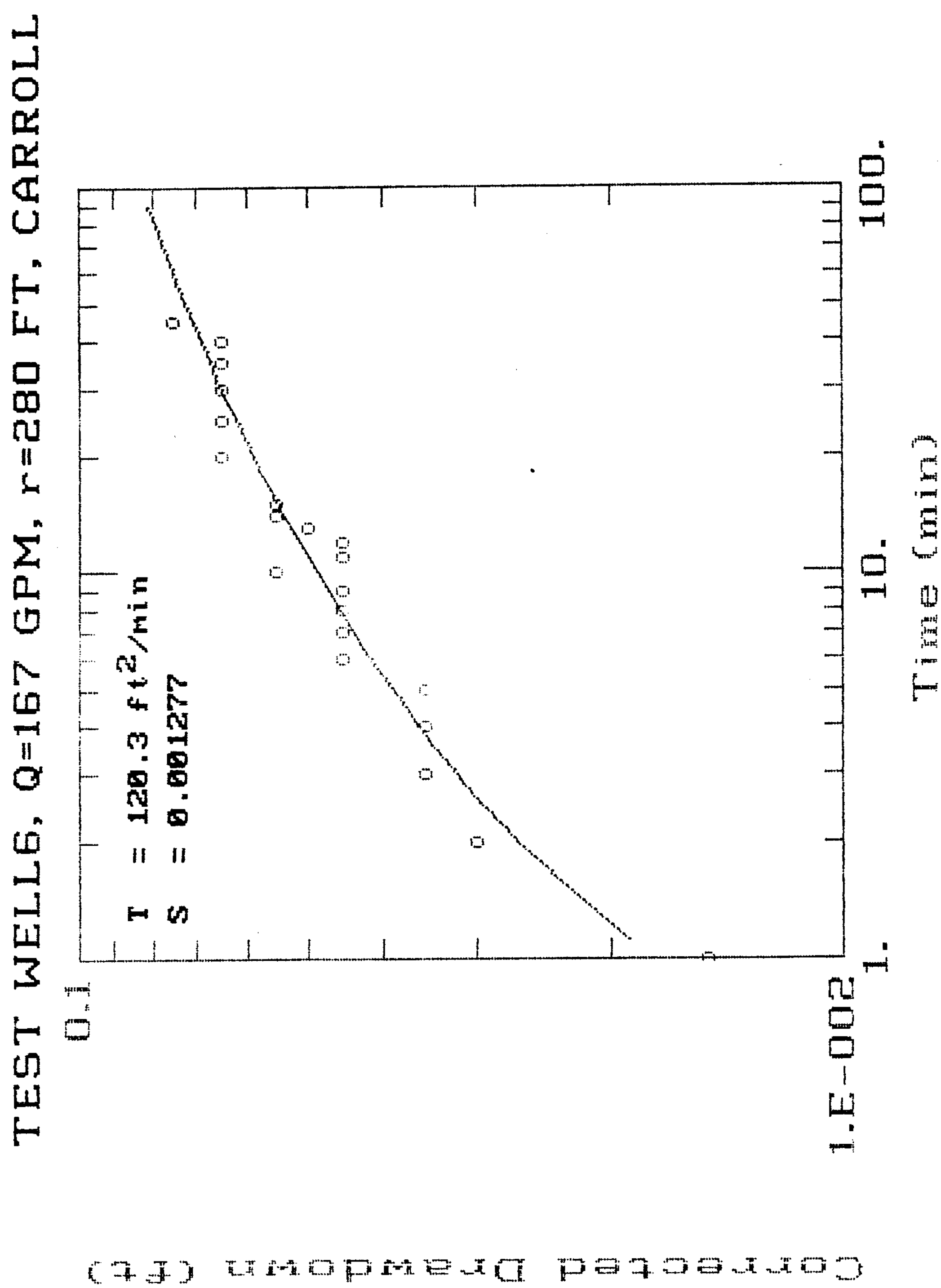

SEAFARM OF WA., AQUIFER TEST, WELL 4 DD
T = 39.05 ft²/min
S = 2.6289E-005
Sy = 0.02542
B = 9.5793E-004
10.
1.
Drawdown (ft)
0.1
1.
10.
100.
1000.
10000.
Time (min)


SEAFARM OF WA., AQUIFER TEST, WELL 1 DD
T = 81.5 ft^2/min
S = 2.2237E-004
Sy = 0.01413
B = 0.03
Drawdown (ft)
10.
1.
0.1
Time (min)
0.1
1.
10.
100.
1000.
10000

SEAFARM OF WA.,12/30/85, ADAMS OBS. WELL



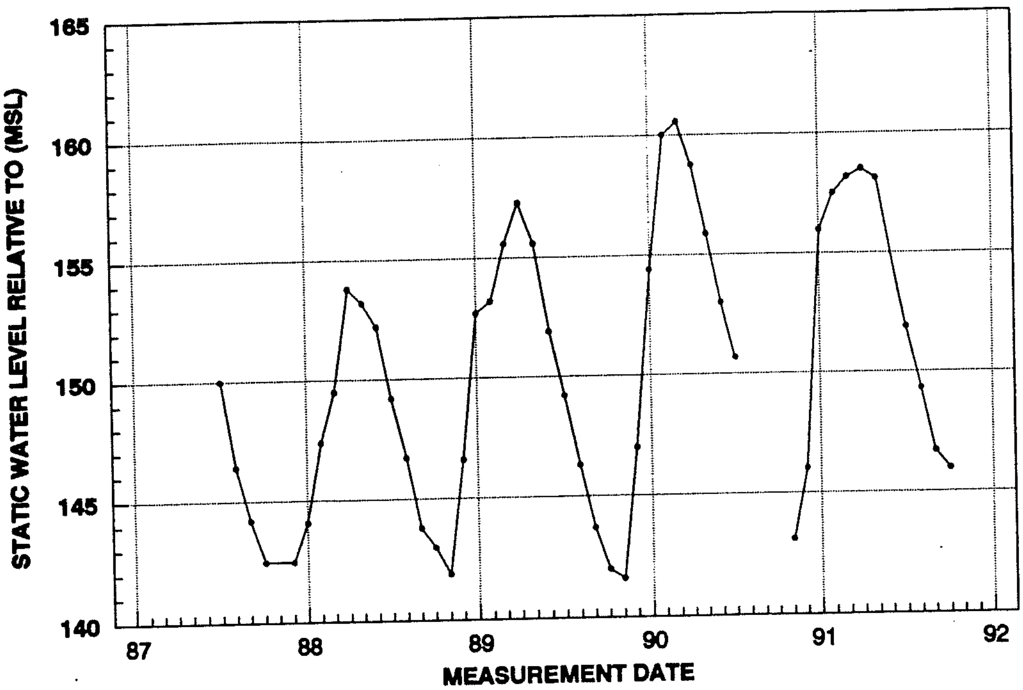

TEST WELL 6, Q=167 gpm, r=280', CARROLL
T = 124.7 ft2/min
S = 0.001127
Corrected Drawdown (ft)
Time (min)
1.
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.
1.
10.
100.


TEST WELL6, Q=167 GPM, r=280 FT, CARROLL
T = 120.3 ft²/min
S = 0.001277
0.1
1.E-002
1.
10.
100.
Time (min)
Corrected Drawdown (ft)

APPENDIX C

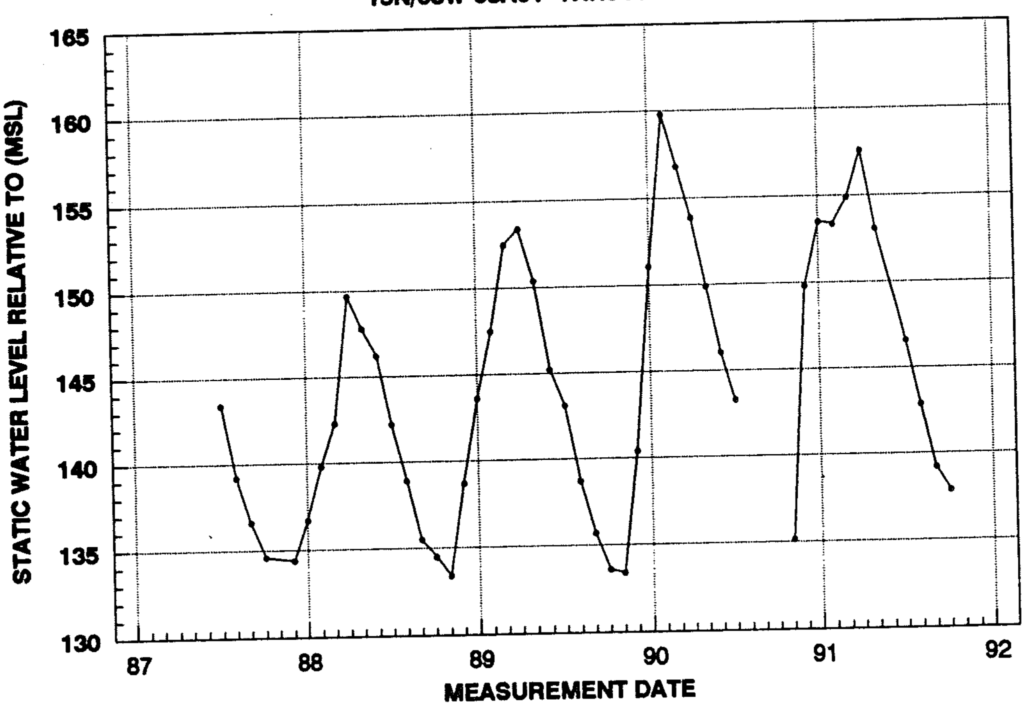
Hydrographs of Selected Wells

15N/03W-02R01 THR003



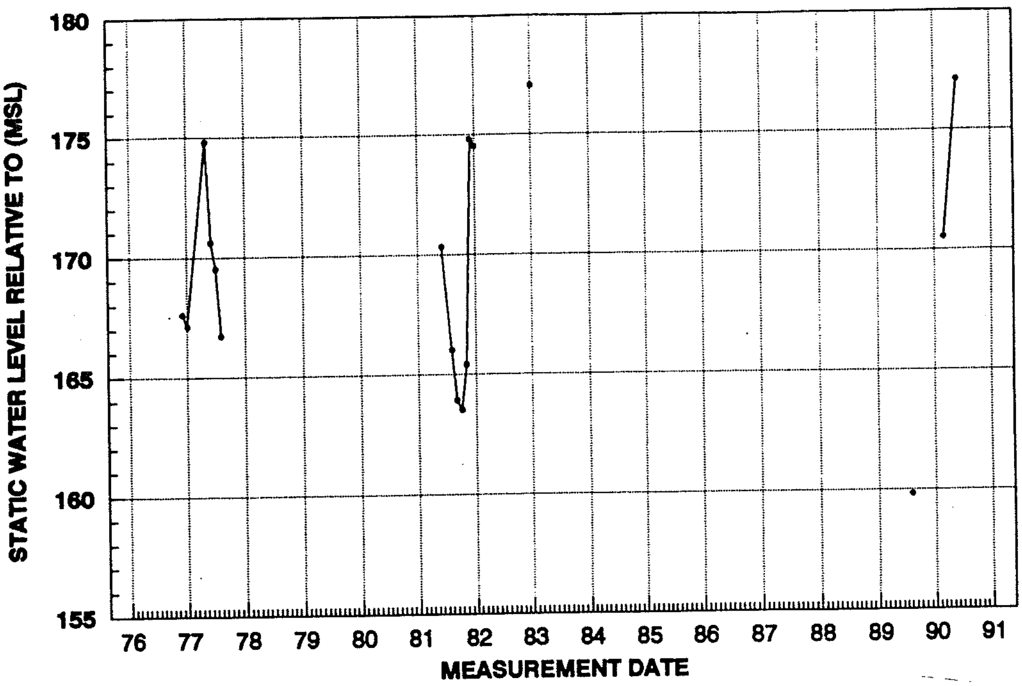
WELL ELEVATION 173.19' (MSL)
WELL DEPTH 145 FEET

15N/03W-03A01 THR044



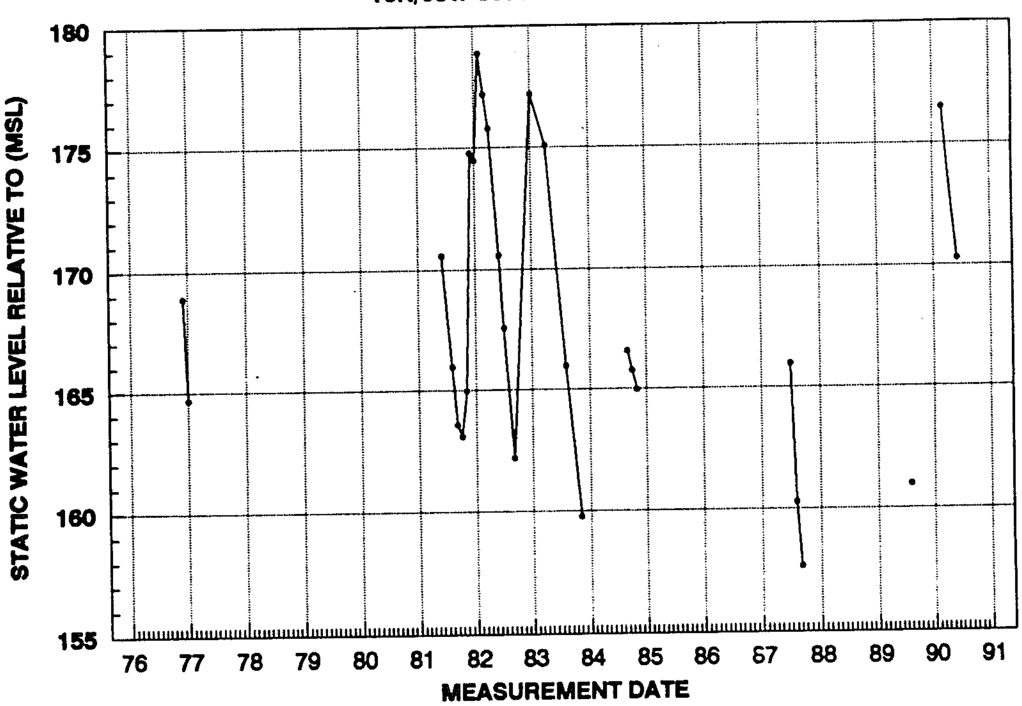
WELL ELEVATION 171.41' (MSL)
WELL DEPTH 132 FEET

16N/03W-36J02 THR119



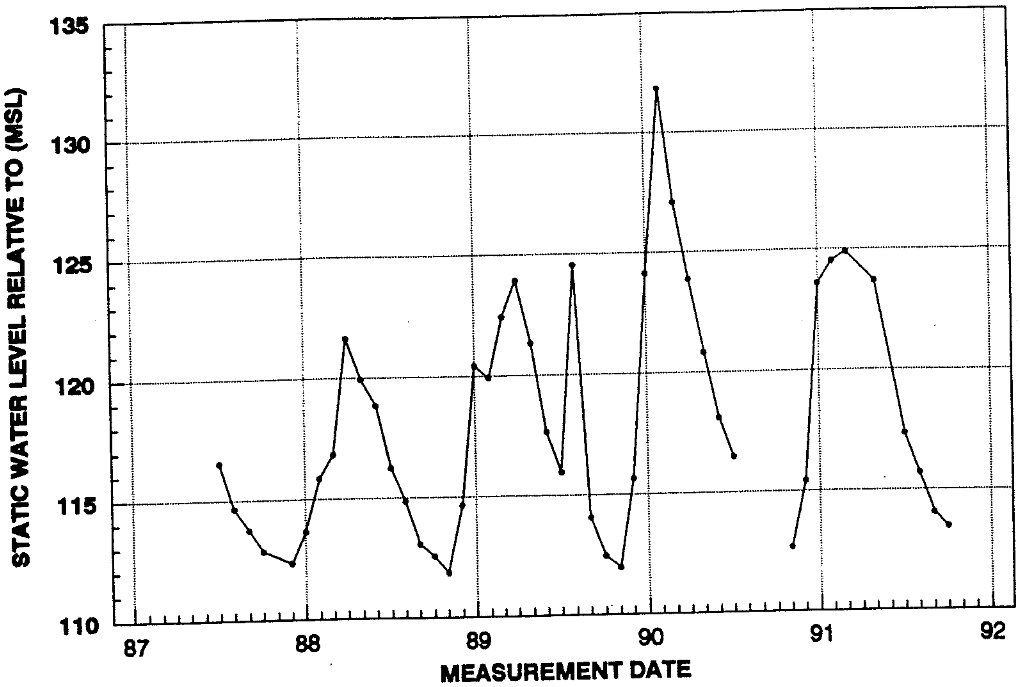
WELL ELEVATION 199.82' (MSL)
WELL DEPTH 138 FEET

16N/03W-36J04 THR082



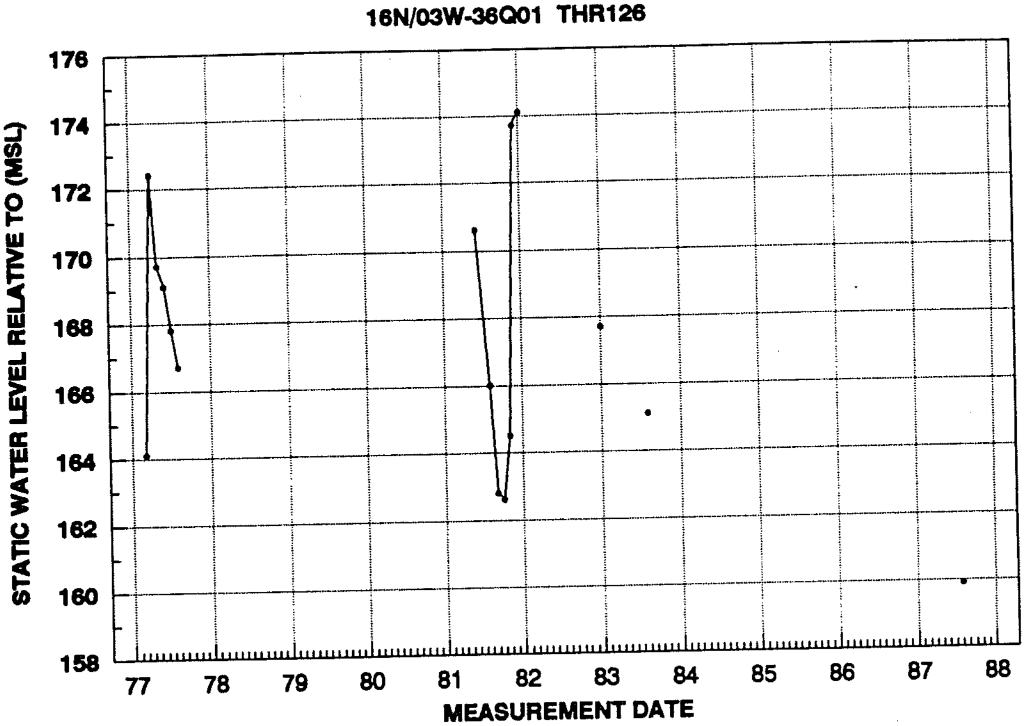
WELL ELEVATION 198.49' (MSL)
WELL DEPTH 59 FEET

16N/03W-33P01 THR015

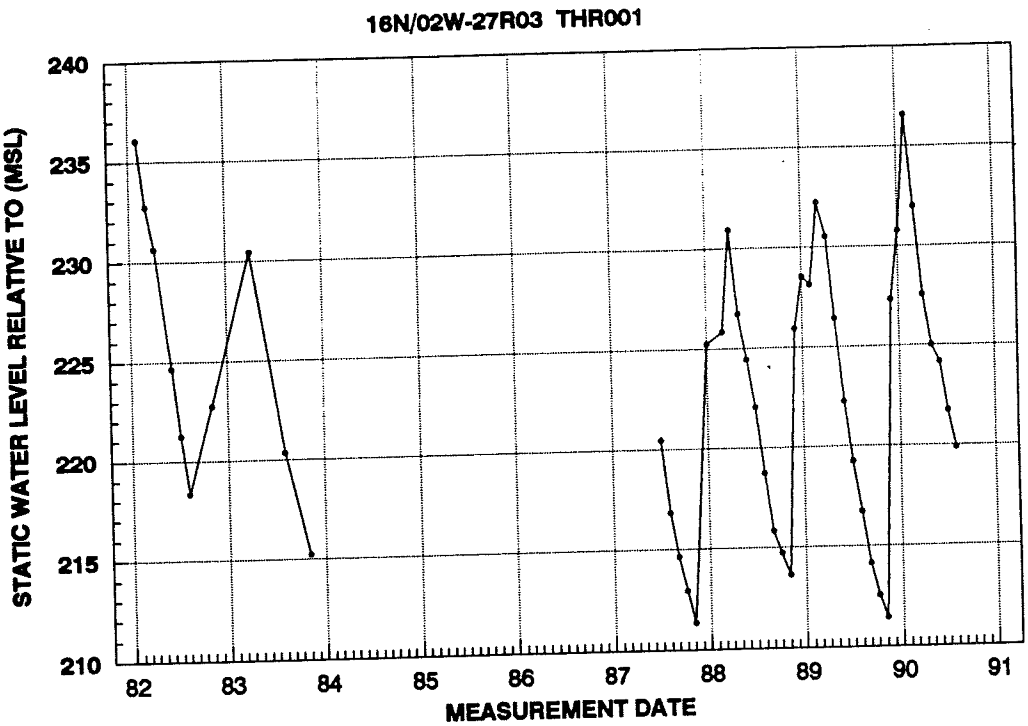


WELL ELEVATION 158.85' (MSL)
WELL DEPTH 105 FEET

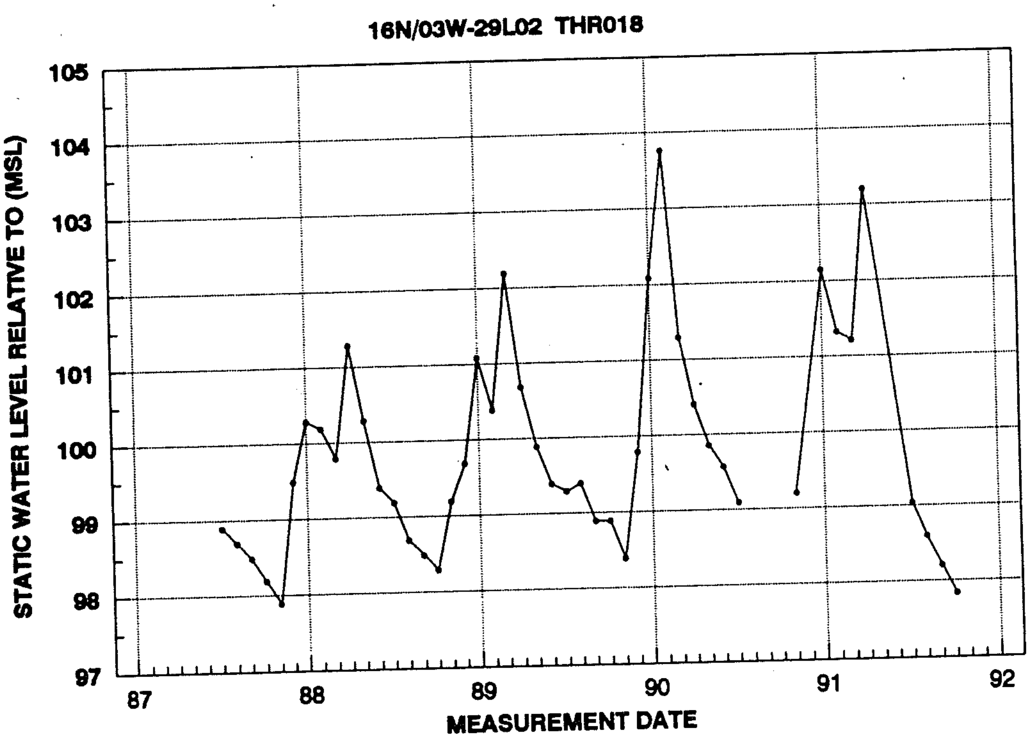
16N/03W-36Q01 THR126



WELL ELEVATION 198.83' (MSL)
WELL DEPTH 48 FEET

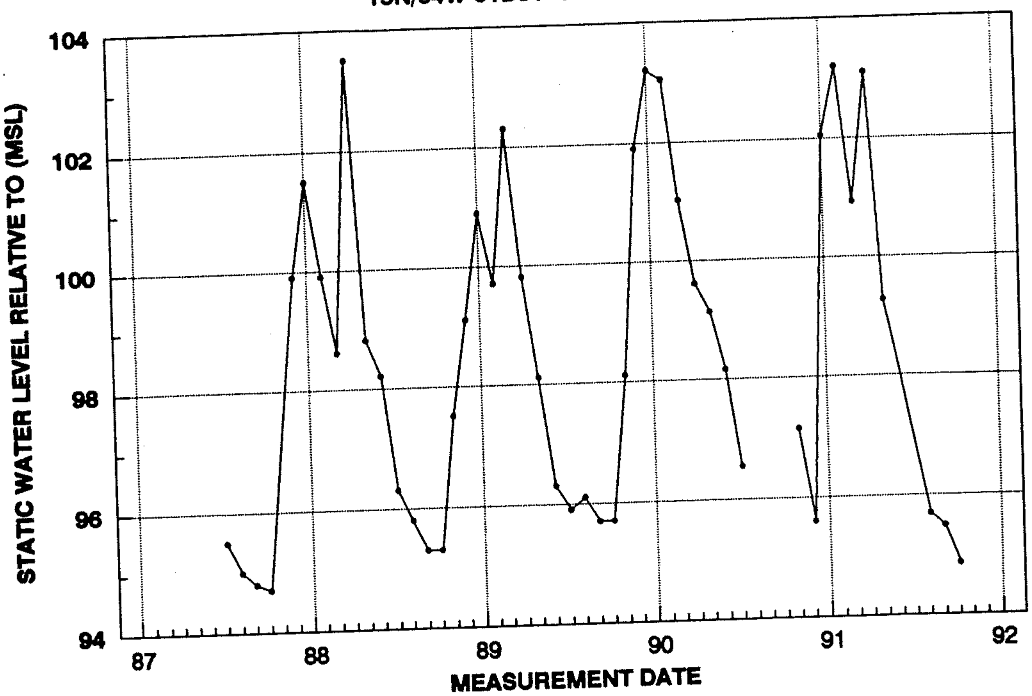


WELL ELEVATION 253.53' (MSL)
WELL DEPTH 65 FEET



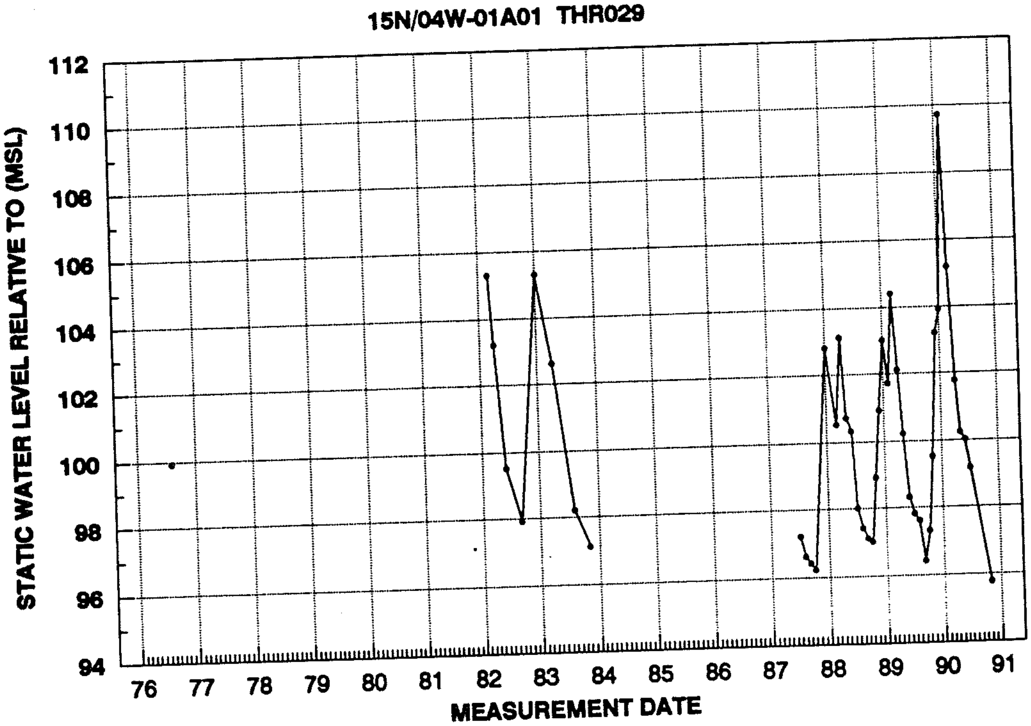
WELL ELEVATION 135.99' (MSL)
WELL DEPTH 126 FEET

15N/04W-01D01 THR026

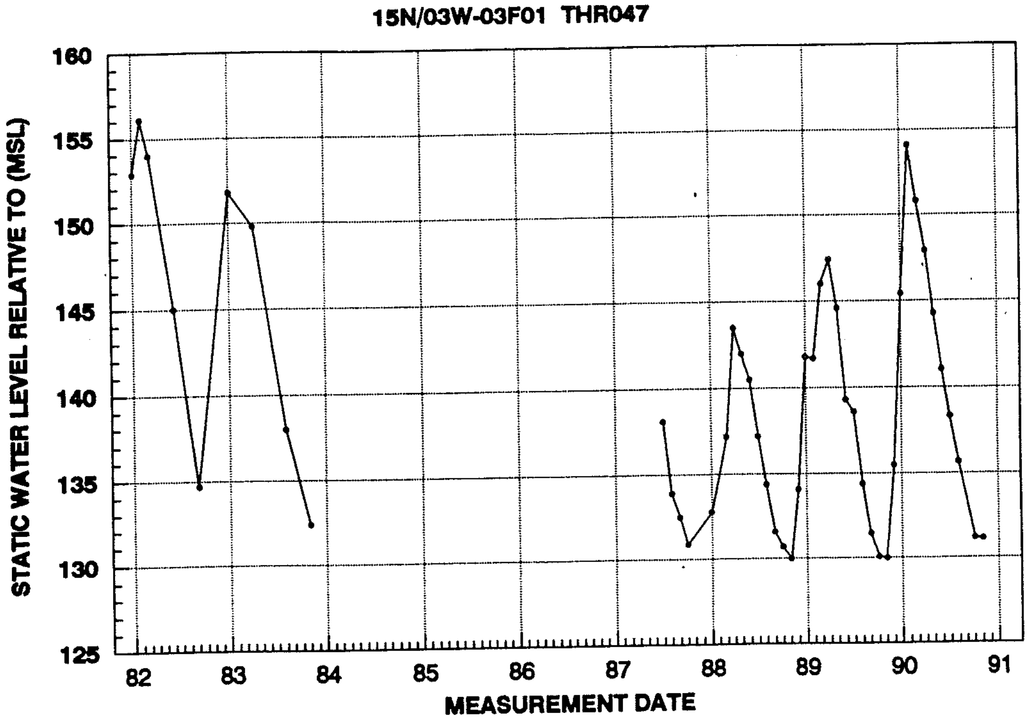


WELL ELEVATION 110.71' (MSL)
WELL DEPTH 136 FEET

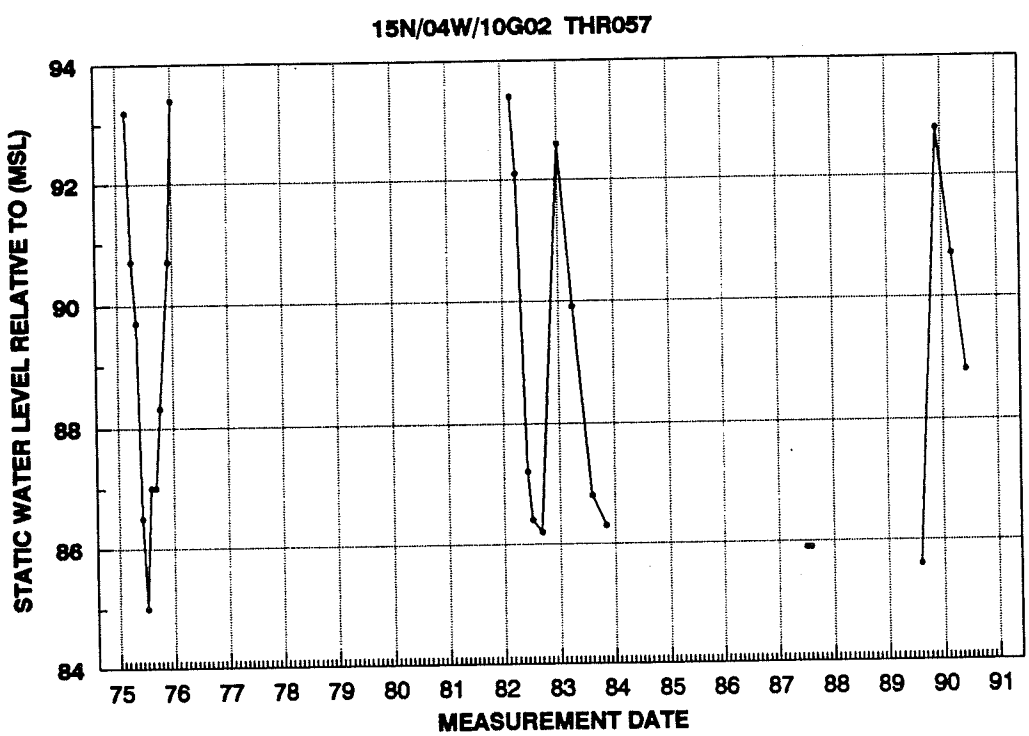
15N/04W-01A01 THR029



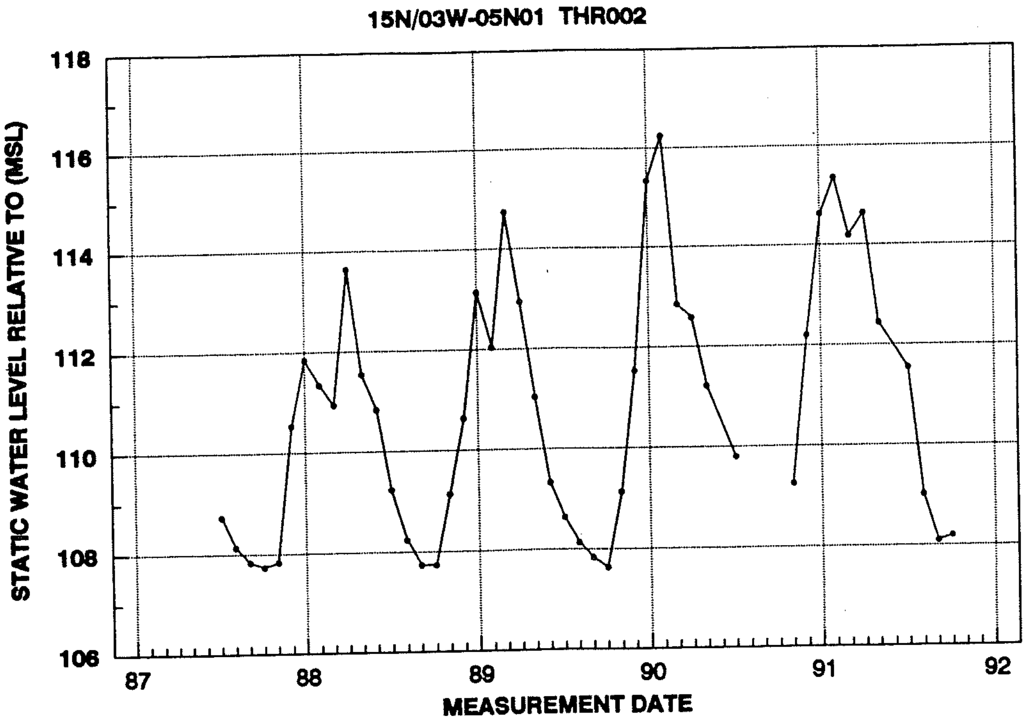
WELL ELEVATION 115.93' (MSL)
WELL DEPTH 42 FEET



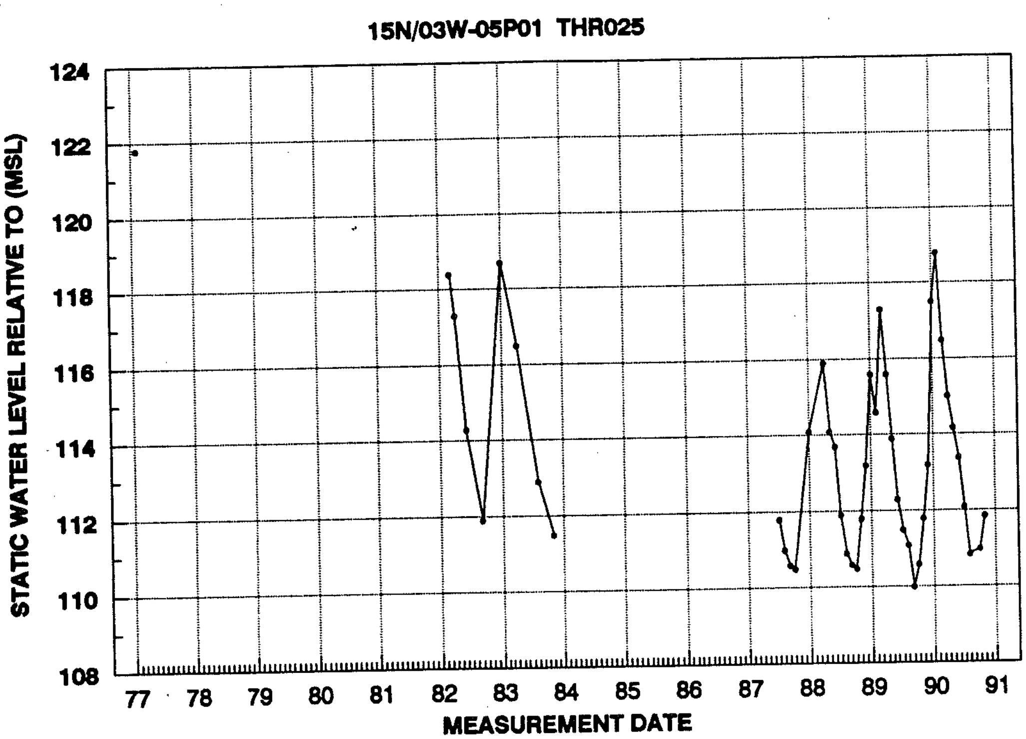
WELL ELEVATION 167.28' (MSL)
DEPTH UNKNOWN



WELL ELEVATION 102.61' (MSL)
WELL DEPTH 26 FEET

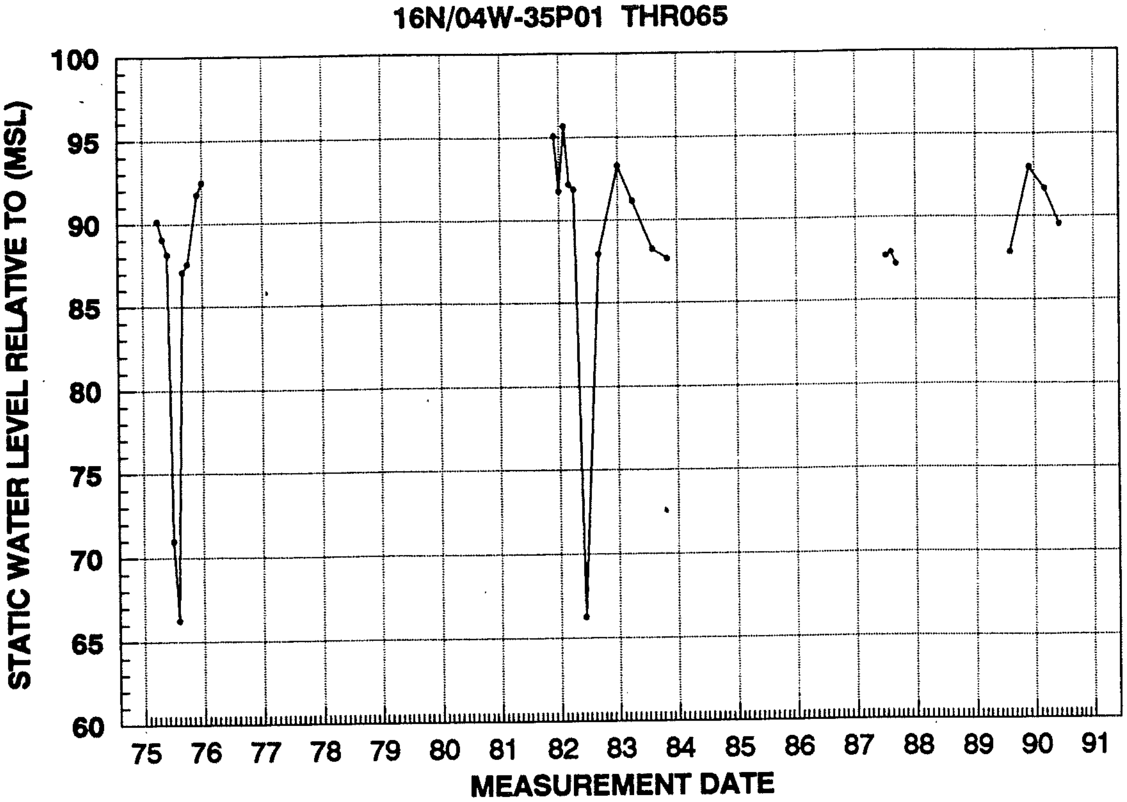


WELL ELEVATION 117.54' (MSL)
WELL DEPTH 86 FEET



WELL ELEVATION 140.80' (MSL)
WELL DEPTH 51 FEET

16N/04W-35P01 THR065



WELL ELEVATION 100.37' (MSL)
WELL DEPTH 112 FEET

APPENDIX D

Summary of Ground And Surface-water Rights Issued For the Scatter Creek/Black River Area

WATER RIGHT #	STATUS	OLD CERT	PRIORTY DATE	LOCATION		OWNER	SOURCE	NO. PONS	USE 1	Q(i)	Q(A)	# ACRES	USE PERIOD	USE 2	Q(i)2	# ACRES	USE PERIOD	USE 3	Q(i)3	# ACRES	USE PERIOD	Q(i)p	Q(a)p
G 2800255	C		00403	05/24/46	15N/03W-24 N2SW4SE4	SHAFFER R H	WELL	1	DS	75.00	15.000	0.0	2	IR	75.00	10.0	2 IS					75.00	15.000
G 2800287	C		00182	06/22/46	15N/03W-03 GL-4	LONG M G	WELL	1	DS	75.00	21.000	0.0	2	IR	75.00	14.0	2 IS					75.00	21.000
G 2800345	C		00191	08/22/46	15N/03W-12 SE4NW4	LENTZ C	WELL	1	IR	100.00	21.000	10.6	IS									100.00	21.000
G 2800397	S		00349	00/00/27	15N/03W-11 NW4SE4	SAGNEISTER J E	WELL	1	IR	350.00	30.000	15.0	06010901										
G 2800398	S		00350	00/00/27	15N/03W-11 TR8 GRD VLY FRT / GDN TR	SAGNEISTER J E	WELL	1	DS	350.00	30.000	0.0	2	IR	350.00	15.0	2 IS						
G 2800429	C		00243	01/09/47	15N/03W-11 TR40 JACKSON MEADOW TRACTS	ADKISON O W	WELL	1	IR	50.00	14.000	7.0	IS									50.00	14.000
G 2800476	C		00312	03/12/47	15N/03W-08 SW4NE4	FRYE C R	WELL	1	IR	50.00	12.500	10.0	IS									50.00	12.500
G 2800525	C		01185	05/16/47	15N/03W-23 NE4NW4	WILLIAMSON C J	WELL	1	IR	105.00	16.000	12.5	IS									105.00	16.000
G 2800527	C		01531	05/16/47	15N/03W-05 SW4SE4	DOWERS W J	WELL	1	IR	150.00	18.750	15.0	IS									150.00	18.750
G 2800612	S		00529	00/00/10	15N/04W-11 NW4SW4	OREGONWWA RRXNAVIGAT	WELL	1	DG	150.00	22.400	0.0	2	RW	150.00	0.0	2						
G 2800656	C		00268	10/25/47	15N/03W-24 SW4NW4	LYON F / C	WELL	1	DS	100.00	20.800	0.0	2	IR	100.00	17.0	2 IS					100.00	20.800
G 2800727	C		00279	02/09/48	15N/03W-10 L12 GRAND VALLEY GRDN TR	ROSSMAIER L	WELL	1	DS	60.00	20.000	0.0	3	ST	60.00	0.0	3	IR	60.00	10.0	3 IS	60.00	20.000
G 2800730	C		00475	02/10/48	15N/03W-12 NW4	SALZER J / M	WELL	1	IR	75.00	25.500	17.0	IS									75.00	25.500
G 2800780	C		00188	03/22/48	15N/03W-05 NW4NE4	THOMPSON C J ET AL	WELL	1	IR	200.00	30.000	20.0	IS									200.00	30.000
G 2800789	C		00814	03/26/48	15N/03W-09 L19 JAMES SUBD	BARTLETT T E	WELL	1	DS	120.00	24.500	0.0	2	IR	120.00	15.5	2 IS					120.00	24.500
G 2800804	C		00679	04/08/48	15N/03W-04 NE4SW4	SCHEY C A	WELL	1	IR	45.00	12.000	8.0	IS									45.00	12.000
G 2800814	C		00824	04/19/48	15N/03W-01 L8 BL6 AM HOME FRUIT TRACTS	FINEIDE A	WELL	1	DS	60.00	18.000	0.0	2	IR	60.00	9.0	2 IS					60.00	18.000
G 2800839	C		00836	05/04/48	15N/04W-02 NW4NE4	MCDOUGALL E J	WELL	1	IR	60.00	24.000	16.0	IS									60.00	24.000
G 2800840	C		00260	04/24/48	15N/03W-09 NW4NW4NW4	MAURER A J ET UX	WELL	1	DS	30.00	3.750	0.0	2	IR	30.00	2.5	2 IS					300.00	30.000
G 2800840	C		00260	04/24/48	15N/03W-08 SE4NE4NE4	PEDERSON HOWARD M	WELL	1	DS	270.00	26.250	0.0	2	IR	270.00	17.5	2 IS					30.00	3.750
G 2800853	C		00314	05/12/48	16N/02W-21 SE4SW4	DEMPSEY S	WELL	1	DS	35.00	6.000	0.0	2	IR	35.00	3.0	2 IS					35.00	6.000
G 2800864	S		00746	00/00/35	16N/03W-31 NW4SE4	JAHNKE E	WELL	1	DS	50.00	20.000	0.0	2	IR	50.00	10.0	2 IS						
G 2800893	C		01198	06/04/48	16N/03W-33 TR2 BL W / E AMER HOME GDN	DAHL J C	WELL	1	IR	450.00	80.000	40.0	IS									450.00	80.000
G 2800943	C		00855	07/01/48	15N/03W-04 SW4NE4	SAUNDERS J E	WELL	1	IR	75.00	16.000	8.0	IS										
G 2800989	C		00589	09/07/48	15N/03W-11 TR2 GRAND VLY FR & GDN TR	HAGERMAN WILLIAM L	WELL	1	IR	250.00	10.000	5.0	IS									250.00	10.000
G 2801067	S		00965	00/00/40	15N/03W-23 S2SE4	SORENSEN E M	WELLS	4	IR	150.00	75.000	50.0	IS										
G 2801074	C		00343	03/01/49	15N/04W-12 E2NW4	SUNDQUIST E	WELLS	2	IR	150.00	19.000	15.0	IS									150.00	19.000
G 2801083	C	E	01104	03/17/49	16N/02W-25 SW4NE4	BAKER K C	WELL	1	DS	50.00	10.000	0.0	2	IR	50.00	5.0	2 IS					50.00	10.000
G 2801153	C		00688	06/28/49	15N/03W-06 E2SE4SW4	BAYDARZ A M	WELL	1	IR	80.00	15.000	12.0	IS									80.00	15.000
G 2801175	C		02760	07/22/49	15N/03W-09 L7 JAMES SUBD	BREWER W F	WELL	1	IR	150.00	70.000	35.0										150.00	70.000
G 2801190	C		00874	08/03/49	15N/03W-11 SE4NW4	KING C F	WELL	1	IR	50.00	20.000	10.0	IS									50.00	20.000
G 2801197	C	E	00652	08/10/49	15N/03W-04 SW4SW4SE4	MANNERS H E	WELL	1	IR	100.00	28.000	14.0	IS									100.00	28.000
G 2801224	C		00449	09/08/49	15N/03W-12 L13 JACKSON FRUIT TRACTS	GOODKNIGHT L G	WELL	1	DS	100.00	18.000	0.0	2	IR	100.00	9.0	2 IS					100.00	18.000
G 2801245	C		01303	10/01/49	15N/03W-12 TR1 TO 6 BL10 AMER HM FR TRS	PRANG E H	WELL	1	IR	50.00	30.000	15.0	IS									50.00	30.000
G 2801254	C		01106	10/11/49	15N/03W-04 S2SE4SW4	WHITE F D	WELL	1	DS	50.00	20.000	0.0	2	IR	50.00	10.0	2 IS					50.00	20.000
G 2801260	C		02551	10/24/49	15N/03W-04 NW4NW4	BETTS C A	WELL	1	IR	350.00	56.000	35.0	IS									350.00	56.000
G 2801297	C		00744	12/08/49	15N/03W-03 S2S2	LOMBARD S D	WELL	1	DS	200.00	22.000	0.0	2	IR	200.00	10.0	2 IS					200.00	22.000
G 2801301	C		00424	12/12/49	15N/02W-06 SW4NE4	POPE I / W	WELL	1	DS	30.00	2.000	0.0		IR	30.00	1.5	IS					30.00	5.000
G 2801306	C		01271	12/14/49	16N/02W-20 SW4SE4	DEMPSEY R	WELL	1	DS	150.00	5.000	0.0	2	DG	150.00	0.0	2	IR	150.00	12.0	IS	150.00	29.000
G 2801316	C		00445	12/22/49	15N/02W-06 SW4SW4	LYNN C C	WELL	1	IR	90.00	18.000	9.0	IS									90.00	18.000
G 2801317	C		01361	12/22/49	15N/02W-06 S2 S2	MCGRAW C E	WELL	2	IR	80.00	33.000	22.0	IS									80.00	33.000
G 2801380	C		00498	02/23/50	16N/02W-33 NE4NE4	SCHINKOLA F	WELL	1	IR	40.00	7.000	5.0	IS									40.00	7.000
G 2801384	C	E	01752	02/24/50	15N/03W-06 NW4SE4	STEELHAMMER G C	WELL	1	IR	150.00	28.000	25.0	IS									150.00	26.000
G 2801425	C		00730	03/21/50	15N/03W-23 S2SE4	SORENSEN E M	WELLS	4	IR	150.00	75.000	50.0	IS									150.00	75.000
G 2801476	C		02174	04/20/50	16N/02W-32 SE4NW4	THOMSEN R	WELL	1	IR	155.00	45.000	30.0	IS									100.00	45.000
G 2801486	C		00649	04/24/50	15N/03W-04 NW4SE4	ECKARD C	WELL	1	DS	100.00	15.000	0.0	2	IR	100.00	10.0	2 IS					100.00	15.000
G 2801492	C		01645	04/27/50	16N/02W-31 NW4SE4	HASKIN H E	WELL	1	IR	55.00	15.000	10.0	IS									55.00	15.000
G 2801493	C		00619	04/27/50	16N/02W-31 NE4SW4	MAZE H B	WELL	1	IR	110.00	28.000	19.0	IS									110.00	28.000
G 2801495	C		01862	04/28/50	15N/03W-11 D DURGAN DLC NO 40	GARSKE L	WELL	1	IR	95.00	25.000	17.0	IS									95.00	25.000
G 2801498	C	E	01055	05/03/50	16N/03W-33 BL15 FACTORY ADDN ROCHESTER	COGWELL M	WELL	1	DS	120.00	45.000	0.0	2	IR	120.00	45.0	2 IS					120.00	45.000
G 2801513	C		01794	05/16/50	15N/03W-02 N2 SW4	ATHANAS G G	WELL	1	IR	100.00	22.000	15.0	IS									100.00	22.000
G 2801520	C	E	02233	05/22/50	16N/02W-27 TR31 TILLEY TRS	FINLEY M A	WELL	1	IR	110.00	20.000	11.0	IS									110.00	20.000
G 2801579	C		00723	07/05/50	16N/03W-31 SE4SW4	BIGLER R	WELL	1	IR	100.00	12.000	8.0	IS									100.00	12.000
G 2801736	C		01023	11/24/50	15N/03W-24 S2S2SE4	SMITH C A	WELL	1	DS	150.00	30.000	0.0	2	IR	150.00	15.0	2 IS					150.00	30.000

WATER RIGHT #	STATUS	OLD CERT	PRIORTY DATE	LOCATION		OWNER	SOURCE	NO. POWS	USE 1	Q(i)	Q(A)	# ACRES	USE PERIOD	USE 2	Q(i)2	# ACRES	USE PERIOD	USE 3	Q(i)3	# ACRES	USE PERIOD	Q(i)p	Q(a)p
G 2801739 C	E	01046	11/28/50	15N/03W-05	BLBB TOWNSITE OF ROCHESTER	NOVAK G E	WELL	1	DS	100.00	20.000	0.0	2	IR	100.00	7.0	2 IS					100.00	20.000
G 2801742 C		01673	11/30/50	15N/03W-10	L6 / 7 GRAND VALLEY GDN TRS	TISCHER C	WELL	1	IR	100.00	40.000	20.0	IS									100.00	40.000
G 2801782 C		01190	01/16/51	15N/02W-06	NE4SE4	OLIVER W H	WELL	1	DS	150.00	50.000	0.0	2	IR	150.00	25.0	2 IS					150.00	50.000
G 2801788 C		02425	01/22/51	15N/02W-30	BYLES DON CLAIM NO 44	DAVIES G	WELL	1	DS	84.00	20.000	0.0	2	IR	84.00	10.0	2 IS					84.00	20.000
G 2801790 C		02683	01/23/51	16N/02W-31	C BYLES DLC 44	MITIGE R F	WELL	1	DS	150.00	64.000	0.0	2	IR	150.00	32.0	2 IS					150.00	64.000
G 2801796 C		01668	01/26/51	16N/03W-32	SW4 SE4	CANADAY L	WELL	1	DS	100.00	40.000	0.0	2	IR	100.00	20.0	2 IS					100.00	40.000
G 2801877 C		00698	03/22/51	15N/03W-24	NE4SW4	KUNSELMAN M C	WELL	1	DS	50.00	12.000	0.0	2	IR	50.00	4.5	2 IS					50.00	12.000
G 2801893 C		01118	04/04/51	16N/02W-33	NW4	AGNEW S A	WELL	1	IR	250.00	110.000	55.0	IS									250.00	110.000
G 2801894 C		02587	04/04/51	16N/02W-26	NE4 NE4	BAKER K C	WELL	1	DS	100.00	40.000	0.0	3	ST	100.00	0.0	3	IR	100.00	20.0	3 IS	100.00	40.000
G 2801913 C		00942	04/23/51	15N/03W-13	L2 COOPER PLACE	STRONG R	WELL	1	IR	60.00	20.000	10.0	IS									60.00	20.000
G 2801984 C		01242	05/31/51	15N/03W-02	L-4 BL-4 AMER HOME FR TR DIV	BROWN W	WELL	1	DS	100.00	20.000	0.0	2	IR	100.00	10.0	2 IS					100.00	20.000
G 2802026 C		00898	07/03/51	15N/03W-10	A GANGLOFF DLC 39	LAWRENCE E T	WELL	1	IR	150.00	20.000	15.0	SIS									150.00	
G 2802059 C		01647	08/01/51	15N/02W-05	SW4NW4	SMITH H J	WELL	1	DS	100.00	20.000	0.0	2	IR	100.00	10.0	2 IS					100.00	20.000
G 2802177 C		01094	10/15/51	15N/03W-11	D DUNCAN DLC NO 40	HILL A D	WELL	1	IR	10.00	8.000	5.0	IS									10.00	8.000
G 2802199 C		01965	11/05/51	16N/02W-30	LANTON-CASE MARGARET DLC 37	NYE D	WELL	1	IR	90.00	40.000	20.0	IS									90.00	40.000
G 2802260 C		01648	12/17/51	16N/02W-31	NW4SE4	LEITNER D	WELL	1	IR	120.00	48.000	24.0	IS									120.00	48.000
G 2802388 C		02751	03/14/52	15N/03W-05	E2SE4SW4	TRIPP A	WELL	1	IR	95.00	30.000	15.0	IS									95.00	30.000
G 2802397 C		01127	03/20/52	15N/03W-06	GL-7	DAYBARZ N H	WELL	1	DS	50.00	20.000	0.0	2	IR	50.00	10.0	2 IS					50.00	20.000
G 2802403 C		01122	03/24/52	16N/03W-33	TR10 P C BREWER TEN ACRE TRS	PARKINSON H	WELL	1	DS	20.00	4.000	0.0	2	IR	20.00	2.0	2 IS					20.00	4.000
G 2802498 C		02364	05/06/52	15N/03W-04	NE4 NW4	JOHNSON L D	WELL	1	DS	150.00	44.000	0.0	2	IR	150.00	22.0	2 IS					150.00	44.000
G 2802502 C		03033	05/07/52	16N/02W-27	L20 VALLEY ACRE TRS	CLARK R H	WELL	1	IR	85.00	24.000	12.0	IS									85.00	24.000
G 2802546 C		01238	05/21/52	15N/03W-24	NE4NW4	HOLLINGER R G	WELL	1	IR	15.00	6.000	3.0	IS									15.00	6.000
G 2802553 C		01821	05/26/52	15N/03W-11	TR-9 JACKSON FRUIT TRS	BLANKENSHIP W	WELL	1	IR	100.00	20.000	10.0	IS									100.00	20.000
G 2802634 C		03375	07/07/52	15N/03W-11	TR21 JACKSON FRUIT TRS	RICH E H	WELL	1	DS	200.00	40.000	0.0	2	IR	200.00	20.0	2 IS					200.00	40.000
G 2803006 C		02618	02/17/53	15N/03W-11	TR35 GR VLT FR / GDN TR	WALTRIP S	WELL	1	DS	100.00	40.000	0.0	2	IR	100.00	20.0	2 IS					100.00	40.000
G 2803074 C	E	01757	03/13/53	15N/03W-06	NW4SE4	STEELHAMMER G C	WELL	1	IR	120.00	28.000	25.0	IS									120.00	28.000
G 2803162 C		02953	04/13/53	16N/03W-31	NE4 SE4	FOSNACHT F	WELL	1	DS	45.00	14.000	0.0	2	IR	45.00	7.0	2 IS					45.00	14.000
G 2803195 C		02648	05/04/53	16N/03W-29	SW4 NW4 SW4	HANELINE R C	WELL	1	DS	100.00	40.000	0.0	2	IR	100.00	20.0	2 IS						
G 2803379 C		02715	09/22/53	16N/02W-19	SW4 NE4 / NW4 SE4	ERICKSON R	SUMP	1	ST	80.00	32.000	0.0	2	IR	80.00	16.0	2 IS					80.00	32.000
G 2803451 C		01840	12/04/53	15N/03W-11	TR-40 JACKSON MEADOW TRS	SIMPSON R O ET UX	WELL	1	IR	40.00	28.000	14.0	IS									40.00	28.000
G 2803552 C		01936	03/23/54	15N/03W-12	L-7 BL-9 AMER HOME FRUIT TRS	LYNN J W	WELL	1	DS	40.00	21.600	0.0	2	IR	40.00	8.0	2 IS					40.00	21.600
G 2803559 C		01910	03/29/54	15N/03W-11	L-10 - 13 GRAND VALLEY FR	PIERCE GARY D ET UX	WELL	1	IR	100.00	40.000	20.0	IS									100.00	40.000
G 2803560 C		02179	03/29/54	15N/03W-01	L5 BL2 AMER HOME FRUIT TRS	PROCTOR W S	WELL	1	DS	100.00	45.600	0.0	2	IR	100.00	20.0	2 IS					100.00	45.600
G 2803951 C		03251	04/01/55	15N/03W-05	N2NW4SW4	FAGERNESS G	WELL	1	IR	60.00	36.000	18.0	IS									60.00	36.000
G 2804012 C		03035	05/24/55	16N/03W-34	GL1	HOLMAN O W	WELL	1	IR	290.00	120.000	60.0	IS									290.00	120.000
G 2804135 C		03515	10/10/55	15N/03W-12	JOSEPHUS AXTEL DLC	SALZER F H	WELL	1	IR	70.00	18.000	9.0	IS									70.00	18.000
G 2804189 C		02786	01/04/56	16N/03W-33	L34 L A BREWER 10AC TR	SHEWMAN F	WELL	1	DS	40.00	5.600	0.0		IR	40.00	10.0	IS					40.00	25.600
G 2804222 C	E	03060	02/16/56	16N/02W-31	N2 SW4 SE4	PARKHURST E F	WELL	1	DS	240.00	60.000	0.0	2	IR	240.00	30.0	2 IS					240.00	60.000
G 2804313 C		03198	05/15/56	16N/03W-31	E2 NE4	GUILES H W	WELL	1	IR	280.00	140.000	70.0	IS									280.00	140.000
G 2804342 C		03471	06/08/56	16N/03W-36	TR31/32 SARJENT HOME TRS	SLAYMAKER H J	WELL	1	ST	50.00	10.000	0.0	2	IR	50.00	5.0	2 IS					50.00	10.000
G 2804390 C		03902	07/31/56	16N/02W-32	NE4	AGNEW S A	WELL	1	DS	1,000.00	200.000	0.0	2	IR	1,000.00	150.0	2 IS					1,000.00	200.000
G 2804619 C		03516	05/29/57	16N/03W-33	TR23 24 29 30 L A BREWER	PRANG E H	WELL	1	IR	240.00	80.000	40.0	IS									240.00	80.000
G 2804725 C		03325	11/15/57	16N/02W-25	SW4 NW4	BAKER K C	WELL	1	DS	200.00	10.000	0.0	2	DS	200.00	0.0	2	IR	200.00	5.0	2 IS	200.00	50.000
G 2804754 C		03274	01/15/58	16N/04W-35	N2 NW4	WHITE O L	INFILTR	1	IR	200.00	120.000	60.0	IS									200.00	120.000
G 2804910 C		03290	07/09/58	16N/02W-29	BL7 SCATTER CREEK PARK	THOMSEN R	INFILTR	1	IR	280.00	56.000	28.0	IS									280.00	
G 2805049 C		03580	10/23/58	15N/03W-04	SW4 SE4	WALTENBERG E	WELL	1	IR	300.00	120.000	14.0	2 SIS	IR	300.00	46.0	2 IS					300.00	46.000
G 2805055 C		03331	10/28/58	16N/03W-30	N2 NW4 NE4	KERWOOD R R	WELL	1	DS	10.00	5.600	0.0										10.00	5.600
G 2805154 C		03710	03/06/59	15N/03W-11	D BURGAN DLC	KNIGHT W V	WELL	1	IR	130.00	26.000	13.0	IS									130.00	26.000
G 2805602 C		04006	05/12/60	15N/03W-04	SW4 NE4 / NW4 SE4	TSCHRITTER F	WELL	1	IR	70.00	56.000	32.0	IS									70.00	56.000
G 2805952 C		04272	05/19/61	15N/04W-01	N2 SE4 NE4	RASMUSON O R / N A	WELL	1	DS	190.00	41.600	0.0	2	IR	190.00	18.0	2 IS					190.00	41.600
G 2805990 C		04482	07/06/61	16N/03W-30	E2 SE4	NICHOLS R L / D A	WELLS	2	DS	230.00	85.600	0.0	2	IR	230.00	40.0	2 IS					230.00	85.600
G 2806027 C		04783	08/17/61	16N/02W-32	L-42 SCATTER CR PARK	THOMSEN R	WELL/IN	2	IR	185.00	46.000	23.0	IS									185.00	46.000
G 2806152 C		04481	01/15/62	16N/03W-32	N2 NW4	NICHOLS R L / D A	WELL	1	ST	410.00	85.600	0.0	2	IR	410.00	40.0	2 IS					410.00	85.600
G 2806165 C		04233	02/02/62	15N/03W-04	S2 SE4 SW4	DIER D / H	WELL	1	DS	40.00	11.600	0.0	2	IR	40.00	3.0	2 IS					40.00	11.600
G 2806362 C		04469	06/28/62	15N/04W-01	SE4 NE4	LUND L	WELL	1	DS	100.00	24.000	0.0	2	IR	100.00	12.0	2 IS					100.00	20.000

WATER RIGHT #	STATUS	OLD CERT	PRIORTY DATE	LOCATION		OWNER	SOURCE	NO. POWS	USE 1	Q(i)	Q(A)	# ACRES	USE PERIOD	USE 2	Q(i)2	# ACRES	USE PERIOD	USE 3	Q(i)3	# ACRES	USE PERIOD	Q(i)p	Q(a)p
G 2806453	C	05359	08/31/62	15N/02W-06	W2 SE4	DANIELSON A J	WELL	1	IR	250.00	33.000	22.0	SIS	IR	250.00	30.0	IS					250.00	60.000
G 2806473	C	04777	09/13/62	15N/03W-11	TR7 GND VALLEY FRUIT / GARDN	PETERSON H M	WELL	1	DS	160.00	5.600	0.0		IR	160.00	30.0	SIS	IR	160.00	9.0	IS	160.00	18.000
G 2806505	C	04784	10/04/62	16N/02W-32	SE4SW4	THOMSEN R	WELL	1	IR	185.00	60.000	30.0	IS									185.00	60.000
G 2806739	C E	05178	05/31/63	15N/03W-24	NE4 SW4	ZUBER D F / J L	WELL	1	DS	10.00	5.600	0.0	2 P	ST	10.00	0.0	2 P	IR	45.00	4.5	PIS	45.00	14.600
G 2807059	C	05049	03/11/64	16N/04W-35	L3 FARMDALE ADD GATE CITY	DREW A M	WELL	1	IR	200.00	18.000	9.5	IS									200.00	18.000
G 2807067	C	04896	03/16/64	15N/03W-01	L4 BL4 AMER HOME FRUIT TRS	WALDRON O	WELL	1	DS	90.00	25.600	0.0	2	IR	90.00	10.0	2 IS					90.00	25.600
G 2807420	C	05552	11/27/64	15N/03W-02	SE4 SE4 SE4	CLEMENTS J E	WELL	1	DS	50.00	21.000	0.0	2	IR	50.00	10.0	2 IS					50.00	22.000
G 2807517	C	06012	12/21/64	16N/04W-35	GL1	HENDRICKS J R	WELL	1	IR	200.00	28.500	19.0	05011001	IR	200.00	35.0	S05011001					200.00	28.500
G 2807740	C	05434	08/13/65	16N/02W-30	LAWTON CASE DLC #37	DOOR W D ET UX	WELLS	2	DS	10.00	1.000	0.0		IR	160.00	30.0	IS					160.00	61.000
G 2807787	C	05445	09/15/65	15N/03W-14	NW4 SE4 SE4	STRONG R M / M M	WELLS	2	DS	60.00	1.250	0.0	2	ST	60.00	0.0	2	IR	60.00	8.0	IS	60.00	17.250
G 2808076	C E	05799	05/09/66	15N/03W-23	SE4 NW4	WHITTAKER G A	WELL	1	IR	300.00	151.200	75.6	PIS									300.00	
G 2808322	C	06122	02/06/67	15N/03W-23	E2 NW4	ZACHER A R	WELL	1	IR	95.00	71.000	35.5	IS									95.00	71.000
G 2808836	C	06279	07/03/67	15N/04W-01	GL8	KLUNDT G J	WELL	1	IR	72.00	30.000	15.0	S05010930	IR	72.00	1.0	05010930					72.00	2.000
G 2808843	C	07125	07/10/67	15N/03W-07	GL2	NELSON C A & G R	WELL	1	IR	80.00	16.000	0.0	05010930									80.00	16.000
G 2809162	C	07448	01/22/68	15N/03W-06	FR NW4 NW4	PAGE V L	WELL	1	DS	400.00	1.000	0.0		ST	400.00	0.0		IR	400.00	74.0	05011001	400.00	150.000
G 2809246	C	06549	02/27/68	15N/03W-08	NE4NE4	PEDERSON P & M	WELL	1	IR	180.00	60.000	40.0	05011001									180.00	60.000
G 2809529	C	07468	04/18/68	15N/03W-06	SE4 NE4	SLOAN J & W	WELL	1	DM	160.00	12.500	0.0		IR	160.00	6.0	05010930					160.00	24.500
G 2810025	C	06673	01/23/69	16N/02W-30	ASHER SARGEANT DLC 41	WA ST D B N	WELL	1	DM	55.00	5.000	0.0		IR	55.00	5.0	05011001					55.00	12.000
G 2810190	C	06722	04/14/69	16N/02W-30	LAWTON CASE DLC 37	WA ST D O N	WELL	2	DM	55.00	3.000	0.0		IR	55.00	4.0	05011001					55.00	9.000
G 2810245	C	06736	06/06/69	16N/03W-33	N2 TR1 L A BREWER 10 AC TR	ROTTER A	WELL	1	DS	50.00	1.000	0.0		ST	50.00	0.0		IR	50.00	4.0	05011001	50.00	8.000
G 2810280	C	07160	06/26/69	16N/03W-31	SE4NE4	DAVIS C F	WELL	1	IR	280.00	58.000	40.0	05010930									280.00	58.000
G 2810351	C	07297	08/12/69	16N/02W-29	BL7 SCATTER CR PK	THOMSEN R	INFILTR	1	IR	240.00	103.000	65.0	S05011001									240.00	
G 2810435	C	07061	09/30/69	15N/03W-06	L12 BL37 ROCHESTER	ROCHESTER WTR ASSN	WELL	1	MU	160.00	99.000	0.0										160.00	99.000
G 2810838	C	07672	05/05/70	15N/03W-09	LOT 12 JAMES SUBD	WHITE E H	WELLS	2	DS	190.00	1.000	0.0		IR	190.00	17.0	05011001		0.00	0.0		190.00	40.000
G 2811412	C	07371	11/27/70	16N/03W-33	L14 L A BREWER 10 AC TR	AMES G H	WELL	1	DS	10.00	1.000	0.0		ST	10.00	0.0		IR	45.00	4.5	04011101	65.00	12.000
G 2811691	C S	01139	03/15/71	16N/03W-32	W2NW4SW4	LANG MIKE	WELL	1	DM	180.00	21.500	0.0										180.00	21.500
G 2812009	C	07642	06/14/71	15N/03W-24	SW4NE4SE4	WUERTH WALTER	WELL	1	DS	20.00	.500	0.0		IR	20.00	3.0	05011001					20.00	6.500
G 2-00016	C		05/11/70	15N/03W-09	TR-20 CHEHALIS VALLEY GDN TR	WEYERHAEUSER CO	WELL	1	IR	1,085.00	105.000	60.0	S03011130									1,085.00	105.000
G 2-00016	C		05/11/70	15N/03W-10	TR-20 CHEHALIS VALLEY GDN TR	WEYERHAEUSER CO	WELL	1	IR	1,085.00	105.000	60.0	S03011130										
G 2-00031	C		05/07/71	16N/02W-27	L32 OF PLAT OF TILLEY TRACTS	VAUGHAN W L & J A	WELL	1	DS	30.00	.500	0.0		IR	30.00	4.0	05011001					30.00	8.000
G 2-00077	C		03/08/71	15N/03W-09	L7 JAMES SUBDIV	FLETCHER ROGER C	WELLS	2	DS	450.00	1.000	0.0		ST	450.00	0.0		IR	450.00	65.0	05011001	450.00	150.000
G 2-00095	C		04/28/71	15N/03W-05	SE4SE4	PEDERSON HOWARD S	WELL	1	IR	90.00	36.000	16.0	05011001									90.00	36.000
G 2-00464	C		02/24/71	15N/03W-13	NW4NW4	HUGHEY A & L	WELL	1	DM	50.00	2.000	0.0										50.00	2.000
G 2-00524	C		04/08/48	15N/03W-10	TR 21 CHEHALIS VALLEY GDN TR	WEYERHAEUSER CO	WELL	1	IR	600.00	132.800	88.5	IS									600.00	132.800
G 2-00632	C		03/19/71	16N/04W-35	GL-1	HENDRICKS JAMES R	WELL	1	IR	200.00	55.000	33.0	05010930									200.00	55.000
G 2-00657	C		05/11/71	16N/02W-30	LAWTON CASE DLC 37 NE4 NW4	WIMATRE MARLENE	WELL	1	DS	150.00	.500	0.0		IR	150.00	25.0	05011001					150.00	50.500
G 2-00696	C		07/21/71	15N/03W-11	TR20 GR VAL FR & GDN TR	GALPIN DONALD H	WELL	1	DS	20.00	1.000	0.0	2	ST	20.00	0.0	2	IR	20.00	4.0	05011001	20.00	10.000
G 2-01025	C		08/22/66	15N/03W-02	TRS 7-8-9-10 JACKSON HDW TR	POTTRATZ LESTER A	WELLS	2	DM	100.00	23.500	0.0										100.00	23.500
G 2-01139	C S		03/15/71	16N/03W-32	W2NW4SW4	N END MOBILE HOME	WELL	1	DM	180.00	21.500	0.0										180.00	21.500
G 2-20006	C		03/02/72	15N/03W-03	L2&3 GRAND VALLEY GARDEN TR	ROCHESTER WATER ASSO	WELLS	2	DM	340.00	27.000	0.0										340.00	27.000
G 2-20022	C		03/08/72	15N/03W-12	SW4SW4	ROEDER SR WILLIAM H	WELL	1	DM	50.00	30.000	0.0										50.00	30.000
G 2-20049	C		03/22/72	15N/03W-06	L2 BL 60 PLAT OF ROCHESTER	ARNOLD KENNETH E	WELLS	2	DS	30.00	1.000	0.0		IR	30.00	1.5	04151001					30.00	4.000
G 2-20130	C		04/11/72	15N/03W-11	TR 19 GRAND VLY FRUIT & GDN	LEE CHRISTINA	WELL	1	DS	10.00	1.000	0.0										10.00	1.000
G 2-20145	C		04/19/72	16N/04W-35	S2SE4SE4	DREWS BERRY FRMS INC	WELL	1	IR	300.00	80.000	40.0	05011001									300.00	80.000
G 2-20146	C		04/19/72	15N/04W-01	E2 NE4 NE4	LUND L ET AL	WELL	1	IR	150.00	56.000	28.0	05011001									150.00	56.000
G 2-20153	C		04/24/72	15N/03W-03	SE4 NE4	CLEMENTS JAMES H	WELL	1	IR	250.00	48.000	24.0	04151001		0.00	0.0			0.00	0.0		250.00	48.000
G 2-20335	C		06/30/72	16N/03W-33	L-2&3 BL-I AMER HOME TRS	GRILL GERALD D	WELL	1	DS	100.00	1.000	0.0		IR	100.00	9.0	04151001					100.00	19.000
G 2-20614	C S		11/17/72	16N/02W-32	C BYLES DLC #40 W2NW4	SEA FARM OF NORWAY	WELLS	4	FS	2,000.00	0.000	0.0		IR	2,000.00	30.0	05011001					2,000.00	2496.000
G 2-20687	C		01/08/73	15N/03W-13	L-9 COOPER PLACE	MCWALLIE EMERSON	WELL	1	DM	50.00	5.000	0.0			0.00	0.0						50.00	5.000
G 2-20800	C		02/27/73	15N/03W-07	GL3	JOHNSON ARVID L	WELL	1	IR	40.00	8.000	4.0	05011001									40.00	8.000
G 2-20839	C		03/12/73	15N/02W-05	SW4 NW4	STRANDER HAROLD E	WELL	1	IR	300.00	72.000	36.0	S05151001									300.00	72.000
G 2-20903	C		03/29/73	15N/03W-11	SE4SE4	SMILEY JAMES G	WELL	1	DM	60.00	10.750	0.0										60.00	10.750
G 2-20904	C		03/29/73	15N/03W-13	NW4NW4	WOLCOTT ROY A	WELL	1	DM	80.00	5.400	0.0										80.00	5.400
G 2-20923	C		04/09/73	16N/04W-26	SE4 NE4	JOHNSON DAREN W	WELL	1	DS	18.00	1.250	0.0	2	ST	18.00	0.0	2	IR	18.00	5.0	05011001	18.00	11.250
G 2-20964	C		04/24/73	16N/04W-35	SW4 NW4	RENNER GARRY	WELL	1	DS	35.00	2.000	0.0		ST	35.00	0.0						35.00	10.800

WATER RIGHT #	STATUS	OLD CERT	PRIORTY DATE	LOCATION	OWNER	SOURCE	NO. POWS	USE 1	Q(i)	Q(A)	# ACRES	USE PERIOD	USE 2	Q(i)2	# ACRES	USE PERIOD	USE 3	Q(i)3	# ACRES	USE PERIOD	Q(i)p	Q(a)p
G 2-20968	C		04/26/73	16N/04W-36 SE4SW4	LUND LENNART ET AL	WELL	1	IR	520.00	214.000	107.0	05011031									520.00	214.000
G 2-20968	C		04/26/73	15N/04W-01 NW4NE4	LUND LENNART ET AL	WELL	1	IR	520.00	214.000	107.0	05011031										
G 2-20969	C		04/27/73	16N/02W-31 NE4NE4	CULP LAVERN D	WELL	1	IR	60.00	24.000	12.0	05011001									60.00	24.000
G 2-20990	C		05/01/73	16N/03W-32 L30 BK14 WRIGHTS ADD ROCHES	HARRIS CHAS E & L J	WELL	1	DS	10.00	1.000	0.0		IR	25.00	4.0	05011001					35.00	9.000
G 2-21004	C		05/02/73	15N/03W-23 SE4SW4	WALSH LEO & BEVERLY	WELL	1	IR	500.00	124.000	62.0	05011001									500.00	124.000
G 2-21023	C		05/09/73	15N/03W-04 SE4SW4SW4	LONG GEORGE A	WELL	1	IR	60.00	10.000	5.0	05011001									60.00	10.000
G 2-21037	C		05/17/73	16N/02W-32 TR 54 PLAT SCATTER CR PARK	WEYRAUCH D J & N E	WELL	1	DS	10.00	1.000	0.0										10.00	1.000
G 2-21076	C		05/29/73	15N/03W-24 NE4 SW4	ZUBER DAVID F	WELL	1	DM	60.00	2.000	0.0		IR	60.00	3.0	05011001					60.00	8.000
G 2-21115	C		06/01/73	15N/03W-02 NE4 SE4	HARDY LLOYD A	WELL	1	DS	30.00	1.000	0.0		IR	30.00	1.0	05011001					30.00	3.000
G 2-21128	C		06/07/73	14N/02W-36 SE4	CAVNESS OTIS N	WELL	1	ST	10.00	2.000	0.0	S	IR	255.00	200.0	S05011001					265.00	172.000
G 2-21431	C		09/04/73	15N/03W-11 L 20 GR VY FR & GDN TR	SHILEY JAMES G	WELL	1	DM	60.00	10.750	0.0										60.00	10.750
G 2-21477	C		09/25/73	15N/03W-24 SW4 SE4	BRANDT KENNETH	WELL	1	DS	260.00	1.000	0.0	S	IR	260.00	26.0	S05011001					260.00	53.000
G 2-21499	C		10/01/73	15N/03W-14 N2 SE4	NICOLL ALFRED A	WELLS	2	DM	120.00	2.500	0.0	2	ST	120.00	0.0	2	IR	120.00	25.0	05011001	120.00	52.500
G 2-21633	C		11/28/73	16N/04W-35 L 1 FARMDALE ADN TO GATE	CORDELL JIM	WELL	1	IR	200.00	34.000	17.0	05011001									200.00	34.000
G 2-21684	C		12/07/73	15N/03W-03 NW4 NW4	BACHMAN THOS C	WELL	1	DS	15.00	1.000	0.0		IR	15.00	1.0	05011001					15.00	2.000
G 2-21754	C		12/28/73	15N/03W-30 SE4SE4	SNECKER DANIEL D	WELL	1	DS	500.00	1.000	0.0		FS	500.00	0.0						500.00	578.000
G 2-21796	C		01/16/74	15N/03W-03 GL-3	ANDERSON GEORGE D	WELL	1	DS	50.00	1.000	0.0		IR	50.00	18.0	05011001					50.00	28.000
G 2-21893	C		02/19/74	16N/04W-36 SW4NE4	DREW BERRY FARMS INC	WELL	1	IR	260.00	70.000	35.0	05011001									260.00	70.000
G 2-21894	C		02/19/74	16N/04W-35 NW4SE4	DREW BERRY FARMS INC	WELL	1	IR	220.00	106.000	53.0	05011001									220.00	106.000
G 2-21928	C		02/22/74	16N/03W-33 N2 SE4	MOORE CLIFFORD E	WELLS	2	IR	170.00	34.000	17.0	05011001									170.00	34.000
G 2-21930	C		01/29/74	16N/01W-21 NW4 NW4	LUCERO RAY ET UX	WELL	1	DS	40.00	1.000	0.0	2	ST	40.00	0.0	2	IR	40.00	4.0	05011001	300.00	52.500
G 2-21972	C		03/06/72	15N/03W-10 TR 3 & 4 JAMES RIVERSIDE TRS	WILDFANG C G	WELLS	3	DM	20.00	2.000	0.0		ST	10.00	0.0		IR	270.00	25.0	05011001	300.00	52.500
G 2-21987	C		03/04/74	15N/03W-04 GL-1	HUMPHREY NATHAN R	WELL	1	DS	100.00	1.000	0.0		IR	100.00	0.0	05011001					100.00	17.000
G 2-22009	C		03/18/74	15N/03W-09 L 3 JAMES SUBD	CARTER JOHN L	WELL	1	IR	250.00	80.000	40.0	05011001									250.00	80.000
G 2-22023	C		03/15/74	16N/03W-33 TR 4 P C BREWER TEN ACRE TR	LETTEER DOUGLAS C	WELL	1	DS	30.00	1.000	0.0		IR	30.00	2.5	05011001					30.00	6.000
G 2-22069	C		02/28/74	16N/02W-25 SE4	RIEGER JACK L	WELL	1	DS	60.00	1.000	0.0		IR	60.00	4.5	05011001					60.00	10.000
G 2-22280	C		04/23/74	16N/03W-33 TR 3 L.A.BREWER TEN AC TR	SALENSKY BEN F	WELL	1	DS	30.00	1.000	0.0		IR	30.00	4.0	05011001					30.00	8.000
G 2-22512	C		05/29/74	16N/02W-31 NW4 SE4	ANTON R ET AL	WELL	1	DS	30.00	1.000	0.0		ST	30.00	0.0						30.00	18.000
G 2-22514	C		05/29/74	15N/03W-10 GANGLOFF DLC 39	BLANKSMA RICHARD	WELL	1	IR	150.00	60.000	30.0	05011001									150.00	50.000
G 2-22688	C		06/20/74	15N/03W-05 N2 NE4	PAULSON MELVIN	WELLS	2	DS	450.00	1.000	0.0		ST	450.00	0.0		IR	450.00	35.0	05011001	450.00	74.000
G 2-22743	C		06/27/74	16N/03W-33 SW4 SW4	HUHTA MAX ET AL	WELL	1	ST	500.00	10.000	0.0		IR	500.00	70.0	05011001					500.00	150.000
G 2-22757	C		06/27/74	15N/03W-10 SE4SW4	ROCHESTER SCHOOL DIS	WELL	1	DM	165.00	28.000	0.0		IR	165.00	5.0	05011001					165.00	38.000
G 2-22849	C		06/27/74	16N/03W-34 NW4 NW4	DANTER C RICHARD	WELLS	2	DM	130.00	23.500	0.0										130.00	23.500
G 2-22992	C		07/24/74	16N/02W-29 L2 BURBANK ACRE TRACTS	SPRINGER BRUCE	WELL	1	DS	35.00	1.000	0.0		IR	35.00	10.0	05011001					35.00	11.000
G 2-23071	C		08/12/74	16N/04W-35 NE4 SE4	LAEL LARRY	WELL	1	DS	12.00	1.500	0.0	2	ST	12.00	0.0	2	IR	12.00	2.0	05011001	12.00	5.500
G 2-23076	C		08/16/74	16N/02W-25 TRT 15 NINA ACRES	GARDNER JAMES	WELL	1	DS	50.00	1.000	0.0		IR	50.00	5.0	05011001					50.00	11.000
G 2-23095	C		08/28/74	16N/02W-25 TRACT 10 NINA ACRES	LANDERS TED	WELL	1	DS	60.00	1.000	0.0		IR	60.00	3.0	05011001					60.00	7.000
G 2-23132	C		09/16/74	16N/02W-25 SE4NE4	SAMPSON DOUGLAS	WELL	1	DS	10.00	1.000	0.0										10.00	1.000
G 2-23150	C		06/03/74	15N/03W-02 L5 B4 AMERICAN HM FRUIT T #3	CLEMENTS JOHN	WELL	1	DS	20.00	1.000	0.0	2	ST	20.00	0.0	2	IR	80.00	8.0	05011001	100.00	17.000
G 2-23190	C		09/27/74	16N/03W-33 TRT4 BLK K AMERICAN HM GD TR	ANDERSON JAMES	WELL	1	DS	35.00	1.000	0.0		IR	35.00	2.5	05011001					35.00	6.000
G 2-23294	C		11/04/74	15N/03W-02 L 7 PRAIRIE ESTATES	PRESTRIDGE & SHELTON	WELL	1	DM	60.00	4.000	0.0										60.00	4.000
G 2-23295	C		11/04/74	15N/03W-03 L 1 PRAIRIE ESTATES	PRESTRIDGE & SHELTON	WELL	1	DM	60.00	3.000	0.0										60.00	3.000
G 2-23296	C		11/04/74	16N/03W-34 TRT 9 LA BREWERS TEN ACRE TS	PRESTRIDGE & SHELTON	WELL	1	DM	80.00	4.000	0.0										80.00	4.000
G 2-23608	C		07/01/74	15N/03W-10 TR 23 GRAND VALLEY GARDEN	CONNELL ALBERT J	WELL	1	DM	50.00	3.000	0.0		IR	50.00	4.0	05011001					50.00	7.000
G 2-23792	C		04/16/75	16N/03W-33 TR 23 L A BREWER 10 ACRE TRS	ROCHESTER WATER ASSO	WELLS	2	MU	200.00	57.400	0.0										200.00	57.400
G 2-23985	C		10/29/75	16N/03W-30 N2NW4SE4 SE4	SNECKER D P & D J	WELL	1	FS	600.00	700.000	0.0										600.00	700.000
G 2-24070	C		02/17/76	16N/03W-33 L-33 BK-19 FACTORY ADD ROCH	ROCHESTER WTR ASSO	WELL	1	DM	90.00	9.000	0.0										90.00	9.000
G 2-24072	C		02/19/76	15N/03W-02 L6&7 B2 AMERICAN HOME FR TRS	HAWKINS C S	WELL	1	DS	110.00	1.000	0.0		IR	110.00	10.0	05011001					110.00	21.000
G 2-24074	C		02/24/76	16N/02W-31 SW4 SW4	SKYWARD HOMES INC	WELLS	2	DM	100.00	18.000	0.0										100.00	18.000
G 2-24075	C		02/24/76	15N/02W-06 SW4NW4	NATIONWIDE ENTER INC	WELLS	2	DM	65.00	18.000	0.0										65.00	18.000
G 2-24109	C		03/24/76	15N/03W-12 L-25 GRAND VALLEY FRT &GAR T	HANCOCK CAROLYN JEAN	WELL	1	DM	45.00	4.000	0.0										45.00	4.000
G 2-24166	C		05/14/76	16N/03W-33 TR-31 L A BREWER TRACTS	HAFNER E C	WELL	1	DS	50.00	1.000	0.0		ST	50.00	0.0		IR	50.00	8.0	05011001	50.00	17.500
G 2-24168	C		05/19/76	16N/02W-29 NE4 SW4	SWEENEY JOHN P	WELL	1	DS	200.00	1.000	0.0		ST	200.00	0.0		IR	200.00	28.0	05011001	200.00	57.500
G 2-24176	C		05/21/76	16N/03W-32 SW4 NE4	PERSSON FRIDOLPH H	WELL	1	DS	10.00	1.000	0.0		IR	10.00	1.0	04151015					10.00	3.000
G 2-24215	C		06/17/76	15N/03W-10 NW4 NW4	WEYERHAEUSER CO	WELL	1	DM	125.00	11.000	0.0		FR	125.00	0.0						125.00	11.000

WATER RIGHT #	STATUS	OLD CERT	PRIORITY DATE	LOCATION		OWNER	SOURCE	NO. POWS	USE 1	Q(i)	Q(A)	# ACRES	USE PERIOD	USE 2	Q(i)2	# ACRES	USE PERIOD	USE 3	Q(i)3	# ACRES	USE PERIOD	Q(i)p	Q(a)p
G 2-24247	C	S	07/29/76	16N/03W-30	SE4SE4	SWECKER DANIEL ET UX	WELL	2	FS	1,400.00	1000.000	0.0										1,500.00	1800.000
G 2-24318	C		10/12/76	15N/03W-06	BLK-53,61,62870 PL ROCHESTER	STEELHAMMER GEORGE C	WELLS	4	FS	2,500.00	4000.000	0.0		IR	2,500.00	40.0	05011001					2,500.00	4000.000
G 2-24319	C		10/12/76	15N/04W-01	GL 3	STEELHAMMER GEORGE C	WELL	1	IR	300.00	160.000	80.0	05011001									300.00	160.000
G 2-24370	C		12/29/76	15N/03W-24	NE4SW4	ZUBER DAVID E	WELL	1	DM	60.00	3.000	0.0										60.00	3.000
G 2-24372	P		12/30/76	15N/03W-01	SE4NW4	BIRCHALL PETER E	WELL	1	DS	10.00	1.000	0.0										10.00	1.000
G 2-24382	C		01/31/77	16N/03W-36	N2SE4	DON SEA FARMS INC	WELLS	4	CI	6,000.00	9600.000	0.0	2	FS	6,000.00	0.0	2					6,000.00	9600.000
G 2-24422	C		02/10/77	15N/03W-01	NW4SW4	NARELIUS GENE JR	WELL	1	DM	56.00	14.000	0.0										56.00	14.000
G 2-24430	C		02/23/77	16N/02W-32	L-24 SCATTER CREEK PARK	T-9-0 RANCH	WELL	1	IR	850.00	450.000	225.0	S05011001									850.00	250.000
G 2-24453	C		03/07/77	15N/03W-09	TR-20 CHEHALIS VALLEY GRD TR	WEYERHAEUSER CO	WELL	1	FP	1,000.00	120.000	0.0	10010501	ME	1,000.00	0.0	03011130	IR	1,000.00	120.0	03011130	1,000.00	400.000
G 2-24488	C		04/05/77	16N/02W-20	SW4SE4	WIENS CONSTRUCTION	WELL	1	DM	190.00	9.500	0.0										190.00	9.500
G 2-24578	P		05/23/77	16N/02W-19	SE4SE4	THURPA INDUSTRIES	WELLS	2	CI	800.00	282.000	0.0		ST	800.00	0.0						509.00	109.000
G 2-24622	C		07/18/77	15N/02W-05	NE4NW4	LAYNE ROBERT C	WELL	1	DM	50.00	8.000	0.0										50.00	8.000
G 2-24677	C		09/27/77	16N/04W-23	E2	DON SEA FOODS INC	WELL	1	FS	7,000.00	0.000	0.0										7,000.00	
G 2-24701	C		10/07/77	15N/02W-06	NW4SE4	S SOUND UTILITY CO	WELL	1	DM	84.00	21.000	0.0										84.00	21.000
G 2-24714	C		10/21/77	15N/02W-06	NW4NW4	LEWIS WAYNE G	WELL	1	DM	60.00	10.000	0.0										60.00	10.000
G 2-24731	G		11/03/77	15N/03W-04	NW4NW4	RANGEL RAUL ET UX	WELL	1	DS	100.00	1.000	0.0		IR	100.00	4.0	05011001					100.00	9.000
G 2-24842	G		04/18/78	15N/04W-11	GL-6	HERTZ FRANCES ET AL	WELL	1	DS	40.00	1.000	0.0		IR	40.00	4.0	05011001					40.00	9.000
G 2-24963	C		07/21/78	15N/02W-06	SW4NE4	LEWIS STANLEY D	WELL	1	DM	45.00	4.000	0.0										45.00	4.000
G 2-24987	G		08/09/78	15N/02W-05	NE4NW4	RITTER ROLAND D	WELL	1	DS	40.00	1.000	0.0		IR	40.00	3.0	05011001					40.00	7.000
G 2-25034	C		09/20/78	16N/03W-31	NW4NE4	CARLSON RICHARD ETUX	WELLS	2	FS	2,400.00	4839.000	0.0										2,400.00	4839.000
G 2-25052	C		11/06/78	16N/03W-36	N3/4	DON SEA FARMS INC	WELLS	2	FS	3,000.00	4839.000	0.0	2	CI	3,000.00	0.0	2					3,000.00	4839.000
G 2-25081	G		11/20/78	16N/03W-33	NE4SW4	RICHARDS H W ET UX	WELL	1	DS	30.00	1.000	0.0		IR	30.00	2.0	05011001					30.00	5.000
G 2-25109	G		01/10/79	15N/02W-05	E2NW4	BALNELLI ROBERT ETUX	WELL	1	IR	400.00	60.000	30.0	05011001									400.00	
G 2-25150	C		03/01/79	16N/02W-21	NE4NE4	BELL ELDON ET UX	WELLS	4	DM	210.00	15.000	0.0		ST	210.00	0.0		FS	210.00	0.0		210.00	80.000
G 2-25200	N		02/09/79	16N/02W-30	ASHER SARGEANT DLC #41	WA ST D O T	WELL	1	DM	55.00	5.000	0.0		IR	55.00	5.0	05011001					55.00	13.000
G 2-25370	G		09/18/79	16N/03W-21	W2E2 & E2W2	DEVRIES/BLACK RIVER	WELLS	2	DM	1,500.00	2.000	0.0	S	ST	1,500.00	0.0	S	IR	1,500.00	400.0	S05011001	200.00	461.000
G 2-25421	G		11/13/79	16N/02W-27	NW4SE4	CAMPBELL JAMES F SR	WELL	1	DS	23.00	1.000	0.0		IR	23.00	3.0	05011001					23.00	7.000
G 2-25427	C		11/29/79	15N/02W-06	NW4NE4NE4	UNWIN D J	WELL	1	DM	60.00	20.000	0.0										60.00	20.000
G 2-25486	C		02/05/80	16N/02W-27	GL-1, SE4SW4	CLEARWATER UTIL INC	WELL	1	DM	50.00	9.000	0.0										50.00	9.000
G 2-25581	G		05/07/80	16N/04W-35	SW4	ROCKWELL ROBERT C	WELL	1	DS	65.00	1.000	0.0	2	IR	65.00	10.0	2 05011001					65.00	21.000
G 2-25590	G		05/02/80	16N/02W-19	GL-1	VALLEY FRESH INC	WELLS	2	IR	200.00	76.000	38.0	IS									200.00	76.000
G 2-25766	C		12/19/80	15N/03W-12	NW4NE4	BRAGT EARL ET UX	WELL	1	DS	50.00	1.000	0.0		ST	50.00	0.0						50.00	34.800
G 2-25847	G		03/25/81	15N/03W-08	SE4NW4	HAMPTON ROBERT JR	WELL	1	ST	300.00	8.500	10.0	IS	IR	337.50	75.0	05011001	IR	162.50	35.0	S05011001	300.00	228.500
G 2-25964	C		07/31/81	16N/03W-29	NE4SW4	BRIARWOOD FARMS	WELL	1	DS	20.00	1.000	0.0		CI	20.00	0.0						20.00	17.000
G 2-25966	C		07/31/81	16N/04W-36	NW4SW4	BRIARWOOD FARMS	WELL	1	DS	20.00	16.000	0.0		CI	20.00	0.0						20.00	16.000
G 2-25967	C		07/31/81	15N/04W-02	S2SW4	VALLEY FARMS	WELLS	3	CI	30.00	24.000	0.0										30.00	24.000
G 2-25968	C		07/31/81	16N/04W-26	NW4SE4	VALLEY FARMS	WELL	1	CI	20.00	16.000	0.0										20.00	16.000
G 2-26014	C		10/10/81	15N/03W-05	NE4NE4	ROCHESTR WTR ASSN	WELL	1	MU	150.00	13.000	0.0		DM	150.00	0.0	S					150.00	13.000
G 2-26060	G		01/13/82	16N/03W-28	TR-D-2 BAKER PRAIRIE TR	DOYLE THOMAS A	WELL	1	IR	30.00	6.000	3.0	05011001									30.00	6.000
G 2-26127	C		02/23/82	16N/03W-32	NW4SE4	ROCHESTER WTR ASSN	WELL	1	DM	50.00	112.000	0.0	S									50.00	
G 2-26289	G		02/03/83	15N/03W-05	NW4SW4	HARRISON VINCE L	WELL	1	DS	135.00	1.000	0.0		IR	135.00	7.0	05011001					135.00	15.000
G 2-26306	C		03/11/83	15N/03W-24	SW4NW4	HANCOCK CAROLYN	WELL	1	DM	60.00	4.500	0.0										60.00	4.500
G 2-26794	C		09/26/85	16N/02W-29	NW4SE4	DEYOUNG LOWELL	WELLS	1	DM	22.00	1.500	0.0		ST	22.00	0.0						22.00	15.000
G 2-26913	C		05/21/86	15N/03W-11	NW4NW4	EASTER FRANK R	WELL	1	IR	85.00	8.000	4.0	05011031	DM	85.00	0.0						85.00	9.000
G 2-26980	C		09/16/86	15N/03W-11	SE4NE4	GOODRICH LEE	WELL	1	DM	17.00	6.000	0.0										17.00	6.000
G 2-27138	G		06/16/87	15N/03W-05	W2NW4SW4	FAGERNESS LEONA	WELL	1	IR	350.00	24.000	30.0	05011001	IR	350.00	30.0	S05011001					350.00	24.000

WATER RIGHT #	STATUS	OLD CERT	PRIORTY DATE	LOCATION		OWNER	SOURCE	NO. PONS	USE 1	Q(i)	Q(A)	# ACRES	USE PERIOD	USE 2	Q(i)2	# ACRES	USE PERIOD	USE 3	Q(i)3	# ACRES	USE PERIOD	Q(i)p	Q(a)p
S 2*05375 C	E	09183	03/03/41	16N/04W-25	S2 SW4	DREW H E	BLACK R	99	IR	1.50	160.000	78.5	04151001									1.50	160.000
S 2*05675 C		01874	03/31/42	15N/03W-09	E2SW4	VORTBERG L C	UNN STR	1	IR	.22	0.000	22.0	IS									.22	
S 2*05813 C		03035	04/07/43	16N/04W-36	SE4NW4	ALFREDSON V O / A E	BLACK R	1	IR	.35	0.000	35.0	IS									.35	
S 2*06019 C		02945	05/06/44	15N/03W-15	NE4NW4	LAWRENCE E T	CHEHALI	1	IR	.20	0.000	25.0	IS									.30	
S 2*06821 C		03373	12/21/45	16N/04W-26	W2 SW4	NELSON H W	BLACK R	1	IR	.20	0.000	20.0	IS									.20	
S 2*06861 C		02687	01/18/46	15N/03W-14	NW4NW4	HINDMAN T M	PRAIRIE	1	IR	.20	0.000	30.0	IS									.20	
S 2*06909 C		02874	02/18/46	15N/03W-23	NW4SE4	WHITTAKER BROS	UNN STR	1	IR	.45	0.000	55.0	IS									.45	
S 2*06910 C		04734	02/18/46	15N/03W-23	GL2	WHITTAKER BROS	CHEHALI	1	IR	.45	0.000	55.0	IS									.45	
S 2*07145 C		03150	05/20/46	15N/03W-22	GL-1	MUNSELL A	CHEHALI	1	IR	.10	0.000	10.0	04151001									.10	
S 2*07176 C		02987	05/27/46	15N/04W-01	GL-9	RAMBO R	CHEHALI	1	IR	.15	0.000	15.0	IS									.15	
S 2*07238 C		06035	06/11/46	15N/03W-15	L DURGIN DLC	GOEBEL F W JR	UNN SL	1	IR	.20	0.000	24.0	IS									.20	
S 2*07829 C		07653	05/20/47	16N/04W-26	GL1	SEGER D T	BLACK R	1	IR	.10	20.000	10.0	IS									.10	20.000
S 2*07984 C		03600	08/15/47	15N/03W-08	GL-3	REYNOLDSON W T	UNN SL	1	IR	.25	0.000	25.0	04151001									.25	
S 2*07984 C		03600	08/15/47	15N/03W-08	GL-2&3	REYNOLDSON W T	CHEHALI	2	IR	.25	0.000	25.0	04151001										
S 2*08022 C		03229	09/11/47	15N/04W-11	GL1	SKAAG C A	CHEHALI	1	IR	.20	0.000	20.0	IS									.20	
S 2*08347 C		03175	04/22/48	15N/04W-01	GL6	JOHNSON E C	CHEHALI	1	IR	.15	0.000	20.0	IS									.15	
S 2*08454 C		04377	06/07/48	16N/04W-36	NE4 NW4	HOLM P E	BLACK R	99	IR	.12	0.000	12.0	IS									.12	
S 2*08807 C		06325	05/25/49	16N/04W-25	SE4SE4	STOUT J E	BLACK R	1	IR	.20	0.000	20.0	IS									.20	
S 2*08915 C	E	03731	07/19/49	15N/04W-01	GL7	FAGERNES S E	CHEHALI	99	ST	.25	0.000	0.0		IR	.25	25.0	IS					.25	
S 2*09358 C		03858	02/03/50	16N/04W-36	NE4NE4	HANGARTNER H J	BLACK R	1	IR	.12	0.000	12.0	IS									.12	
S 2*09643 C		04501	05/29/50	15N/04W-01	GL8	KLUNDT G J	CHEHALI	1	IR	.14	0.000	14.0	IS									.14	
S 2*10018 C		04665	12/06/50	15N/03W-09	TR13 / 14 JAMES SUBDIV	DUNCAN B M	UNN STR	1	IR	.22	0.000	25.0	IS									.22	
S 2*10261 C		04159	04/24/51	15N/04W-12	SE4NW4	SUNDQUIST E	UNN STR	1	IR	.05	0.000	5.0	IS									.05	
S 2*11923 C		05782	12/26/52	16N/04W-26	GL-1	BRANDT C O	BLACK R	1	IR	.05	0.000	5.0	IS									.05	
S 2*13511 C		08018	02/10/55	16N/04W-35	E2 NW4 SW4	MALONEY L	UNN SL	2	IR	.03	6.000	3.0	IS									.03	6.000
S 2*15104 C		08395	09/18/58	16N/04W-25	SE4SE4	COOPER B C	BLACK R	1	IR	.50	100.000	50.0	IS									.50	100.000
S 2*15292 C		08444	02/19/59	15N/03W-07	GL2	NELSON C A / G	CHEHALI	1	IR	.05	10.000	5.0	IS									.05	10.000
S 2*15896 C		07949	02/01/60	16N/04W-35	NW4 NW4	WHITE O L ET AL	BLACK R	1	IR	.18	64.000	32.0	SIS		0.00	0.0						.18	36.000
S 2*16610 C		09174	03/30/61	16N/04W-36	N2NW4, TR-4&5 FARMDALE ADD	DREW A M	BLACK R	1	IR	.72	144.000	72.0	04151001									.72	114.000
S 2*16610 C		09174	03/30/61	16N/04W-25	S2SW4	DREW A M	BLACK R	1	IR	.72	144.000	72.0	04151001										
S 2*17128 C		08748	02/06/62	15N/03W-15	L DURGIN DLC	GOEBEL F W ET UX	UNN SL	1	IR	.66	132.000	66.0	IS									.70	144.000
S 2*17223 C		09305	04/09/62	16N/04W-35	NW4NW4	RENNER G B	BLACK R	1	IR	.30	60.000	30.0	04151001									.30	60.000
S 2*17327 C		08616	06/04/62	15N/04W-01	GL1	CARLSON R L	UNN SL	1	IR	.60	120.000	60.0	SIS		0.00	0.0						.60	120.000
S 2*18809 C		10007	12/11/64	16N/04W-36	SE4NW4	DREWS BERRY FARMS	BLACK R	1	IR	1.40	280.000	140.0	IS									1.40	280.000
S 2*19689 C		10769	06/03/66	15N/04W-11	GL-1	BANICK L J	CHEHALI	1	IR	.15	30.000	15.0	06010916									.15	30.000
S 2*19689 C		10769	06/03/66	15N/04W-11	SE4NE4	BANICK L J	UNN SL	1	IR	.15	30.000	15.0	06010916										
S 2*20097 C		10178	02/14/67	15N/03W-08	GL1	FOSNACHT F A	CHEHALI	1	IR	.53	128.000	85.0	06010930									.53	128.000
S 2*20257 C		10547	05/23/67	15N/03W-24	NW4SW4	TEDDER F W	UNN SL	1	IR	.25	50.000	25.0	05011001									.25	50.000
S 2*20258 C		10569	05/23/67	15N/03W-23	NE4NE4SE4	TICKNOR R C	UNN SL	1	IR	.39	70.000	39.0	06010831									.39	70.000
S 2*20632 C		10433	11/15/67	16N/04W-36	TR5 FARMDALE ADDN TO GATE	SCHULZ E	BLACK R	1	IR	.26	52.000	26.0	06010930									.26	52.000
S 2*20647 C		10810	11/24/67	15N/03W-17	NW4SE4NE4	BLURTON LEE R ET UX	UNN SPR	1	DS	.01	1.000	0.0		ST	.01	0.0						.01	2.000
S 2*20689 C		10719	01/02/68	16N/04W-25	S2SE4	SLEVELAND I ET UX	BLACK R	99	IR	.70	140.000	70.0	05011001									.70	140.000
S 2*20689 C		10719	01/02/68	16N/03W-31	W2NW4	SLEVELAND I ET UX	BLACK R	99	IR	.70	140.000	70.0	05011001										
S 2*21633 C		10956	06/05/69	16N/04W-36	NW4 NE4 & NE4 NW4	HOLM P E	BLACK R	99	IR	.70	58.000	40.0	05011031									.70	58.000
S 2*21985 C		11672	01/26/70	16N/04W-35	N2NW4NW4	RENNER G	BLACK R	1	IR	1.33	135.000	60.0	S05011031									1.33	39.000
S 2-00057 C			03/17/71	16N/04W-36	N2NE4SW4	JOHNSON LUCILLE	BLACK R	1	IR	.54	78.000	36.0	05011001									.54	78.000
S 2-00826 C			06/30/67	16N/04W-25	SW4	DREWS BERRY FARMS	BLACK R	1	FP	4.00	150.000	75.0	02150601									4.00	150.000
S 2-00951 C			05/18/71	15N/03W-17	W2NW4NW4	CRAIG LLOYD	UNN STR	1	ST	.01	.500	0.0		IR	.09	5.0	05011001					.10	11.500
S 2-20048 C			03/22/72	15N/03W-05	NE4 SE4	GUSTAFSON RAGNOR	UNN SPR	1	DS	.01	1.000	0.0		ST	.02	0.0						.03	4.000
S 2-20143 C			04/19/72	16N/04W-36	N2NE4SW4	JOHNSON JOHN ESTATE	BLACK R	1	IR	.25	30.000	15.0	05011001									.25	30.000
S 2-20332 C			06/29/72	16N/02W-19	NW4 NW4	HESS WILLIAM A	UNN MAR	1	ST	.02	1.000	0.0		WL	.02	0.0	3	FS	.02	0.0	3	.02	2.000
S 2-20922 C			04/05/73	15N/03W-22	GL-6	WHITTAKER DAVID	CHEHALI	1	IR	1.11	320.000	160.0	05011001									1.11	320.000
S 2-21013 C			05/07/73	15N/03W-22	GL-1	TICKNER R C	CHEHALI	1	IR	1.00	100.000	50.0	S05011001									1.00	100.000
S 2-21014 C			05/07/73	15N/03W-22	GL-1	WALKING/WALKING	CHEHALI	2	IR	1.00	100.000	50.0	05011001									1.00	100.000

WATER RIGHT #	STATUS	OLD CERT	PRIORTY DATE	LOCATION	OWNER	SOURCE	NO. POWS	USE 1	Q(i)	Q(A)	# ACRES	USE PERIOD	USE 2	Q(i)2	# ACRES	USE PERIOD	USE 3	Q(i)3	# ACRES	USE PERIOD	Q(i)p	Q(a)p
S 2-21242	C		07/09/73	15N/03W-17 N2 SW4	THOMPSON H G	UNN STR	2	ST	.20	8.500	0.0		IR	.20	20.0	05011001					.20	48.500
S 2-22010	C		03/18/74	15N/03W-09 W2 SW4	FLETCHER ROGER ET UX	UNN STR	3	IR	.60	60.000	30.0	05011001									.48	60.000
S 2-22140	C		03/28/74	15N/04W-13 SE4NE4	MOORE DUANE ET UX	UNN SPR	1	DS	.02	1.000	0.0		ST	.02	0.0		IR	.02	2.5	05011001	.02	4.000
S 2-22429	C		05/14/74	15N/04W-01 GL-1	BLAKE LEROY	UNN SL	1	IR	1.50	240.000	120.0	05011001									1.50	240.000
S 2-23820	C		05/19/75	15N/03W-16 GL 2	JAMES STANLEY E	UNN SL	2	IR	.60	60.000	30.0	05011001									.60	60.000

Location Map of Well and Stream Monitoring Sites

Plate 1

WASHINGTON STATE
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ECOLOGY

Land Use Map of the Scatter Creek/Black River Study Area

Plate 2

Surficial Geology of the Scatter Creek/Black River Area

Plate 3

Scatter Creek/Black River Head Map for August 1989

Plate 4

Scatter Creek/Black River Head Map for December 1989

Plate 5

Scatter Creek/Black River Head Map for March 1990

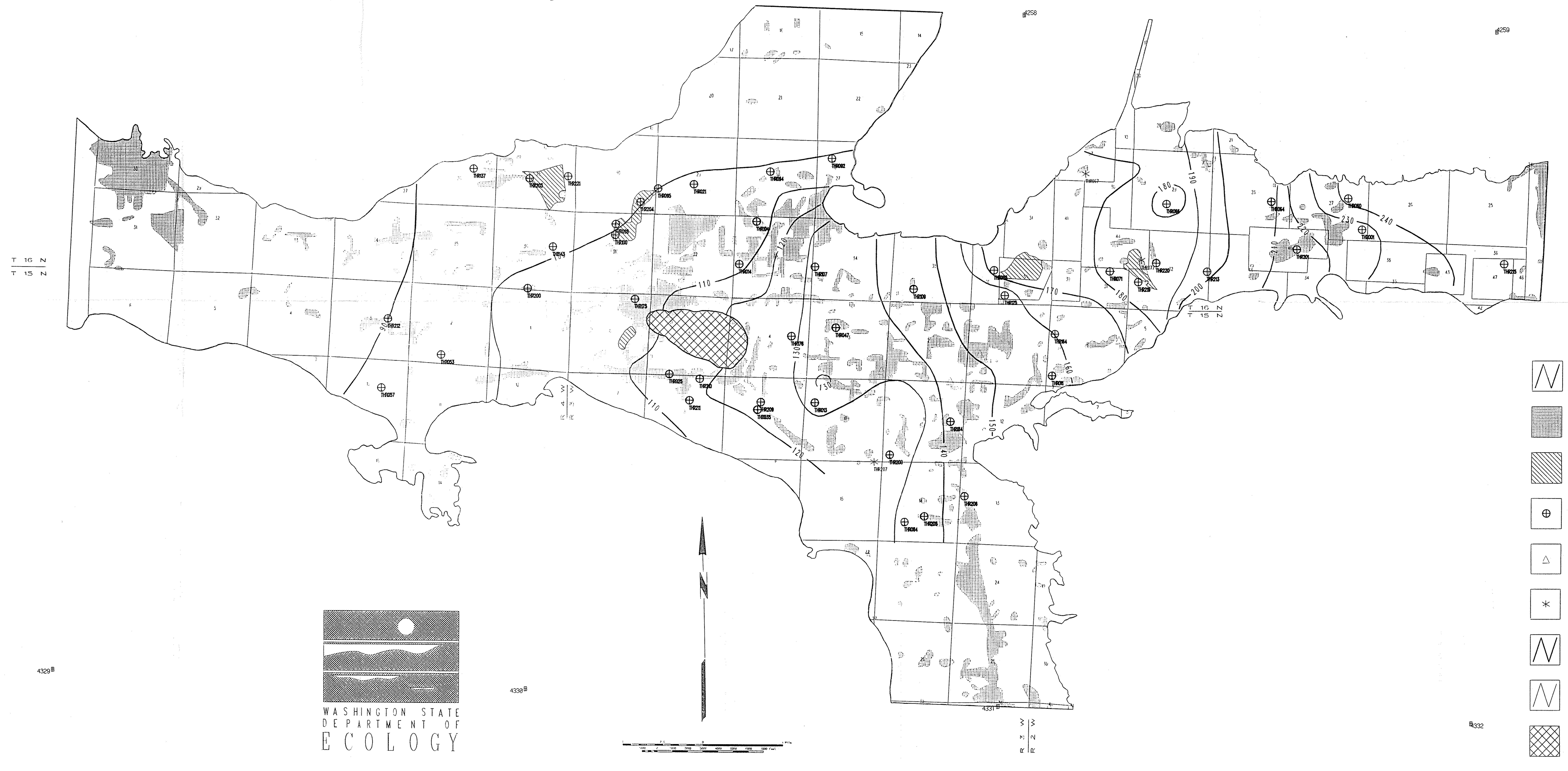
Plate 6

Scatter Creek/Black River Head Map for June 1990

Plate 7

Ground Water Nitrate Concentrations and Associated Land Uses in the Scatter Creek/Black River Study Area

Plate 8



Legend

- Study Area Boundary and Approximate Extent of Valley Aquifer
- Residential/High Density Land Use Land Cover
- Fish Hatcheries Land Use Land Cover
- Wells sampled for nitrates with concentrations less than 4.0 mg/l
- Wells sampled for nitrates with concentrations between 4 and 9.9 mg/l
- Wells sampled for nitrates with concentrations greater than 9.9 mg/l
- Water Level Contour Lines for December, 1989 in feet above MSL Contour Interval = 10'
- Public Land Survey
- Bedrock

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