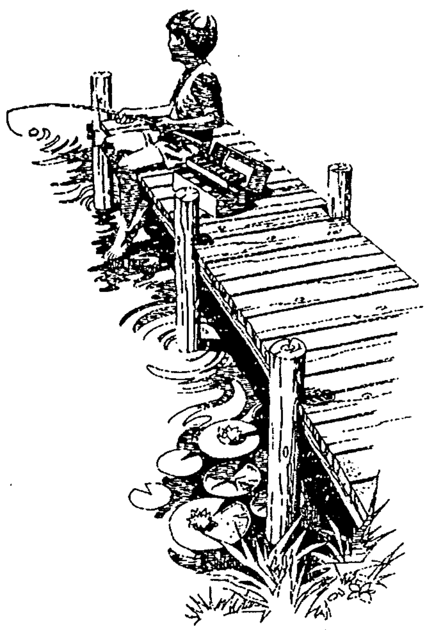
Thurston County

Water Resources Monitoring Report
1996 - 1997 Water Year



Report Includes:

Water Quality
Stream Flows
Lake Levels
Precipitation
Groundwater Data

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Prepared by:

Thurston County Storm and Surface Water Program
and Thurston County Environmental Health Division

In Cooperation With:

City of Olympia Public Works, Water Resources Program
City of Lacey Public Works, Water Resources Program
City of Tumwater Public Works Department
Washington State Department of Ecology

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Ground Water Monitoring Report

Chapter Includes:

Monitoring Methods
Water Quality Standards
North County Ambient Monitoring Network
South Thurston County Study Areas

Ground Water Monitoring Report
1996-1997 Water Year

This section contains ground water quantity and quality data collected by the Thurston County Environmental Health Division during the 1996-1997 water year (October 1996 through September 1997). The County has a monitoring network in both the north and south parts of the County. This is the second year a summary of the ground water data has been included in the annual Water Resources Monitoring Report. Figure 1 shows the locations of all of the monitored wells throughout the county.

The North County ground water data presented in this report was collected under the regional ground water program which was established by and is funded under an agreement between Thurston County and the incorporated municipalities of Lacey, Olympia and Tumwater. The regional ground water program applies to the area of Thurston County designated as Ground water Management Area No. 10, North Thurston County by the State Department of Ecology. Ground water monitoring data and interpretation (only part of the regional ground water program) are the focus of this report. The South County monitoring was funded through a variety of funds, including the Thurston Conservation District, the County and the State Department of Health. The South County monitoring is focused on areas where ground water problems have already been identified.

The objectives of the ground water monitoring program are to:

- Collect baseline information about the quantity and quality of ground water in North Thurston County through an ambient monitoring network;
- Evaluate data gathered to assess trends in flow and quality over time;
- Monitor selected agricultural facilities in the southern part of the county though existing drinking water wells;
- Identify and investigate problem areas and areas of concern.

Where possible and appropriate, data collected during the 1996-1997 water year are compared to data collected previously by the County, samples submitted by well owners, and the United States Geological Survey (USGS). In 1989 the USGS conducted a large ground water sampling effort to investigate the hydrology and quality of ground water in northern Thurston County (Water Resources Investigations Report 92-4109).

Monitoring Methods

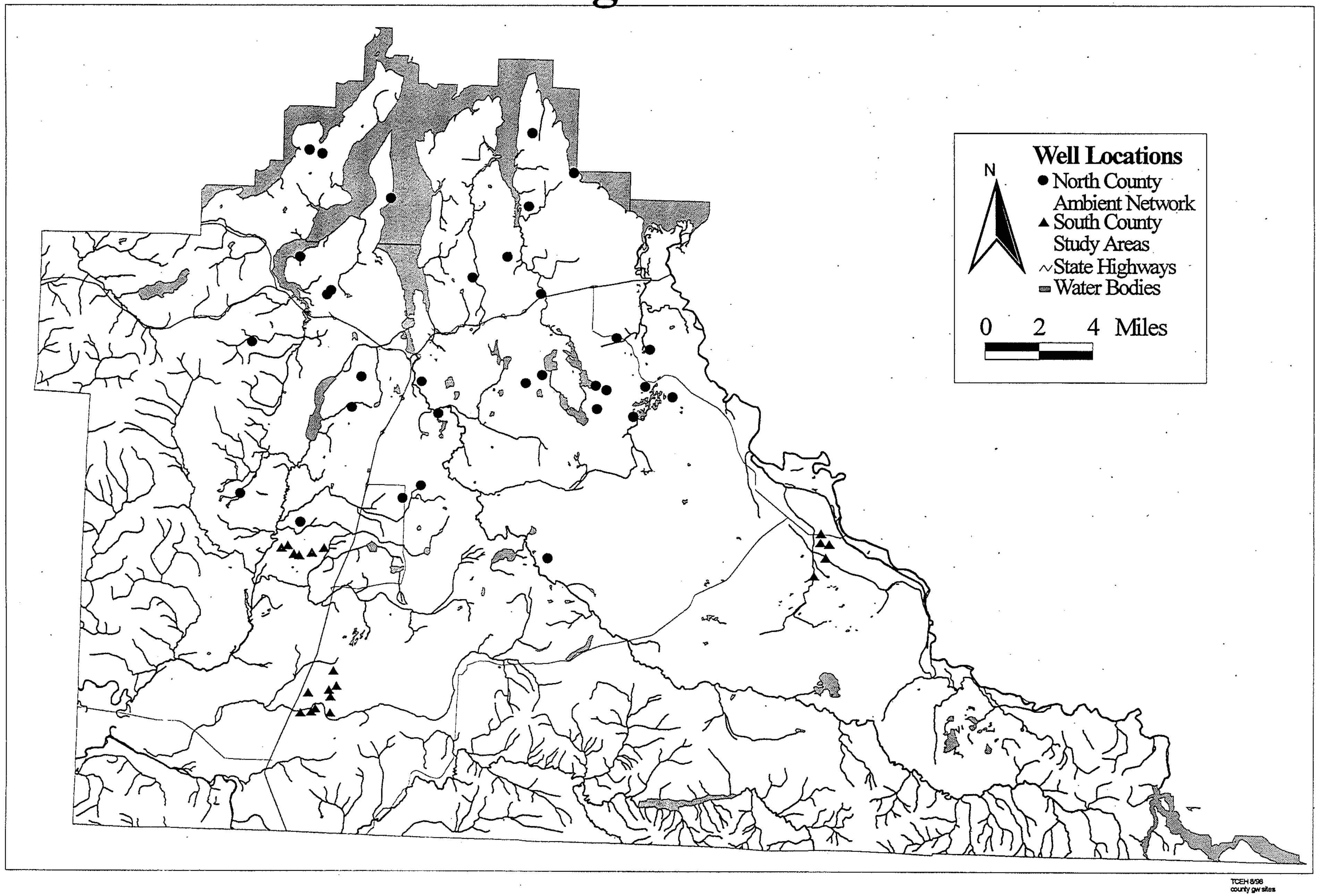
Water Quantity

Ground water levels were measured from the top of the well casing to the nearest tenth or hundredth of a foot below ground surface using an electric tape well probe. Static water level conditions were measured when access was possible. A few wells are either buried underground or there is no available holes in which to slip the e-tape. All wells from which data were collected are private individual and public supply wells. The majority of them are in use, so at times water levels reflected effects of recent pumping. When a well was actively pumping, the water level was allowed to stabilize (within 5 minutes) before the water level was measured. The effects of long-term pumping at the well or near-by wells are reflected in the water level measurements.

Water level data measured relative to depth below ground surface (BGS) were converted to equivalent elevations relative to mean sea level (MSL) to better understand relative conditions between aquifer levels and location within the county

Most well locations were not surveyed; locations by latitude and longitude and elevation were determined from topographic maps or from digitized aerial photographs. Elevation data was collected from digitized one-foot contour maps (reported to the tenth of a foot) or surveyed (reported with elevation to the hundredths of a foot).

Figure 1 - Thurston County Ground Water Monitoring Sites 1996 - 1997



Water Quality

Water quality data collected for the ambient monitoring network consist of parameters measured in the field at the time of sample collection, and chemical data analyzed in a laboratory after sample collection. Samples were collected as near the wellhead as possible and always before any water treatment units in the system. When possible, samples were also collected ahead of holding tanks (pressure tanks). If samples were collected after the holding tank, additional volume was purged.

Parameters measured in the field at the time of sample collection included pH, specific conductance (uS/cm), temperature (EC) and dissolved oxygen (mg/L). A Hydrolab multi-parameter field instrument was used to measure these parameters while well water was actively being purged prior to sample collection. Well diameter, well depth and water level information were used to estimate the volume of water needed to be removed from the well casing to obtain a sample representative of formation (aquifer) water. Formation water was assumed to be actively recharging the well casing when, at a minimum, field parameters have stabilized. A sample was collected after field parameters had stabilized or when at least three casing volumes had been removed from the well.

North County well samples were analyzed for nitrate+nitrite (NO_3+NO_2 as N). South County well samples were analyzed for nitrate+nitrite (NO_3+NO_2 as N), total iron and total manganese.

Chemical parameters, including nitrates, iron and manganese, were analyzed in a Washington Department of Ecology accredited analytical laboratory. Samples were collected directly into bottles provided by the lab, were capped, labeled, and stored in a cooled ice chest (4E C). Back in the office, the samples were transferred to a refrigerator until shipped to the lab for analysis. Chain of custody forms were submitted with each sample shipment.

Appropriate quality assurance/quality control measures were conducted by the laboratory. A replicate sample was taken for every ten samples submitted "blind" to the laboratory so that an evaluation could be made regarding the stability of inorganic constituents in the aquifer. None of the data were reported as unusable or "flagged" by the lab.

Water Quality Standards

The Washington State drinking water standards are established in Chapter 246-290 WAC. The maximum contaminant levels (MCLs) for measured parameters are provided on Table 1. The primary standards are based upon health criteria; the secondary standards are based upon aesthetic considerations, such as taste and staining potential.

In addition to the drinking water standards, Washington State has Ground water Quality Standards, Chapter 173-200 of the Washington Administrative Code (WAC). These standards were developed with the understanding that it is much more expensive to clean contaminated ground water than to prevent contamination in the first place. Depending upon the type and amount of contaminant and the location, it may be impossible or economically unfeasible to clean the water so that it could be used for drinking water. Under Chapter 173-200 degradation of ground water is acceptable only when: 1) it is in the overriding public interest and, 2) when all known, available, and reasonable methods of prevention, control, and treatment are used.

It is important to recognize that the drinking water standards, such as the nitrate standard at 10 mg N/L, is not the amount it is acceptable to pollute ground water to; it is the level of contaminant that is considered unsafe to drink. Chapter 173-200 states that it is not acceptable to pollute ground water without taking the available steps to minimize or eliminate the impacts.

With the above in mind, Thurston County has adopted a resolution that acts as a warning system for areas with polluted ground water. Using a Early Warning Level of 2 mg N/L nitrate and a Contaminant Action Level of 4 mg N/L nitrate, the County monitors the situation or implements an appropriate response to prevent further contamination of the ground water.

Table 1
Drinking Water Standards

Parameter	Primary Maximum Contaminant Level	Secondary Maximum Contaminant Level
Nitrate as N	10.0 mg/L	--
Iron	--	0.3 mg/L
Manganese	--	0.05 mg/L
Specific Conductivity	--	700 Fmhos/cm

Monitoring Programs

There were two separate well monitoring programs conducted in Thurston County during the 1996-97 water year. The North County Ambient Monitoring Network consisted of 32 wells scattered throughout northern Thurston County and were selected to represent ambient ground water condition.

There were also three impact studies in southern Thurston County. These studies were focused upon agricultural activities (dairies and poultry facilities) and were located at:

Gifford Road - two wells upgradient and four wells down gradient from a dairy
Violet Prairie - a total of 13 wells surrounding two dairies and a poultry operation
Yelm - two wells upgradient and four wells down gradient from a poultry facility

These wells were selected to quantify the impact the agricultural activities are having on the nitrate concentrations in drinking water aquifers. Static water levels and nitrate+nitrite, iron and manganese samples were taken twice a year. Location maps and the results from the South County study areas follow the North County section (page 351).

North County Ambient Monitoring Network

Of the North County 32 ambient monitoring wells (Figure 2), 25 are privately owned by individuals, two are owned by businesses, two are owned by a private water purveyor, and three are owned by local jurisdictions (Thurston County, City of Olympia and City of Lacey). Permission was obtained by all owners before including the wells in the monitoring network. Figure 2 shows the locations of wells used in the ambient monitoring network. All of the wells monitored by Thurston County are given a well ID number, such as 17N/01E-06C01; this represents a well in Township17 North, Range 1 East, Section 6, quarter-quarter section area C, well number 1. The Township, Range, and Section numbers in Figure 2 can be used to identify the well ID numbers.

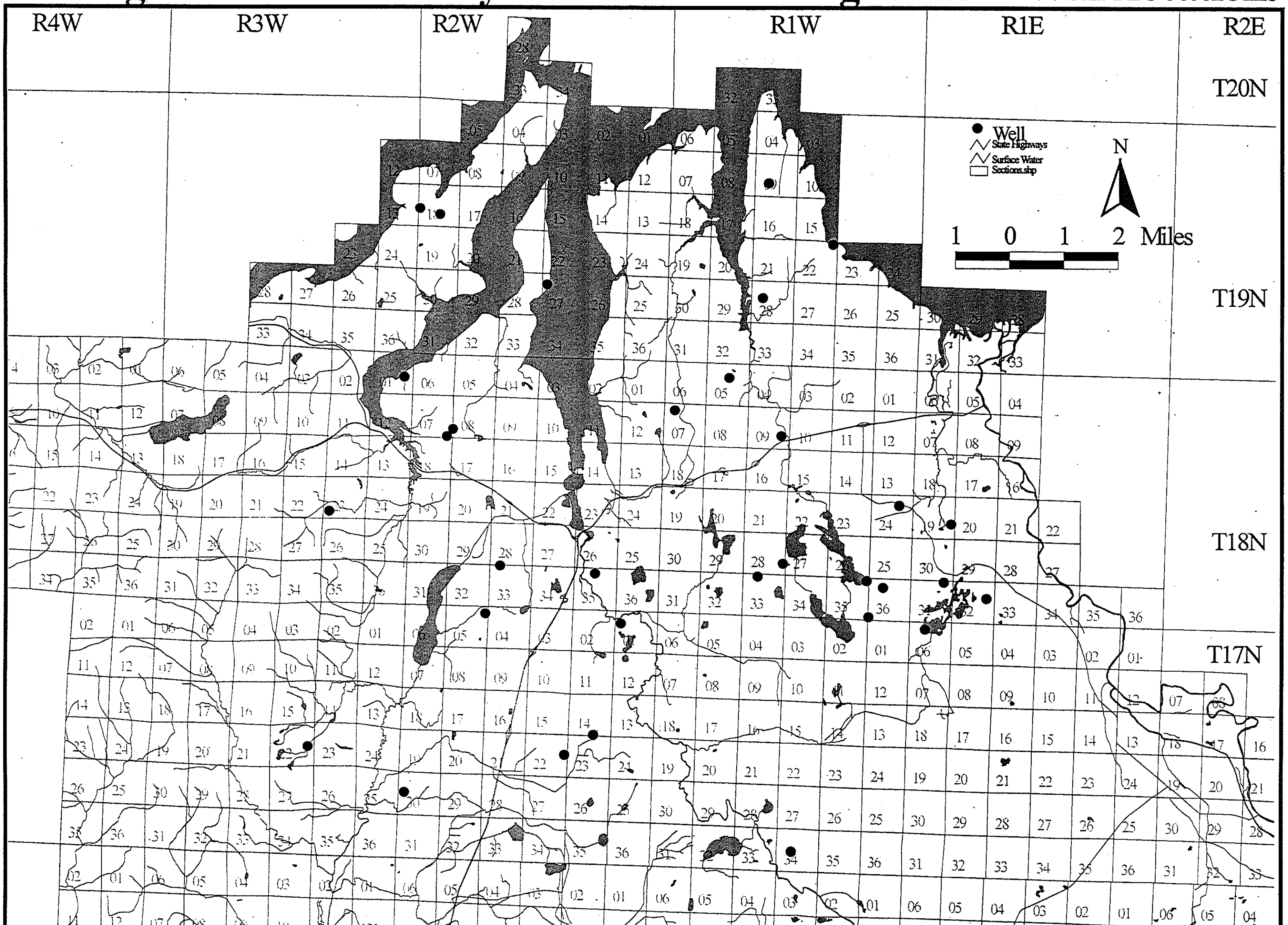
¼-¼ Section Numbers			
D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Geohydrologic Units. Table 2 summarizes the numbers of wells that withdraw water from each of the aquifers in Thurston County and the approximate elevation of the bottom of the well relative to mean sea level. The Vashon till unit is generally not a water-bearing formation and is included in Table 2 for reference only. Geohydrologic units are listed on Table 2 in order from shallowest (Vashon recessional outwash) to deepest (Bedrock).

Table 2
Geohydrologic Units and Well Elevations
North County Ambient Monitoring Network

Geohydrologic Unit		Number of wells	Elevation Range (MSL) of Bottom of Wells
Vashon recessional outwash	Qvr	2	129 to 140 feet
Vashon till	Qvt	0	-
Vashon advance outwash	Qva	14	38 to 289 feet
Kitsap Formation	Qf	2	9 to 35
Penultimate deposits	Qc	7	-90 to 37 feet
Undifferentiated deposits	TQu	4	-141 to -36 feet
Bedrock	Tb	3	-34 feet to 155

Figure 2 - North County Ambient Monitoring Network Well Locations



The hydrogeologic characteristics of each of the seven units listed on Table 2 vary substantially. The units are listed in order from shallowest (youngest) to deepest (oldest). The three uppermost units were deposited by a single geological event, the Vashon glacial advance.

The Vashon recessional outwash (Qvr) is an unconfined sand-and-gravel aquifer that yields adequate volumes of water where saturated or where water is locally perched. In some areas it is an important aquifer, but in much of the county it is too thin to be a reliable aquifer. As the shallowest aquifer, it is also the most susceptible to pollution. It has a very high degree of interaction with surface water bodies. This unit is primarily of glacial origin but includes some recent stream deposits.

The Vashon till (Qt) is a confining unit of compact unsorted sand, gravel and boulders in a matrix of silt and clay. Although the till is not a reliable producer, thin lenses of clean sand and gravel do yield usable amounts of ground water; none of the network wells tap these lenses. This unit has an extremely important effect on the flow of shallow ground water in Thurston County. It can act as an important protective layer, partially shielding wells from surface pollution and diverting flows to surface water. It is also responsible for ground water flooding in parts of Thurston County by greatly reducing the rate at which shallow ground water can move downward during periods of high rainfall. In parts of northern Thurston County, late glacial period lake clay deposits are included within the Vashon till unit.

The Vashon advance outwash (Qva) is the uppermost major sand-and-gravel aquifer, which generally yields abundant ground water for public supplies mostly under confined conditions. In some areas, this unit may be relatively thin and often is more sand than gravel. This aquifer also has a significant amount of interaction with surface water, especially the larger streams such as the Deschutes and Nisqually Rivers.

The Kitsap Formation (Qf) is a clay-and-silt confining unit with lenses of sand and gravel that provide some limited yield of ground water. This nonglacial unit is older than the Vashon deposits and can best be seen along the marine shorelines of northern Thurston County.

The confined Penultimate deposits (Qc) also serves as a major aquifer in the county and supplies water to McAllister and Allison Springs and many major municipal wells. It represents sediments laid down during the next-to-last (penultimate) glaciation. It is sometimes referred to as the "sea-level aquifer" because its top is found near sea level in the northern part of Thurston County. The water from this aquifer generally discharges directly into Puget Sound without much interaction with other surface waters.

The Undifferentiated deposits (TQu) contains both aquifers and confining beds, and is tapped by only a few wells in the county because of it is deep, not enough is known about it to make it a completely predictable aquifer, and it commonly has water quality problems. Many wells tapping this unit produce water with high levels of iron and manganese, and in some cases hydrogen sulfide and iron bacteria. In northeastern Thurston County, this unit is over 1,000 feet thick. In spite of its limitations, this unit is expected to be an increasingly important sources of water in the future. The reasons for this are its thickness and the general lack of hydraulic continuity with surface water.

The Bedrock unit (Tb) also is generally unreliable as an aquifer, but locally does provide limited volumes of water that are contained in fractures and joints. The bedrock unit consists of dark volcanic rocks (basalt and andesite) in the Bald and Black Hills and sandstone and claystone in the Maytown uplands and Michigan Hill areas.

Most of the wells sampled withdraw water from the Vashon advance outwash because this is the shallowest aquifer that produces reliably abundant quantities of good-quality ground water. As with the Vashon recessional outwash aquifer (which occurs at a shallower depth), the advance outwash is vulnerable to contamination from human activities at the ground surface. The Penultimate and Undifferentiated deposits are also reliable sources of abundant, good-quality ground water. These aquifers are deeper than the Vashon deposits and thus, are protected to a greater degree from contamination sources resulting from surface activities.

Table 3 provides elevation data, formation tapped, and identification number for each well in the North County network. Most wells consist of 6-inch diameter steel casing and are open at the bottom.

Table 3
Well IDs and Elevations
North County Ambient Monitoring Network

Aquifer	Well ID	Land Elevation (feet MSL)	Well Depth (feet BGS)	Elevation of Bottom of Well (feet MSL)
Qvr	17N/02W-05A02	172	32	140
Qvr	18N/01W-35A04	161	32	129
Qva	17N/01E-06C01	100	52.1	47.9
Qva	17N/02W-01E02	160	92	68
Qva	17N/02W-14Q02	200	40	160
Qva	17N/02W-22H02	196	66.7	129.3
Qva	17N/03W-22J01	200	98	102
Qva	18N/01W-05G02	110	56	54
Qva	18N/01W-07C01	175	62.5	112.5
Qva	18N/01W-24B02	242	103	139
Qva	18N/01W-28J01	185	127	58
Qva	18N/01W-33C01	208	73	135
Qva	18N/01W-36N01	218	180	38
Qva	18N/02W-07R01	170	125	45
Qva	18N/03W-23N01	330	41	289
Qva	19N/01W-09L02	190	90	100
Qf	18N/02W-08N03	155	120	35
Qf	19N/02W-18M01	80	71	9
Qc	18N/01E-31A01	83	92	-9
Qc	18N/01E-32H02	253	216	37
Qc	18N/01W-09J01	105	195	-90
Qc	18N/02W-35B02	185	157	28
Qc	18N/03W-01J02	70	75	-5
Qc	19N/01W-28F02	120	98.6	21.4
Qc	19N/02W-27D04	70	115	-45
TQu	18N/01E-19J02	39	92.5	-53.5
TQu	18N/01W-36C02	195	336	-141
TQu	19N/01W-22A01	65	143	-78
TQu	19N/02W-18K02	130	166	-36
Tb	17N/01W-34L02	280	125	155
Tb	17N/02W-30E03	186	146	40
Tb	18N/02W-33C01	270	304	-34

Note: Qvr = Vashon recessional outwash, Qva = Vashon advance outwash, Qf = Kitsap Formation, Qc = penultimate deposits, TQu = undifferentiated deposits, and Tb = bedrock.

Water Levels. Water levels were measured quarterly in September and December of 1996 and April and July of 1997. Due to inaccessibility, water levels were not measured at all wells during all four quarters.

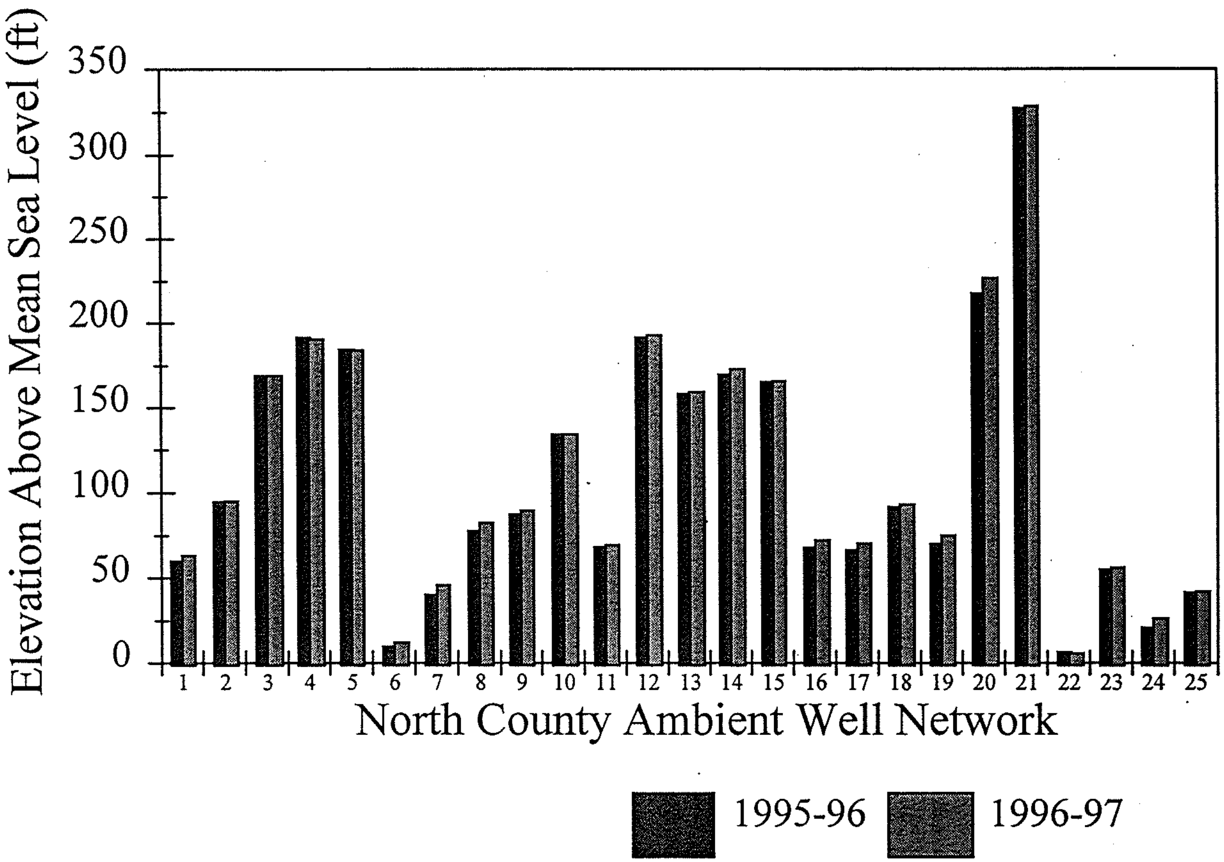
Figure 3 compares the average water levels of the 25 wells monitored in 1995 with average water levels in 1996. A majority of the wells had slightly higher water levels in 1996.

Figure 4 shows a summary of long-term water level data available for well 18N/02W-07R01. Long-term data are not available for other wells in the ambient monitoring network. This well draws water from the Vashon advance unit at an elevation of 45 feet MSL (or a depth of about 125 below ground surface). The Vashon advance is the most frequently tapped aquifer in the county.

A comparison of the 1996-97 water year annual low and high water levels with historical data indicate that water levels at this locale have remained relatively stable. However, the gradual rise in static water level since water year 1993-94 matches the gradual increase in yearly rainfall for the county (Figure 5). In the decade between 1984-85 and 1994-95, only two years had above average rainfall.

Figure 3 - Elevation of Water in Wells

Comparison of Yearly Averages



Well Label	Well ID
1	17N/01E-06C01
2	17N/02W-01E02
3	17N/02W-05A02
4	17N/02W-14Q02
5	17N/02W-22H02
6	18N/01E-19J02
7	18N/01E-31A01
8	18N/01E-32H02
9	18N/01W-05G02
10	18N/01W-07C01
11	18N/01W-09J01
12	18N/01W-24B02
13	18N/01W-28J01
14	18N/01W-33C01
15	18N/01W-35A04
16	18N/01W-36C02
17	18N/01W-36N01
18	18N/02W-07R01
19	18N/02W-08N03
20	18N/02W-33C01
21	18N/03W-23N01
22	19N/01W-22A01
23	19N/01W-28F02
24	19N/02W-18K02
25	19N/02W-18M01

Figure 4 - Long Term Water Levels

Well ID# 18N/02W-07R01

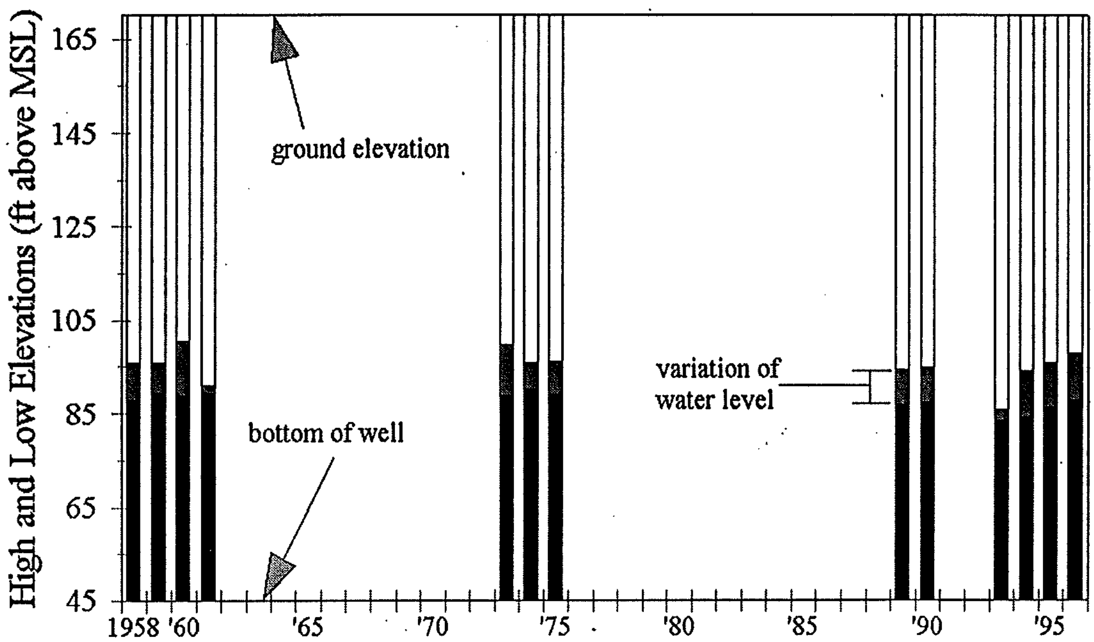
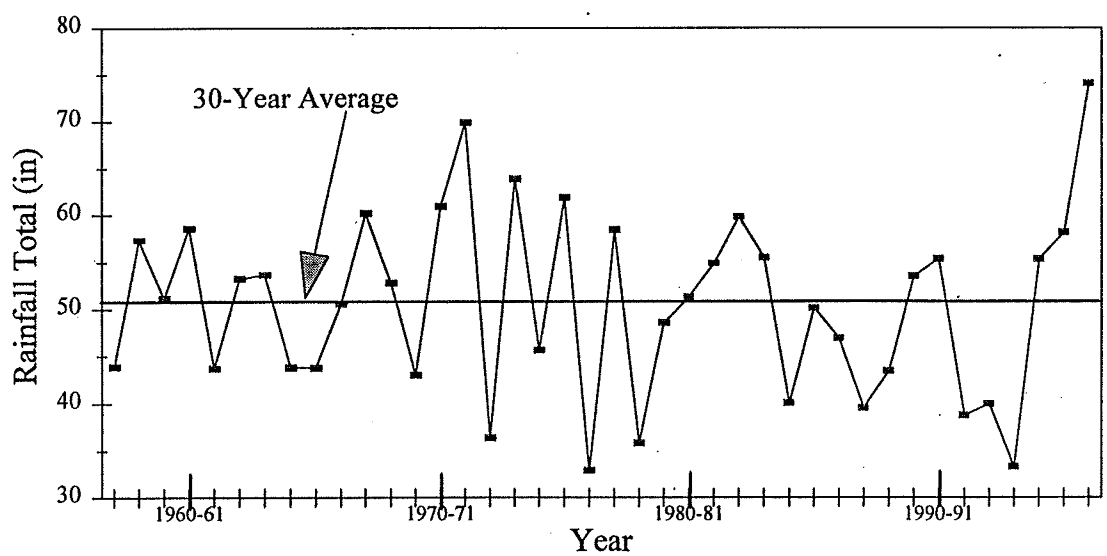


Figure 5 - Yearly Rainfall Totals*

By Water Year (October - September)



*Rainfall data provided by NOAA at the Olympia Airport

<u>Water Quality</u>. The following discussion on the North County ambient monitoring network presents water quality data for both field and analytical constituents. Field parameters were collected at 29 wells; the remaining three wells were used to collect water level data only.

Field Parameters. Table 4 provides basic statistics of field parameter data for wells in the ambient monitoring network, including minimum, maximum, and average values. Nitrate values are discussed separately on page 349. Appendix A provides detailed field parameter and nitrate data for all wells in the North County ambient monitoring network. Of the six hydrogeologic units tapped by the ambient monitoring network, most data were collected from the Vashon advance outwash (n=13) and the Penultimate deposits (n=7).

Specific conductance is the only field parameter for which a (secondary) maximum contaminant level (MCL) has been established - 700 µmhos/cm @ 25 °C. Only one well exceeded the conductivity Maximum Contaminant Level; 17N/01W-34L02 had a conductivity of 822 µmhos/cm @ 25 °C in April 1997. Data was not collected on this well in 1995-96. This well had a conductivity of 700 µmhos/cm @ 25 °C in June 1989 (Drost and others, 1998). This well draws its water from bedrock in an area where ground commonly contains high levels of chloride. The chloride is thought to have originated as connate seawater; in other words sea water that was trapped in the bedrock at the time it was deposited (Noble and Wallace, 1966).

Specific conductance and pH tend to increase from the shallower to the deeper aquifers. This results from the water in the deeper aquifers generally having spent more time in contact with the rocks that make up the aquifer framework. This has allowed the water to dissolve more minerals from the rocks. The pH levels also increase with depth for the same reason. The pH is highest in the bedrock because as the local volcanic bedrock weathers and breaks down it produces calcite. The easily-dissolved calcite (calcium carbonate) acts as a chemical base, increasing the pH.

The deeper aquifers tend to have lower levels of dissolved oxygen and nitrate because both constituents originate from above. Dissolved oxygen comes from natural contact with the atmosphere and nitrate originates primarily as a contaminant from human activities at the surface.

Water from the Vashon advance outwash (QVa) is slightly acidic to neutral as indicated by pH values. The low specific conductance values indicate the water is relatively soft and does not contain substantial amounts of inorganic salts, organic matter or dissolved gases. It is well oxygenated and, with an average dissolved oxygen content of 5.4 mg/L, is oxidizing. The maximum value of 10.7 mg/L indicates relatively recent recharge events and that the water may be slightly corrosive.

Field parameters for the shallower Vashon recessional outwash (QVr) are few in number (n=2); however, available data indicate that field conditions are similar to those for the Vashon advance outwash.

The field parameter data appear to show that wells in the Kitsap Formation and the shallower aquifers are chemically similar in most parameters and the three deeper aquifers appear to form another chemically similar group. This pattern is generally similar to the patterns found in the 355 wells in northern Thurston County sampled in 1989 by Drost and others (1998).

Field parameters measured for the Penultimate deposit (Qc) show minor but consistent differences from the Vashon advance outwash. The median pH for the Vashon advance outwash was slightly acidic at 6.8, while the median pH for the Penultimate deposit was slightly basic at 7.1. Lower concentrations of dissolved oxygen (average = 1.8 mg/L) in the Penultimate deposit is consistent with what is generally expected for water in deeper aquifers with a longer residence time and a slower rate of recharge. Specific conductance is slightly higher while nitrate is significantly lower.

Too few data points are available for the undifferentiated deposits (TQu) (n=2) and Tertiary bedrock (Tb) (n=3) to make significant conclusions about the aquifers. However, field parameter values do indicate alkaline conditions (higher pH) and much lower oxygen levels than for the units above the Penultimate deposits. Alkaline conditions are typically associated with waters quite low in dissolved oxygen. This combination of high pH and low oxygen levels is consistent with that identified by the USGS investigation (Drost and others, 1998) for these deeper deposits, and likely reflects the effect of slower recharge rates and longer contact time between ground water and aquifer materials. The longer contact time also allows more minerals to be dissolved into the water, increasing the conductivity, alkalinity, and buffering capacity of the water.

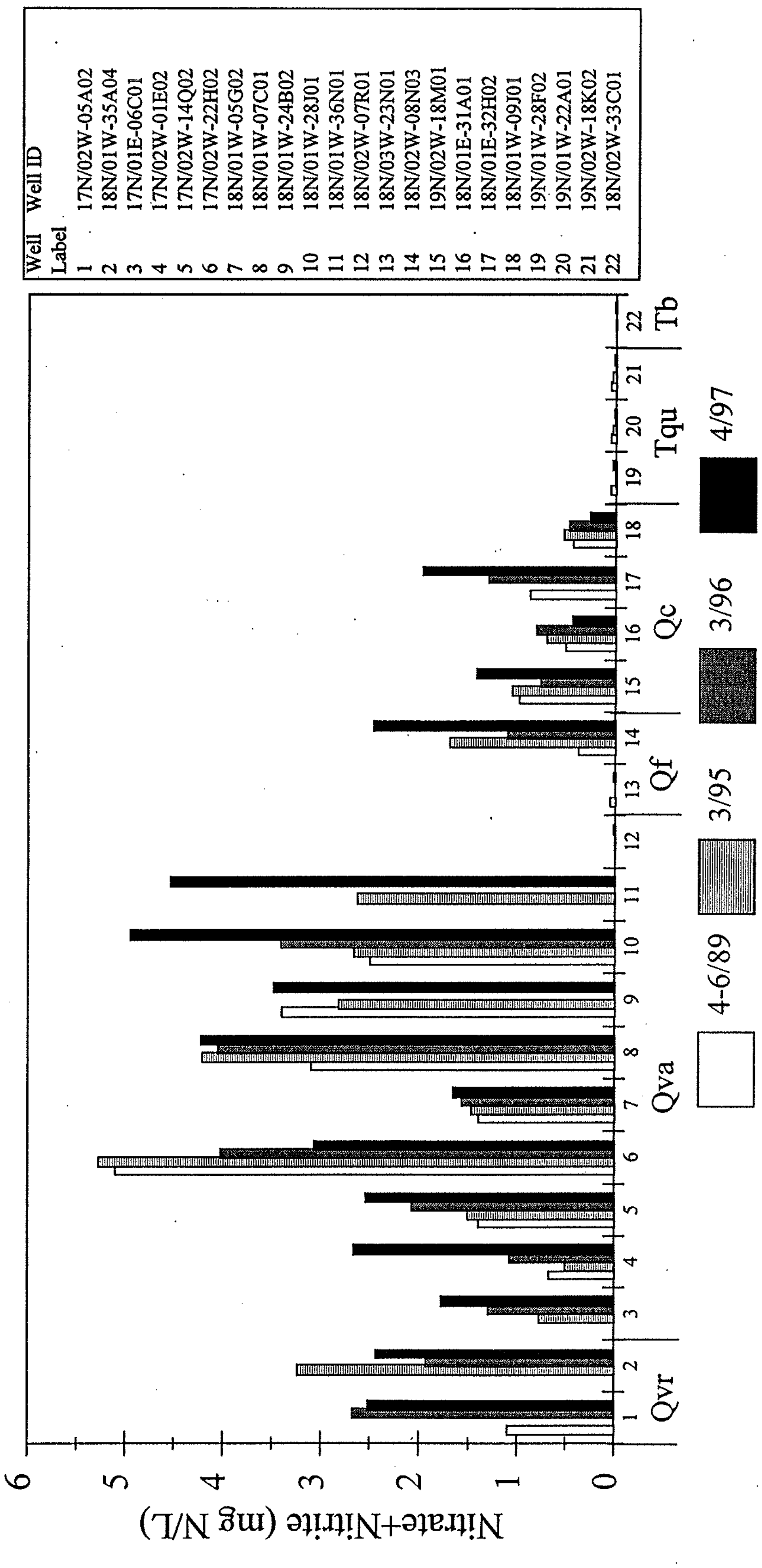
Table 4
Monitoring Parameter Data Summary
Minimum, Maximum and Average Values
North County Ambient Monitoring Network

Aquifer		Number of Wells	pH*	Specific Conductance (μmhos/cm @ 25 °C)	Temperature (°C)	Dissolved Oxygen (mg/L)	Nitrate+Nitrite (mg N/L)
Vashon recessional outwash **Qvr**	Min	2	6.1	125	10.5	2.9	2.44
	Max		7	142	10.6	6.9	2.52
	Avg		6.6	134	10.5	4.9	2.48
Vashon advance outwash **Qva**	Min	13	6	91	9.5	0.06	0.02
	Max		7.6	341	11.6	10.5	4.95
	Avg		6.8	163	10.7	5.4	2.31
Kitsap Formation **Qf**	Min	2	6.4	127	9.9	6.8	1.43
	Max		6.9	178	10.8	8.9	2.47
	Avg		6.7	152	10.3	7.8	1.95
Penultimate deposits **Qc**	Min	7	6.5	130	9.6	0.1	0.02
	Max		8	327	11.3	7.8	1.97
	Avg		7.1	189	10.3	1.8	0.4
Undifferentiated deposits **Tqu**	Min	2	7.9	158	10.2	0.03	0.02
	Max		8.2	214	11.4	0.06	0.02
	Avg		8	186	10.8	0.04	0.02
Bedrock **Tb**	Min	3	6.8	154	8.2	0.06	0.02
	Max		9.2	822	10.5	3	0.16
	Avg		8.9	383	9.5	1.06	0.06

* pH average values were calculated as medians.

Figure 6 - Nitrate Levels by Year

North County Wells Grouped by Aquifer

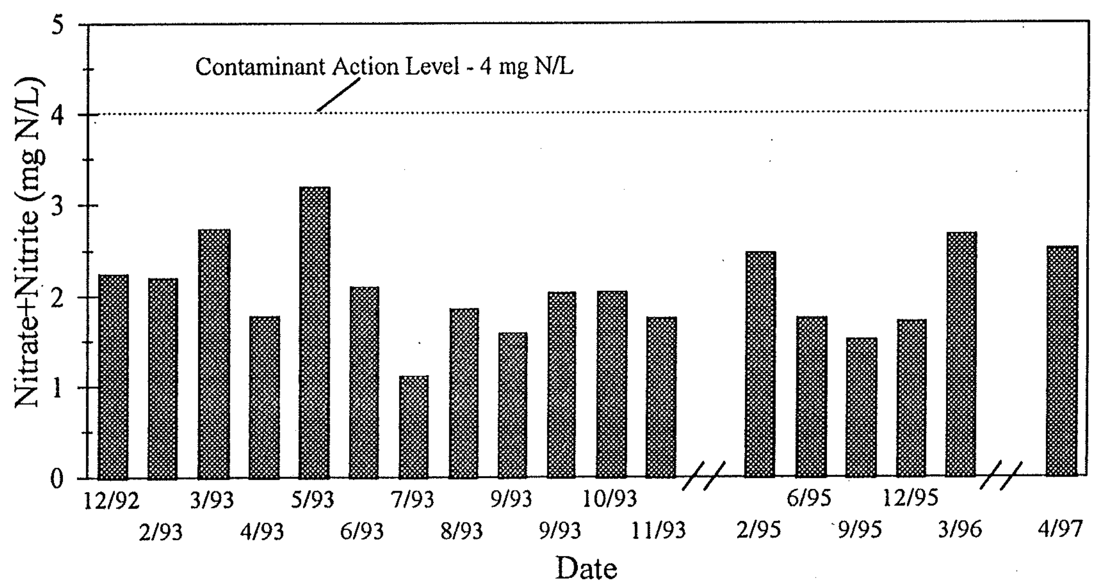


Nitrate. Samples were collected from 29 wells for nitrate+nitrite (NO_3+NO_2 as N) analysis in April 1997. Table 4 shows summary nitrate results for each aquifer for the 1996-97 water year. No wells in the ambient monitoring network exceeded the MCL. However, 10 wells exceeded the Early Warning Level of 2 mg N/L and three wells exceeded the Contaminant Action Level of 4 mg N/L.

Figure 6 compares the 1996-97 nitrate+nitrite levels in wells with data from 1989 (Drost and others, 1998) and 1995-96. Wells without comparison data were not included in the graph. Data is taken from the same period during the year to avoid seasonal effects. Ten of the 22 wells compared in Figure 6 showed increased nitrate levels since 1989. Nitrate levels have increased in all but the two deepest aquifers, the undifferentiated deposits (Tqu) and bedrock (Tb).

Figure 7 displays the nitrate concentrations in one typical well over several years. The nitrate values show a fair amount of variability from month to month, with seasonal peaks in the spring. This pattern is common among those wells in Thurston County that exhibit seasonal variation patterns. This well exceeded the Early Warning Level for nitrate several times but is below the Contaminant Action Level.

Figure 7 - Nitrate Levels
In Well 17N/02W-05A02



Iron and Manganese. Samples were not analyzed for iron or manganese in 1996-1997. Data from 1995-96 is available in the 1995-96 Water Resources Monitoring Report (Thurston Co., 1997). Metals will be analyzed for in 1997-98.

Data from the 1989 USGS investigation and other smaller county projects indicate an inverse relationship between nitrate and iron and manganese concentrations. Elevated iron and manganese concentrations (above the MCL) generally occur with relatively low nitrate concentrations (below about 2 mg/L). Elevated nitrate levels also tend to occur with low iron and manganese concentrations. This apparent trend is most pronounced at very high levels of either iron and manganese or nitrate and is less noticeable at relatively low concentrations. There is a more detailed discussion of the relationship between nitrate and metals concentrations in the Violet Prairie section, page 356.

North County Ground water Quality Summary

Annual rainfall has been above the thirty-year average since the 1994-95 water year (figure 5). The 1996-97 water year had almost 150% of the average annual rainfall (74 inches compared to 50). The 1994-95 water year was preceded by almost a decade of below-average rainfall. The 1988-89 sampling by the U.S. Geological Society was at the end of a three-year dry period. Periods of increased rainfall increase the probability that nitrogen compounds would be "pushed" through the soil and into aquifers rather than be processed by chemical and biological activities into organic nitrogen compounds that would be used by plants or converted into nitrogen gas.

For most wells, nitrate values increased between 1989 and 1997 (table 5). The averages were calculated from a set of 22 wells that had at least two spring samples (taken between March and June). Most wells were sampled three out of the four years.

Average nitrate values have risen from 1.3 mg N/L in 1989-90 to 1.8 in 1996-97; the warning level is 2, the action level is 4 and the drinking water standard is 10 mg N/L. The maximum nitrate value was 4.95 mg N/L at 18N/01W-28J01, in the Vashon advance aquifer. Wells with nitrate levels below the detection limit (<0.10 mg/L) in 1989 have nitrate levels in 1996-97 that have generally remained the same. It is not known what specifically caused nitrate levels to increase at each well. Two possible causes are increased development, with more sewage effluent discharged into the ground, and increased rainfall.

Table 5
Average Nitrate+Nitrite Concentrations by Year
North County Ambient Monitoring Network

Year	1989-90	1994-95	1995-96	1996-97
Average	1.3 mg N/L	1.5 mg N/L	1.5 mg N/L	1.8 mg N/L
Number of samples	17	19	18	22

1997-98 North County Ambient Monitoring Program

Eight more wells will be added to the network for a total of 40 wells. In addition to nitrate sampling, iron and manganese samples will also be taken twice a year. There are no other planned changes in the monitoring program; water level measurements will continue to be taken quarterly and field parameters and water quality samples will be taken twice a year following the same protocols as the 1996-97 monitoring.

With the collection of additional iron and manganese data it is hoped that the relationship between nitrate and iron and manganese concentrations will become more clear. The nitrate values will also be tracked to determine if the recent increases since 1994-95 continue.

South Thurston County Study Areas

There were also three impact studies in southern Thurston County. These studies were focused on agricultural activities (dairies and poultry facilities) and were located at (figures 6, 7 and 8, respectively):

Gifford Road - two wells up gradient and four wells down gradient from a dairy
Violet Prairie - a total of 13 wells around two dairies and a poultry operation
Yelm - two wells up gradient and four wells down gradient from a poultry facility

These wells were selected to quantify the nitrate impact the livestock activities are having on the drinking water aquifers. Static water levels, temperature, pH, conductivity, and dissolved oxygen measurements, and nitrate+nitrite, iron and manganese samples were taken.

Gifford Road

This rural area is located off Littlerock Road, just south of 113th Ave and north of the town of Littlerock (Figure 8). Six wells were selected to monitor the impact of a dairy on ground water. The dairy spreads manure on-site year-round, putting significant amounts of nitrate into surface and ground water during the winter when rain causes runoff and the cover crop is dormant and not using the nitrogen in the manure.

Monitoring was started in March 1995 and is expected to continue through 1998. Table 5 shows the sampling results of the wells. Well 17N/02W-31JA is located in the middle of the pasture and in the past has been surrounded by liquid manure during applications. The nitrate level in this well is the second highest recorded in the County at 52 mg N/L in 1996 and 44 in 1997.

A well just west of the dairy had the highest nitrate level in 1996 of 63 mg N/L. This well has since been replaced by a deeper well, 17N/03W-36JB. Well 17N/03W-36JB has been sampled twice since installation and has very low nitrate levels; the last sample taken in 1997 had a nitrate concentration of 0.021 mg N/L.

Figure 8 - Gifford Road Study Area Well Locations

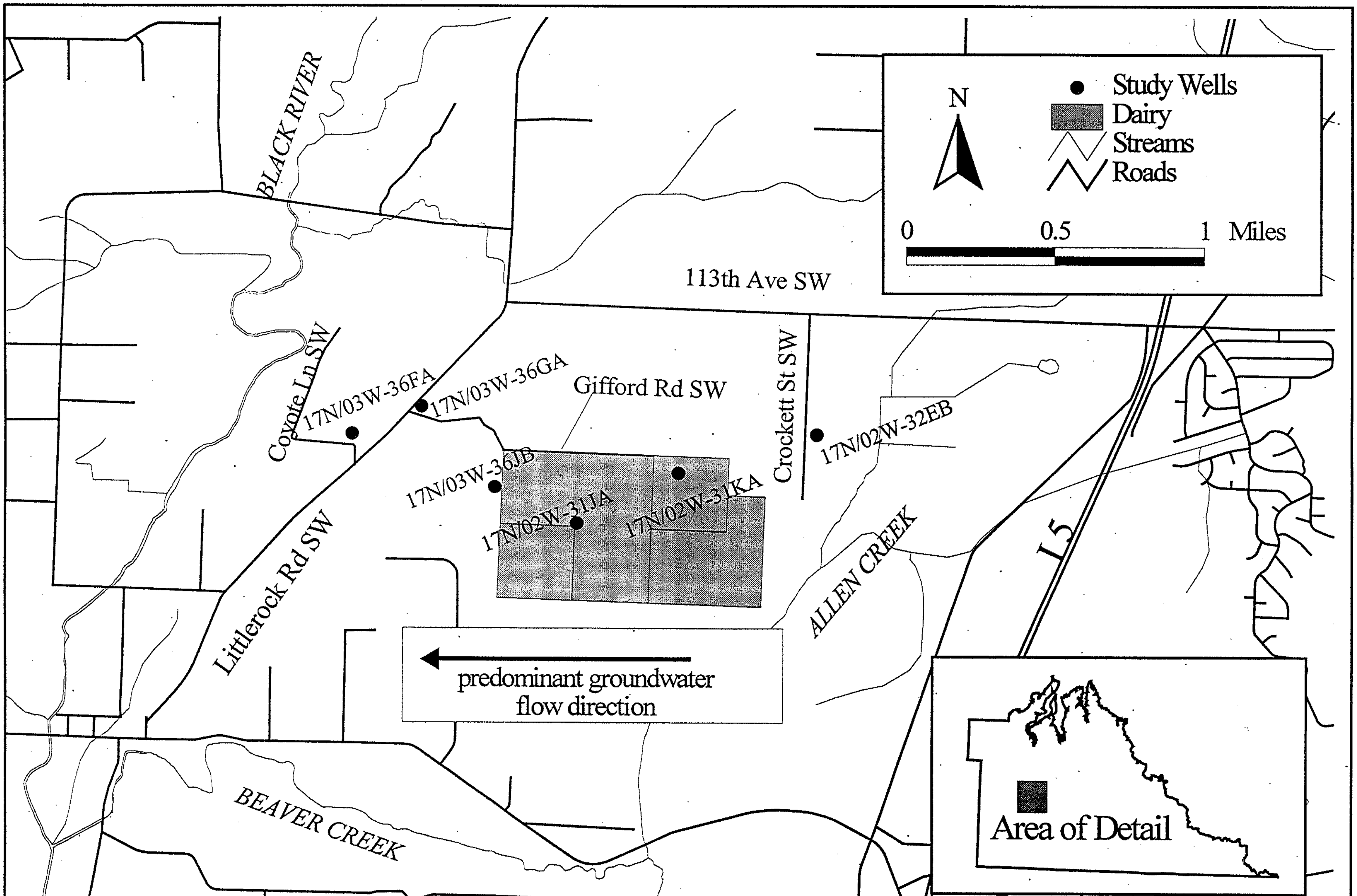
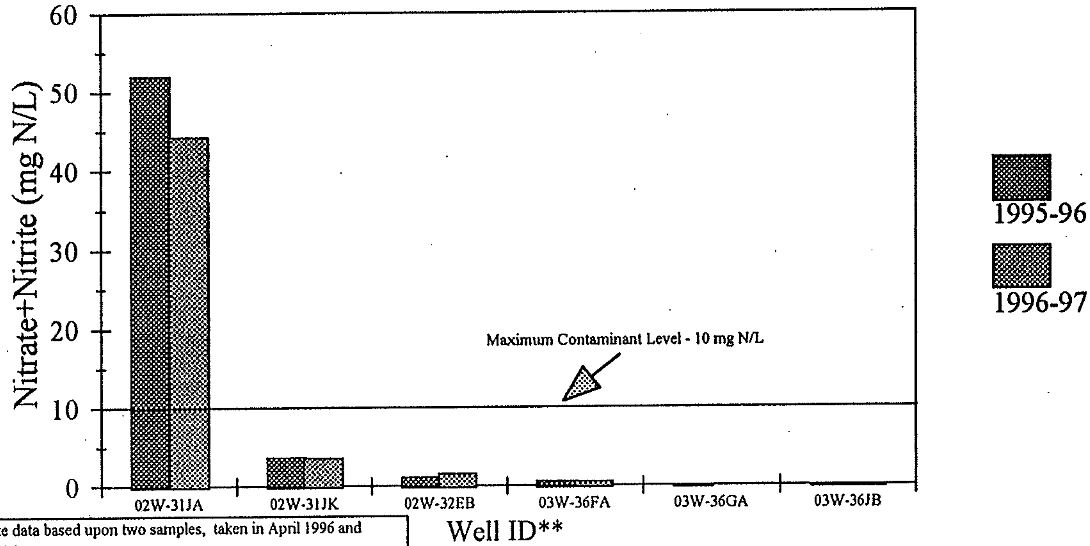


Table 6 Gifford Road Study Area Monitoring Results Water Years 1995-96 and 1996-97							
Local ID#	Date	Time	Static Water Level (ft)	Bottom Elevation (MSL)	Nitrate+Nitrite (mg N/L)	Iron (mg/L)	Manganese (mg/L)
17N/02W-31JA	04/15/96	1320		135	52.000		
17N/02W-31JA	06/04/97	1240			44.300	0.038	0.007
17N/02W-31KA	10/24/95	1200	22.38	188			
17N/02W-31KA	04/15/96	1245	13.50		3.670		
17N/02W-31KA	06/04/97	1315	15.79		3.570	0.062	0.002
17N/02W-32EB	04/15/96	1046		168	1.150		
17N/02W-32EB	06/04/97	1010			1.550	0.015	0.003
17N/03W-36FA	04/15/96	1500		120	0.534		
17N/03W-36FA	06/04/97	1100			0.496	1.190	0.046
17N/03W-36GA	10/24/95	1445	11.70	75			
17N/03W-36GA	04/15/96	1445	10.10		0.014		
17N/03W-36GA	10/17/96	1200	11.85		0.005		
17N/03W-36JA	4/15/96	1350			63.300		
17N/03W-36JB	04/15/96	1350	11.00	60	0.005		
17N/03W-36JB	06/04/97	1140			0.021	0.240	0.280

Table 6 shows the disparity in nitrate levels between the dairy well, 17N/02W-31JA, and the other wells around it. The County keeps a database of the nitrate samples analyzed at the Environmental Health lab (usually submitted by property owners). A review of the available data shows that neighboring wells had nitrate concentrations ranging from non-detection to 5.3 mg N/L, with no discernable pattern between them or the study wells. The lab data spans between 1994 and 1997.

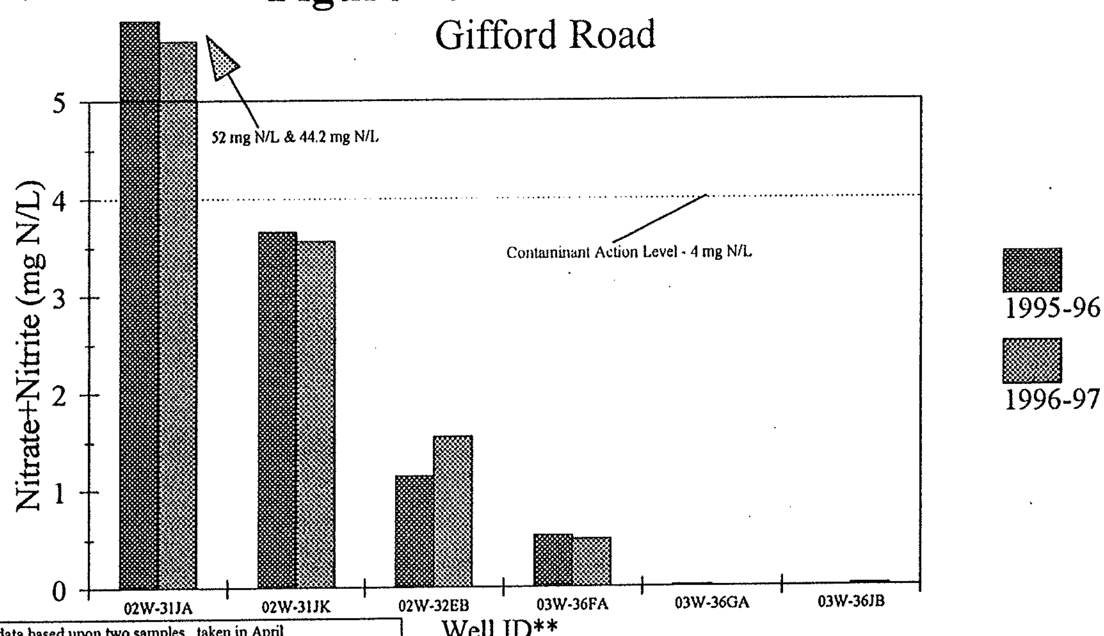
Figure 9 - Nitrate Levels* by Year
Gifford Road



* Nitrate data based upon two samples, taken in April 1996 and June 1997.
** Gifford Road well ID's are preceded by 17N/

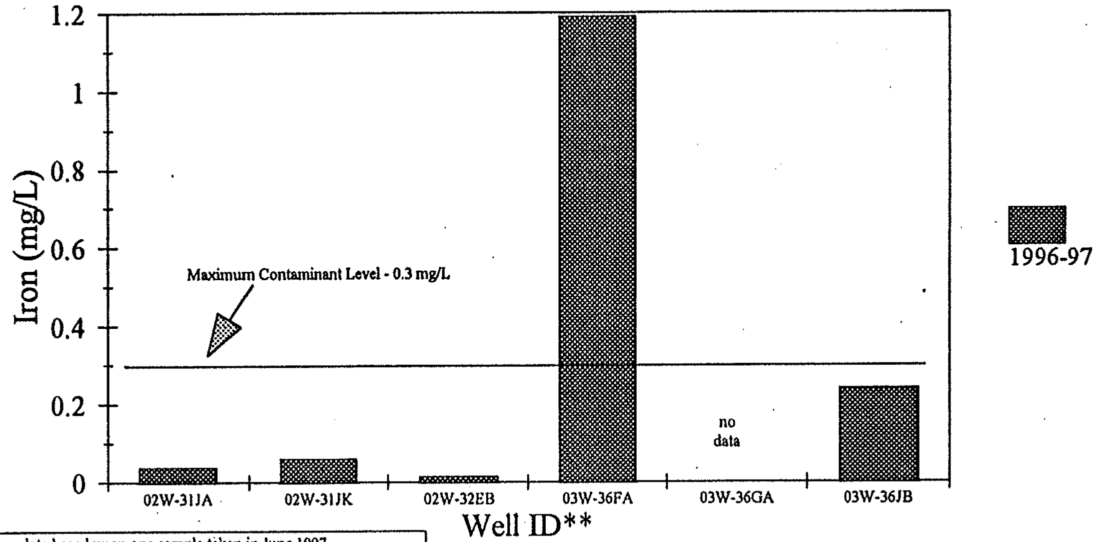
Figures 9 and 10 compare the Gifford Road nitrate levels between 1995-96 and 1996-97. The scale on Figure 10 was reduced to allow examination of the other five wells' nitrate levels. Well 17N/02W-31JA exceeded the drinking water standard for nitrate by 4 times in 1997. Well 17N/03W-36JA was not shown in figures 9 and 10 as it was replaced by -36JB for domestic use in 1996. 1996-97 data is not available for 17N/03W-36GA as the well pump was not functioning at the time of sampling.

Figure 10 - Nitrate Levels*
Gifford Road



* Nitrate data based upon two samples, taken in April 1996 and June 1997.
** Gifford Road well ID's are preceded by 17N/

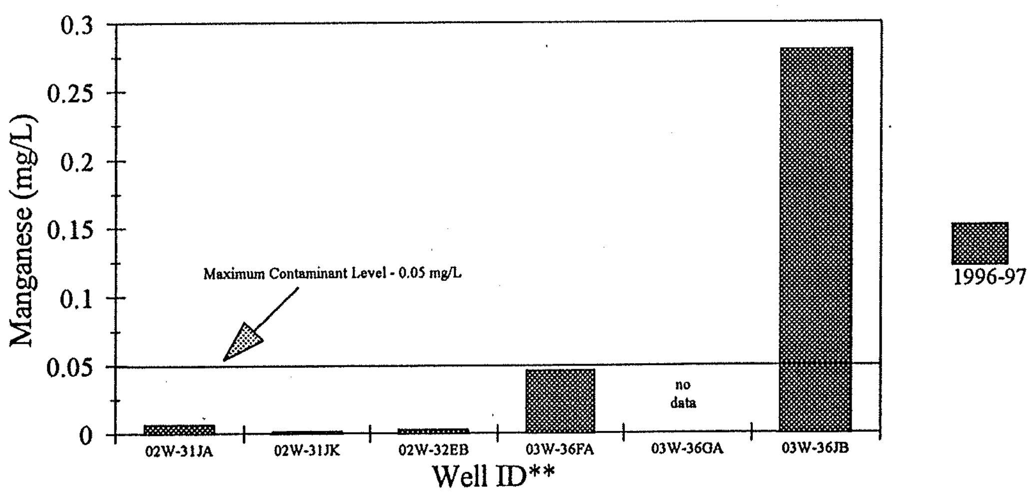
Figure 11 - Iron Levels*
Gifford Road



*Iron data based upon one sample taken in June 1997.
**Gifford Road well ID's are preceded by 17N/

Well 17N/03W-36FA had a very high iron level at 1.19 mg/L, almost four times the water quality criteria. This well also had an elevated manganese concentration compared to the other study wells. Well 17N/03W-36JB also had a high iron level, although it was below the maximum contaminant level. However, the manganese concentration was 0.280 mg/L, almost six times the standard.

Figure 12 - Manganese Levels*
Gifford Road



*Manganese data based upon one sample taken in June 1997.
**Gifford Road well ID's are preceded by 17N/

At this time, there is not enough data to determine if the dairy operation has impacted other wells beyond the obvious impacts at the abandoned well (17N/03W-36JA) and the well at the dairy, 17N/02W-31JA. The dairy operator is currently examining the possibility of vacating the site and developing it. If approved, the land use change is expected to significantly reduce the nitrogen loading to the ground water. The County will continue to monitor the wells through 1998. Monitoring beyond that point will be re-examined based upon the proposed land-use change and the budget priorities.

Violet Prairie

Violet Prairie sits just east of Interstate 5 off the Grand Mound exit. This area is mainly agricultural in nature, although in the past decade large amounts of land have been converted into housing. There have been many different livestock operations in the study area (Figure 13), including a fish farm, a rabbit farm, several poultry operations, and dairies. During the 1996-97 monitoring just two dairies were active. A poultry operation off Gibson and 169th was shut down for a few years but was reactivated in 1998.

Violet Prairie is part of the Scatter Creek/Black River aquifer, which drains to the south-west from Tenino to Oakville, Grays Harbor County (Sinclair and Hirschey, 1992).

> The Scatter Creek/Black River aquifer is contained within highly transmissive sand and gravel drift deposits of Penultimate and Vashon Age [*the last two glacial periods*]. The aquifer is unconfined and is recharged principally from local precipitation and seasonal seepage from area streams and rivers. ...

In general terms, Violet Prairie could be described as a gravel-filled trough, tilted slightly to the south-west. Due to the gravelly nature of the soils and the lack of any confining layers, such as hardpan or clay layers, rainwater and anything it picks up quickly reaches the aquifer.

As a result of the above, any contaminants such as nitrates are washed down with rainwater and are not removed before entering the aquifer. A major source of nitrates in the area is manure applications by livestock operations. Manure, if applied during the growing season at appropriate rates, can be used by cover crops. This greatly reduces the amount of nitrogen compounds that are available to be carried by rainwater into the aquifer. If manure is applied during the winter, little nitrogen is used by the dormant plants while heavy rainfall washes the manure downward.

During the 1996-97 sampling, one of the dairies had installed a large manure lagoon (SIZE = XXX million gallons) in order to store manure during the winter. The other dairy was in the process of designing a lagoon but was still spreading manure year-round.

The ground water under Violet Prairie is generally slightly acidic, low in conductivity and well oxygenated (table 7). For the 1996-97 water year, the median pH was 6.6, the average conductivity was 193 Fmhos/cm at 25 EC and the average dissolved oxygen was 7.2 mg/L. Nitrate levels in Violet Prairie averaged 6.25 mg N/L (as nitrate+nitrite), with the highest level at well 16N/02W-32FA at 18.60 mg N/L (figure 14).

Figure 13 - Violet Prairie Study Area Well Locations

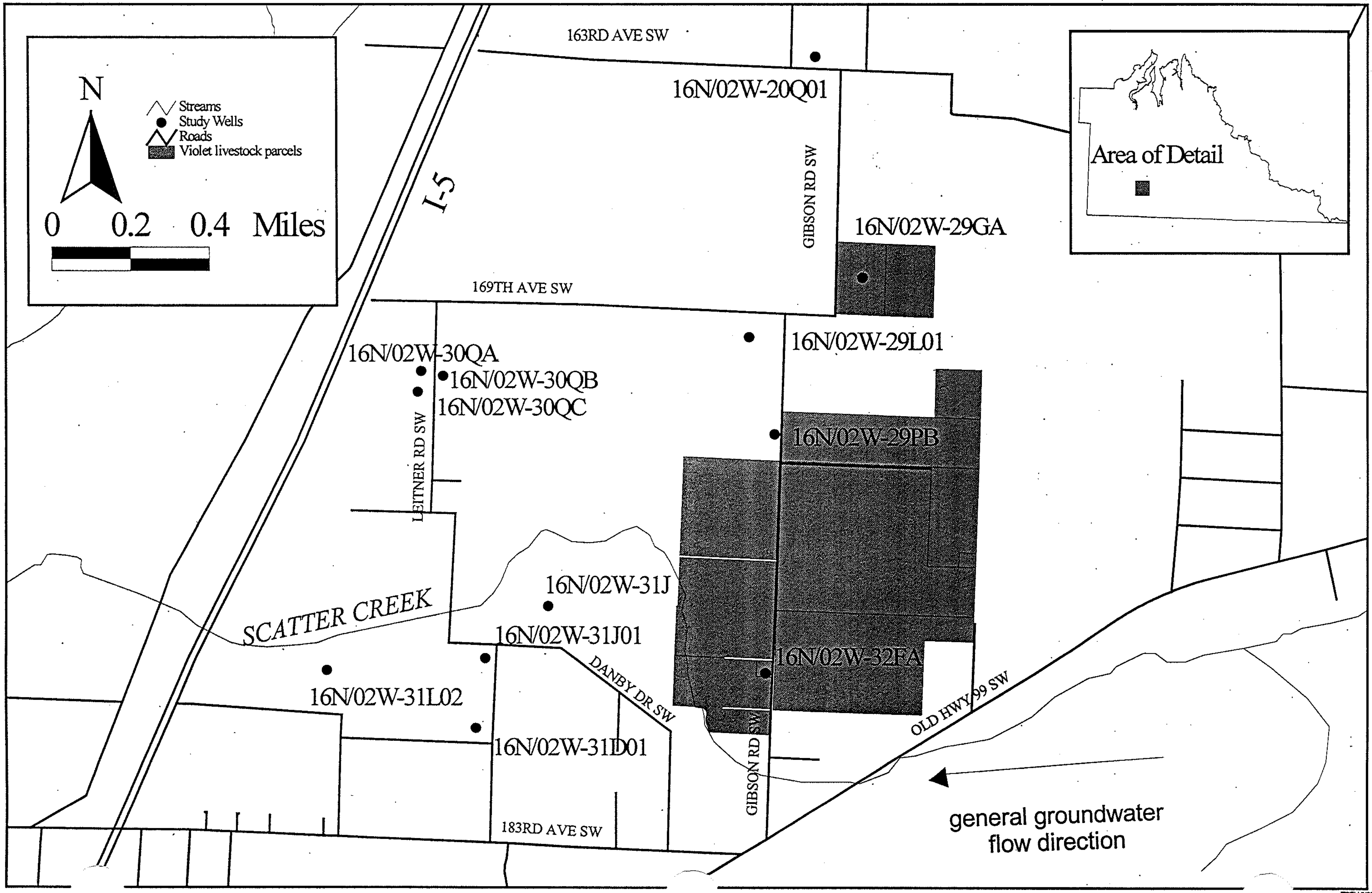


Table 7 Violet Prairie Study Area Water Years 1995-96 and 1996-97												
Local Well ID	Elevation (ft - MSL)	Well Depth (ft - BGS)	Well Bottom Elev (ft -MSL)	Date	Static Water Level (ft)	pH	Cond (umhos/cm @ 25 C)	Temp (deg C)	Dissolved Oxygen (mg/L)	Nitrate+ Nitrite (mg N/L)	Iron (mg/L)	Manganese (mg/L)
16N/02W-20Q01	203.93			05/22/96		6.2	112	11.02	9.92	4.370		
16N/02W-20Q01	203.93			05/28/97		6.3	102	11.06	10.03	3.190	0.163	0.002
16N/02W-29GA	209.17	77	132.17	05/22/96	24.25	5.9	151	11.31	0.12	6.970		
16N/02W-29GA	209.17	77	132.17	05/28/97	25.78	6.0	156	11.00	0.12	0.604	1.860	0.277
16N/02W-29L01	224.5	80	144.5	05/22/96	23.25	6.7	146	10.48	8.50	3.800		
16N/02W-29PB	219.3	105	114.3	05/22/96		6.6	137	10.67	6.12	3.020		
16N/02W-29PB	219.3	105	114.3	05/28/97		6.7	143	10.80	6.74	2.770	0.034	0.002
16N/02W-30QA	218	88	130	05/23/96		6.7	184	10.20	9.41	7.360		
16N/02W-30QA	218	88	130	05/29/97		6.7	191	10.51	9.54	6.870	0.045	0.002
16N/02W-30QB	212	70	142	05/23/96	19.10	6.6	198	10.38	11.53	9.550		
16N/02W-30QB	212	70	142	05/29/97	20.65	6.6	187	10.46	10.01	6.310	0.050	0.002
16N/02W-30QC	212	60	152	05/23/96	21.20	6.7	203	10.45	10.17	9.160		
16N/02W-30QC	212	60	152	05/29/97	22.15	6.8	201	10.84	10.21	7.670	0.075	0.002
16N/02W-31D01	209	65	144	05/23/96	6.36	6.3	169	10.30	6.96	7.680		
16N/02W-31D01	209	65	144	05/29/97	16.21	6.3	199	10.52	3.73	8.440	0.475	0.012
16N/02W-31J	207			05/22/96	9.60	6.1	254	10.12	8.00	4.550		
16N/02W-31J	207			05/28/97	10.13	6.3	240	10.60	6.62	4.580	0.020	0.002
16N/02W-31J01	199	40	159	05/23/96	21.20	6.8	191	10.45	7.33	6.380		
16N/02W-31J01	199	40	159	05/29/97	22.00	6.8	193	10.77	6.77	4.810	0.027	0.002
16N/02W-31L02	204	77	127	05/23/96		6.6	146	10.02	6.51	4.550		
16N/02W-31L02	204	77	127	05/29/97		6.5	166	10.16	6.10	4.880	0.102	0.002
16N/02W-32FA	212	35	177	05/28/97	15.05	6.3	348	11.50	9.03	18.600	0.122	0.002

MSL - mean sea level
BGS - below ground surface

Well -32FA is situated in a depression in one of the dairy pastures. During heavy manure applications or rainfall, run-off collects around the well house. Until late 1997, there was also no sanitary seal on the well casing (essentially a cover on the top of the well casing to prevent mice and other undesirable objects from falling down the well). This well has had nitrate levels as high as 45 mg N/L (March 1995) (figure 14).

The 1995-96 nitrate average for the study wells in Violet Prairie was 6.12 mg N/L. This does not include well -32FA as it was not sampled. Removing well -32FA's nitrate result from the 1996-97 average drops it from 6.25 mg N/L to 5.01. This is still above the County's 4 mgN/L Contaminant Action Level.

Out of the 22 samples taken in Violet Prairie between 1996 and 1997, 20 were greater than 2 mg N/L, 19 were greater than 4, and 6 were greater than 10 mg N/L. These results are similar to other Violet Prairie well samples analyzed by the County's laboratory. 43 nitrate samples were taken by well owners in the vicinity (from the study area west to Interstate 5) between 1994 and 1998. Of these samples, 32 were greater than 2 mg N/L, 22 were greater than 4, and 3 exceeded the drinking water standard.

There is not enough data to determine if the reduction in nitrate levels in 1996-97 is part of a trend due to the implementation of better manure handling practices and the installation of a manure lagoon or if it is caused by other factors, such as climate. Monitoring of Violet Prairie is funded to continue through 1999. Additional monitoring into the 21st century will depend upon available funds and department priorities.

One well that stood out from the others is 16N/02W-29GA. This well is one of the production wells used at the poultry operation. Compared to the other wells, -29GA has lower pH and almost no dissolved oxygen (0.12 mg/L in May 1997). It also has substantially higher metals levels concentrations than the other wells; at least 10 times for iron and over 100 times for manganese.

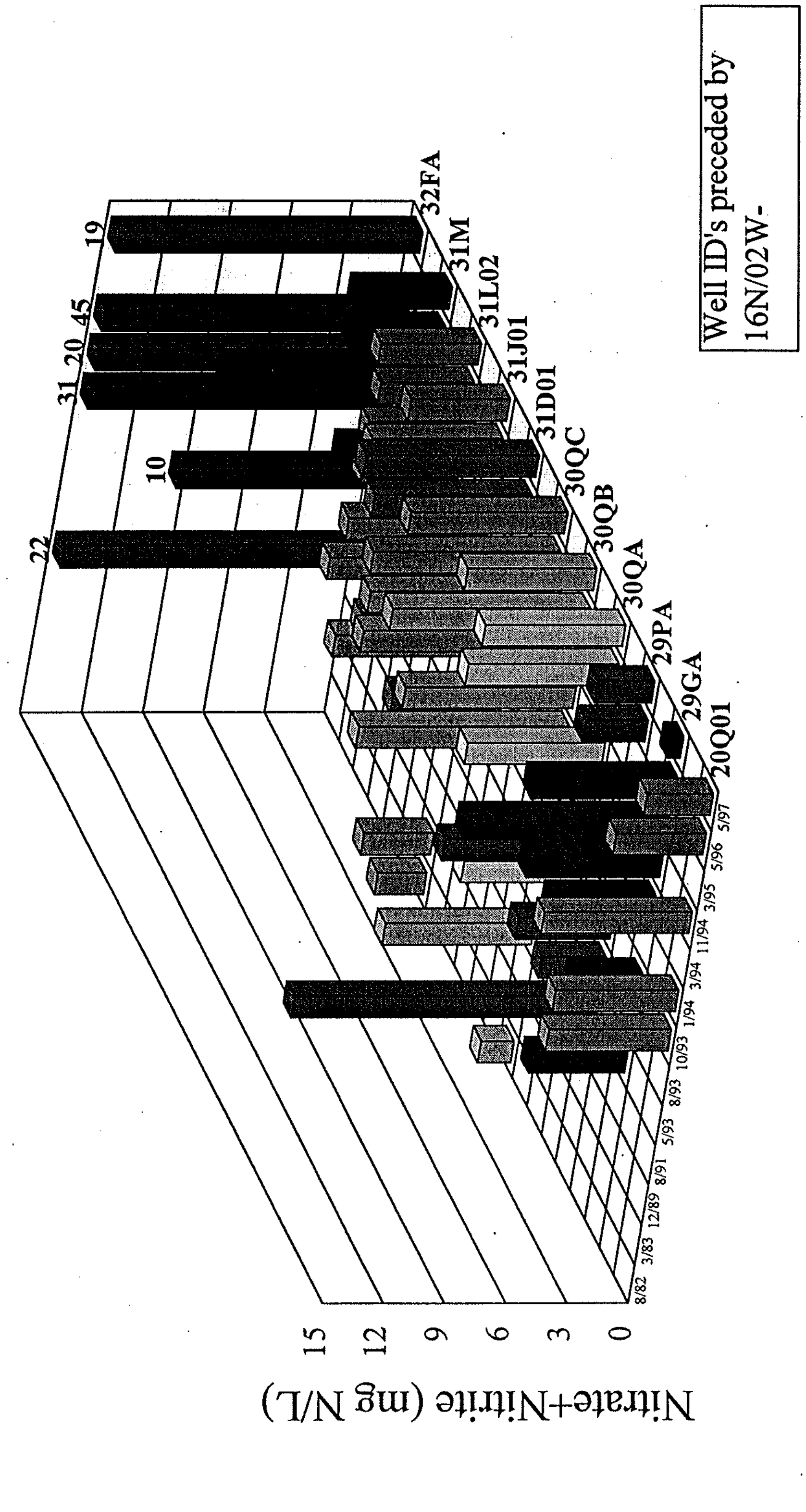
The nitrate levels at the well are highly variable, dropping from 9.96 mg N/L in March 1995 to 6.97 in May 96 to 0.604 in May 1997. Recent data from the 1997-98 water year (April 1998) showed the nitrate level had increased to 4.64 mg N/L. At the same time the iron level dropped from 1.86 mg/L to 0.025. These reductions in contaminant levels may be due to the period when the poultry operation was out of operation and no manure was being generated or spread on the site.

Based upon limited data, it appears that the well's water quality is being influenced by biological processes in the vicinity. The combination of low pH, low dissolved oxygen, elevated temperature, and elevated iron and manganese suggests that bacteria are consuming organic matter from some source. The bacterial activity generates heat and consumes oxygen. The low levels of dissolved oxygen causes iron and manganese to changes from insoluble to soluble forms. This process is very common in Thurston County ground water and is generally responsible for elevated levels of iron and manganese (Drost and others, 1998).

Well 16N/02W-29L01, just one-third mile southwest of -29GA shows none of the characteristics of it's neighbor. Dissolved oxygen levels are above 8 mg/L and the nitrate and metal concentrations are stable. The bottoms of both wells are at similar elevations; -29L01 is at 144 feet-mean sea level, while -29GA is at 132 ft. The deepest of the study wells, 16N/02W-29PB is only one-half mile away, with a bottom elevation of 114 ft. -29PB shares similar dissolved oxygen and nitrate levels with -29L01.

It is not known for sure why nearby wells, at depths above and below well -29GA do not share the same characteristics. Sometimes bacterial action can produce very localized changes in water chemistry that change back to the dominant regional chemical conditions outside the area of bacterial effects.

Figure 14 - Nitrate Levels
Violet Prairie 1982-1997



Yelm Study Area

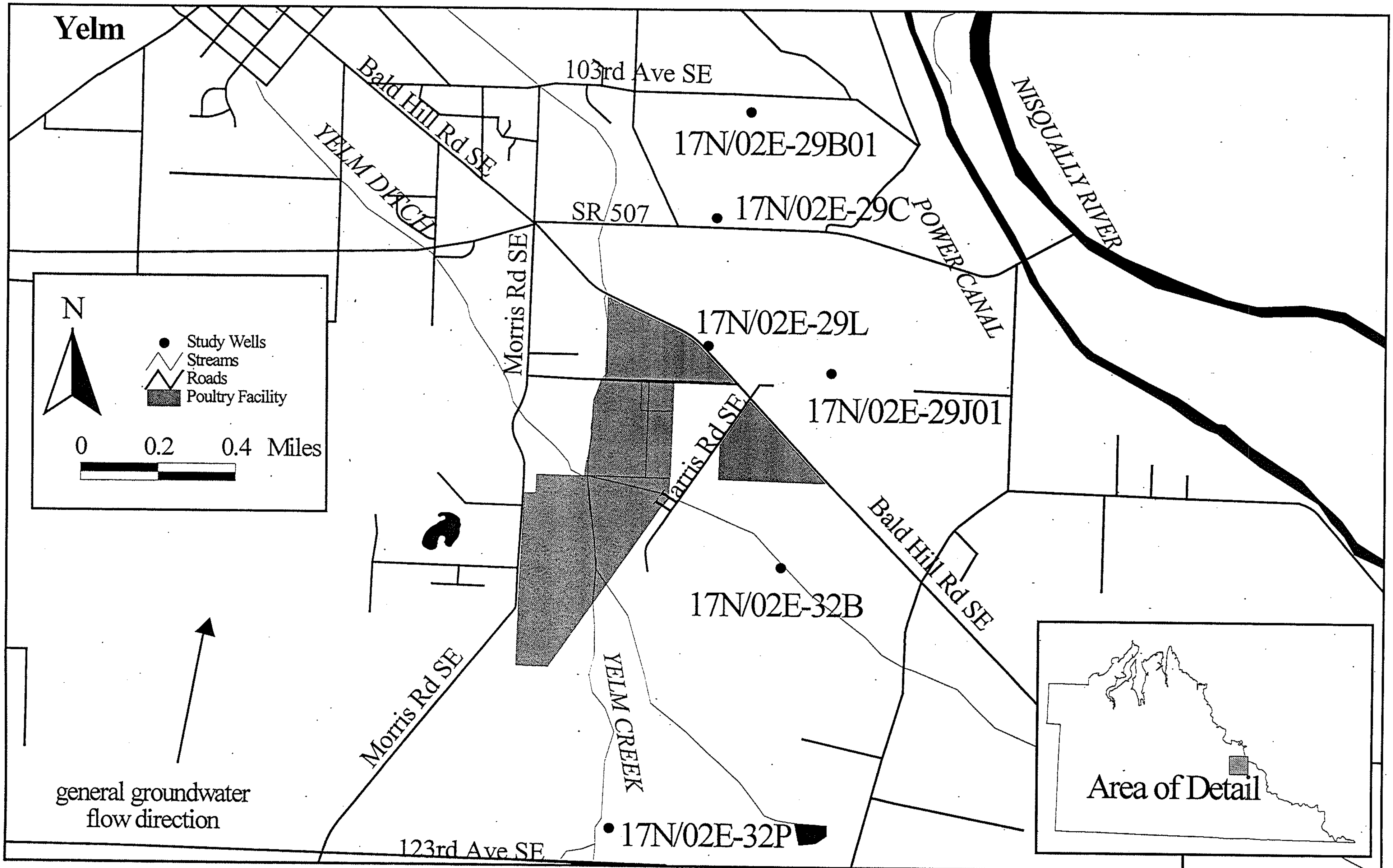
The Yelm study area is one mile southeast of the City of Yelm. Six wells were selected to monitor the effects of a large poultry facility on ground water in 1994. Generally, there are three aquifers in the study area, separated by two aquitards (cemented till and compacted silty layers) (Erickson, 1998). Most wells in the area use the middle aquifer, the Vashon advance outwash aquifer.

Table 8
Yelm Study Area
Water Years 1993-94 through 1996-97

Local ID	Date	Sur. Elev (ft- MSL)	Well Depth (ft)	Well Bottom Elev. (Ft-MSL)	SWL (ft - BGS)	pH	Cond (Emhos/cm @ 25C)	Temp (deg C)	DO (mg/L)	Nitrate+ Nitrite (mg N/L)	Iron (mg/L)	Manganese (mg/L)
17N/02E-29B01	4/25/94	350	50	300	10.2	6.4	287	11.07	6.76	1.08		
17N/02E-29B01	05/30/97	350	50	300	8.30	6.4	146	11.93	4.94	3.65	0.039	0.0030
17N/02E-29C	4/25/94	355	100	255	24.28	6.2	431	11.47	9.89	1.36		
17N/02E-29C	5/21/96	355	100	255	17.6	6.3	139	10.13	6.56	4.07		
17N/02E-29C	05/30/97	355	100	255	21.08	6.3	116	9.52	5.43	1.98	0.014	0.0015
17N/02E-29J01	4/26/94	350	107	243	26.4	7.7	69	11.62	5.41	13.3		
17N/02E-29J01	5/21/96	350	107	243	3.1	7.7	74	11.54	4.88	0.854		
17N/02E-29J01	06/03/97	350	107	243		7.7	80	11.89	4.30	0.86	0.005	0.0015
17N/02E-29L	11/15/93	346	35	311		7.0	155	10.45	3.04	2.53	0.039	0.0015
17N/02E-29L	2/22/94	346	35	311	20.49	6.8	172	10.45	6.50	8.13	0.116	0.0015
17N/02E-29L	5/23/94	346	35	311	17.8	6.8	193	10.87	6.96	10.3	0.113	0.004
17N/02E-29L	8/22/94	346	35	311	23.6	6.4	186	10.91	9.26	10.3	0.102	0.004
17N/02E-29L	5/21/96	346	35	311	7.35	6.3	128	9.60	6.70	2.92		
17N/02E-29L	06/03/97	346	35	311	9.80	6.4	103	9.40	6.70	0.82	0.237	0.0080
17N/02E-32B	4/26/94	345	103	242		7.5	179	11.16	2.03	0.005		
17N/02E-32B	5/21/96	345	103	242		7.5	203	11.16	0.42	0.19		
17N/02E-32B	06/03/97	345	103	242		7.4	216	11.49	0.50	0.02	0.071	0.0090
17N/02E-32P	4/25/94	375	100	275	33.18	7.5	186	11.99	1.60	1.91		
17N/02E-32P	5/21/96	375	100	275		7.4	211	11.26	1.49	1.65		
17N/02E-32P	06/03/97	375	100	275		7.4	230	11.69	1.94	2.57	0.027	0.0015

MSL - mean sea level BGS - below ground surface

Figure 15 - Yelm Study Area Well Locations



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Five of the study wells use the Vashon advance outwash aquifer, ranging in depth from 50 to 107 feet deep. Well 17N/02E-29L is more shallow at 35 feet and uses the Vashon recessional outwash aquifer. Figure 15 shows the location of the poultry facility and the study wells.

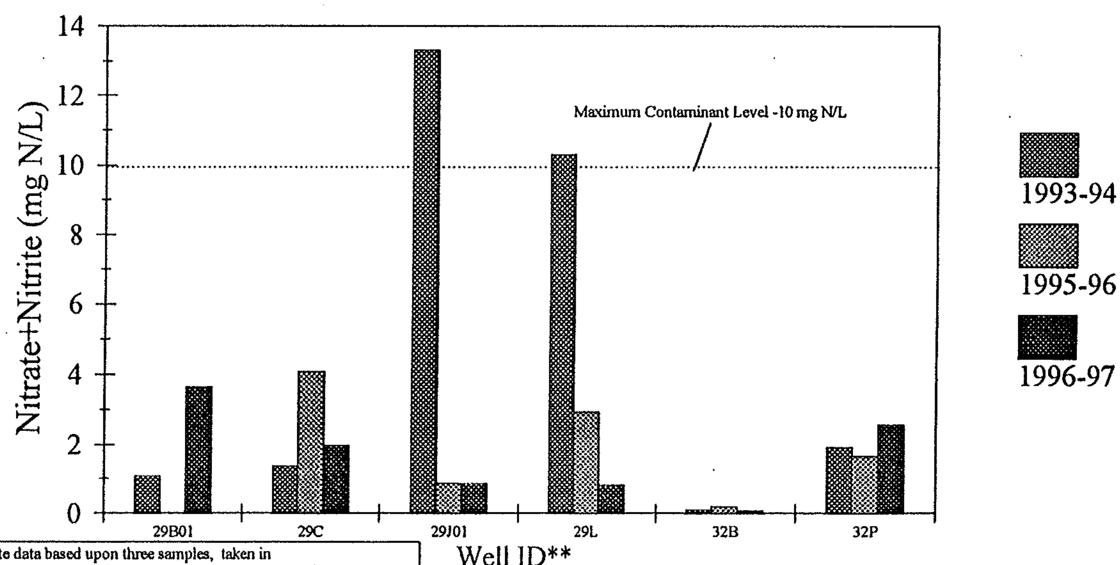
The poultry facility was spreading manure year-old during the 1996-97 sampling. It is working with the Thurston Conservation District to develop a farm plan and construct a building for winter-time manure storage. This work is to be completed in late 1998.

Table 8 shows the available data from the study wells. The two up-gradient wells, 17N/02E-32P and -32B are of similar depth, 100 and 103 feet deep, respectively. They also share a slightly basic pH, similar conductivity, temperature, and low dissolved oxygen levels. Well -29L is typical of shallow wells in that it has acidic pH (closer to the pH of rainwater), moderate conductivity and is well oxygenated.

Of the six wells sampled, only well -32B has not exceeded the warning level of 2 mg N/L. 20 samples have been collected from these six wells since 1994; nine were greater than 2 mg N/L, five were greater than 4, and 3 were greater than 10 mg N/L.

The shallow well, -29L, had nitrate levels that ranged from 2.53 mg N/L in November, 1993, up to 10.3 in both May and August, 1994, then dropped down to 2.92 in May 1996 and then 0.82 mg N/L in June, 1997. Well 17N/02E-29J01 also had a drastic reduction in nitrate levels from 13.3mg N/L in April, 1994 to 0.854 in May, 1996 and 0.86 in June, 1997. Note that well -29J01 is over 70 feet deeper than -29L and in a lower aquifer.

Figure 16 - Nitrate Levels*
Yelm Study Area



* Nitrate data based upon three samples, taken in April 1994, May 1996 and June 1997.
** Yelm well ID's are preceded by 17N/02E-

The two wells further down gradient had smaller peaks in nitrate levels in the following years. Well 17N/02E-29C's nitrate levels increased from 1.36 mg N/L in April, 1994 to 4.07 in May, 1996 and then decreased to 1.98 in May, 1997. Well -29C is of similar depth as -29J01 and about 0.3 miles north of the poultry facility.

The northen-most study well, 17N/02E-29B01, is 0.6 miles north of the facility. The well depth is 50 feet below ground surface . The nitrate levels increased from 1.08 mg N/L in April, 1994 to 3.65 in April, 1997.

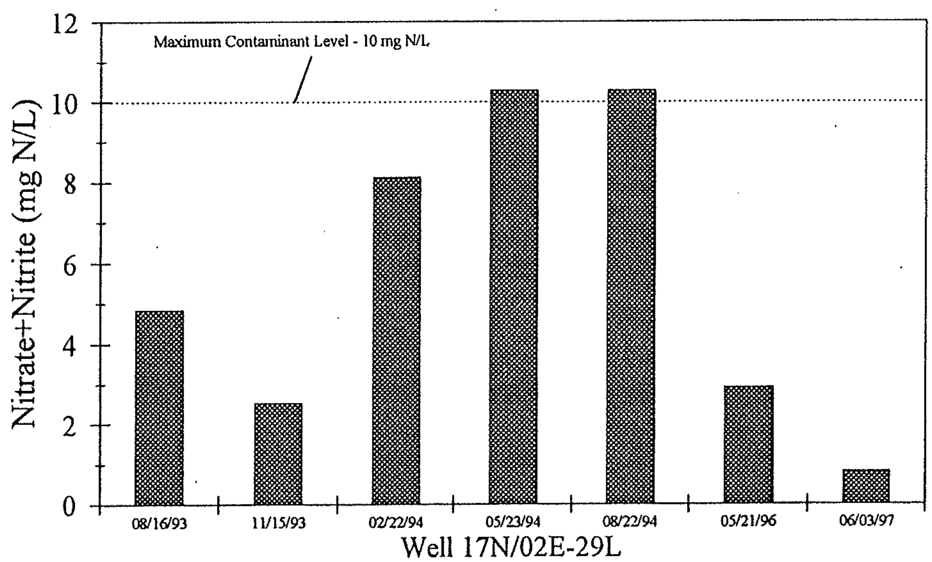
Erickson (pg 15, 1998) suggested using a velocity rate of between one and two feet/day for the advance outwash aquifer as a best estimate. Calculations of ground water velocity were based upon the following assumptions:

1. the poultry facility is the source of the nitrate increase in wells -29C and -29B01,
2. a nitrate plume started flowing northward in early 1994 (based on nitrate results from well -29L, the shallow well across the street from the facility),
3. the generalized ground water flow direction is north-northeast.

The average ground water velocity would need to be 2.2 feet/day to reach well -29C by May 1996 and 2.9 feet/day to reach well -29B01 by April, 1997. These velocities do not take into account the vertical distance the theoretical nitrate plume would have to cover in order to reach the bottoms of the wells (at 100 and 50 feet deep for wells -29C and -29B01, respectively).

Figure 17 - Nitrate Levels

Yelm Shallow Study Well



There is not enough data to determine if the increases in nitrate are a result of a single nitrate plume or from multiple sources. Data from the 1997-98 water year shows that the nitrate levels in wells -29C and -29B01 have continued to increase; the nitrate levels were 5.69 and 8.07 mg N/L in May 1998 for the two wells.

There are also no dramatic shifts in nitrate levels associated with low dissolved oxygen levels and elevated metals levels as was the case in Violet Prairie.

The iron and manganese levels in Yelm were low in general, based upon one round of samples in June, 1997. Metals levels have increased slightly at well -29L since November, 1993. No samples exceeded the 0.3 mg/L Maximum Contaminant Levels for iron, although well -29L was closest at 0.237 mg/L. Manganese levels were less than 20% of the standard.

Monitoring of the six Yelm wells will continue through the 1998-99 water year. Monitoring after that is uncertain.

Appendix A
North Thurston County Ambient Monitoring Network Data
1996-1997

Local ID	Date	Time	Elevation (ft - MSL)	Static Water Level (ft)	Static Water Elevation (ft - MSL)	pH	Conductivity @25c (umhos/cm)	Temp (deg C)	Dissolved Oxygen (mg/L)	Nitrate (mg N/L)
17N/01E-06C01	09/25/96	0940	100	39.10	60.90					
17N/01E-06C01	04/10/97	1325	100	35.08	64.92	6.5	148	10.51	5.50	1.78
17N/01E-06C01	07/17/97	1213	100	36.47	63.53					
17N/01W-34L02	04/11/97	1550	280	35.51	244.49	6.8	822	8.20	3.03	0.16
17N/01W-34L02	07/16/97	1525	280	39.58	240.42					
17N/02W-01E02	09/24/96	0950	160	66.23	93.77					
17N/02W-01E02	12/18/96		160	64.90	95.10					
17N/02W-01E02	04/11/97	1350	160	62.97	97.03	6.2	187	11.60	1.09	2.66
17N/02W-01E02	07/16/97	1410	160	65.39	94.61					
17N/02W-05A02	09/24/96	1010	172	3.70	168.30					
17N/02W-05A02	12/17/96	1645	172	2.68	169.32					
17N/02W-05A02	04/15/97	1415	172			7.0	142	10.48	2.88	2.52
17N/02W-05A02	07/18/97	1308	172	3.64	168.36					
17N/02W-14Q02	09/24/96	0929	200	13.30	186.70					
17N/02W-14Q02	12/18/96		200	9.50	190.50					
17N/02W-14Q02	04/11/97	1500	200	4.81	195.19	6.0	117	10.51	6.08	2.54
17N/02W-14Q02	07/16/97	1434	200	9.95	190.05					
17N/02W-22H02	09/24/96	0916	196	15.35	180.65					
17N/02W-22H02	12/18/96		196	10.42	185.58					
17N/02W-22H02	04/17/97	1100	196	9.13	186.87	6.7	136	11.55	4.04	3.07
17N/02W-22H02	07/16/97	1455	196	12.54	183.46					
17N/02W-30E03	04/15/97	1120	186	19.51	166.49	8.9	172	9.79	0.06	0.02
17N/02W-30E03	07/18/97	1206	186	25.00	161.00					
17N/03W-22J01	04/15/97	1310	200	22.30	177.70	6.4	91	9.47	9.11	1.06
17N/03W-22J01	07/18/97	1231	200	29.60	170.40					
18N/01E-19J02	09/25/96	1139	38	28.38	9.62					
18N/01E-19J02	12/18/96		38	22.95	15.05					
18N/01E-19J02	04/16/97	1111	38	25.70	12.30					
18N/01E-19J02	07/16/97	1301	38	26.94	11.06					
18N/01E-31A01	09/25/96	1214	100	60.55	39.45					
18N/01E-31A01	12/17/96		100	53.70	46.30					
18N/01E-31A01	04/10/97	1240	100	48.51	51.49	6.7	153	10.40	4.24	0.44
18N/01E-31A01	07/16/97	1230	100	53.76	46.24					
18N/01E-32H02	09/25/96	0912	255	175.13	79.87					
18N/01E-32H02	04/11/97	1150	255	170.36	84.64	7.0	146	10.10	7.79	1.97
18N/01E-32H02	07/19/97		255							
18N/01W-05G02	09/26/96	1024	110	22.05	87.95					
18N/01W-05G02	12/17/96	1120	110	21.15	88.85					
18N/01W-05G02	04/09/97	1240	110	18.80	91.20	6.8	167	10.33	10.53	1.66
18N/01W-05G02	07/17/97	1523	110	19.84	90.16					
18N/01W-07C01	09/26/96	0907	175	41.79	133.21					
18N/01W-07C01	12/17/96		175	41.92	133.08					
18N/01W-07C01	04/09/97	1150	175	38.08	136.92	6.4	154	11.07	8.86	4.23
18N/01W-07C01	07/17/97	1504	175	40.69	134.31					
18N/01W-09J01	09/26/96	1035	105	36.80	68.20					
18N/01W-09J01	12/17/96		105	36.60	68.40					
18N/01W-09J01	04/10/97	1045	105	33.38	71.62	7.1	203	9.60	0.34	0.26
18N/01W-09J01	07/17/97	1543	105	34.75	70.25					
18N/01W-24B02	09/25/96	1046	242	53.02	188.98					
18N/01W-24B02	12/17/96		242	51.90	190.10					
18N/01W-24B02	04/10/97	1150	242	45.23	196.77	7.4	341	11.33	3.68	3.48
18N/01W-24B02	07/16/97	1330	242	50.25	191.75					
18N/01W-28J01	09/25/96	1020	185	26.32	158.68					
18N/01W-28J01	12/19/96		185	26.39	158.61					
18N/01W-28J01	04/10/97	1440	185	24.43	160.57	6.9	191	10.96	8.62	4.95
18N/01W-28J01	07/16/97	1119	185	25.28	159.72					
18N/01W-33C01	09/25/96	1001	208	37.75	170.25					
18N/01W-33C01	12/19/96		208	38.60	169.40					
18N/01W-33C01	04/10/97	1505	208	31.60	176.40					
18N/01W-33C01	07/16/97	1050	208	33.44	174.56					

Data collected by Thurston County Environmental Health

Appendix A
North Thurston County Ambient Monitoring Network Data
1996-1997

Local ID	Date	Time	Elevation (ft - MSL)	Static Water Level (ft)	Static Water Elevation (ft - MSL)	pH	Conductivity @25c (umhos/cm)	Temp (deg C)	Dissolved Oxygen (mg/L)	Nitrate (mg N/L)
18N/01W-35A04	09/25/96	1550	175	9.90	165.10					
18N/01W-35A04	12/19/96		175	8.65	166.35					
18N/01W-35A04	04/10/97	1610	175	8.36	166.64	6.1	125	10.59	6.91	2.44
18N/01W-35A04	07/16/97	1622	175	9.61	165.39					
18N/01W-36C02	09/25/96	1203	195	126.49	68.51					
18N/01W-36C02	12/19/96		195	124.80	70.20					
18N/01W-36C02	04/16/97	1158	195	118.97	76.03					
18N/01W-36C02	07/18/97	1120	195	120.64	74.36					
18N/01W-36N01	09/25/96	0852	210	143.26	66.74					
18N/01W-36N01	01/21/97		210	143.20	66.80					
18N/01W-36N01	04/11/97	1040	210	135.20	74.80	6.8	202	10.07	7.30	4.54
18N/01W-36N01	07/18/97	932	210	137.22	72.78					
18N/02W-07R01	09/30/96		170	78.84	91.16					
18N/02W-07R01	01/01/97		170	81.86	88.14					
18N/02W-07R01	04/16/97	1445	170	72.24	97.76	7.4	150	10.00	0.06	0.02
18N/02W-07R01	07/18/97	1500	170	74.28	95.72					
18N/02W-08N03	12/18/96		155	85.40	69.60					
18N/02W-08N03	04/16/97	1545	155	76.35	78.65	6.4	127	9.89	8.86	2.47
18N/02W-08N03	07/18/97	1527	155	78.57	76.43					
18N/02W-33C01	12/17/96		270	40.00	230.00					
18N/02W-33C01	04/15/97	1550	270	30.12	239.88	9.2	154	10.51	0.08	0.01
18N/02W-33C01	07/18/97	1328	270	59.56	210.44					
18N/02W-35B02	04/16/97	1020	185	100.54	84.46	7.3	204	10.34	0.08	0.02
18N/02W-35B02	07/16/97	955	185	101.54	83.46					
18N/03W-01J02	04/16/97	1645	70	33.93	36.07	7.9	130	9.72	0.07	0.04
18N/03W-01J02	07/18/97	1551	70	34.51	35.49					
18N/03W-23N01	09/27/96	0905	330	3.05	326.95					
18N/03W-23N01	12/18/96		330	1.23	328.77					
18N/03W-23N01	04/16/97	1320	330	0.43	329.57	7.6	139	11.03	0.16	0.02
18N/03W-23N01	07/18/97	1432	330	1.91	328.09					
19N/01W-09L02	04/09/97	1500	190			7.3	97	10.73	5.74	0.06
19N/01W-22A01	09/26/96	1010	65	59.78	5.22					
19N/01W-22A01	12/17/96		65	59.35	5.65					
19N/01W-22A01	04/09/97	1600	65	58.87	6.13	8.2	214	10.17	0.03	0.02
19N/01W-22A01	07/17/97	1418	65	59.95	5.05					
19N/01W-28F02	09/26/96	0935	120	64.45	55.55					
19N/01W-28F02	12/17/96		120	64.40	55.60					
19N/01W-28F02	04/09/97	1340	120	63.24	56.76	8.0	159	10.77	0.13	0.04
19N/01W-28F02	07/17/97	1447	120	63.05	56.95					
19N/02W-18K02	09/27/96	0955	130	104.78	25.22					
19N/02W-18K02	12/18/96		130	104.80	25.20					
19N/02W-18K02	04/17/97	1210	130	103.55	26.45	7.9	158	11.45	0.06	0.02
19N/02W-18K02	07/18/97	1718	130	102.60	27.40					
19N/02W-18M01	09/27/96	0942	80	39.14	40.86					
19N/02W-18M01	12/18/96		80	38.10	41.90					
19N/02W-18M01	04/17/97	1255	80	37.63	42.37	6.9	178	10.77	6.77	1.43
19N/02W-18M01	07/18/97	1700	80	37.28	42.72					
19N/02W-27D04	04/17/97	1530	70	33.15	36.85	6.5	327	11.26	0.06	0.01
19N/02W-27D04	07/18/97	1626	70	32.54	37.46					

Data collected and reported by Thurston County Public Health and Social Services Department,
Environmental Health Division, Resource Protection Section
For information call (360)754-4111