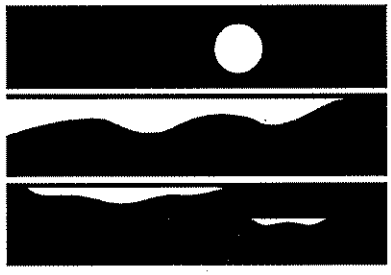

Sumas-Blaine Surficial Aquifer Nitrate Characterization

May 1998

Publication No. 98-310

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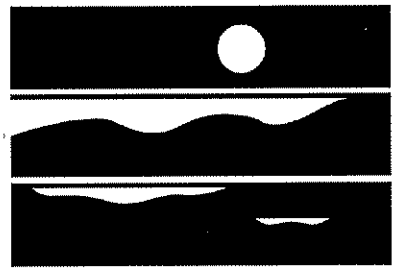

Sumas-Blaine Surficial Aquifer Nitrate Characterization

by
Denis Erickson

Environmental Investigations and Laboratory Services Program
Toxics Investigations Section

Conducted for the Department of Ecology
Water Quality Program

May 1998

Water Body Numbers
WA-01-1010, WA-01-2010
WA-01-1002, WA-01-1450

Publication No. 98-310
printed on recycled paper

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Abstract

Two hundred and forty-eight (248) water-supply wells and two (2) springs were sampled for nitrate and chloride over a ten-week period from February 18 through April 29, 1997. All sampled wells and springs obtained water from the Sumas-Blaine Surficial Aquifer. The results of this project provide a unique spatial view of the spring nitrate+nitrite-N concentrations in the surficial aquifer essentially free of seasonal variation. Nitrate+nitrite-N concentrations ranged from less than the detection limit (0.01 mg/L) to 53 mg/L. Nitrate+nitrite-N concentrations at 53 sites (21%) exceeded 10 mg/L, the drinking water standard for public water-supply systems. Upgradient land uses most frequently identified in association with wells having 10 mg/L nitrate+nitrite-N or greater were raspberries and dairy. Cooperators assisting with well identification and sampling included the US Geological Survey, Whatcom County Health Department, Western Washington University, The Evergreen State College and the Natural Resources Conservation Service.

Acknowledgments

Many people contributed to this project and their assistance is gratefully acknowledged:

- Well owner cooperation made this project possible.
- Steve Cox, United States Geological Survey, provided well locations and construction information for candidate wells.
- Chris Chesson, Whatcom County Health Department, reviewed the QAPP, provided well locations and well construction information for candidate wells, and reviewed the draft report.
- John Gillies, Natural Resource Conservation Service, reviewed the Quality Assurance Project Plan, helped identify candidate wells, and reviewed the draft report.
- Scott Babcock, professor at Western Washington University, reviewed the Quality Assurance Project Plan, provided student sampling assistance, and reviewed the draft report.
- These staff and volunteers with the Washington State Department of Ecology provided assistance:
  - ◊ Dave Garland, Northwest Regional Office, requested this project, reviewed the Quality Assurance Project Plan, helped conduct sampling, and reviewed the draft report.
  - ◊ John Tooley helped with sampling and transformed project data to ARC/INFO format. Mike Woodall prepared figures for the report.
  - ◊ Sampling assistants included: Pam Marti, hydrogeologist; Jim Cubbage, environmental specialist; Mike Hutchison, former WWU student; Luis Camacho, former student of The Evergreen State College; and Leora Nanus and David Stasney, graduate students at Western Washington University.
  - ◊ Larry Goldstein, Environmental Investigations Section Manager, reviewed the Quality Assurance Project Plan and the draft report, and provided Section management support.
  - ◊ Karin Feddersen and Pam Covey, Manchester Environmental Laboratory, monitored sample flow and testing. Casey Maggert, chemist with Manchester Environmental Laboratory, conducted nitrate analyses.
  - ◊ Charles Pitz, hydrogeologist, reviewed the draft report.
  - ◊ Joan LeTourneau, secretary, edited and formatted the report.

Introduction

Purpose

The purpose of this project was to define the spring nitrate concentration distribution in the Sumas-Blaine Surficial Aquifer, the principal surficial aquifer in the Nooksack River watershed. Nitrate, one of the most frequently identified contaminants found in groundwater, is soluble in water and mobile in groundwater. Prior to this study, the spatial distribution of summer nitrate concentration was known for the eastern portion of the Sumas-Blaine Surficial Aquifer. The results of this project provide a unique spatial view of the nitrate distribution in the surficial aquifer that is essentially free of seasonal variation.

Sumas-Blaine Surficial Aquifer

The Sumas-Blaine Surficial Aquifer is the principal surficial aquifer in the Nooksack Watershed in northwestern Whatcom County. The aquifer lateral boundaries as defined by Tooley and Erickson (1996) are shown in Figure 1. In the eastern part of the study area the Sumas-Blaine Surficial Aquifer coincides with the Sumas Aquifer described by Cox and Kahle (1993) where the Sumas Aquifer is unconfined. As with the Sumas Aquifer, the Sumas-Blaine Surficial Aquifer is hydraulically connected to the Abbotsford Aquifer of Canada. The combined international aquifer system is known as the Abbotsford-Sumas Aquifer.

The Sumas-Blaine Surficial Aquifer is an extensive water-table aquifer that continuously underlies an area of about 150 square miles. The aquifer consists mostly of saturated sand and gravel of glacially genetic deposits as well as mixed gravel, sand, silt and clay alluvial deposits of the Nooksack and Sumas Rivers. The thickness of these deposits ranges from less than 25 feet near Blaine to greater than 75 feet thick near Sumas. In most areas, the base of the aquifer consists of silty and clayey glacial sediments that transmit water less readily than the overlying aquifer. The water table is shallow, typically less than 10 feet below land surface. Exceptions occur near Sumas where the depth to water exceeds 50 feet and near the eastern margin of the aquifer where depths exceed 25 feet.

The Sumas-Blaine Surficial Aquifer readily interacts with rivers, streams, lakes and ditches in the watershed. In general, groundwater flows toward the tributaries and mainstems of the Nooksack River, Sumas River and Dakota Creek. The generalized groundwater-flow pattern for the Sumas-Blaine Surficial Aquifer is shown in Figure 2. Figure 2, modified from Tooley and Erickson (1996), was constructed using well water levels and stream elevations at points where streams crossed land surface elevation contours.

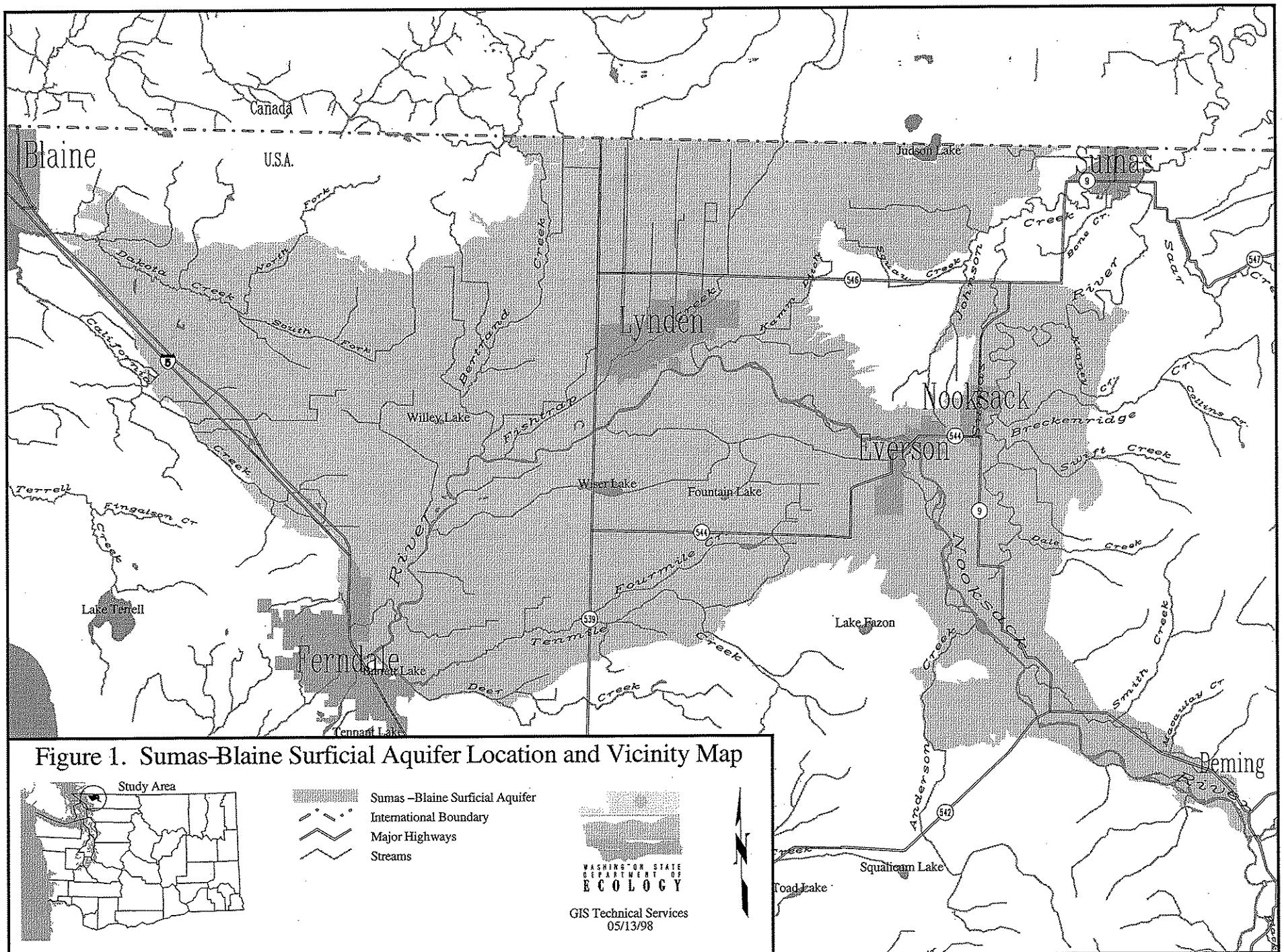


Figure 1. Sumas-Blaine Surficial Aquifer Location and Vicinity Map

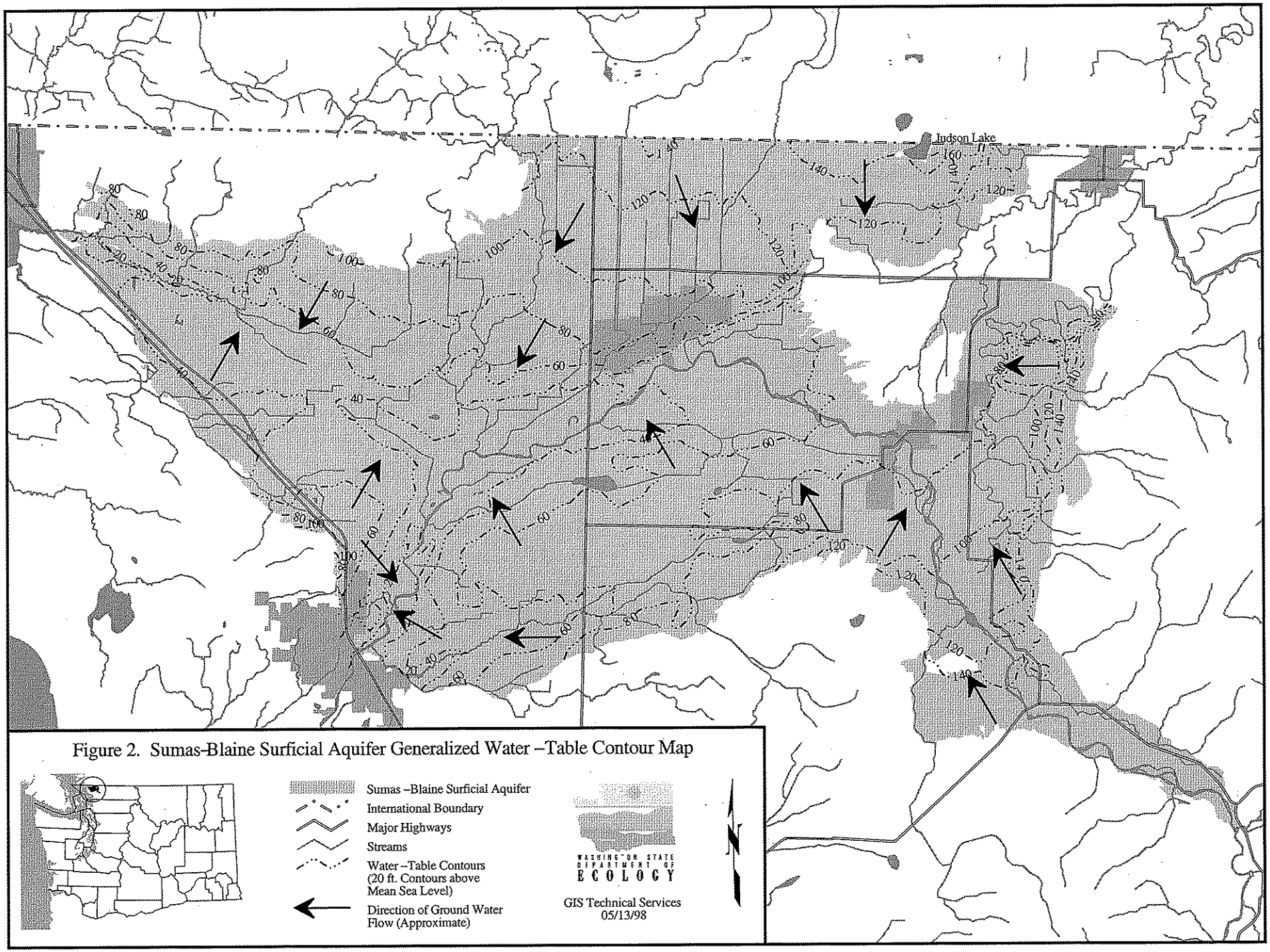


Figure 2. Sumas-Blaine Surficial Aquifer Generalized Water –Table Contour Map

Although the aquifer is recharged primarily by direct infiltration of precipitation, it is also hydraulically connected to and recharged by throughflow from the Abbotsford Aquifer and water-bearing zones beneath uplands near Sumas and east of Blaine.

Hydraulic conductivity of glacial and alluvial deposits is highly variable, commonly ranging over numerous orders of magnitude (Davis and DeWeist, 1966; Freeze and Cherry, 1979). Cox and Kahle (1993), using specific capacity data from 164 wells completed in the Sumas Aquifer, reported hydraulic conductivity values ranging from 7 to 7,800 feet per day.

Agriculture is the dominant land use in the study area; major crops grown include grass, corn, raspberries, and seed potatoes. The density of dairies in the study area is among the highest in the state (Environmental Investigations and Laboratory Services, 1996).

Methods

Well Selection

Wells were identified and selected for sampling using three approaches.

The first and preferred approach was to select wells that have been sampled previously by Ecology (Erickson and Norton, 1990; Garland and Erickson, 1994) and the US Geological Survey (Cox and Kahle, 1993). Also, wells in the Ecology Northwest Regional Office monitoring networks at Judson Lake and north of Lynden at Pangborn Road were sampled. Overall, about 100 wells sampled in previous investigations or in current monitoring networks were sampled for this project. Most of these wells were located in the eastern portion of the study area.

The second approach was to identify candidate wells from the Whatcom County Health Department Well and Septic System databases. Candidate wells were selected from the databases using well locations and depths that coincided with occurrence and thickness of the Sumas-Blaine Surficial Aquifer. The extent and geometry of the aquifer were previously described by Tooley and Erickson (1996). About 100 wells were identified and sampled using this approach.

For the third approach, used in those areas where no wells were identified using the previous two approaches, sampling teams canvassed well owners door-to-door. About 50 sites were identified and sampled using this approach.

Criteria used to select sites for sampling were:

- the well or spring tapped the Sumas-Blaine Surficial Aquifer
- the water was untreated prior to the sampling point
- a well log was available or the well depth was known
- the well owner allowed sampling

The locations of the sampled wells are shown in Figure 3. In some areas of the aquifer we were unable to locate any wells for sampling. In these areas wells were used for irrigation and were not operating during the sampling period, and households were served by public water-supply systems. The most notable data gaps occurred in three areas:

- north-northwest of Lynden
- a band about a mile wide on both sides of the Nooksack River between Everson and Ferndale
- the vicinity of the town of Nooksack

As a result there is a limited understanding of the surficial aquifer nitrate and chloride concentrations in these areas.

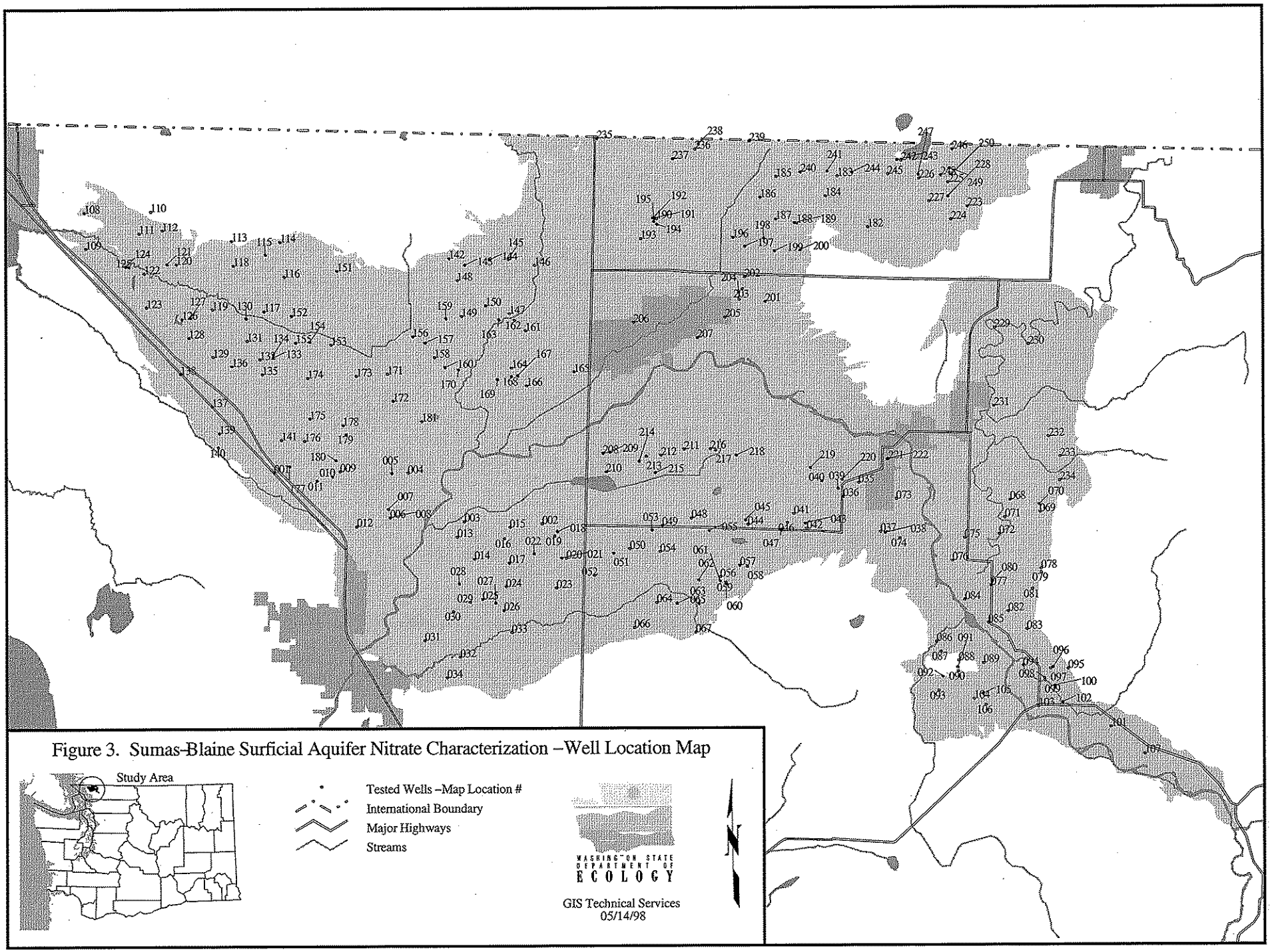


Figure 3. Sumas-Blaine Surficial Aquifer Nitrate Characterization –Well Location Map

Sampling

Two-hundred-and-forty-eight (248) wells and two (2) springs were sampled in the Sumas-Blaine Surficial Aquifer (Figure 3). This represents a density of about 1.7 sampling sites per square mile of aquifer surface area. The well identification codes, State Plane Coordinates, well depth, and upgradient land use for each of the sampled wells are listed in Appendix A, Table A-1. The depths of sampled wells ranged from 9 to 92 feet and averaged about 32 feet.

Sampling was conducted over a ten-week period between February 18 and April 29, 1997. Numerous people participated in the sampling including Ecology staff from the Environmental Investigations Program and Water Quality Program as well as students from Western Washington University and The Evergreen State College. Commonly two to three teams, consisting of two members each, conducted sampling simultaneously. Sampling procedures are described in Appendix B. To maintain uniformity of sampling procedures, a quality assurance project plan (Erickson, 1997) was prepared for this project and the methods described in the plan were followed by the sampling teams. Samples were transported to Manchester Environmental Laboratory, Manchester, Washington and tested for nitrate+nitrite-N and chloride.

During sampling, sample teams determined and recorded the land use immediately upgradient of each well. The upgradient direction was estimated either from the water-table map in Tooley and Erickson (1996) or from local topographic expression.

Data Management

All laboratory data generated at Manchester Environmental Laboratory were managed by the Laboratory Information Management System (LIMS) and reported electronically in ASCII format and as paper reporting sheets. Project data were entered and managed in the Environmental Investigations and Laboratory Services Program Microsoft Access™ database. Results for each well were mailed to individual well owners on June 30, 1997. For wells with nitrate concentrations greater than 5 mg/L, a nitrate fact sheet prepared by the Washington State Department of Health was enclosed with the mailout to the well owner.

Results and Discussion

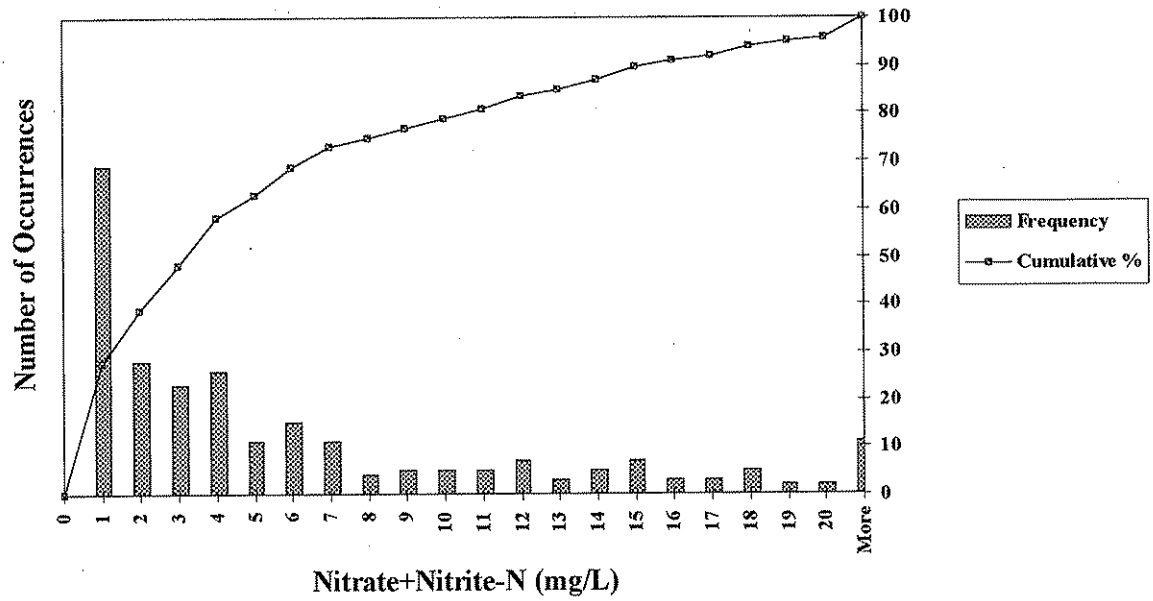
Quality Assurance

The analytical results for this project are considered acceptable for use without qualification. Laboratory quality assurance samples included duplicate blanks, duplicate samples, matrix spikes, and check (control) standards. Field quality assurance samples included 29 duplicate samples and two reference samples. Quality assurance results are described in detail in Appendix C.

Nitrate + Nitrite-N

Nitrate+nitrite-N concentrations for each sampling site are listed in Appendix D, Table D-1. Concentrations ranged from less than the detection limit (0.01 mg/L) to 53 mg/L. A histogram and cumulative frequency distribution of the nitrate results are shown in Figure 4.

Figure 4. Nitrate+Nitrite-N Concentration Frequency Distribution.



Descriptive statistics of central tendency of the nitrate+nitrite-N results are summarized as follows:

Arithmetic Mean = 5.8 mg/L
Median = 3.1 mg/L
Geometric Mean = 1.6 mg/L

(For these statistics non-detect concentrations are set to half the method detection limit = 0.005 mg/L)

The Washington State Department of Health has established a 10 mg/L drinking water standard (Maximum Contaminant Level or MCL) for nitrate-N in public water supply systems (Chapter 246-290 WAC). Nitrate+nitrite-N concentrations exceeded 10 mg/L at 53 (21%) of the sampled sites in the Sumas-Blaine Surficial Aquifer. At 98 sites (39%) nitrate+nitrite-N concentrations exceeded 5 mg/L.

Figure 5 is a generalized contour map of nitrate+nitrite-N results. The contours were determined using a kriging algorithm in the Surfer™ software package. The contour locations should be considered approximate. The figure shows three concentration ranges: less than 5 mg/L, 5 to 10 mg/L and greater than 10 mg/L. Nitrate concentrations tend to be greater than 10 mg/L in three broad areas:

- the northeastern portion of the aquifer in the Judson Lake vicinity
- the Bertrand Creek drainage
- the south-central portion of the aquifer, area south of Lynden between Four Mile Creek and the Nooksack River

Previous studies have reported elevated nitrate concentrations in the Sumas-Blaine Surficial Aquifer. In the eastern portion of the aquifer Cox and Kahle (1993) reported that 27% of 236 wells sampled in the Sumas Aquifer showed concentrations exceeding 10 mg/L with a mean nitrate concentration of 6 mg/L. Garland and Erickson (1994) reported nitrate+nitrite-N concentrations as high as 73 mg/L and a median concentration of 2.3 mg/L for 21 wells in a three-square-mile area north of Lynden. Erickson and Norton (1990) reported nitrate+nitrite-N concentrations for 27 wells in the Bertrand Creek drainage ranged from less than 0.01 to 24 mg/L with a mean of 6.7 mg/L. Cox and Kahle (1993) identified the major sources of nitrate for the Sumas Aquifer as animal wastes, inorganic fertilizer applications, and septic systems. Because of the spatial and temporal variability of the sampling, these data are not suitable for identifying nitrate trends over time.

Chloride

Chloride concentrations for all sampling sites are listed in Appendix D, Table D-1. Concentrations ranged from 0.8 to 301 mg/L. The frequency distribution for chloride concentrations is shown in Figure 6.

The statistics of central tendency for chloride concentrations are summarized as follows:

Arithmetic Mean = 13.7 mg/L
Median = 8.3 mg/L
Geometric Mean = 8.7 mg/L

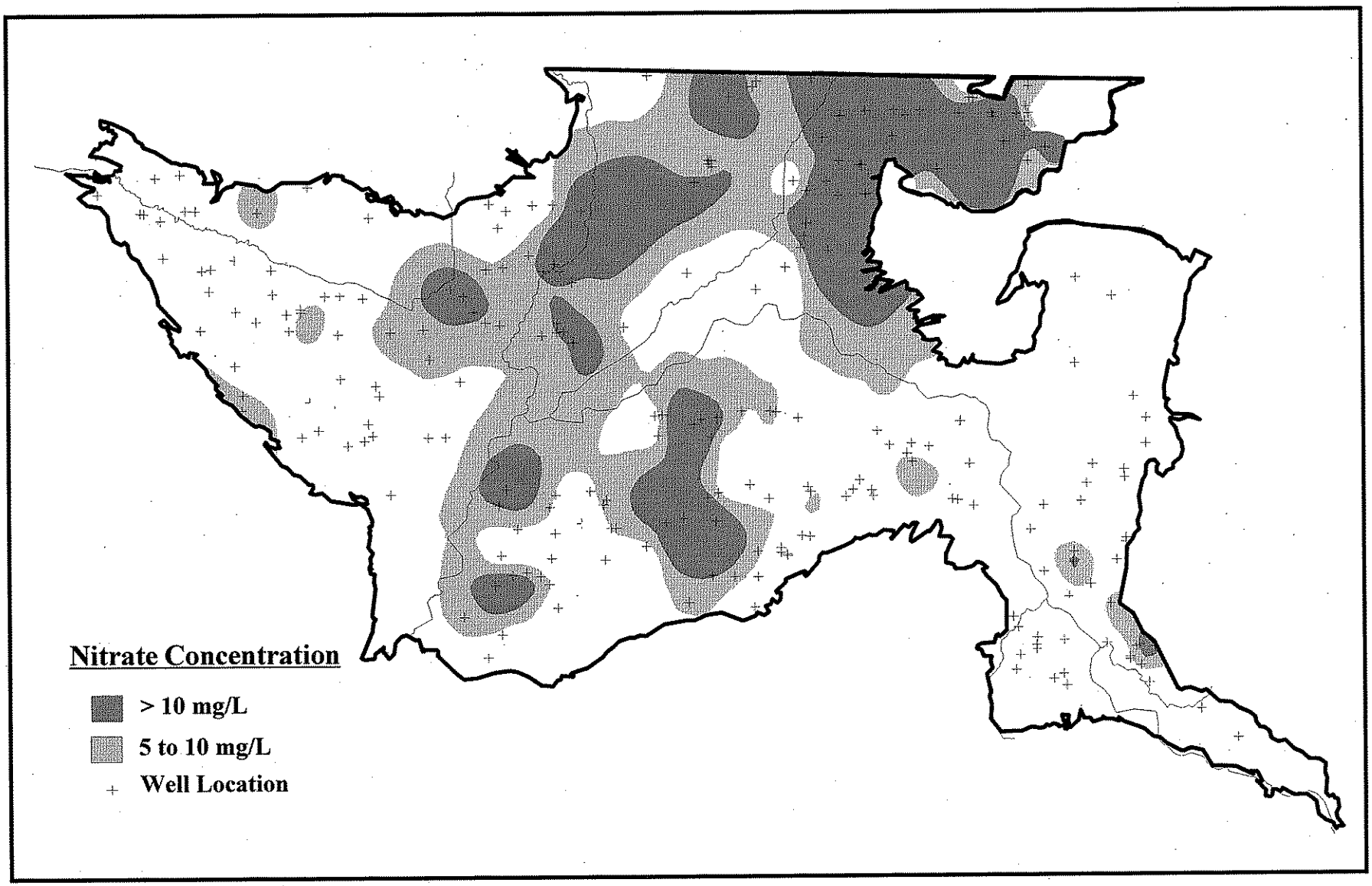
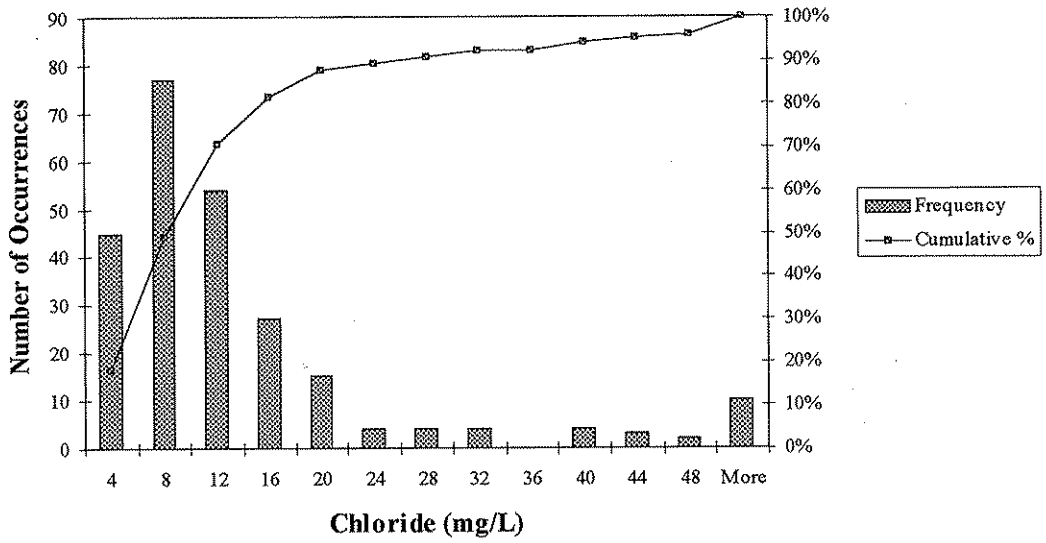


Figure 5. Areas with Elevated Nitrate+Nitrite-N, Sumas-Blaine Surficial Aquifer Nitrate Characterization.

Figure 6. Chloride Concentration Frequency Distribution.



Chloride is present in animal waste, including human waste, and is commonly considered a conservative tracer in groundwater. Erickson (1994) used chloride as an indicator of leakage from dairy waste storage ponds and for land application of dairy wastes. Chloride concentrations in wastewater for two dairies in the watershed ranged from 139 to 962 mg/L. Cox and Kahle (1993) reported that chloride concentrations in natural groundwater in the basin are generally small and they believed that background concentrations, derived primarily from infiltrated precipitation, should be less than 4 mg/L. They reported that typical chloride concentrations in the Sumas Aquifer ranged from 4 to 20 mg/L and they believed that chloride concentrations in this range resulted from land use practices that included land application of dairy manure, fertilizer application, and septic systems. Based on an association with bromide occurrence, Cox and Kahle attributed chloride concentrations greater than 20 to 25 mg/L to connate sea water trapped during the last glacial episode.

Figure 7 is a generalized contour map of the chloride distribution in the Sumas-Blaine Surficial Aquifer. Four chloride concentration ranges are shown: less than 4 mg/L, 4-20 mg/L, 20-50 mg/L and greater than 50 mg/L. For most of the aquifer, chloride concentrations ranged between 4 and 20 mg/L. In the western portion of the aquifer high chloride concentrations are associated with single wells and are probably related to connate sea water. In the eastern portion of the aquifer broader areas where chloride concentrations are consistently elevated (greater than 20 mg/L) include the:

- southeast portion of the aquifer midway between Everson and Deming on the east and the west sides of the Nooksack River
- area about a mile southwest of Everson
- south-central portion of the aquifer near Ten Mile Creek and Four Mile Creek

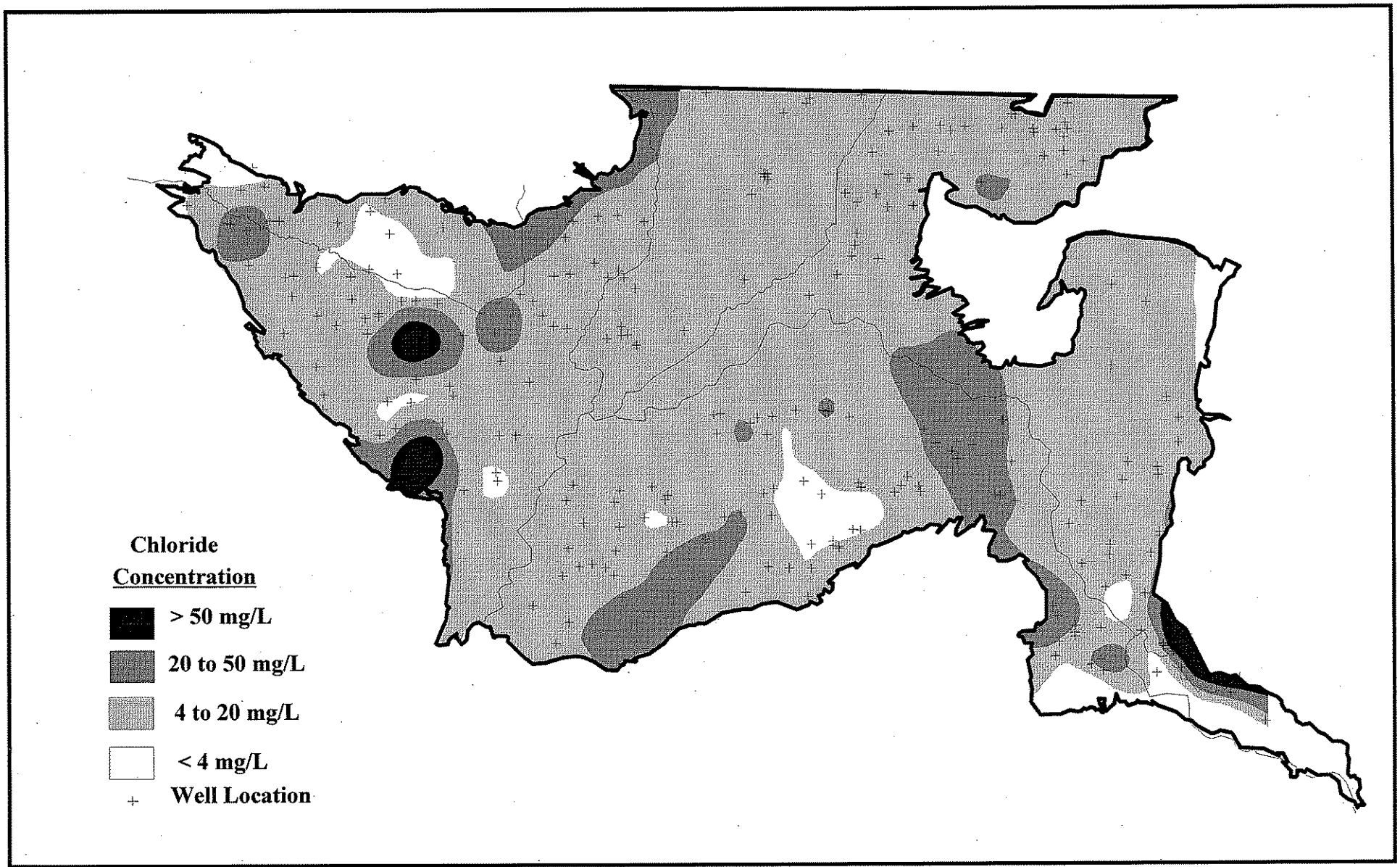
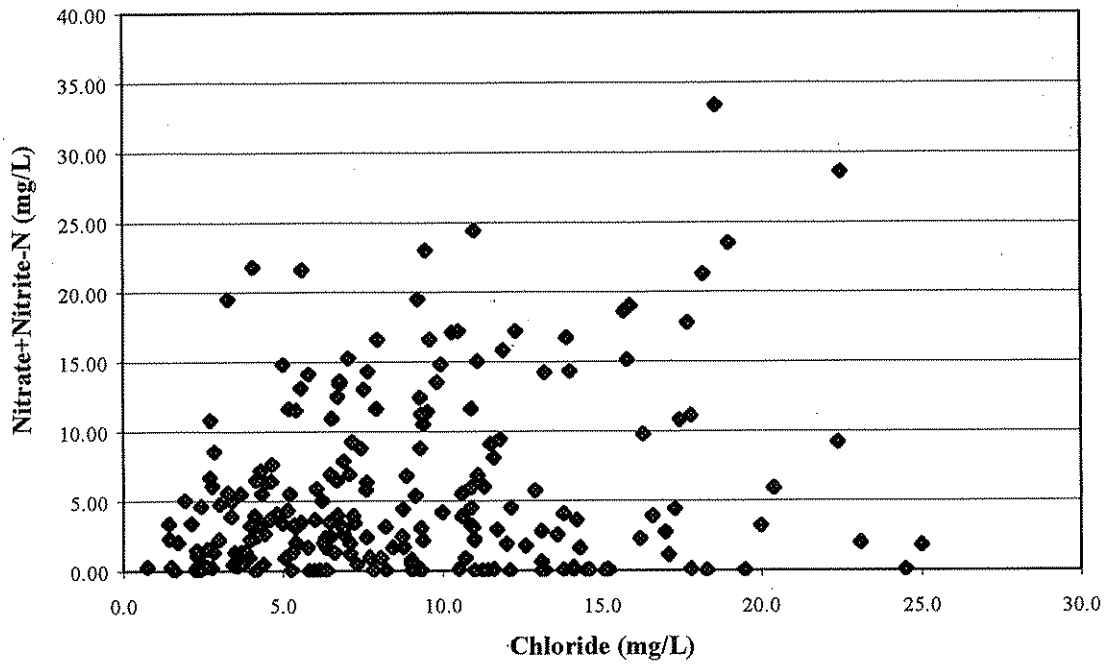


Figure 7. Chloride Concentrations, Sumas-Blaine Surficial Aquifer.

The Washington State Board of Health has established a Secondary MCL for chloride of 250 mg/L for public water supply systems. The Secondary MCL for chloride is not a health-based standard but is based on the salty taste at concentrations greater than the MCL. One well (NO39422K1), located along the eastern boundary of the aquifer, exceeded 250 mg/L chloride with a concentration of 301 mg/L.

A comparison of Figures 5 and 7 indicates little spatial correlation of chloride and nitrate+nitrite-N concentrations. A scatter plot of chloride and nitrate+nitrite-N for corresponding wells is shown in Figure 8. For scale purposes the plot does not include chloride concentrations greater than 30 mg/L or nitrate+nitrite-N concentrations greater than 40 mg/L. The plot, which represents 90% of the study data, shows a fairly uniform scatter of data points. Linear regression analysis shows no significant correlation (R^2= 0.001). Also, linear regression analysis of the logarithmically transformed data shows no significant correlation (R^2=0.005).

Figure 8. Chloride and Nitrate+Nitrite-N Concentrations for Corresponding Study Wells.



Land Use

The sampling teams identified land use hydraulically upgradient of each sampled well. The upgradient direction for groundwater was estimated using water-table contours from Tooley and Erickson (1996) or from the local topographic expression. The land use results should be considered qualitative for the following reasons:

- only land use immediately upgradient of the wells was identified
- the groundwater flow direction was estimated from regional patterns and local patterns may be more complex
- past land use was not identified

The land use upgradient of each well is listed in Appendix A, Table A-1 and summarized in Table 1. In many instances multiple land uses were identified for a single well. The most frequently identified land uses upgradient of sampled wells in the study area and their frequency of occurrence are: pasture (26%), dairy (24%), raspberries (22%), rural residential (20%), and wooded (10%).

Table 1 also lists the land uses upgradient of wells with nitrate+nitrite-N concentrations exceeding 10 mg/L. The land uses most frequently identified upgradient of wells with greater than 10 mg/L nitrate+nitrite-N are: raspberries (51%), dairy (32%), pasture (13%), corn (7.5%) and woods (7.5%). Raspberry and dairy land uses, highlighted in Table 1, were identified more frequently in association with wells with elevated nitrate than they were for the overall study. Nitrate loading from dairy activities has been well documented in the area but nitrate loading from raspberry production has not.

Table 1. Ugradient Land Uses, Sumas-Blaine Surficial Aquifer Nitrate Characterization.

Land Use [1]	All Sampling Sites Number of Occurrences [2]	All Sampling Sites Percent of All Sites [3]	Wells with NO3+NO2-N Greater than 10 mg/L Number of Occurrences [4]	Wells with NO3+NO2-N Greater than 10 mg/L Percent of Wells [5]
Berries	5	2.0	3	5.7
Blueberries	2	0.8	0	0.0
Cranberries	2	0.8	0	0.0
Raspberries	56	22	28	53
Strawberries	5	2.0	1	1.9
Cattle	1	0.4	1	1.9
Dairy	60	24	18	34
Feedlot	2	1	1	1.9
Chickens	3	1.2	1	1.9
General agriculture	19	7.6	2	3.8
Pasture	65	26	7	13
Corn	9	3.6	4	7.5
Potatoes	3	1.2	0	0.0
Orchard	5	2.0	0	0.0
Grapes	1	0.4	0	0.0
Tulips	1	0.4	0	0.0
Tree farm	3	1.2	0	0.0
Nursery	1	0.4	1	1.9
Residential	14	5.6	2	3.8
Rural residential	49	20	1	1.9
Gravel pit	3	1.2	1	1.9
Quarry	1	0.4	0	0.0
Landfill	1	0.4	0	0.0
Cemetery	2	0.8	1	1.9
Wooded	26	10	4	7.5
Wetlands	1	0.4	0	0.0
Not recorded	9	3.6	3	5.7
Sum=	349	140	79	149
Sites=	250		53	

Conclusions

1. Results from this project for the first time have defined the spring nitrate and chloride concentrations for the Sumas-Blaine Surficial Aquifer. Elevated concentrations of nitrate in groundwater confirm the susceptibility of the Sumas-Blaine Surficial Aquifer to contamination from surface activities.

2. The results confirm that a widespread nitrate contamination problem exists in the Sumas-Blaine Surficial Aquifer. Substantial portions of the aquifer have concentrations of nitrate+nitrite-N exceeding 10 mg/L, the drinking water standard for public water supply systems. Of the 250 sites sampled 53 (21%) had concentrations that exceeded 10 mg/L and 98 sites (39%) exceeded 5 mg/L. Areas showing widespread elevated nitrate+nitrite-N include the:

   - northeastern portion of the aquifer in the Judson Lake vicinity
   - Bertrand Creek drainage
   - south-central portion of the aquifer, area south of Lynden between Four Mile Creek and the Nooksack River

3. Regression analysis shows little correlation between chloride and nitrate+nitrite-N concentrations for corresponding wells.

4. Raspberries and dairy were the most frequently identified land uses upgradient of wells that exceeded 10 mg/L nitrate+nitrite-N.

Recommendations

1. Ecology should design and implement a study to assess the effect of raspberry production on nitrogen loading to the Sumas-Blaine Surficial Aquifer. To be useful, study components should include design and installation of local groundwater monitoring networks, fertilizer application tracking, and long-term monitoring (2 to 5 years).

2. Ecology should encourage, support, and cooperate in studies that determine rates and timing of fertilizer and manure applications. These studies should lead to Best Management Practices that, when implemented, reduce nitrogen loading to groundwater.

3. Ecology should design and implement a groundwater monitoring network to assess nitrate concentration trends over time in the Sumas-Blaine Surficial Aquifer. The design will need to consider the spatial and temporal variability of nitrate concentrations. The network should consist of both existing water-supply wells and monitoring wells installed for the primary purpose of providing water quality samples.

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Appendices

APPENDIX A

Table A-1. Well Construction Information

Table A-1. Well Data, Sumas-Blaine Surficial Aquifer.

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	Depth (feet)	Upgradient Land Use
001	NO39101A1	3/12/97	1489940	1309670	20	Rural residential
002	NO39201N1	3/10/97	1517780	1304296	25	General agriculture
003	NO39203Q1	3/10/97	1509695	1304532	31	Pasture
004	NO39204C1	3/11/97	1503812	1309594	25	Rural residential
005	NO39204D1	3/11/97	1502139	1309573	21	Rural residential
006	NO39204M1	3/10/97	1501943	1304954	25	Pasture
007	NO39204N1	3/10/97	1501773	1305821	26	Pasture
008	NO39204N2	3/10/97	1501947	1304948	24	Not recorded
009	NO39205D1	3/11/97	1496785	1309757	20	Rural residential
010	NO39206A1	3/10/97	1495977	1309255	28	Wooded
011	NO39206B1	3/11/97	1494385	1308794	29	Not recorded
012	NO39208C1	3/11/97	1498492	1304045	24	Not recorded
013	NO39210F1	3/11/97	1508941	1302939	20	Blueberries, pasture
014	NO39210J1	3/12/97	1510733	1300641	40	Pasture
015	NO39211B1	3/12/97	1514440	1303937	26	Wooded, pasture
016	NO39211F1	3/11/97	1513875	1302767	30	Tree farm, strawberries
017	NO39211K1	3/12/97	1514375	1300227	47	Pasture
018	NO39212C1	3/12/97	1519363	1303459	32	Rural residential
019	NO39212C2	3/14/97	1519078	1303023	24	Pasture, raspberries
020	NO39212K1	3/12/97	1520290	1300697	27	Rural residential, pasture
021	NO39212K2	3/12/97	1519796	1300723	20	Rural residential, pasture
022	NO39212M1	3/12/97	1516956	1301180	23	Not recorded
023	NO39213F1	3/13/97	1519247	1297631	33	Corn, berries, pasture
024	NO39214C1	3/13/97	1514024	1297774	35	Rural residential
025	NO39214E1	3/14/97	1511586	1296460	28	Pasture
026	NO39214L1	3/13/97	1513801	1295295	21	Pasture, quarry
027	NO39214L2	3/13/97	1512946	1296080	24	Corn, dairy
028	NO39215B1	3/10/97	1509143	1298076	21	Tree farm
029	NO39215J1	3/13/97	1510263	1296171	21	Pasture, berries
030	NO39215L1	3/10/97	1508550	1295217	24	Berries
031	NO39221H1	3/13/97	1505531	1292181	27	Residential, wooded
032	NO39222K1	3/13/97	1509206	1290485	17	Not recorded
033	NO39223B1	3/12/97	1514617	1293012	10	Pasture
034	NO39227C1	3/13/97	1507839	1288341	23	Residential
035	NO39301C1	3/25/97	1550638	1308472	49	Wooded
036	NO39301E1	3/25/97	1549046	1307026	39	Gravel pit
037	NO39301R1	3/25/97	1552906	1303379	46	Gravel pit, pasture
038	NO39301R2	4/29/97	1553411	1303284	40	Gravel pit
039	NO39302A1	3/20/97	1548533	1307843	39	Wooded
040	NO39302B1	3/27/97	1546830	1308647	20	Wooded, rural residential
041	NO39302M1	3/25/97	1543925	1305268	36	Dairy
042	NO39302P1	3/25/97	1545257	1303727	11	Pasture, orchard
043	NO39302P2	3/25/97	1545094	1304275	24	Pasture, orchard
044	NO39303N1	3/27/97	1539187	1304170	20	Raspberries, dairy

Table A-1. Well Data, Sumas-Blaine Surficial Aquifer.

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	Depth (feet)	Upgradient Land Use
045	NO39303N2	3/28/97	1538934	1304640	40	Dairy, raspberries
046	NO39303R1	3/25/97	1543287	1304344	12	Dairy
047	NO39303R2	3/25/97	1542638	1303669	40	Dairy
048	NO39304N1	3/25/97	1533296	1304846	40	Tree farm, raspberries
049	NO39305Q1	3/25/97	1530245	1304094	9	Raspberries
050	NO39307H1	3/21/97	1526850	1301685	29	Raspberries
051	NO39307K2	3/25/97	1525187	1301212	24	Dairy, raspberries
052	NO39307N1	3/28/97	1523220	1298923	30	Dairy
053	NO39308C1	3/26/97	1529200	1303598	32	Raspberries, dairy
054	NO39308F2	3/26/97	1530007	1301359	20	Raspberries, dairy
055	NO39309C1	3/26/97	1535140	1303510	25	Raspberries, dairy
056	NO39309Q2	3/26/97	1536288	1298738	25	Raspberries, strawberries
057	NO39310M1	3/27/97	1538321	1299916	20	Pasture, rural residential
058	NO39310M2	3/27/97	1539125	1299820	32	Pasture, rural residential
059	NO39316A1	3/26/97	1536879	1298152	21	Dairy, chickens, raspberries
060	NO39316A2	3/26/97	1536942	1297994	34	Dairy
061	NO39316B2	3/27/97	1536294	1298287	23	Dairy, wooded
062	NO39316C1	3/20/97	1534043	1298401	24	Pasture
063	NO39316F1	3/21/97	1534064	1295939	37.5	Pasture
064	NO39317F1	3/28/97	1529657	1296094		Pasture
065	NO39317H1	3/28/97	1531787	1295980		Dairy, pasture
066	NO39317N1	3/12/97	1527316	1293489	20	Raspberries
067	NO39321D2	3/12/97	1533712	1293005	30	General agriculture
068	NO39404F1	4/15/97	1566432	1306677	32	Pasture
069	NO39404H1	4/14/97	1569508	1305402	41	Raspberries
070	NO39404H2	4/14/97	1569429	1306184	44	Pasture, raspberries
071	NO39404M1	4/15/97	1565873	1304846	41	Wetlands
072	NO39404N1	4/15/97	1565289	1303113	52	Dairy, pasture, wooded
073	NO39406E1	4/14/97	1554565	1306789	67	Dairy
074	NO39407D1	4/14/97	1554949	1302731	50	General agriculture
075	NO39408C1	4/14/97	1561683	1302735	46	Dairy
076	NO39408E1	4/14/97	1560416	1300378	57	Raspberries
077	NO39408R1	4/15/97	1564430	1297795	35	Pasture, dairy
078	NO39409J1	4/14/97	1569621	1299543	70	General agriculture
079	NO39409J2	4/14/97	1569628	1299144	25	Rural residential
080	NO39409N1	4/15/97	1564605	1298275	20	Rural residential, pasture
081	NO39409R1	4/14/97	1568726	1297420	67	Pasture
082	NO39416F1	4/14/97	1566180	1295082	22	Dairy
083	NO39416Q2	4/17/97	1568127	1293241	33	Dairy, chickens
084	NO39417C1	4/14/97	1561695	1296295	36	Raspberries
085	NO39417J1	4/17/97	1564126	1293896	60	Dairy
086	NO39419A1	4/15/97	1558725	1291972	31	Rural residential
087	NO39420E1	4/15/97	1559193	1290949	43	Rural residential
088	NO39420F1	4/15/97	1561043	1289993	60	General agriculture

Table A-1. Well Data, Sumas-Blaine Surficial Aquifer.

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	Depth (feet)	Upgradient Land Use
089	NO39420H1	4/15/97	1563630	1289733	41	Rural residential
090	NO39420L1	4/15/97	1560985	1288896	46	Rural residential
091	NO39420L2	4/15/97	1560940	1289287	54	Rural residential, pasture
092	NO39420M1	4/17/97	1559388	1288330	33	Rural residential, pasture
093	NO39420N1	4/17/97	1558963	1286893	46	Rural residential
094	NO39421K1	4/29/97	1567721	1289453	35	Rural residential, pasture
095	NO39422K1	4/16/97	1572374	1289112	38	Dairy
096	NO39422L1	4/16/97	1570815	1289274	30	Dairy
097	NO39422M1	4/16/97	1570549	1289126	22	Dai ry, pasture
098	NO39422M2	4/16/97	1569938	1288141	32	General agriculture
099	NO39422N1	4/16/97	1569955	1287900	39	General agriculture
100	NO39422P1	4/16/97	1570999	1287332	30	Corn
101	NO39426L1	4/16/97	1576804	1283107	37	Rural residential, wooded
102	NO39427C1	4/16/97	1571802	1285632	37	Raspberries, rural residential
103	NO39427D2	4/16/97	1569292	1285200	52	Residential
104	NO39429A1	4/17/97	1562626	1286032	28	Rural residential, landfill
105	NO39429A2	4/17/97	1563551	1286518	42	Rural residential
106	NO39429A3	4/17/97	1563859	1285401	18	Rural residential
107	NO39436D1	4/16/97	1580325	1280319	40	Pasture
108	NO40108A1	3/27/97	1470290	1336741	20	General agriculture
109	NO40108R1	3/26/97	1470437	1333011	23	Pasture, wooded
110	NO40110D1	3/26/97	1477147	1336853	22	Rural residential
111	NO40110E1	3/27/97	1475940	1334578	19	Rural residential, general agriculture
112	NO40110F1	3/24/97	1478345	1334875	21	Rural residential, general agriculture
113	NO40111J1	3/24/97	1485568	1333795	14	Rural residential, dairy
114	NO40112J1	3/24/97	1490628	1333643	18	Pasture
115	NO40112Q1	3/27/97	1489090	1332350	20	Rural residential
116	NO40113A1	3/14/97	1491059	1330041	25	Pasture, raspberries
117	NO40113Q1	3/28/97	1488942	1326443		Pasture
118	NO40114A1	3/26/97	1485749	1331212	26	Rural residential
119	NO40114P1	3/24/97	1483542	1326652	21	Rural residential
120	NO40115A1	3/25/97	1479804	1331384	22	Rural residential, pasture
121	NO40115B2	3/25/97	1478840	1331387	11	Pasture
122	NO40115E1	3/24/97	1476448	1330428	30	Not recorded
123	NO40115N1	3/24/97	1476693	1326883	22	Rural residential
124	NO40116A1	3/25/97	1474539	1331164	19	Rural residential
125	NO40116A2	3/27/97	1474873	1331121	16	Rural residential
126	NO40122A1	3/24/97	1480379	1325653	27	Pasture
127	NO40123D1	3/24/97	1481241	1325780	28	Rural residential
128	NO40123M1	3/25/97	1481094	1323706	20	Rural residential
129	NO40123Q1	3/26/97	1483606	1321722	16	Rural residential
130	NO40124D1	3/25/97	1487070	1325697	20	Wooded
131	NO40124M1	3/25/97	1487168	1323373	20	Not recorded
132	NO40124P1	3/25/97	1488514	1321444	30	Rural residential

Table A-1. Well Data, Sumas-Blaine Surficial Aquifer.

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	Depth (feet)	Upgradient Land Use
133	NO40124Q1	3/25/97	1489892	1321633	23	Rural residential, pasture
134	NO40124Q2	3/26/97	1489890	1321940	23	Rural residential
135	NO40125B1	3/26/97	1488752	1319872	30	Residential
136	NO40126A1	3/26/97	1485571	1320733	24	Rural residential
137	NO40126Q1	3/25/97	1483492	1316550	12	Residential
138	NO40127A1	3/24/97	1480209	1319944	18	Rural residential
139	NO40135G1	3/27/97	1484253	1313747	25	Residential, feedlot
140	NO40135K1	3/26/97	1484160	1312266	21	Feedlot
141	NO40136H1	3/27/97	1490720	1313035	17	Rural residential
142	NO40210N2	3/10/97	1508154	1331911	38	Pasture, general agriculture
143	NO40210Q1	3/28/97	1509802	1331239		General agriculture
144	NO40211N1	4/28/97	1512384	1331765	30	Rural residential, dairy
145	NO40211P1	4/28/97	1514356	1331834	31	Dairy
146	NO40211R1	4/28/97	1517071	1331180	29	Nursery, general agriculture
147	NO40214P1	3/10/97	1514449	1326156	43.1	Raspberries
148	NO40215F1	3/12/97	1509022	1329622	26	Dairy
149	NO40215Q1	3/10/97	1509466	1325882	26	Raspberries
150	NO40215R2	3/10/97	1511979	1326993	26	Raspberries
151	NO40217D1	3/14/97	1496495	1330646	25	Pasture
152	NO40219D1	3/14/97	1491797	1325961	30	General agriculture, pasture
153	NO40219J1	3/14/97	1495873	1322946	28	Pasture, dairy
154	NO40219L1	3/12/97	1493687	1323226	25	Pasture
155	NO40219M1	3/12/97	1492229	1323159	26	Pasture, strawberries, grapes
156	NO40221G1	3/12/97	1504357	1323795	25	Corn, dairy
157	NO40221J5	3/10/97	1505644	1323128	17	Raspberries
158	NO40221R6	3/10/97	1506621	1321618	30	Raspberries
159	NO40222D1	3/28/97	1507832	1325661		Pasture
160	NO40222N7	3/11/97	1507719	1320565	18	Pasture
161	NO40223A3	3/11/97	1516133	1324386	23	Strawberries
162	NO40223B2	3/10/97	1514986	1325482	35	Raspberries
163	NO40223D4	3/10/97	1513362	1325509	42.5	Raspberries
164	NO40223P4	3/11/97	1514674	1320513	30	Pasture
165	NO40225B1	3/11/97	1521143	1320076	40	Rural residential
166	NO40226A4	3/11/97	1516230	1318642	33	Dairy
167	NO40226B1	3/11/97	1515304	1319692	30	Pasture, raspberries
168	NO40226C1	3/11/97	1514653	1319616	32	Pasture, raspberries
169	NO40226D2	3/11/97	1513207	1319296	15	Pasture, raspberries
170	NO40227C1	3/11/97	1509123	1320311	32	Raspberries
171	NO40228D5	3/12/97	1501701	1319906	22	Pasture, general agriculture
172	NO40228M1	3/12/97	1502302	1317059	20	Cranberries, blueberries
173	NO40229C1	3/13/97	1498494	1319680	20	Pasture, general agriculture
174	NO40230G1	3/13/97	1493456	1319485	40	Raspberries
175	NO40231B1	3/27/97	1493668	1315242	20	Dairy
176	NO40231F1	3/21/97	1493120	1312929	20	Pasture, dairy

Table A-1. Well Data, Sumas-Blaine Surficial Aquifer.

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	Depth (feet)	Upgradient Land Use
177	NO40231N1	3/11/97	1491542	1310307	23	Wooded
178	NO40232C1	3/13/97	1497096	1314552	21	Pasture
179	NO40232E1	3/13/97	1497440	1313608	28	Wooded
180	NO40232N1	3/13/97	1496355	1310909	21	Wooded
181	NO40233A1	3/13/97	1505256	1314943	33	Orchard
182	NO40301P1	3/20/97	1551679	1335082	39-49	Dairy
183	NO40302B1	3/14/97	1548547	1340337	22-26.5	Corn, wooded
184	NO40302F1	3/14/97	1547309	1338286	35	Dairy, raspberries
185	NO40303B1	3/13/97	1542223	1340297	29	Wooded, dairy
186	NO40303E1	3/21/97	1540539	1338171	20	Raspberries
187	NO40303Q1	3/20/97	1542167	1335915	30	Dairy
188	NO40303R2	4/28/97	1544325	1335518	73	Raspberries
189	NO40303R3	4/28/97	1544105	1335548	73	Raspberries
190	NO40305N1	3/12/97	1529764	1336007		Potatoes, dairy
191	NO40305N2	2/18/97	1529565	1336054	24	Potatoes, dairy
192	NO40305N3	3/19/97	1529381	1336084	26	Corn, potatoes, dairy
193	NO40307H1	3/19/97	1528113	1333932	21	Dairy, raspberries
194	NO40308D1	3/12/97	1529795	1335434		Woods, general agri., dairy
195	NO40308D2	3/12/97	1529475	1335729	46	Dairy, rural residential
196	NO40309G1	4/28/97	1537717	1334027	65	Corn
197	NO40309H1	3/13/97	1538961	1333103	21	Dairy, corn
198	NO40310F1	3/13/97	1540909	1333950	21	Raspberries
199	NO40310K1	3/14/97	1542026	1332604	30	Dairy, raspberries
200	NO40311E1	3/14/97	1544688	1332727	30-36	Raspberries
201	NO40315L1	4/28/97	1541039	1327333		Not recorded
202	NO40316A1	3/14/97	1538917	1329927	27-32	Raspberries
203	NO40316H1	4/28/97	1538682	1328690	58	Strawberries, raspberries
204	NO40316H2	4/28/97	1538348	1327599	28	Residential
205	NO40316Q1	4/28/97	1536854	1325742	50	Residential
206	NO40319A1	4/28/97	1527331	1325214	40	Residential
207	NO40321E1	4/28/97	1533991	1323614	Surface	Residential
208	NO40331L1	3/25/97	1524120	1311570	30	Wooded, dairy
209	NO40331L2	3/24/97	1524822	1311698	19	Dairy
210	NO40331P3	3/26/97	1524440	1309664	30-36	Residential, dairy
211	NO40332H1	3/27/97	1532552	1311986		Pasture, general agriculture
212	NO40332L1	3/24/97	1530138	1311373	50	Pasture, residential, wooded
213	NO40332M1	3/24/97	1528607	1311239	26	Cattle, cemetery
214	NO40332M2	3/21/97	1527878	1310744	20-25	Pasture
215	NO40332P1	3/24/97	1529559	1309566	40	Dairy, cranberries
216	NO40333F1	3/24/97	1535302	1311999	29	Dairy
217	NO40333G1	3/24/97	1535860	1311881	28	Dairy
218	NO40333J1	3/21/97	1537994	1311322	30-33	Raspberries
219	NO40335P1	3/20/97	1545672	1310022		Dairy
220	NO40335R2	3/24/97	1548950	1308794	51	Dairy, orchards, wooded

Table A-1. Well Data, Sumas-Blaine Surficial Aquifer.

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	Depth (feet)	Upgradient Land Use
221	NO40336J1	3/20/97	1553745	1310925	35-51	Residential
222	NO40336J2	3/20/97	1553638	1310901	21-37	Residential
223	NO40405L1	4/29/97	1562069	1337212	38	Dairy
224	NO40405N2	4/29/97	1560365	1335848	85	Pasture
225	NO40406A1	2/18/97	1560102	1339677	70-75	Raspberries
226	NO40406C1	2/18/97	1557053	1340112	66-71	Raspberries, dairy
227	NO40406G1	3/13/97	1558078	1337730	12-20	Dairy, raspberries
228	NO40406H1	2/18/97	1560073	1338244	40	Raspberries
229	NO40417R1	4/15/97	1564884	1324581	40	Pasture, dairy
230	NO40421B1	4/15/97	1568364	1322830	Surface	Tulips, wooded
231	NO40429H2	4/14/97	1564780	1316419	59	Dairy, cemetery
232	NO40434D1	4/14/97	1570403	1313231	30	Wooded
233	NO40434F1	4/15/97	1571598	1311142	51	Wooded
234	NO40434P1	4/14/97	1571563	1308669	57	Wooded
235	NO41331E1	3/21/97	1523568	1344274	25-30	Wooded
236	NO41332J1	3/19/97	1533796	1343155	24	Wooded, berries
237	NO41332Q1	3/12/97	1531474	1342173	25	Raspberries
238	NO41333M1	3/13/97	1534163	1343694	38-43	Pasture
239	NO41334E1	3/13/97	1539465	1343956	12-20	Raspberries, chickens
240	NO41335N1	3/13/97	1544727	1340754	20-28	Raspberries
241	NO41335Q1	3/12/97	1547491	1340832	18-25	Corn, raspberries
242	NO41336J1	3/13/97	1555158	1341937		Not recorded
243	NO41336J2	2/18/97	1554776	1341994	87-92	Orchard
244	NO41336N1	3/13/97	1550055	1340740	22-26	Raspberries
245	NO41336Q1	2/18/97	1553765	1340526	26-34	Berries
246	NO41431H1	3/12/97	1560514	1343068		Raspberries
247	NO41431P1	3/13/97	1556973	1340479		Raspberries, dairy
248	NO41431Q1	2/18/97	1559316	1340410	42-50	Raspberries
249	NO41431R1	2/18/97	1560229	1341124	77	General agriculture, raspberries
250	NO41431R2	2/18/97	1560467	1340455	60-71	General agriculture, raspberries
				Average=	31.5	
				Minimum=	9	
				Maximum=	92	

APPENDIX B

Sampling Procedures

Wells and water lines were purged prior to sampling. Samples were obtained from taps as close to the wellhead as possible. To minimize the effects of storage tanks, samples were obtained, if possible, when the pump was discharging. To do this a "Y " fitting was attached to the tap and samples were obtained from one "Y" outlet while a majority of the flow was discharged to a suitable location through the other "Y" outlet via an attached hose. A short section of polyethylene tubing was attached to the sample "Y" outlet to direct water to sample bottles. Specific conductance, pH, and temperature were measured periodically during purging. Purging continued until these parameters stabilized (change less than 10%) for two consecutive 10-minute periods of purging.

Samples were placed in bottles obtained from Manchester Laboratory. Bottle materials, preservatives and holding times for the target analytes are listed below:

Parameter	Bottle	Preservative	Holding Time
Nitrate+nitrite-N	125 mL, wide mouth polyethylene	Sulfuric acid to pH<2 Cool to 4°C.	28 Days
Chloride	125mL, wide mouth polyethylene	Cool to 4 C.	28 Days

All samples were placed in coolers with ice. Nitrate+nitrite-N samples were preserved with sulfuric acid to a pH of<2. Sulfuric acid was added to sample bottles at the Manchester Environmental Laboratory before bottles were shipped to sampling teams. Coolers were transported by Ecology staff to the Ecology Headquarters Building. The Ecology laboratory courier transported samples to the Ecology/EPA Manchester Environmental Laboratory in Manchester, Washington.

Analytical Procedures

Nitrate+nitrite-N concentrations were determined using EPA Method 353.2 or Standard Methods (18th Edition) 4500 NO3-F (Manchester Environmental Laboratory, 1994). Chloride concentrations were determined using EPA Method 300.0 or Standard Methods (18th Edition) 4110B.

Well Locations

All sampled wells were located on 1:24000 topographic maps. In addition we determined locations of most wells using the Magellan Global Positioning System (GPS) instrumentation. The well locations in this report are digitized from the topographic maps.

APPENDIX C

Quality Assurance

Field

Field quality assurance samples consisted of 29 duplicate samples and two reference samples. Field duplicates consisted of two samples from the same well using identical sampling procedures. After the initial sample was collected the pump was shut off for about ten minutes to allow the aquifer to equilibrate. The second sample was obtained by repeating the purging and sampling procedure. Duplicate samples collected this way can be used to estimate overall sampling and analytical precision.

The duplicate sample results are shown in Table C-1. Relative percent differences of the mean (RPDs) are used to express the precision of duplicate results. RPD is defined as the ratio of the difference and the mean of duplicate sample results expressed as a percentage. In general low RPDs indicate good sampling and analytical precision and high RPDs suggest poor precision. The RPDs for the project are also listed in Table C-1.

The duplicate results indicate that sampling and analytical precision was very good for the study. RPDs averaged 9.5% for nitrate+nitrite-N and 5.5% for chloride. One set of duplicates on 3/37/97 had an RPD for nitrate+nitrite-N of 41% (4.04 and 2.66 mg/L). The RPD for chloride duplicate was also high at 26%. The cause of the variation is unknown but is probably due to sampling error. Another nitrate+nitrite-N duplicate was high at 53% (0.031 and 0.018 mg/L) on 4/15/97 but in this instance the RPD is a poor indicator of precision because the values are close to the detection limit (0.01 mg/L).

Stu Lombard of the Quality Assurance Section at Manchester, Washington provided reference sample material for nitrate+nitrite-N and chloride. A reference sample is a specially prepared sample with a known concentration of constituents and is used to estimate analytical accuracy. The samples were prepared by Joan Vandersypen, laboratory technician at Western Washington University, an accredited laboratory, located in Bellingham, Washington. The reference samples were prepared as per instructions and placed in sample bottles and submitted to Manchester Laboratory as well samples. The results are shown below in Table C-2. RPDs for reference samples for nitrate+nitrite-N were 9.1% and 1.6% and for chloride were 3.7% and 1.3%.

Laboratory

All analytical results are considered acceptable for use. Quality assurance reviews are attached. Routine laboratory quality control procedures were used to estimate laboratory precision and accuracy for this project. Laboratory quality control tests are done on each set of 20 or fewer samples and consist of duplicate blanks, duplicate samples, a spiked sample, and a check (control) standard. Manchester Laboratory's quality control samples and procedures are discussed in Manchester Environmental Laboratory's Standard Operating Procedures for laboratory test procedures (nitrate-nitrite-N and chloride).

Table C-1. Field Quality Assurance Results, Sumas-Blaine Surficial Aquifer Nitrate Characterization.

Site ID	Date	Sample ID	NO3/NO2-N	RPD	Chloride	RPD
NO40112Q1	3/27/97	97139717	4.04		1.62	
NO40112Q1	3/27/97	97139718	2.66	41.2	1.25	25.8
NO40114A1	3/26/97	97139706	7.06		6.93	
NO40114A1	3/26/97	97139707	6.77	4.2	7.23	4.2
NO40123M1	3/25/97	97139654	0.818		4.01	
NO40123M1	3/25/97	97139655	0.968	16.8	3.4	16.5
NO40211P1	4/28/97	97189765	4.72		12.1	
NO40211P1	4/28/97	97189766	4.24	10.7	12.2	0.8
NO40215Q1	3/10/97	97119604	10.7		17.1	
NO40215Q1	3/10/97	97119605	10.9	1.9	17.8	4.0
NO40222D1	3/28/97	97139722	3.06		10.7	
NO40222D1	3/28/97	97139723	3.11	1.6	11.2	4.6
NO40226B1	3/11/97	97119613	5.84		6.48	
NO40226B1	3/11/97	97119614	7.05	18.8	6.92	6.6
NO39211F1	3/11/97	97119669	5.62		4.43	
NO39211F1	3/11/97	97119670	5.4	4.0	4.28	3.4
NO39212K1	3/12/97	97119678	6.88		6.5	
NO39212K2	3/12/97	97119679	5.86	16.0	6.06	7.0
NO39212M1	3/12/97	97119680	0.28		0.732	
NO39212M1	3/12/97	97119681	0.259	7.8	0.78	6.3
NO39215J1	3/13/97	97119686	15.8		11.6	
NO39215J1	3/13/97	97119687	15.8	0.0	12.2	5.0
NO39302P1	3/25/97	97139810	1.3		3.65	
NO39302P1	3/25/97	97139812	1.31	0.8	3.73	2.2
NO39303N2	3/28/97	97139836	2.45		6.2	
NO39303N2	3/28/97	97139837	2.25	8.5	6.47	4.3
NO39308C1	3/26/97	97139825	5.67		2.72	
NO39308C1	3/26/97	97139826	6.42	12.4	2.86	5.0
NO39316B2	3/27/97	97139829	1.32		6.79	
NO39316B2	3/27/97	97139830	1.32	0.0	6.44	5.3
NO39404H2	4/14/97	97169843	2.57		13.2	
NO39404H2	4/14/97	97169844	2.53	1.6	14	5.9
NO39409J1	4/14/97	97169726	0.12		15.3	
NO39409J1	4/14/97	97169727	0.103	15.2	15.1	1.3
NO39420L1	4/15/97	97169739	0.973		7.84	
NO39420L1	4/15/97	97169740	0.982	0.9	7.61	3.0
NO39421K1	4/29/97	97189769	2.13		9.42	
NO39421K1	4/29/97	97189770	2.19	2.8	9.35	0.7
NO39422K1	4/16/97	97169745	7.77		296	
NO39422K1	4/16/97	97169746	8.09	4.0	306	3.3
NO39427C1	4/16/97	97169856	0.097		18	
NO39427C1	4/16/97	97169857	0.087	10.9	17.6	2.2
NO39429A2	4/17/97	97169752	1.61		62.9	
NO39429A2	4/17/97	97169753	1.74	7.8	59.3	5.9
NO40111J1	3/24/97	97139648	5.62		7.75	
NO40111J1	3/24/97	97139649	5.96	5.9	7.48	3.5
NO40228M1	3/21/97	97119624	7.22		4.2	
NO40228M1	3/12/97	97119625	7.08	2.0	4.42	5.1
NO40233A1	3/13/97	97119633	3.11		6.97	
NO40233A1	3/13/97	97119634	3.47	10.9	6.62	5.2
NO40303Q1	3/20/97	97129337	15.1		7.08	
NO40303Q1	3/20/97	97129338	15.4	2.0	7.03	0.7
NO40331P3	3/26/97	97139821	5.61	17.4	7.06	19.3
NO40331P3	3/21/97	97129343	4.71		5.77	
NO40331P3	3/21/97	97129344	4.72	0.2	5.86	1.5
NO40332L1	3/24/97	97139802	11.2		5.38	
NO40332L1	3/24/97	97139803	11.8	5.2	5.45	1.3

Site ID	Date	Sample ID	NO3/NO2-N	RPD	Chloride	RPD
NO40417R1	4/15/97	97169848	0.031		9.14	
NO40417R1	4/15/97	97169850	0.018	53.1	9.51	4.0
			Average=	9.5	Average=	5.5
			Minimum=	0.0	Minimum=	0.7
			Maximum=	53.1	Maximum=	25.8

Table C-2. Reference Sample Results ,Sumas-Blaine Surficial Aquifer Nitrate Characterization

	Date	NO2/NO3-N	Chloride
Sample 9716-9760	4/18/97	2.1	34.8
Manchester Lab		2.3	36.1
RPD		9.1	3.7
Sample 9718-9773	4/29/97	0.95	14.9
Manchester Lab		0.965	15.1
RPD		1.6	1.3

RPD= Relative percent difference of the duplicate mean.

APPENDIX D

Table D-1. Nitrate+Nitrite-N and Chloride Results

Table D-1. Water Quality Results, Sumas-Blaine Surficial Aquifer Nitrate Characterization.

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	NO3+NO2-N		Chloride
001	NO39101A1	3/12/97	1489940	1309670	1.12		17.1
002	NO39201N1	3/10/97	1517780	1304296	4.16		10.0
003	NO39203Q1	3/10/97	1509695	1304532	19.00		15.9
004	NO39204C1	3/11/97	1503812	1309594	2.19		11.0
005	NO39204D1	3/11/97	1502139	1309573	0.64		13.1
006	NO39204M1	3/10/97	1501943	1304954	1.31		3.5
007	NO39204N1	3/10/97	1501773	1305821	0.27		1.5
008	NO39204N2	3/10/97	1501947	1304948	4.07		4.8
009	NO39205D1	3/11/97	1496785	1309757	0.04		8.2
010	NO39206A1	3/10/97	1495977	1309255	0.03		13.2
011	NO39206B1	3/11/97	1494385	1308794	0.01		120.0
012	NO39208C1	3/11/97	1498492	1304045	2.03		5.4
013	NO39210F1	3/11/97	1508941	1302939	7.84		6.9
014	NO39210J1	3/12/97	1510733	1300641	3.63		6.0
015	NO39211B1	3/12/97	1514440	1303937	2.23		11.0
016	NO39211F1	3/11/97	1513875	1302767	5.51		4.4
017	NO39211K1	3/12/97	1514375	1300227	0.01	U	13.1
018	NO39212C1	3/12/97	1519363	1303459	8.08		11.6
019	NO39212C2	3/14/97	1519078	1303023	5.47		3.7
020	NO39212K1	3/12/97	1520290	1300697	6.88		6.5
021	NO39212K2	3/12/97	1519796	1300723	5.86		6.1
022	NO39212M1	3/12/97	1516956	1301180	0.27		0.8
023	NO39213F1	3/13/97	1519247	1297631	1.79		25.0
024	NO39214C1	3/13/97	1514024	1297774	0.01	U	4.2
025	NO39214E1	3/14/97	1511586	1296460	6.32		4.5
026	NO39214L1	3/13/97	1513801	1295295	0.04		13.8
027	NO39214L2	3/13/97	1512946	1296080	9.76		16.3
028	NO39215B1	3/10/97	1509143	1298076	0.92		7.7
029	NO39215J1	3/13/97	1510263	1296171	15.80		11.9
030	NO39215L1	3/10/97	1508550	1295217	19.50		9.2
031	NO39221H1	3/13/97	1505531	1292181	5.37		9.2
032	NO39222K1	3/13/97	1509206	1290485	0.01		19.5
033	NO39223B1	3/12/97	1514617	1293012	0.07		24.5
034	NO39227C1	3/13/97	1507839	1288341	15.10		15.8
035	NO39301C1	3/25/97	1550638	1308472	0.48		49.2
036	NO39301E1	3/25/97	1549046	1307026	10.90		40.7
037	NO39301R1	3/25/97	1552906	1303379	1.15		31.8
038	NO39301R2	4/29/97	1553411	1303284	2.20		38.1
039	NO39302A1	3/20/97	1548533	1307843	1.19		36.1
040	NO39302B1	3/27/97	1546830	1308647	2.05		30.7
041	NO39302M1	3/25/97	1543925	1305268	2.46		6.5
042	NO39302P1	3/25/97	1545257	1303727	1.31		3.7
043	NO39302P2	3/25/97	1545094	1304275	0.88		3.7
044	NO39303N1	3/27/97	1539187	1304170	8.55		2.9
045	NO39303N2	3/28/97	1538934	1304640	2.35		6.3
046	NO39303R1	3/25/97	1543287	1304344	3.08		5.4
047	NO39303R2	3/25/97	1542638	1303669	0.01	U	5.8
048	NO39304N1	3/25/97	1533296	1304846	2.20		3.0
049	NO39305Q1	3/25/97	1530245	1304094	3.92		4.1
050	NO39307H1	3/21/97	1526850	1301685	53.00		27.4
051	NO39307K2	3/25/97	1525187	1301212	18.60		15.7
052	NO39307N1	3/28/97	1523220	1298923	0.01	U	28.5
053	NO39308C1	3/26/97	1529200	1303598	6.05		2.8
054	NO39308F2	3/26/97	1530007	1301359	21.80		4.1
055	NO39309C1	3/26/97	1535140	1303510	5.00		3.4
056	NO39309Q2	3/26/97	1536288	1298738	0.46		3.4

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	NO3+NO2-N		Chloride
057	NO39310M1	3/27/97	1538321	1299916	2.02		1.7
058	NO39310M2	3/27/97	1539125	1299820	0.72		3.6
059	NO39316A1	3/26/97	1536879	1298152	2.64		4.4
060	NO39316A2	3/26/97	1536942	1297994	0.01	U	15.2
061	NO39316B2	3/27/97	1536294	1298287	1.32		6.6
062	NO39316C1	3/20/97	1534043	1298401	4.74		3.0
063	NO39316F1	3/21/97	1534064	1295939	0.48		4.4
064	NO39317F1	3/28/97	1529657	1296094	6.82		11.1
065	NO39317H1	3/28/97	1531787	1295980	6.32		7.6
066	NO39317N1	3/12/97	1527316	1293489	6.40		4.6
067	NO39321D2	3/12/97	1533712	1293005	0.01	U	18.3
068	NO39404F1	4/15/97	1566432	1306677	3.25		10.9
069	NO39404H1	4/14/97	1569508	1305402	1.78		12.6
070	NO39404H2	4/14/97	1569429	1306184	2.55		13.6
071	NO39404M1	4/15/97	1565873	1304846	3.14		8.2
072	NO39404N1	4/15/97	1565289	1303113	5.72		12.9
073	NO39406E1	4/14/97	1554565	1306789	4.48		10.9
074	NO39407D1	4/14/97	1554949	1302731	3.41		7.2
075	NO39408C1	4/14/97	1561683	1302735	3.61		14.2
076	NO39408E1	4/14/97	1560416	1300378	3.48		5.6
077	NO39408R1	4/15/97	1564430	1297795	14.30		14.0
078	NO39409J1	4/14/97	1569621	1299543	0.11		15.2
079	NO39409J2	4/14/97	1569628	1299144	0.01	U	11.4
080	NO39409N1	4/15/97	1564605	1298275	1.66		8.5
081	NO39409R1	4/14/97	1568726	1297420	0.79		9.0
082	NO39416F1	4/14/97	1566180	1295082	3.64		4.6
083	NO39416Q2	4/17/97	1568127	1293241	6.80		8.9
084	NO39417C1	4/14/97	1561695	1296295	0.38		3.5
085	NO39417J1	4/17/97	1564126	1293896	1.52		2.7
086	NO39419A1	4/15/97	1558725	1291972	0.01	U	43.0
087	NO39420E1	4/15/97	1559193	1290949	2.74		44.4
088	NO39420F1	4/15/97	1561043	1289993	1.91		12.0
089	NO39420H1	4/15/97	1563630	1289733	0.96		4.0
090	NO39420L1	4/15/97	1560985	1288896	0.98		7.7
091	NO39420L2	4/15/97	1560940	1289287	0.92		8.1
092	NO39420M1	4/17/97	1559388	1288330	0.01	U	12.1
093	NO39420N1	4/17/97	1558963	1286893	3.97		6.7
094	NO39421K1	4/29/97	1567721	1289453	2.16		9.4
095	NO39422K1	4/16/97	1572374	1289112	7.93		301.0
096	NO39422L1	4/16/97	1570815	1289274	17.50		60.2
097	NO39422M1	4/16/97	1570549	1289126	0.41		55.5
098	NO39422M2	4/16/97	1569938	1288141	0.91		10.7
099	NO39422N1	4/16/97	1569955	1287900	3.88		16.6
100	NO39422P1	4/16/97	1570999	1287332	3.20		20.0
101	NO39426L1	4/16/97	1576804	1283107	0.02		11.3
102	NO39427C1	4/16/97	1571802	1285632	0.09		17.8
103	NO39427D2	4/16/97	1569292	1285200	0.43		2.5
104	NO39429A1	4/17/97	1562626	1286032	0.06		2.3
105	NO39429A2	4/17/97	1563551	1286518	1.68		61.1
106	NO39429A3	4/17/97	1563859	1285401	0.05		7.8
107	NO39436D1	4/16/97	1580325	1280319	0.23		2.8
108	NO40108A1	3/27/97	1470290	1336741	0.01	U	1.6
109	NO40108R1	3/26/97	1470437	1333011	4.06		13.8
110	NO40110D1	3/26/97	1477147	1336853	0.33		3.6
111	NO40110E1	3/27/97	1475940	1334578	4.60		2.4
112	NO40110F1	3/24/97	1478345	1334875	1.35		5.3
113	NO40111J1	3/24/97	1485568	1333795	5.79		7.6

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	NO3+NO2-N		Chloride
114	NO40112J1	3/24/97	1490628	1333643	2.44		8.7
115	NO40112Q1	3/27/97	1489090	1332350	3.35		1.4
116	NO40113A1	3/14/97	1491059	1330041	0.19		2.3
117	NO40113Q1	3/28/97	1488942	1326443	1.53		2.6
118	NO40114A1	3/26/97	1485749	1331212	6.92		7.1
119	NO40114P1	3/24/97	1483542	1326652	1.10		2.3
120	NO40115A1	3/25/97	1479804	1331384	1.99		7.1
121	NO40115B2	3/25/97	1478840	1331387	1.45		2.3
122	NO40115E1	3/24/97	1476448	1330428	0.11		58.4
123	NO40115N1	3/24/97	1476693	1326883	0.08		11.6
124	NO40116A1	3/25/97	1474539	1331164	0.06		5.3
125	NO40116A2	3/27/97	1474873	1331121	0.03		59.9
126	NO40122A1	3/24/97	1480379	1325653	0.13		9.3
127	NO40123D1	3/24/97	1481241	1325780	2.40		7.6
128	NO40123M1	3/25/97	1481094	1323706	0.89		3.7
129	NO40123Q1	3/26/97	1483606	1321722	0.04		14.1
130	NO40124D1	3/25/97	1487070	1325697	2.60		6.9
131	NO40124M1	3/25/97	1487168	1323373	2.81		13.1
132	NO40124P1	3/25/97	1488514	1321444	1.68		6.4
133	NO40124Q1	3/25/97	1489892	1321633	10.90		6.5
134	NO40124Q2	3/26/97	1489890	1321940	5.49		10.6
135	NO40125B1	3/26/97	1488752	1319872	4.40		17.3
136	NO40126A1	3/26/97	1485571	1320733	0.54		9.0
137	NO40126Q1	3/25/97	1483492	1316550	3.92		7.2
138	NO40127A1	3/24/97	1480209	1319944	3.87		10.6
139	NO40135G1	3/27/97	1484253	1313747	4.40		8.8
140	NO40135K1	3/26/97	1484160	1312266	11.10		17.8
141	NO40136H1	3/27/97	1490720	1313035	0.28		2.6
142	NO40210N2	3/10/97	1508154	1331911	0.01	U	47.8
143	NO40210Q1	3/28/97	1509802	1331239	0.48		7.3
144	NO40211N1	4/28/97	1512384	1331765	0.24		14.1
145	NO40211P1	4/28/97	1514356	1331834	4.48		12.2
146	NO40211R1	4/28/97	1517071	1331180	23.50		19.0
147	NO40214P1	3/10/97	1514449	1326156	28.60		22.5
148	NO40215F1	3/12/97	1509022	1329622	0.09		10.5
149	NO40215Q1	3/10/97	1509466	1325882	10.80		17.5
150	NO40215R2	3/10/97	1511979	1326993	6.47		4.2
151	NO40217D1	3/14/97	1496495	1330646	0.03		9.0
152	NO40219D1	3/14/97	1491797	1325961	1.19		3.8
153	NO40219J1	3/14/97	1495873	1322946	1.34		2.8
154	NO40219L1	3/12/97	1493687	1323226	3.29		5.4
155	NO40219M1	3/12/97	1492229	1323159	4.33		5.2
156	NO40221G1	3/12/97	1504357	1323795	17.80		17.7
157	NO40221J5	3/10/97	1505644	1323128	16.60		9.6
158	NO40221R6	3/10/97	1506621	1321618	9.23		7.2
159	NO40222D1	3/28/97	1507832	1325661	3.09		11.0
160	NO40222N7	3/11/97	1507719	1320565	7.62		4.7
161	NO40223A3	3/11/97	1516133	1324386	6.65		2.7
162	NO40223B2	3/10/97	1514986	1325482	13.00		7.5
163	NO40223D4	3/10/97	1513362	1325509	11.60		5.2
164	NO40223P4	3/11/97	1514674	1320513	14.80		10.0
165	NO40225B1	3/11/97	1521143	1320076	3.11		4.3
166	NO40226A4	3/11/97	1516230	1318642	17.10		10.3
167	NO40226B1	3/11/97	1515304	1319692	6.45		6.7
168	NO40226C1	3/11/97	1514653	1319616	3.03		9.3
169	NO40226D2	3/11/97	1513207	1319296	3.23		4.0
170	NO40227C1	3/11/97	1509123	1320311	8.78		9.3

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	NO3+NO2-N		Chloride
171	NO40228D5	3/12/97	1501701	1319906	5.90		43.0
172	NO40228M1	3/12/97	1502302	1317059	7.15		4.3
173	NO40229C1	3/13/97	1498494	1319680	9.42		11.8
174	NO40230G1	3/13/97	1493456	1319485	1.52		114.0
175	NO40231B1	3/27/97	1493668	1315242	1.39		3.8
176	NO40231F1	3/21/97	1493120	1312929	5.51		5.2
177	NO40231N1	3/11/97	1491542	1310307	0.05		2.4
178	NO40232C1	3/13/97	1497096	1314552	0.04		6.4
179	NO40232E1	3/13/97	1497440	1313608	1.67		8.8
180	NO40232N1	3/13/97	1496355	1310909	0.45		3.7
181	NO40233A1	3/13/97	1505256	1314943	3.29		6.8
182	NO40301P1	3/20/97	1551679	1335082	9.18		22.4
183	NO40302B1	3/14/97	1548547	1340337	13.40		6.8
184	NO40302F1	3/14/97	1547309	1338286	13.50		6.8
185	NO40303B1	3/13/97	1542223	1340297	11.60		10.9
186	NO40303E1	3/21/97	1540539	1338171	14.10		5.8
187	NO40303Q1	3/20/97	1542167	1335915	15.25		7.1
188	NO40303R2	4/28/97	1544325	1335518	13.50		9.8
189	NO40303R3	4/28/97	1544105	1335548	17.20		10.5
190	NO40305N1	3/12/97	1529764	1336007	6.00		11.3
191	NO40305N2	2/18/97	1529565	1336054	2.93		11.7
192	NO40305N3	3/19/97	1529381	1336084	1.61		14.3
193	NO40307H1	3/19/97	1528113	1333932	13.10		5.6
194	NO40308D1	3/12/97	1529795	1335434	11.40		9.5
195	NO40308D2	3/12/97	1529475	1335729	0.04		36.4
196	NO40309G1	4/28/97	1537717	1334027	0.01	U	14.5
197	NO40309H1	3/13/97	1538961	1333103	19.50		3.3
198	NO40310F1	3/13/97	1540909	1333950	12.40		9.3
199	NO40310K1	3/14/97	1542026	1332604	14.20		13.2
200	NO40311E1	3/14/97	1544688	1332727	11.20		9.3
201	NO40315L1	4/28/97	1541039	1327333	24.40		11.0
202	NO40316A1	3/14/97	1538917	1329927	16.60		8.0
203	NO40316H1	4/28/97	1538682	1328690	15.00		11.1
204	NO40316H2	4/28/97	1538348	1327599	8.77		7.5
205	NO40316Q1	4/28/97	1536854	1325742	0.01	U	6.0
206	NO40319A1	4/28/97	1527331	1325214	0.04		14.6
207	NO40321E1	4/28/97	1533991	1323614	1.69		5.8
208	NO40331L1	3/25/97	1524120	1311570	3.36		5.0
209	NO40331L2	3/24/97	1524822	1311698	10.50		9.4
210	NO40331P3	3/26/97	1524440	1309664	5.01		6.2
211	NO40332H1	3/27/97	1532552	1311986	3.48		6.5
212	NO40332L1	3/24/97	1530138	1311373	11.50		5.4
213	NO40332M1	3/24/97	1528607	1311239	12.50		6.7
214	NO40332M2	3/21/97	1527878	1310744	32.30		39.8
215	NO40332P1	3/24/97	1529559	1309566	3.86		3.4
216	NO40333F1	3/24/97	1535302	1311999	8.89		29.6
217	NO40333G1	3/24/97	1535860	1311881	0.92		5.1
218	NO40333J1	3/21/97	1537994	1311322	0.01		15.1
219	NO40335P1	3/20/97	1545672	1310022	5.90		20.4
220	NO40335R2	3/24/97	1548950	1308794	0.01	U	60.0
221	NO40336J1	3/20/97	1553745	1310925	2.75		17.0
222	NO40336J2	3/20/97	1553638	1310901	1.98		23.1
223	NO40405L1	4/29/97	1562069	1337212	16.70		13.9
224	NO40405N2	4/29/97	1560365	1335848	3.07		6.9
225	NO40406A1	2/18/97	1560102	1339677	0.05		6.2
226	NO40406C1	2/18/97	1557053	1340112	42.00		26.2
227	NO40406G1	3/13/97	1558078	1337730	33.40		18.6

Report ID	Site ID	Date Sampled	State Plane X	State Plane Y	NO3+NO2-N	Chloride
228	NO40406H1	2/18/97	1560073	1338244	11.60	7.9
229	NO40417R1	4/15/97	1564884	1324581	0.02	9.3
230	NO40421B1	4/15/97	1568364	1322830	2.43	4.2
231	NO40429H2	4/14/97	1564780	1316419	0.03	11.0
232	NO40434D1	4/14/97	1570403	1313231	2.24	4.0
233	NO40434F1	4/15/97	1571598	1311142	1.97	6.3
234	NO40434P1	4/14/97	1571563	1308669	1.21	7.1
235	NO41331E1	3/21/97	1523568	1344274	2.27	16.2
236	NO41332J1	3/19/97	1533796	1343155	3.39	2.1
237	NO41332Q1	3/12/97	1531474	1342173	21.60	5.6
238	NO41333M1	3/13/97	1534163	1343694	5.97	10.9
239	NO41334E1	3/13/97	1539465	1343956	14.30	7.7
240	NO41335N1	3/13/97	1544727	1340754	13.60	6.8
241	NO41335Q1	3/12/97	1547491	1340832	23.00	9.5
242	NO41336J1	3/13/97	1555158	1341937	5.03	1.9
243	NO41336J2	2/18/97	1554776	1341994	0.04	6.4
244	NO41336N1	3/13/97	1550055	1340740	17.20	12.3
245	NO41336Q1	2/18/97	1553765	1340526	14.80	5.0
246	NO41431H1	3/12/97	1560514	1343068	9.06	11.5
247	NO41431P1	3/13/97	1556973	1340479	21.30	18.2
248	NO41431Q1	2/18/97	1559316	1340410	10.80	2.7
249	NO41431R1	2/18/97	1560229	1341124	5.58	3.3
250	NO41431R2	2/18/97	1560467	1340455	2.28	1.4
				Minimum=	0.01 U	0.8
				Maximum=	53.00	301.0
				Arith Mean=	5.82	13.7
				Median=	3.13	8.3
				Geom. Mean=	1.70	8.68

U= Analyte not detected above listed value.