A Department of Ecology Report

Northcentral Sumas - Blaine Surficial Aquifer Nitrate Characterization Project - June 1999

Abstract

Studies over the last 10 years have documented extensive nitrate contamination of the Northcentral Sumas-Blaine Surficial Aquifer in Whatcom County largely from agricultural sources. The aquifer is a candidate for long-term monitoring. However, spatial and temporal variability of nitrate concentrations in shallow groundwater in an agricultural setting poses a challenge to identify long-term trends. This study investigates two alternative methods, volunteer well owner sampling and commercial field test kits, that may help to reduce the cost of a large-scale monitoring program. Fifty-three water-supply wells in the Northcentral Sumas-Blaine Surficial Aquifer were sampled and tested for nitrate+nitrite-N in June 1999. Volunteer well owners sampled 29 wells and mailed samples to Ecology for analysis at Manchester Environmental Laboratory. At the same time, an Ecology sampling team sampled 38 wells including 14 of the wells sampled by volunteer well owners. The 38 Ecology samples were tested for nitrate+nitrite-N at Manchester Environmental Laboratory and for nitrate-N by the sampling team using a commercial field test kit. Results show that nitrate+nitrite-N concentrations remain elevated in large portions of the aquifer. Concentrations ranged from 0.012 to 22.1 mg/L with a mean of 9.95 mg/L and median of 10.3 mg/L. Over 50 percent of the wells sampled showed nitrate+nitrite-N concentrations in excess of 10 mg/L, the nitrate drinking water standard for public water-supply systems. Nitrate+nitrite-N concentrations from this study are similar to results from previous studies of the Northcentral Sumas-Blaine Surficial Aquifer in 1990, 1991, and 1997. Volunteer results compared favorably with Ecology co-samples showing a linear correlation coefficient of 0.9774. To reduce monitoring costs, volunteer well owner results can be included in a monitoring program provided the samplers are adequately trained. Test kits may be useful for monitoring; they provide immediate results at a lower cost but they introduce additional variability.

Background

The Sumas-Blaine Surficial Aquifer in northern Whatcom County is a candidate for long term nitrate monitoring. It is the principal surficial aquifer in the Nooksack River Watershed (Tooley and Erickson, 1996), and, from a water quality perspective, is one of the most severely affected aquifers in Washington State. The aquifer occupies an area of about 150 square miles, is a major source of drinking water, and, because it is unconfined (a water-table aquifer), is susceptible to contamination from surface activities.

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The Sumas-Blaine Surficial Aquifer consists mostly of sand and gravel deposits of glacial origin as well as mixed gravel, sand, silt and clay alluvial deposits of the Nooksack and Sumas rivers. The aquifer ranges in thickness from less than 25 feet near Blaine to greater than 75 feet thick near Sumas. The depth to water is typically less than 10 feet. The aquifer readily interacts with rivers, streams, lakes, and ditches in the watershed. Regionally, groundwater flow is toward the major drainages (Nooksack River) which in the study area is toward the south.

Agriculture is the dominant land use over much of the aquifer. Major crops include grass, corn, raspberries, strawberries, and seed potatoes, and the density of dairies is among the highest in the state (Ecology, 1996). Previous studies have reported elevated nitrate concentrations in extensive areas of the aquifer and discontinuous occurrences of pesticides (Cox and Kahle, 1999; Garland and Erickson, 1994; Erickson and Norton, 1990; and Erickson, 1998). In the hydraulically connected and upgradient Abbotsford Aquifer in British Columbia to the north, agriculture (poultry industry) also has been identified as a major source of nitrate contamination (Liebscher et al., 1992; Wassenaar, 1995; and Zebarth et al., 1998). The study area for this project is the Northcentral portion of the Sumas-Blaine Surficial Aquifer as shown in Figure 1. This area is selected because it is characterized by elevated nitrate concentrations.

Determining nitrate trends in shallow groundwater, in an agricultural setting such as the Sumas-Blaine Surficial Aquifer, poses a particular challenge. Nitrate concentrations in this setting show considerable spatial and temporal variability, which may or may not be seasonal. To define the variability adequately for trend analysis, a large number of samples must be collected and tested over time. Sample collection, in terms of labor alone, represents a major expense. A possible cost-effective solution is to have volunteer well owners sample their wells. If the data collected were reliable, volunteer monitoring could become a major component of groundwater monitoring for the Sumas-Blaine Surficial Aquifer. This method could also be applied to other aquifers in Washington State.

Another major expense is the cost of laboratory analyses. A possible cost-saving alternative is to supplement laboratory test results with results obtained using commercial field test kits. Test kits have two advantages: the analyses are cheaper (not including the initial costs for the meter), and the results are available immediately. The disadvantage of the test kits is that precision and bias of results may not be comparable to laboratory results.

Purpose

The purpose of this project is threefold:

- To provide nitrate data that can be combined with past and future data to define nitrate trends for the Northcentral portion of the Sumas-Blaine Surficial Aquifer,

- To evaluate the effectiveness of having volunteer well owners sample their own wells for nitrate, and

- To evaluate the efficacy of using a commercial test kit to determine nitrate concentrations.

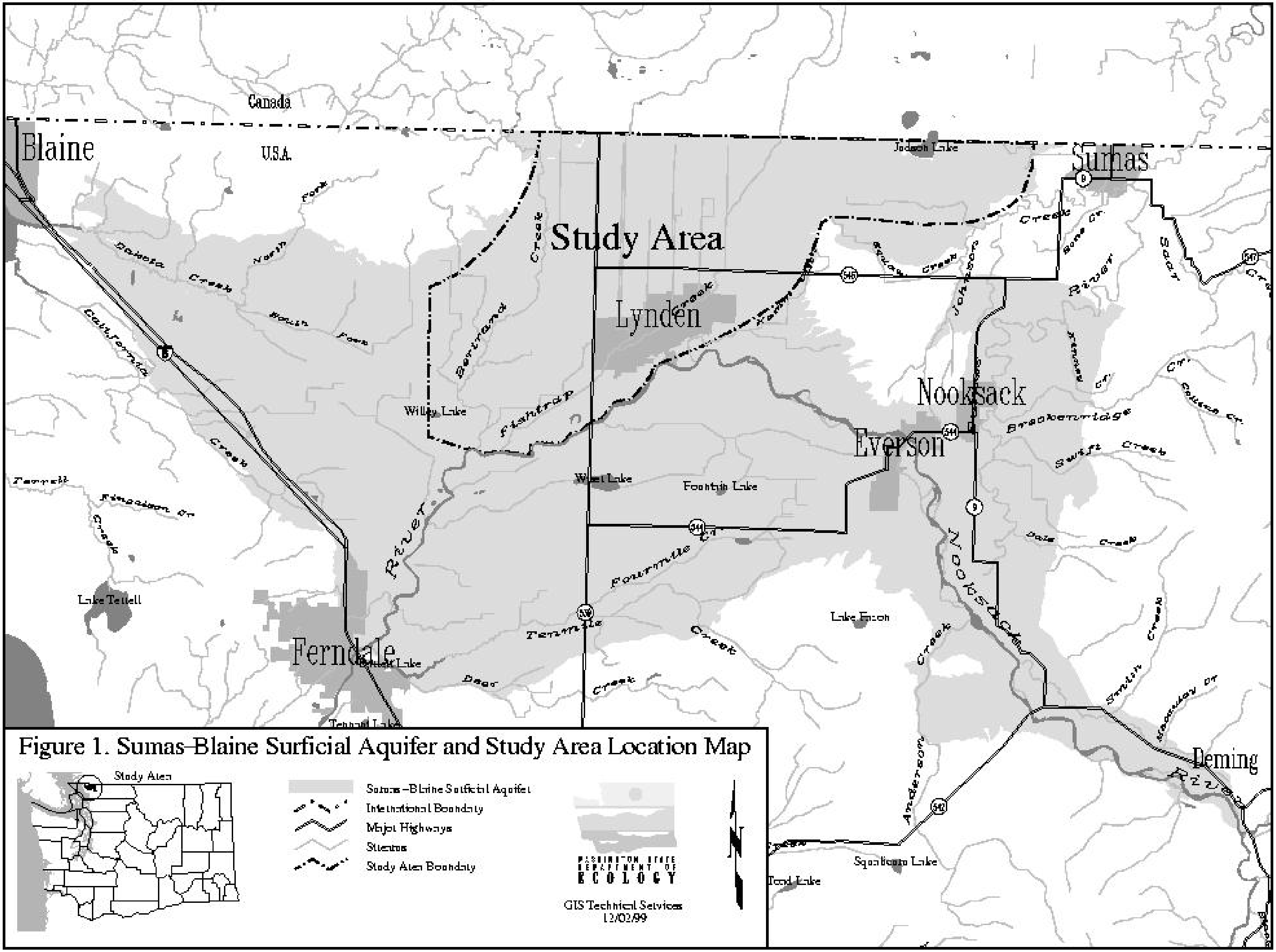

Figure 1. Sumas-Blaine Surficial Aquifer and Study Area Location Map

Methods

Sample Collection

A total of 53 water-supply wells known to draw water from the Sumas-Blaine Surficial Aquifer were sampled and tested for nitrate+nitrite-N. Nearly all of the samples were obtained between June 1 and June 9, 1999. Volunteer well owners sampled 29 wells and mailed samples to Ecology for analysis at Manchester Environmental Laboratory. At the same time, an Ecology sampling team sampled 38 wells including 14 of the wells sampled by volunteer well owners. The 38 Ecology samples were tested for nitrate+nitrite-N at Manchester Environmental Laboratory and for nitrate-N by the sampling team using a commercial field test kit.

Well Selection

Most of the 53 wells in the network had been sampled previously by Ecology. Forty-eight of the wells were sampled by Ecology in 1997 as part of the nitrate characterization of the Sumas-Blaine Surficial Aquifer.

Criteria for well selection are listed as follows:

- The well draws water only from the Sumas-Blaine Surficial Aquifer.
- The well owner allows access to the well or is willing to sample the well.
- The water is untreated prior to the sampling point.
- A well log is available or the well depth is known.
- The well is completed in the upper portion of the aquifer (preferred).
- An historic record of nitrate concentrations is available (preferred).

Well Owner Contacts

Initially, a letter that discussed the nitrate-in-groundwater issue and requested their assistance was sent to each candidate well owner. A follow-up phone call was made about two weeks after the letter was sent. Greater than 90% of the well owners contacted agreed to participate in the project either as volunteer samplers or allowing Ecology to sample their well. About 7 to 10 days before sampling was to occur, the following materials were sent to each volunteer sampler: Sampling Instruction Sheet for Well Owners, Sampling Checklist, sample bottle (with preservative), and sampling adapter.

Sampling Methods

Sampling methods are described in detail in Appendix A. Samples were obtained from outside taps as close to the wellhead as possible. Wells were purged a minimum of 15 minutes prior to obtaining the sample. To minimize the potential effects of water storage tanks, samples were collected using a “Y” adapter at the tap. The “Y” adapter allowed the sample to be collected while the well was discharging at a high rate thus bypassing the storage tank.

Test Methods

Manchester Environmental Laboratory (MEL) performed all laboratory analyses for this project. Laboratory nitrate+nitrite-N (NO3+NO2-N) concentrations were determined using Standard Method 4500 NO3-F (Manchester Environmental Laboratory, 1994; APHA, 1992).

Nitrate (NO3-N) concentrations were determined by the Ecology investigator in the field using a CHEMetrics V-1000 Photometer with a Nitrate 3 Analyte Module. With this field test kit a pre-prepared solution in a vacuum-sealed ampoule is mixed with the sample water and the colorimetric effects, which are proportional to analyte concentration, are measured with the photometer. Dilutions with de-ionized water were prepared using standard volumetric glassware when sample concentrations exceeded the testing range of the kit (0-15 mg/L). Samples were collected in 120 milliliter glass bottles with no preservative and tested the same day the sample was collected.

The laboratory method determined the sum of the nitrate and nitrite concentrations as nitrogen whereas the test kit determine the concentration of only nitrate as nitrogen. Because nitrite is unstable in groundwater and is readily oxidized to nitrate, it is assumed that both the laboratory and test kit results are a measure of nitrate concentration.

Quality Assurance

Quality assurance results for laboratory testing are described in detail in Appendix B. The quality of data reported for this project is judged to be acceptable for use without qualification with the exception of results from two sites (NO40211R1 and NO40211P1). These two results are qualified as estimates (J) because analyses occurred after the holding time of 28 days.

Laboratory precision averaged 0.5% and spike recoveries averaged 96%. The overall sampling and analytical precision using field duplicate results is estimated to range from 1 to 14% with a mean of 6%.

Data Management

All laboratory data generated by MEL was managed using the Laboratory Information Management System (LIMS) and reported in electronic format (ASCII) files to the project lead. Project data was entered and managed using an ACCESS project database. Results for each individual well were sent to well owners in July 1999.

Results

Nitrate+Nitrite-N Concentrations

Nitrate+nitrite-N results for all well sites for this study are shown on Table C-1, Appendix C. The spatial distribution of results are shown in Figure 2. Concentrations ranged from 0.012 to 22.1 mg/L with an arithmetic mean of 9.95 mg/L and median of 10.3 mg/L. Twenty seven of the

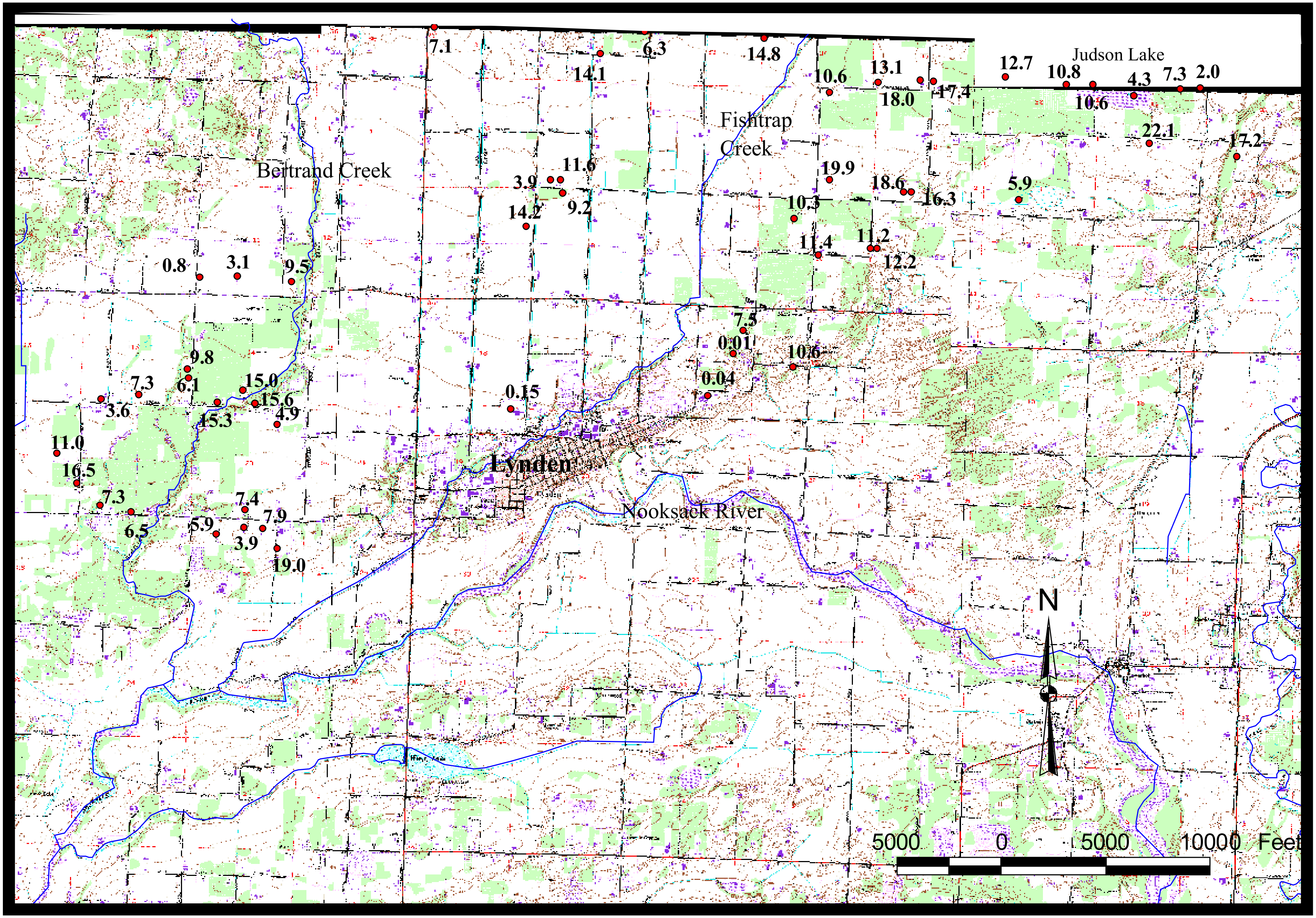

Figure 2. Northcentral Sumas-Blaine Surficial Aquifer Nitrate Concentrations, June 1999.

53 wells sampled showed concentrations that exceeded 10 mg/L, the drinking water standard for public systems (Washington State Department of Health, 1994). Spatial data gaps in the distribution of wells are apparent in Figure 2, particularly in the area north of Lynden and east of Bertrand Creek. No drinking water wells were available for sampling in this area and irrigation wells that are known to exist were not operating at the time of sampling.

Four synoptic broad-scale sampling events for nitrate+nitrite-N had been conducted previously for wells in the Northcentral Sumas-Blaine Surficial Aquifer. Cox and Kahle (1999) sampled and tested 61, 33, and 37 wells in the study area in summer 1990, spring 1991, and summer 1991, respectively. In spring 1997, Erickson (1998) sampled 75 wells in the study area for nitrate+nitrite-N. Summary statistics for nitrate-nitrite-N results for these studies and the current study are listed in Table 1 and plotted in Figure 3.

Table 1. Summary Statistics for Nitrate+Nitrite-N Results for the Northcentral Sumas-Blaine Surficial Aquifer 1990-1999.

Sampling Period	**May-Aug[1] 1990**	**Apr-May[1] 1991**	**July-Sept[1] 1991**	**Feb-Apr[2] 1997**	**June 1999**
N	61	33	37	75	53
Minimum	<0.05	<0.05	<0.05	<0.01	0.012
Maximum	23	43	22	42	22.1
Median	6.7	8.6	6.7	9.2	10.3
Mean	7.1	9.4	6.8	10.4	10.0
Std Deviation	6.1	8.6	6.0	8.4	5.6
Geometric Mean	3.0	4.7	2.4	4.6	6.6

< = less than

Sources:

[1]Cox and Kahle, 1999

[2]Erickson, D., 1998

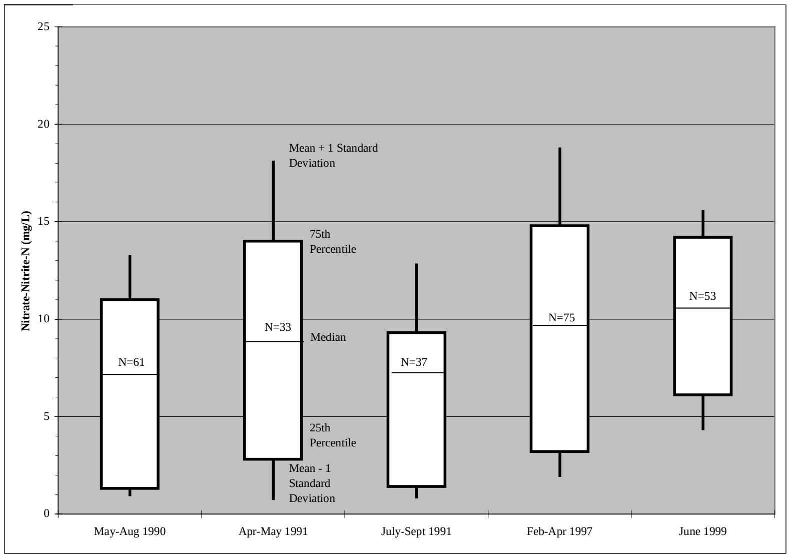

Figure 3. Summary of Nitrate+Nitrite-N Results, Northcentral Sumas-Blaine Surficial Aquifer, 1990-1999.

These studies were designed to provide an estimate of the spatial distribution of nitrate+nitrite-N concentrations and were not specifically designed to define nitrate-nitrite-N trends. Wells were not selected randomly and only about 10 of the same wells were sampled in each of the studies. Wells selected for the June 1999 study were biased to wells with elevated nitrate+nitrite-N concentrations as evidenced by the high concentration of the 25th percentile. In addition, the studies were conducted at varying times of the year in an area where seasonal variations are expected to be substantial (Cox and Kahle, 1999). Nevertheless, the results do provide a qualitative basis for comparing nitrate+nitrite-N concentrations over time. The data verify that nitrate+nitrite-N concentrations continue to remain elevated in substantial portions of the Sumas-Blaine Surficial Aquifer.

Volunteer Results

The results for the 14 sites co-sampled by volunteers and Ecology are listed in Table C-2. Of the 14 sample sets, 11 were collected the same day, two were collected a day apart and one set was obtained 14 days apart. The results are plotted in Figure 4. The best-fit regression line has a correlation coefficient (R^2) of 0.9774. The mean and standard deviation of the Ecology samples are 10.2 and 4.22 mg/L, respectively, and the mean and standard deviation of volunteer results are 10.3 and 4.33 mg/L. The RPD for Ecology and volunteer sample pairs ranges from 0.1 to 24% with a mean of 5.2% (N=14) which is close to the estimated overall sampling and analytical precision of 6% for the project. An RPD is the relative percent difference and is defined as the ratio of the difference and the mean of a sample pair expressed as a percentage. Low RPDs represent good precision and high RPDs represent poor precision.

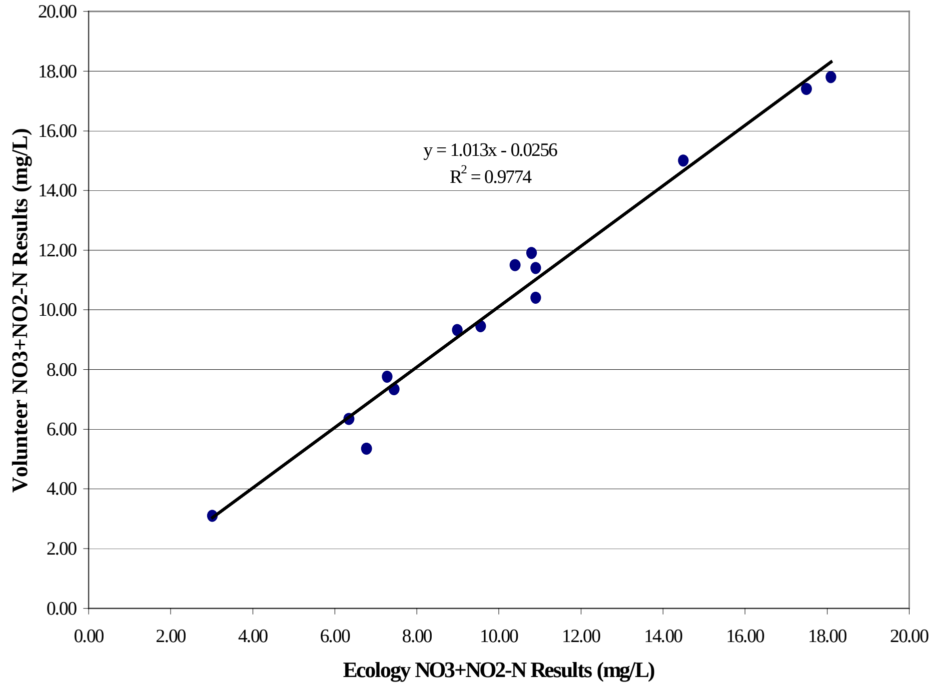

Figure 4. Ecology and Volunteer Results at Co-Sampled Sites.

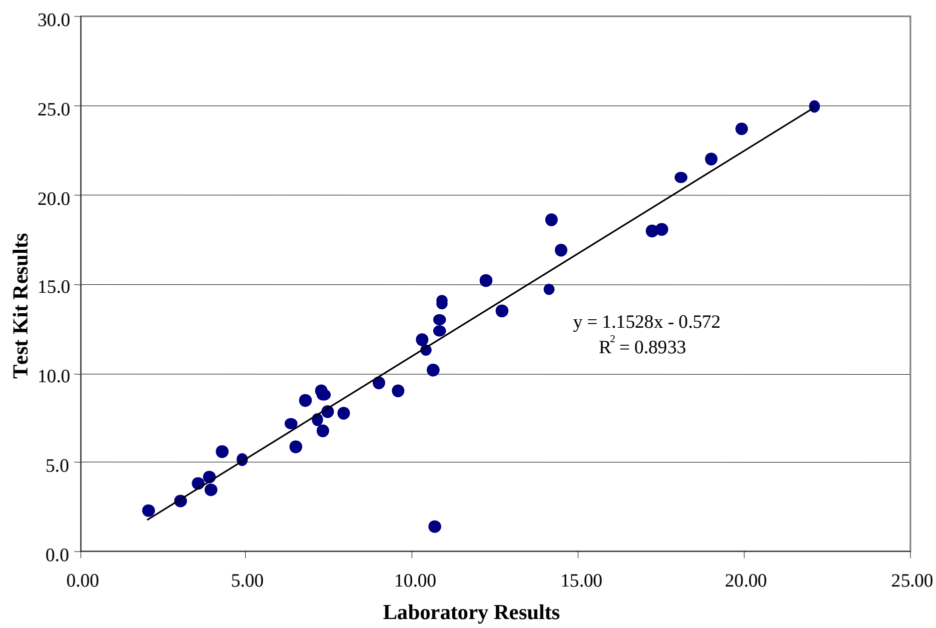

Figure 5. Laboratory and Test Kit Results.

Overall, the volunteer sampling program was easy to implement. Most of the well owners that were contacted had agreed to allow their well to be sampled previously, and most were interested and concerned about the quality of their well water. A number of well owners were more enthusiastic about sampling their well rather than having Ecology sample the well. Of the 29 well owners who agreed to sample, two did not submit samples. One well owner became too busy at the time of sampling and the other was the subject of an Ecology enforcement action.

Ecology sample handling and volunteer sample handling differed in one potentially significant aspect. Ecology samples were iced continuously after they were collected and volunteer samples were sent through the mail un-iced. Based on the close agreement of Ecology and volunteer results, degradation of nitrate+nitrite-N samples due to un-iced samples appears to have been insignificant.

Field Test Kit Results

Thirty-eight samples collected by Ecology were tested for nitrate+nitrite-N at Manchester Environmental Laboratory and were tested by the sampling investigator for nitrate-N with a commercial field test kit. The field test kit results were measured the evening of the same day that the samples were collected. The paired laboratory and test kit results are listed in Table C-3, Appendix C. Summary statistics are listed below in Table 2.

Table 2. Comparison of Laboratory and Test Kit Results.

	Laboratory	Test Kit
N	38	38
Minimum	2.1	1.4
Maximum	22.1	25.0
Median	9.93	9.25
Mean	10.1	11.0
Standard Deviation	5.0	6.2

RPDs of sample pairs range from 2 to 27% with a mean of 12% (excluding the outlier discussed below). The test kit and laboratory results are plotted in Figure 5. The correlation coefficient (R^2) of the best-fit linear regression line is 0.8933. Overall, test kit results tend to be slightly higher than laboratory results and they are less precise (show more variability).

The test kit result from one site (NO40403B1) disagrees substantially from the laboratory result. The test kit indicated a concentration of 1.4 mg/L and the laboratory reported a concentration of 10.6 mg/L. The disagreement is likely the result of human error during the dilution of the sample for the test kit analysis.

Test kit results, excluding the cost of the photometer, are cheaper than laboratory tests. The average cost to conduct a field nitrate test including ampoules, labor (assuming 3 tests/hour at $20/hour), and two quality control samples per batch of 10 samples, is about $7.75. The cost to conduct a nitrate+nitrite-N test at Manchester Environmental Laboratory is $12. The initial cost of the photometer, nitrate module, and ampoules for 20 tests was $610. The cost of replacement ampoules is $1.10 each.

Conclusions

1. Nitrate+nitrite-N concentrations in the Northcentral portion of the Sumas-Blaine Surficial Aquifer remain elevated with concentrations ranging from 0.012 to 22.1 mg/L, an arithmetic mean of 9.95 mg/L and median of 10.3 mg/L. Twenty seven of 53 wells sampled showed concentrations that exceeded 10 mg/L, the drinking water standard for public systems.

2. Volunteer well owner and Ecology results are comparable at 14 co-sampled sites. The observed consistency was probably the result of attentive samplers combined with defined sampling procedures that included system purging and full-stream sampling using "Y" adapters. The use of volunteer well owners in a monitoring program appears to be feasible provided samplers are properly instructed and they follow instructions carefully.

3. Nitrate+nitrite-N concentrations of volunteer samples did not show alteration as a result of being sent un-iced through the mail.

4. Nitrate test kit results show poorer precision (12% RPD, excluding one outlier) than laboratory results but are about $4.25 cheaper per test. Also, test kit results are immediately available whereas laboratory results are usually available after about a month. If test kit nitrate data are to be included in trend determinations, sufficient quality control samples (duplicates and check standards) should be conducted to estimate precision and bias of results.

Recommendations

1. A groundwater monitoring program should be designed and implemented to define long-term trends of nitrate concentrations in the Sumas-Blaine Surficial Aquifer. Characteristics of the monitoring program should include: sampling of identical wells over time, comparable sampling and analytical methods, and definition of seasonal variability. To reduce sampling costs and to provide a local presence, volunteer well owners should be included in the monitoring program.

2. Monitoring wells should be installed in areas where no water-supply wells exist for sampling. The most notable data gap is the area north of Lynden.

3. To reduce costs, test kit results could be included in the monitoring program. If test kit nitrate data are to be included in trend determinations, sufficient quality control samples (duplicates and check standards) should be conducted to estimate precision and bias of results.

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