Lens Groundwater Study Final Report

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LENS GROUNDWATER STUDY

Final Report

Prepared for:
Department of Ecology
Centennial Clean Water Fund

Submitted by:
Whatcom County

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1 INTRODUCTION

The availability of adequate supplies of clean water for both instream and out-of-stream uses throughout much of Whatcom County has become an increasingly serious problem in recent years. Successfully meeting existing and future water needs given the questions regarding the physical and legal availability of the resource, as well as concerns with water quality prompted the development of this study. The study focuses on groundwater in a 200 square mile area in the northern part of the county and was developed through the cooperative efforts of Whatcom County, United States Geological Survey and the Cities of Lynden, Sumas, Everson and Nooksack.

1.1 AUTHORIZATION AND FUNDING

Whatcom County was the lead agency in developing a grant proposal under Ecology's Centennial Clean Water Fund program. The grant was obtained in 1989 and work began in 1990. The technical portion of the study was carried out by the United States Geological Survey who also provided funding assistance for the project. The Cities of Lynden, Sumas, Everson and Nooksack assisted to varying extents with funding and guidance for portions of the project. Administration and reporting was performed by Whatcom County.

1.2 BACKGROUND

Shallow groundwater found within the glacial sediments of the Nooksack River flood plain and the upper Sumas Valley region of Whatcom County and British Columbia provide much of the domestic, irrigation and municipal water supply for the area. Examples of some the the water quality problems which have been identified in the area include nitrates, some pesticides, iron, and chlorides. Some of these contaminants have been found at levels exceeding those considered safe for drinking water under the Safe Drinking Water Act.. The presence of contaminants in water can limit its' ability to be used as a source of drinking water due to the increased costs of treatment, monitoring and source protection. The nature and extent of the quality problems has not been well understood making it difficult to develop appropriate management strategies

In addition to the quality concerns, there are quantity problems which raise serious questions about how future and in some cases current water needs will be met. Obtaining legal permission from the Department of Ecology to use water for many needs is currently very difficult. In-stream restrictions on withdrawals has restricted the use of surface water since flow limitations were established in the mid-1980's. More recently, getting legal permission to use groundwater has become very difficult due to the recognition that groundwater contributes to surface water flows (hydraulic continuity). Tribal water claims to water supplies both on and off reservation, as well as changes in the State role for allocation, has cast even more uncertainty into the allocation picture.

1.3 PURPOSE OF THE STUDY

The purpose of the study was to obtain technical information on the nature and extent of groundwater problems with an emphasis on quality, and to use this information to develop management strategies that would help meet current and future water needs. Specific tasks which were identified to accomplish this included:

- <u>Groundwater Technical Study:</u>

  The need for better technical information was identified. The United States Geological Survey was hired to take the lead on the collecting and analysizing water quality data, delineating and characterizing the hydrostratigraphic units, the chemistry of the major hydrogeologic units, the extent of existing water quality problems and possible trends, and the identification of sources of problems where possible.

- <u>Public Education and Involvement:</u>

  In recognition of the importance the resource to each person in the area, as well as their role in contributing to the problems and ultimately the solutions, specific avenues to educate and involve them in the project were identified and carried out.

- <u>Technical Review and Policy Development:</u>

  Effective solutions to the problems identified require participation and involvement of many individuals and agencies with jurisdiction in the area (on both sides of the border). Efforts to better coordinate existing actions as well as to identify additional management actions needed were considered an essential component of the project.

2. GROUNDWATER TECHNICAL STUDY

The United States Geological Survey (USGS) was responsible for the groundwater technical section of the project. The technical study was divided into four sections - reconnaissance data collection/compilation, definition of the groundwater flow system, description of the groundwater chemistry of the major hydrologic units and water quality analysis. A general description of the requirements for each of these elements follows. A draft of the USGS report which includes specific information on each of these areas can be found in Appendix A. The report also provides a detailed description of the study area, the study methods used and conclusions/recommendations.

The report must go through an extensive formal review process with the USGS before it is available for public distribution. It is not expected to be available until late December of 1994. In recognition of the importance of the data, and its ability to be used in some fashion prior to 1994, the USGS prepared an abstact summarizing the significant findings in December of 1993. The abstract is included at the beginning of Appendix A and is available for public dissemination.

2.1 RECONNAISSANCE DATA COLLECTION

The purpose of this section was to descrribe the size and extent of the geohydrologic units overlying the bedrock within the study area using existing data. This required collecting, and evaluatin existing water well files, selecting approximately

2.2 DEFINITON OF GROUNDWATER FLOW SYSTEM

A description of the groundwater flow system was to be included. Information on water level data from about 600 wells, measurements of water levels in 20 - 30 wells taken on a monthly basis, and specific capacity data were to be used in developing the description.

2.3 CHEMISTRY OF HYDROLOGIC UNITS

Different hydrologic units are likely to have different water quality chemistry. The purpose of this section was to describe the water quality of each of the units identified and if possible, include any trends which may be identified. Additional samples were collected and analyzed, at times on a monthly basis, to assist in this evaluation.

2.4 WATER QUALITY ANALYSIS

The purpose of this section was to obtain sufficient data (including land use) to determine the sources of the water quality problems identified. At a minimum, nitrate, chloride and iron sources were to be examined. Particular attention was to be focused on determining which sources were natural and which were anthropogenic in origin.

3 EDUCATION AND PUBLIC INVOLVEMENT

The public involvement and education component of the study was directed at informing citizens and purveyors about local groundwater problems and providing them with information to assist them in minimizing impacts. In addition to the mechanisms listed below, citizen involvement and education is being evaluated through the efforts of the Interntational Task Force described in Section 4 - Technical Review and Policy Development.

3.1 FREE NITRATE TESTING

The Whatcom County Health Department, with assistance from staff and volunteers of the WSU Cooperative Extension, offered free nitrate testing to county residents in July of 1993. Nitrate was used as the focus for the testing because it was relatively inexpensive and is a good general indicator of overall water quality. The purpose of the testing was:

- To help residents obtain specific information about the quality of their water supplies;
- To provide citizens with educational information on groundwater - what it is, how it can become contaminated, steps that individuals can take to prevent contamination, and what to do if supplies already have problems; and
- To obtain additional information that might assist in understanding the nature and extent of water quality problems in the area.

Testing was offered at three locations on July 15th and the 22nd. A consultant was hired to help generate educational materials and develop the best mechanism to inform the public know about the testing. Outreach methods included:

- 8,500 brochures were designed, printed and mailed to residents within the area. An insert in each brochure described the testing opportunity and provided instructions for taking the test. A copy of the brouchure and insert are included in Appendix B.
- Press releases were developed and sent to several radio stations,
- Newspaper ads were printed in two local papers, the Bellingham Herald and Lynden Tribune. The ads were run two times per week for four weeks. A copy of the newspaper announcement is included in Appendix B.
- A flyer was developed describing the testing opportunity. 3,000 were printed and distributed by volunteers to many businesses and offices/agencies throughort the area. Copies were also provided at the Health Department. A copy of the flyer is included in Appendix B.

A total of 304 samples were analysed during the two day period. When residents brought in a sample for analysis they were asked to spend about 10 minutes with staff and volunteers so that additional information could be collected, the sample analysed and educational material provided and discussed. A sample form identifying the kind of information collected from each person is included in Appendix B. It includes information on where they heard about the free testing, well location/type, sample collection data, potential sources of contamination around around the well, and interest in any follow-up opportunities.

While the sample was analysed residents recieved information on the limitations of the test, what the results mean, health concerns, what to do to protect water quality, and what to do if there was a problem. Three flyers were provided and are included in Appendix B. Other informational material such as agricultural Best Management Practices and septic system care and maintenance was also available for those interested.

Of the 304 samples collected, 154 were at background levels of 3 ppm or less with 54 greater than the drinking water standard of 10 ppm. The remaining 96 samples indicated that groundwater was being impacted by human activities although peat bogs are a possible source of natural high levels of nitrates. Many people indicated they would be interested in participating in follow-up activities. In addition, the Bellingham Herald printed a story on the sampling (refer to Appendix B).

3.2 MEETINGS

A number of meetings were held throughout the study to update participants in the project on the status of the various activities and to receive feedback and recommendations. Many of these meetings were open to the public. Copies of the agendas, dates and locations for some of these meetings are provided in Appendix C.

The public has also been invited to attend the meetings of the Abbottsford/Sumas International Task Force described in Section 4. At the last meeting wtih the participants on December 3, 1993, a recommendation was made to expand education efforts to the various councils (cities and county) and to include the public. The USGS agreed to assist with the presentation.

3.3 OTHER ACTIVITIES

A wide variety of mechanisms were used to assist in the public education and involvement effort for this program. The sensitive nature of the information being dealt with required that these efforts be handled very carefully. Examples of the other education efforts undertaken were:

Northwest Washington Fair

In the summer of 1990, Whatcom County participated in an educational/public information booth in conjuction with the Soil Conservation Service, Council of Governments, Conservation District and Department of Ecology. The purpose of the booth was to provide information regarding projects for promoting water quality. The booth received a Commercial Booth award for its' "hands on" involvement of fair participants.

Lake Whatcom Day

The County developed and staffed a booth a the annual Lake Whatcom Day celebration. The booth provided information on various aspects of groundwater - what it is, how it can become contaminated and what individuals can do to prevent contamination from occurring.

"Water Whys" Radio Program

On June 26th, a half hour radio program (Water Whys) was devoted to groundwater. Topics covered included how groundwater becomes contaminated, how to protect it, general background information, what we know about it locally and how to participate in the free nitrate testing opportunity.

Newspaper Coverage

Throughout the course of the study, many articles have been printed in newspapers both in British Columbia and Whatcom County discussing various aspects of the program and general issues. A copy of some of these articles are provided in Appendix D, including some of the press releases prepared.

4 TECHNICAL REVIEW AND POLICY DEVELOPMENT

The need for technical review of the information generated, coordination and communication between the jurisidictions on both sides of the border, and the development of management strategies, was an important component of this study. To assist with meeting these needs, a series of meetings were held throughout the study. Some of the intial meetings were mainly informational in nature, allowing agencies and others on both sides of the border to exchange data and updates on activities. These meetings were generally well attended with representatives from both sides of the border. Refer to Appendix E. for a copy of some of the agendas, meeting dates and participants.

From these early meetings it was clear that groundwater problems in the Abbottsford/Sumas area were truly international in nature. Problems were identified on both sides of the border, with some contaminants found at levels exceeding those considered safe for drinking water, and groundwater flow was shown to be generally southward from Canada to the U.S.. To assist in developing strategies to address these concerns an Interagency cross-border groundwater committee was formed, again with representatives from the U.S. and Canada. The Committee met on a regular basis for many months.

As a result of the problems identified through both the LENS study and other reports generated on the Canadian side of the border, as well as the discussions through the various Committees and meetings, the Environmental Cooperation Council requested a presentation on the Abbottsford Sumas aquifer in October of 1992. Based on the information received, in November 1992, the Council created the Abbotsford-Sumas Aquifer International Task Force. The Task Force was created to assist in developing a coordinated approach to protecting the resource (both quality and quantity). The Task Force has been meeting every 2 to 3 months in order to develop specific recommendations to meet this goal.

The most recent draft of a report describing the role of the Task Force, history, and specific recommendations, is included in Appendix F. This particular version will be revised and submitted to the Environmental Cooperation Council in May of 1994 for review, comment and approval. It is anticipated that the Task Force will continue to meet, providing an on-going mechanism tq address the various concerns.

APPENDIX A

HYDROLOGY AND WATER QUALITY IN LOWLAND GLACIAL AQUIFERS OF WHATCOM COUNTY, WASHINGTON AND BRITISH COLUMBIA, CANADA

By Stephen Cox and Sue Kahle[1]

Prepared for public workshop presentation at Lynden, Washington, sponsored by Whatcom County Health Department, December 3, 1993

ABSTRACT

Ground water is an important source of domestic, municipal, and irrigation supply in a 225 square-mile agricultural area of the Fraser-Whatcom Lowland. Population growth and the increasing concerns about local ground-water-quality have increased the demand for additional sources of high-quality ground water, leading to the need for a regional appraisal of the ground-water system. During a study from 1990 to 1992, water-level, lithologic, and water-quality data were collected from more than 600 wells and were used with existing information to describe the ground-water system and its water quality.

The area is underlain largely by glacial sediments that overlie Tertiary bedrock and that range in thickness from 0 to 600 feet. Lithologic information from geologic maps and well logs was used to construct 10 lithologic sections, which were used to identify four principal geohydrologic units: a coarse-grained glacial unit that overlies two predominantly fine-grained glacial units, which in turn overlie the bedrock unit. Seventy-five percent of wells within the study area are finished in the coarse-grained glacial unit, which is highly permeable and capable of supplying large quantities of water; the fine-grained and bedrock units are much less permeable and supply only small quantities. The coarse-grained glacial unit, which is much more permeable than the fine-grained and bedrock units, allows more precipitation to recharge the ground-water system than do the less permeable units, but it is also much more susceptible to contamination from land-use activities.

The principal source of ground water is recharge from precipitation. In the study area precipitation ranges from 35 to 60 inches per year, and estimates of recharge range from 15 to 45 inches per year. The general movement of ground water is from recharge areas in the uplands to discharge areas at lower altitudes. The major discharge areas are along streams; however, the extensive areas of artificially drained farmlands are also significant discharge areas.

Ground-water samples from more than 340 wells were analyzed for concentrations of nitrate and chloride. Nitrate concentrations ranged from less than 0.1 to 43 milligrams per liter as nitrogen. Median concentrations of nitrate were 3.8 milligrams per liter in the coarse-grained glacial aquifer and less than 0.1 milligram per liter in all other geohydrologic units. Locally within the coarse-grained glacial aquifer, anaerobic conditions precluded the presence of nitrate nitrogen; in these areas, any nitrogen present was in the ammonia form. The presence of nitrous oxide in three ground-water samples and the identification of denitrifying bacteria confirm that denitrification is occurring in some parts of the aquifer; thus, the quantity of nitrate in ground water is being reduced locally.

In the coarse-grained glacial aquifer, nitrate concentrations exceeded the primary drinking water standard of 10 milligrams per liter in more than 25 percent of the wells sampled. In the deeper geohydrologic units, nitrate concentrations exceeded the drinking water standard in less than 2 percent of the wells sampled. The primary sources of nitrate in ground water are related to land-use activities, which include the storage of barnyard manures and their subsequent application to fields, the application of nitrogenous fertilizers to crops, and the use of domestic septic systems.

HYDROLOGY, WATER QUALITY, AND SOURCES OF NITRATE IN LOWLAND GLACIAL AQUIFERS OF WHATCOM COUNTY, WASHINGTON AND BRITISH COLUMBIA, CANADA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report

Prepared in cooperation with the

WHATCOM COUNTY

HYDROLOGY, WATER QUALITY, AND SOURCES OF NITRATE IN LOWLAND GLACIAL AQUIFERS OF WHATCOM COUNTY, WASHINGTON AND BRITISH COLUMBIA, CANADA

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U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report

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WHATCOM COUNTY PLANNING DEPARTMENT

Tacoma, Washington
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U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

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ILLUSTRATIONS

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TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
acre-foot (acre-ft)	1,233	cubic meter
degree Fahrenheit (°F)	°C = 5/9 x (°F-32)	degree Celsius

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

HYDROLOGY, WATER QUALITY, AND SOURCES OF NITRATE IN LOWLAND GLACIAL AQUIFERS OF WHATCOM COUNTY, WASHINGTON AND BRITISH COLUMBIA, CANADA

By Stephen Cox and Sue Kahle

ABSTRACT

INTRODUCTION

The Nooksack River flood plain and the upper Sumas Valley region of Whatcom County and British Columbia is a farming region developed on the glacial sediments of the northern Puget Sound Lowlands. Shallow ground water found within these sediments currently supplies much of the domestic, irrigation, and municipal water for the area. Although the supply of shallow ground water is ample and its quality was considered "good" in 1960 (Washington Department of Conservation, 1960), an increasing number of water-quality problems have been identified. Large concentrations of nitrate and iron commonly are found in ground waters throughout the area, and at several wells where historical data is available, a trend of increasing nitrate concentration is shown. Areas of salt and corrosive waters have been identified. Ethelene dibromide (EDB), a pesticide once commonly used in berry farming, also has been found in ground waters at several locations.

Declining water-quality conditions and increasing population growth have resulted in an increased demand for supplies of potable ground water. Attempts to find additional sources of potable ground water have been hampered in part due to the lack of a detailed knowledge of the hydrologic conditions of the area. Previous hydrologic investigations within this area have been limited in either scope or areal extent. Because of the need for a current, comprehensive hydrologic assessment on the area, the U.S. Geological Survey (USGS), in cooperation with the Whatcom County Planning Department (WCPD), began a study to conduct an area wide appraisal of the hydrogeology and water quality of the glacial aquifers in the area centered around the municipalities of Lynden, Everson, Nooksack, and Sumas.

Purpose and Scope

This report describes the results of a study to: (1) define, to the extent that available data allow, the general lithology of glacial sediments within the study area; (2) delineate and characterize hydrostratigraphic units; (3) on the basis of data collected during this study along with existing data from other agencies, characterize the water quality of individual hydrostratigraphic units; (4) delineate the extent of existing water-quality problems; and (5) evaluate the sources of existing water-quality problems.

Objective and Approach

The objective of this investigation is to conduct an appraisal of the ground-water hydrology and water quality of the glacial aquifers within the study area. The investigation will focus on the extent and thickness of the principle hydrostratigraphic units, current water quality of those units, and evaluation of significant sources of known contaminants. Information from well logs and surficial geologic maps have been used to construct 10 hydrogeologic sections and to map the extent of primary hydrogeologic units. Reconnaissance water-quality samples were collected from 300 wells to provide information on the vertical and areal distribution of dissolved nitrate and chloride in ground water. Detailed water chemistry samples were obtained from 125 wells; pesticides and trace metals also were sampled from 20 wells. Additional water-quality samples were collected to aid in the analysis of potential sources of nitrate contamination. To the extent that data allow, variations in water chemistry are described. Information and data used in this investigation was obtained from field work performed as part of this investigation as well as the files of other government agencies and individuals.

Well-Numbering System

Because the study area includes area in both the United States and Canada, two well-numbering systems were used in this report. Both well-numbering systems are based on the geographical location of the well. Wells located within Whatcom County are identified by the well-numbering system used by the USGS in the State of Washington. Wells located within British Columbia are identified by the well-numbering system used by the British Columbia Ministry of Environment.

The well-numbering system used by the USGS in the State of Washington is based on the rectangular grid system of the Public Land Survey. The Willamette baseline and meridian form bases of a grid system that indicates township, range, section, and 40-acre subsection. The well number is created by first listing the number of the township and range followed by the section number and the letter representing the 40-acre subsection. For example, 40N/03E-12P02 (see figure 1a) indicates the second well identifed within the 40-acre subsection identified as "P", in section 12 of township 40 north, range 03 east. The part before the hypen indicates township and range, township 2 north, range 3 east, which are north and east of the Willamette baseline and meridian. Following the hyphen, the two-digit number indicates the section. The letter indicates the 40-acre division within the section. The last number indicates that this is the second well identified in this subsection.

The well-numbering system used by the British Columbia Ministry of Environment is based on the divisions of primary quadrangles of the National Topographic System of Canada. Each primary quadrangle is 4 degrees of latitude by 8 degrees of longitude. For purposes of numbering wells, they are subdivided as shown in figure 1b. Each primary quad is first subdivided into 16 1 degree of latitude by 2 degrees of longitude subdivisions that are identified by letter. These quads then are subdivided into 100 6 by 12-minute quads that are further subdivided through a process of repeated quartering. Three successive quarterings produce subdivisions that are 45 seconds of latitude by 1 minute 30 seconds of longitude. The area of this subdivision is about 589 acres. Wells located within this subdivision are numbered sequentially from one. To number the well, the sequential number is added to the subdivision identifier. For example, well 92G.008.1.2.3.-12 indicates the twelth well located in the 45 second by 1 minute 30 second subdivision known as 92G.008.1.2.3. For this study, all wells are located in subdivisions 92G.007.1.1.1 through 92G.009.4.4.4.

Acknowledgments

The authors would like to gratefully acknowledge the assistance that has been provided by numerous individuals and agencies. First and foremost, to the many private well owners who provided information and access to their wells; this type of investigation would not have been possible without your assistance. Dr. Charles Flora provided access to 11 years of weekly water-quality data. Hayes Drilling Company provided extensive geologic information from well logs. The Whatcom County Health Department provided water-quality information. The Washington Department of Ecology provided water-quality and water-level information associated with in-progress research investigations. The British Columbia Ministry of Environment and Environment Canada provided extensive hydrologic and water-quality data for wells in British Columbia, in addition to providing invaluable assistance in obtaining water samples.

DESCRIPTION OF STUDY AREA

The study area lies within the transborder region between the United States and Canada. This geographic region, which is referred to locally as either the Fraser Lowland or the Whatcom Basin, encompasses about 1,000 mi^2 and is bounded on the north by the Coast Mountains of British Columbia, on the southeast by the Casacade and Chuckanut Mountains, and on the southwest by the Strait of Georgia (see fig. 2). The study area occupies about 225 mi^2 in the southwestern portion of the Fraser Lowland near the Cascade foothills. Eighty-two percent of the study area is within Whatcom County, and the remaining area is within British Columbia.

The land surface of the study area is dominated by glacial features and can be characterized into three general categories; the outwash plain, the hummocky uplands, and the alluvial flood plains. The study area falls mostly within the outwash plain category with smaller areas of hummocky uplands occurring on the southern and northwestern margins. The alluvial flood plain of the Nooksack River arcs across the study area from east to west, while the Sumas River flood plain follows the study area's eastern border.

The outwash terrace is a broad expanse of glacial outwash sediments whose surface has limited relief. In places, these sediments have been incised by streams, rivers, or glacial meltwater, and other depressions also have been created by glacial kettles. Because of the shallowness of the water table in this low lying area, many of the depressions now contain lakes or ponds, and marshy conditions occurred in many areas, some of which developed into peat bogs and organic soils.

The upland areas occur above the level of accumulation of the glacial sediment that make up the outwash terrace. These areas generally have a hummocky surface and are poorly drained. During the heavy winter rains, standing water tends to accumulate within depressions.

The northeastern portion of the study area is dominated by the Sumas River flood plain, which is a flat, low lying, poorly drained area that has at times been subject to flooding. North of the study area within the Sumas flood plain, a large shallow lake existed prior to being drained in the 1920's.

Prior to logging during the 1800's, most of the study area was heavily forested with western red cedar, western hemlock, and Douglas fir being the dominant tree species. The lush understory is composed of an assortment of water tolerant species. In the lowland portion of the study area, most of the forest cover has been displaced by agriculture, although some forested woodlot and regrowth areas remain. Much of the agricultural lands have been planted to hay, pasture, and other forage crops suitable for supporting dairy operations. In addition to pasture lands, berry production makes up a significant portion of agricultural lands within the study area.

Drainage

The study area is drained by two prominent rivers--the Nooksack and the Sumas--and by a number of creeks and drainage ditches that empty into one of these rivers. The Nooksack River originates in the Cascade Range to the east of the project area, with most (72 percent) of its drainage area occurring upstream of the study area. The Nooksack River traverses the study area for a distance of 25 miles with an average gradient of 4 feet per mile below Everson and 10.4 feet per mile above Everson. At high flows, the Nooksack River has overflowed its banks near the town of Everson, and a portion of the flow enters the Sumas River drainage.

Tributaries to the Nooksack River include Bertrand, Fishtrap, Tenmile, and Anderson Creeks.

The Sumas River flows northward, draining the eastern portion of the study area and adjacent Cascade foothills before leaving the study area and discharging to the Fraser River 10 miles northeast of Abbotsford.

Because much of the study area was initially poorly drained, numerous surface drainage ditches and subsurface tile drains have been built. The primary purpose of installing drainage systems is to remove excess surface and shallow ground water to allow greater agricultural use of the land. The extent of surface-water features and soils mapped as being more than 90 percent drained are shown in figure 3. Soils within the Canadian portion of the study area are generally undrained (Bernard Zebarth, ___________, oral commun., 1993).

Climate

The climate of the study area and the Fraser Lowlands is strongly influenced by its location (Phillips, 1966). The maritime air from the Pacific has a moderating effect on climate, while the Cascade and Rocky Mountains shield the region from cold air masses moving south from Canada. The region experiences warm dry summers and mild rainy winters. Winter weather generally consists of a steady progression of low pressure systems from the Pacific bringing cloudy and rainy conditions; however, infrequent high pressure systems over the interior bring cold northeasterly winds that resemble cold continental conditions. The mean annual temperature is 49°F, with the warmest weather occurring in July and the coldest in January. The frost-free growing season generally begins around mid May and ends in mid October.

Precipitation within the Fraser Lowlands is quite variable. Annual precipitation within the study area ranges from about 32 inches per year near Ferndale to over 60 inches per year near Aldergrove. Isohyetal lines (contours of equal rainfall) generated from rainfall data provided from United States and Canadian weather services are shown in figure 4. The orographic effect of both the Coast Mountains of British Columbia and the Cascade Range of Washington is clearly visable.

Although the amount of precipitation that falls on the portions of the study area is large, irrigation of agricultural crops is warranted because the timing of periods of high precipitation do not coincide with periods of large evapotranspiration. Precipitation falls mainly during the period from October through April, while maximum evapotranspiration occurs between June and August. A water budget analysis based on Thornthwaite's method, computed for the Clearbrook Weather Station (Washington Department of Conservation, 1960) shows the relation between annual precipitation and annual potential evapotranspiration that results in a soil moisture deficit condition occurring during the months of June, July, and August. Irrigation during this period ranges from 3 to 10 inches of water.

Development and Cultural Features

Development of the study area by white men began in the 1860's. Initially the area was covered with dense stands of Douglas fir, cedar, and hemlock, providing rich resources for an economy based on lumber. The Nooksack River provided an avenue for the transportation of logs and lumber. Agriculture developed as land was cleared, particularly on the flatter lying bottom land along the river that was more easily cleared and cultivated. All of the lowland virgin forests have long since been cut and the economy of the study area is now largely related to agriculture.

Important agricultural activities include dairy products, raspberries, strawberries, blueberries, and poultry production. Whatcom County is the leading dairy producing county in the State of Washington and 30 percent of all raspberries grown within the United States come from Whatcom County (Washington Agricultural Statistics Service, 1991). The British Columbia portion of the study area is also an agricultural area. About 60 percent of the poultry production within British Columbia is located near the study area and 60 percent of the British Columbia agricultural land within the study area is planted to raspberries (Liebsher and others, 1992).

The study area is a rural area. There are a number of incorporated communites within the study area. In the Whatcom County portion are the communities of Lynden, Everson, Nooksack, and Sumas. These towns make up __ percent of the study area and according to the 1990 census, the populations are ___, ___, ___, ___, respectively. Additional development has occurred in the unincorporated areas, particularly along State Route 529 (the Guide Meridian) and in the vicinity of Hinotes and Nugents Corner. The British Columbia portion of the study area includes the community of Huntingdon and portions of the communities of Abbotsford and Clearbrook. Total population within the study area is estimated to be _____.

Add paragraph on population growth increasing residential pressure on both rural and ag lands. Rural population growth. (figure 5)

Ground water is the source of all water supplies throughout the study area with the exception of the city of Lynden, which uses water from the Nooksack River. Individual wells and water associations supply water to residences outside of incorporated areas. The cites of Lynden, Everson, and Sumas also provide centralized waste-water disposal systems. On-site septic systems are used throughout the rest of the study area.

Soils

The soils within the study area exhibit a remarkable level of diversity in soil characteristics. In the Whatcom County portion of the study area, there are 105 soil classifications (name, SCS, written commun., date) (Luttmerding, 1981). The diversity is largely the result of variability in the underlying geologic deposits and variations in surface relief and drainage. Soils are generally friable and easy to dig, unless stoney. Vegetation grows rapidly in all soils. Peat deposits have developed in several areas and have accumulated to thicknesses up to 30 feet (Riggs, 1944).

There are several primary soil associations that are based largely on geologic parent material of the soils. Soils in the flood plains of the Nooksack and Sumas Rivers and Anderson Creek are generally loamy but can be further divided into the excessively well drained soils, and the silt-clay rich soils that require artificial drainage. This soil distinction forms the basis for distinguishing surficial geologic deposits within the previously mapped alluvial unit (Easterbrook, 1976). In the Sumas Valley the silty clay-rich soils are extensive and hydrologically significant in that they can create confined conditions in shallow aquifers and are a barrier to the downward movement of rain waters.

Glacial-outwash terrace soils are situated north and south of the Nooksack flood plain. The texture of these soils ranges from silty loam to gravelly loam. Drainage of these soils ranges from well drained to poorly drained due in large part to differences in topography and slope. Large peat deposits have developed in depressions on these soils. These soils are the primary agricultural soils of the area, are well suited for intensive agriculture, and are capable of producing a wide range of climatically adaptable crops.

Soils derived from glacial marine deposits are situated along the southern and northwestern margins of the study area. These soils are heavy, deep soils whose drainage ranges from moderately well to poorly drained. The hummocky, undulating land surface results in variability in drainage and increases cost and difficulty associated with crop production. Agriculture on these soils is largely limited to hay and pasture.

STUDY METHODS

Hydrogeologic Methods

Most of the hydrogeologic data used in this study to describe and delineate the ground-water system came from approximately 625 wells whose locations are shown on plate 1. The wells were inventoried during the initial phase of the project. The well inventory process included field locating the well and establishing its location on air photos; determining the latitude, longitude, and land-surface altitude of well location from topographic maps; where possible, measuring the water level in the well and collecting a reconnaissance water-quality sample; verification of general well construction details listed on drillers' logs, such as casing diameter and material; tabulating and interpreting lithologic and hydraulic information on drillers' logs; and, finally, coding and entering information into the National Water Information System (NWIS) data base.

The selection of wells to be inventoried utilized several criteria. The primary consideration was to get adequate areal representation of the surficial aquifer. In general, only wells having Washington State or British Columbia drillers' water-well reports were selected; however, in instances where well selection was limited, wells without official reports were also used. Exploration wells drilled for coal, gas, or geotechnical purposes were also used to obtain lithologic information. In many instances, only one or two wells in a given section (one square mile) were available to inventory. In instances where several wells were available, field personnel were given the discretion to choose wells that would provide good spatial distribution of sampling points.

Determining the physical extent of the major hydrogeologic units was accomplished largely through the compilation of a map of surficial geology and the construction of 10 lithologic sections. The geologic map compiled for this study is based on existing geologic maps of western Whatcom County (Easterbrook, 1976) and the geologic maps of the New Westminister (Armstrong, 1976) and Mission (Armstrong, 1977). For the purpose of this study, several of the geologic units recognized by Armstrong (1977) were combined to form a single geologic unit. The Holocene alluvium mapped by Easterbrook (1976) was divided into fine-grained and coarse-grained units based on soils maps (U.S. Department of Agriculture Soil Conservation Service, 1992) and well records. The fine-grained alluvium, which is prominent in the Sumas Valley, appears to be continuous with the Salish lacustrine silts mapped by Armstrong (1977).

The subsurface extent of hydrogeologic units was mapped primarily by correlating lithologies recorded in drillers' reports. Drillers' descriptions of materials encountered during drilling were assigned to one of five lithologic units: (1) peat, (2) fine-grained unconsolidated deposits, (3) coarse-grained unconsolidated deposits, (4) bedrock, and (5) undifferentiated unconsolidated deposits where descriptive information was unavailable or incomplete. Ten lithologic sections were constructed (see plate 2) in a north-south and east-west grid. The sections were constructed by correlation of drillers' lithologic descriptions, surficial geologic maps, and examination of lithologic materials at outcrops. In the Canadian part of the study area, existing fence diagrams (Halstead, 1986) of subsurface geology were also used in the construction of the lithologic sections. Where sufficient data existed, primarily for the shallow deposits, hydrogeologic units were correlated from well to well. Correlating deeper hydrogeologic units was much more difficult due to fewer logs available and sometimes less-precise drilling records. Although adequate drilling records exist for shallow unconsolidated deposits in the study area, records for wells exceeding 100 feet are, for the most part, rare. Most of the logs of deep wells that are available were recorded during coal exploration, where the primary emphasis of drilling was to determine the location of coal-bearing strata within the Tertiary bedrock, rather than to accurately record changes in lithology of the overlying unconsolidated material. Delineation of the principal hydrogeologic units of the study area--the Sumas aquifer, the Everson-Vashon unit, the Vashon aquifer, and the bedrock aquifer--will be discussed in the hydrogeology section of this report.

The Sumas aquifer was the only hydrogeologic unit whose thickness could be mapped. The extent of this unit was taken to be the extent of the surficial coarse-grained deposits in the study area. A thin deposit of fine-grained alluvium is included with the Sumas aquifer where it overlies coarse-grained material in the Sumas Valley and in downstream reaches of the Nooksack River. An isopach map of the Sumas aquifer was drawn based on the thickness of coarse-grained material encountered by wells that penetrated this unit. The top of the fine-grained unit below the Sumas aquifer, the Everson-Vashon unit, was also mapped. A depth-to-bedrock map was constructed using information from geophysical and geological investigations (Finn and others, 1984; Gower and others, 1985; Halstead, 1986; and Gordy, 1988) and drilling records.

The ground-water flow system of the Sumas aquifer is depicted in part by a water-level map. This map was constructed using water levels measured in 450 wells at the time of inventory, plus additional water-level information contained in Johanson (1988) and Kohut (1987). The inventory water levels, which were collected over a 6-month period, were adjusted to account for seasonal variation. Monthly water levels were measured in 25 wells within the study area from August 1970 to November 1991. Records from British Columbia Ministry of Environment (BCME) and Environment Canada (EC) wells were also used to quantify seasonal variation in ground-water levels.

Estimations of the horizontal hydraulic conductivity for each hydrogeologic unit were made using specific-capacity data. Only data from those wells that had the most complete and reliable set of specific-capacity information (discharge rate, longer term test, drawdown, well-construction data, and geologic log) were used. Of the 626 wells inventoried, 219 had such information. Two different sets of equations were used, depending on how the well was finished. For wells that had a screened, perforated, or open-hole interval, the modified Theis equation (Ferris and others, 1962) was first used to estimate transmissivity values. This equation is:

(1)

where T = transmissivity of the hydrogeologic unit in square feet per day;

Q = discharge, or pumping rate, of the well in cubic feet per day;

s = drawdown in the well, in feet;

t = length of time the well was pumped, in days;

r = radius of the well, in feet; and

S = storage coefficient, which is a dimensionless decimal.

The equation was solved for transmissivity using Newton's iterative method (Carnahan and others, 1969, p. 171). Next, the following equation was used to calculate horizontal hydraulic conductivity:

(2)

where K_h = horizontal hydraulic conductivity of the hydrogeologic unit in feet per day;

T = transmissivity, as calculated above; and

b = thickness of the hydrogeologic unit, in feet, approximated using the length of the open interval.

The use of the open interval to approximate the thickness of the hydrogeologic unit assumes that the wells are open to the entire thickness of the unit, which was almost never the case. Nevertheless, this assumption is necessary because the equations are derived on the basis of horizontal flow only, that is, vertical flow is nonexistent (or at least insignificant). In a homogeneous unit, these conditions occur only if a well penetrates the entire thickness of the unit. However, in glacial systems horizontal flow is indeed likely to be much greater than vertical flow because the unit's heterogeneity leads to horizontal hydraulic conductivities that are generally much larger than the vertical hydraulic conductivities. Thus, even though the wells are rarely open to the entire thickness of the unit, the assumption that they are is reasonable for glacial systems.

A second equation was used to estimate hydraulic conductivities for wells having only an open end, and thus no vertical dimension to the opening. Bear (1979) provides an equation for hemispherical flow to an open-ended well just penetrating an aquifer. When modified for spherical flow to an open-ended well within an aquifer, the equation becomes:

(3)

where K_h = horizontal hydraulic conductivity of the hydrogeologic unit in feet per day;

Q = discharge, or pumping rate of the well, in cubic feet per day;

s = drawdown in the well, in feet; and

r = the well radius, in feet.

This second equation is based on the assumption that flow can occur equally in all directions; specifically that horizontal and vertical hydraulic conductivities are equal. As discussed above, this is not likely to be true for glacial systems. However, the errors associated with violating this assumption are likely to be less than those that would occur in trying to fit the Theis equation to the open-ended well geometry. In fact, hydraulic conductivities were calculated using both approaches for open-ended wells, and the values from using the Bear equation for open-ended wells more closely resemble the hydraulic conductances calculated for the screened wells.

Water-Quality Methods

The sampling and analytical methods used for the water-quality phase of this study follow standard guidelines used by the USGS. These procedures are described in Techniques of Water-Resources Investigations (Greeson and others, 1977; Wood, 1981; Friedman and Erdmann, 1982; Fishman and Friedman, 1985; and Wershaw and others, 1987).

Water-quality sampling was conducted at two levels, a reconnaissance sampling and a subsequent in-depth water-quality sampling. The reconnaissance sampling provided limited water-quality information from many wells; the in-depth sampling provided more extensive water-quality information and was obtained on a smaller number of wells.

The reconnaissance water-quality survey was conducted during the well inventory period, March to August 1990. At the time a well was inventoried, an unfiltered water sample was collected from all wells that would supply a readily available and representative sample. These samples were analyzed for specific conductance, total nitrate plus nitrite, and dissolved chloride. A total of 329 reconnaissance samples were thus collected. The data from these samples formed the basis for mapping the areal distribution of nitrate and chloride within the study area, and were used to guide the selection of sampling sites at which more-detailed chemical analysis would be done.

Between August 1990 to November 1991, monthly samples were collected from 25 wells and analyzed for the same parameters as in the reconnaissance survey. These samples were used to document seasonal variations. Reconnaissance-level nitrate samples were analyzed by the U.S. Geological Survey National Water-Quality Laboratory (NWQL) in Arvada, Colo., following the procedure in Wood (1981). The reconnaissance-level chloride samples were analyzed by the U.S. Bureau of Reclamation (USBR) Water Quality Laboratory in Boise, Idaho, using potentiometric titration procedures (APHA, 1989).

At the detailed water-quality sampling level, water samples were collected from 115 wells for one or more of six suites of water-quality parameters. The six suites and the number of sampling sites for each suite are listed below. Sampling within British Columbia was coordinated with the British Columbia Ministry of Environment and Environment Canada. The detailed-level sampling occurred during August 1990, April and May 1991, and October 1991.

Suite	Sites
General water-quality parameters	115
Nutrients	75
Seepage-related parameters	111
Major ions	35
Pesticides and volatile organic compound	21
Trace elements	23

General water-quality parameters were collected at each sampling site; these included temperature, specific conductance, pH, and dissolved oxygen. The major-ion suite included alkalinity, silica, iron, manganese, calcium, magnesium, potassium, sodium, chloride, sulfate, and nitrate. The nutrient suite included nitrate, nitrite, organic nitrogen, ammonia, and orthophosphate. The septage-related parameters included boron, dissolved organic carbon (DOC), bromide, and methylene blue active substances (MBAS, or detergents). Trace elements included barium, beryllium, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, silver, strontium, vanadium, and zinc. The pesticide and volatile organic compounds included 12 triazines and other nitrogen-containing herbicides, 10 carbonate insecticides or metabolites, and volatile organic compounds such as ethylene dibromide (EDB), dichloropropane (DCP), and trichloroethane (TCE).

The sampled wells were selected to provide broad geographic coverage and to be representative of all hydrogeologic units. The number of wells selected for sampling within each hydrogeologic unit was approximately proportional to the total number of wells inventoried in each unit. Wells from which samples were analyzed for concentrations of pesticides and volatile organic compounds were selected largely on the basis of predominant land use in the vicinity of the well, hydrogeologic unit susceptible to contamination, and previous sampling, which indicated concentrations of nitrates well above background concentrations.

Water samples were collected primarily from the existing plumbing of wells equipped with submersible pumps. Considerable effort was made to obtain the sample from a tap close to the wellhead and before the water entered a pressure tank; however, water samples from about 40 percent of the wells sampled had passed through a pressure tank. All samples were collected prior to any water treatment, such as chlorination or softening. The well system was run for a period of time to flush water lines and the pressure tank. The water sample was directed from the tap to a closed-system flow chamber equipped to monitor temperature, specific conductance, pH, and dissolved oxygen. Sample bottles were filled after the flushing period and after the water-quality parameters measured in the flow chamber were stable for a period of at least 5 minutes. Bacteria samples were collected at the tap.

Determinations of pH, specific conductance, dissolved-oxygen concentration, and alkalinity were made in the field using methods outlined by Wood (1981). Dissolved-oxygen concentrations were determined by meter; however, concentrations below 1 mg/L were checked using either a Winkler titration (American Public Health Association, 1979) or Rhodazine-D colorimetric method (White and others, 1990). The dissolved-oxygen probe was not used on water that had a strong sulfur smell.

After collection, samples were preserved and stored according to standard USGS procedures (Pritt and Jones, 1989). Samples requiring laboratory analysis were sent to the laboratory by first-class mail on the next work day. All sampling equipment was cleaned and rinsed as appropriate before subsequent samples were collected.

Water samples for analysis of fecal-coliform and fecal-streptococci bacteria were collected directly from the tap and were not filtered or treated. All of the bacteria samples were processed in the field within 6 hours of collection. All other samples requiring laboratory analysis were analyzed by the NWQL in Arvada, Colo. Analytical procedures used at the NWQL are described by Fishman and Friedman (1983) and Wershaw and others (1987).

As part of the quality-assurance program for this study, field instruments for the measurement of specific conductance, pH, and dissolved-oxygen concentrations were calibrated at the beginning of each work day with known standards. Percent of samples for analysis by the NWQL and the USBR laboratory were collected in duplicate on a random basis. Reference samples were submitted for chloride and MBAS. As a result of the poor laboratory performance on the MBAS samples, the resulting data were subsequently discarded. Reference samples for most inorganic constituents were submitted as blind samples by the NWQL into the sample stream. Appropriate standards were spiked into each sample for organic analysis to determine the percentage of constituent recovered.

The resulting analytical data from the NWQL were initially reviewed by their staff and then released to the local USGS district office in Tacoma, Wash., where they were further reviewed by district personnel who are more familiar with the hydrologic context from which the samples were collected. With the exception of the MBAS data, all of the laboratory data appeared to be of good quality.

A final quality-assurance check was sample splits between NWQL and laboratories used by BCMR and EC. Those data, tabulated in appendix E, were comparable.

GROUND-WATER HYDROLOGY

The basic principles of ground-water hydrology are described by Heath (1983) and are described in more detail by Freeze and Cherry (1979). Much of the material that follows applies specifically to the study area in the Fraser-Whatcom basin. The reader is referred to Heath (1983) and Freeze and Cherry (1979) for more comprehensive discussions of ground-water hydrology.

The Hydrologic Cycle and the Occurrence of Ground Water

The constant circulation of water from the oceans to the atmosphere, to land and back again to the ocean, is referred to as the hydrologic cycle. An appreciation of some of the complexities involved in the movement of water through the subsurface portion of the hydrologic cycle will be helpful in understanding the ground-water system of the study area. A schematic diagram of the hydrologic cycle and the occurrence of ground water is shown in figure 6.

Precipitation in the form of rain or snow is the source of all fresh ground water. Precipitation that falls on the land surface can follow several pathways; runoff to streams and lakes, evaporation back to the atmosphere, or infiltration into the ground. Some of the water entering the soil is drawn up by plant roots and returned to the atmosphere by way of transpiration; soil water can also be evaporated directly to the atmosphere. Water that percolates below the root zone and continues to percolate downward to the water table is referred to as recharge; when it reaches the water table it becomes ground water. Gravity moves ground water from higher altitudes toward lower altitudes, insuring that ground water will eventually return to the ocean. However, some ground water returns to the land surface as seepage to springs, lakes, or streams prior to reaching the ocean.

Ground water occurs in saturated geologic materials (sediments and fractured rock) beneath the land surface of nearly all areas of the Earth. However, only a small fraction of saturated geologic materials can yield ground water in usable quantities. Aquifers are defined by Heath (1983) and others as geologic deposits that can yield ground water to wells or springs in usable quantities. Confining or semi-confining units, on the other hand, are geologic materials that, due to their low permeability, will not yield water in usable quantities. Confining units also restrict the movement of ground water into and out of adjacent aquifers.

From this standpoint, all saturated geologic materials that underlie the Earth's surface can be classified as either aquifers or confining units. The distinction between an aquifer and a confining unit, however, is site specific and will vary from place to place. Variations arise from interpretation of what constitutes a usable quantity and of the scale or size of area under consideration. Geologic materials are not homogeneous, and highly permeable aquifers such as the ones that exist throughout much of the study area have localized areas of fine-grained, low permeability materials that yield much smaller quantities of ground water. The reverse situation is also common. Confining units can have lenses of coarse-grained material that will yield small quantities of ground water for limited periods that are nevertheless suitable for domestic use.

Within aquifers, ground water occurs under two different conditions (see fig. 6b). In the unconfined, or water-table, condition, the aquifer is only partially saturated with water and the upper surface of the saturated zone (the water table) is free to rise and fall with changes in recharge and discharge. Under these conditions the level of water within a well will be equal to the level of the adjacent water table in the aquifer. Most of the wells within the study area tap unconfined aquifers.

Confined conditions occur when the aquifer (bounded above and below by confining units) is completely filled with water. Because the aquifer is completely filled, the upper surface of the saturated zone cannot rise and fall in response to changes in recharge and discharge. This situation results in the development of hydrostatic pressure within the aquifer that causes water levels in wells tapping this unit to rise above the top of the aquifer. A well that taps such a system is called an artesian well. If the pressure is sufficient to raise the water above land surface, the well flows and is called a flowing artesian well. Confined ground water has a pressure (potentiometric) surface analogous to the water-table surface and, like the water table, this potentiometric surface fluctuates in response to changing recharge and discharge conditions.

Ground water within the study area is found in both unconsolidated sediment and consolidated bedrock. In the loose unconsolidated sediment, water moves through the numerous pore spaces that separate the individual particles. In dense consolidated bedrock, water can only move through interconnected cracks, joints, fractures, and solution channels, which are generally much less numerous and less productive than the interstitial pore spaces of unconsolidated sediments. In general, water production in wells from bedrock aquifers is much lower than in wells tapping sand and gravel aquifers, unless the bedrock well encounters large solution channels.

Hydrogeologic Framework

In order to determine the extent, geometry, and hydrologic significance of the geologic material in the study area, an explanation of the origin and an assessment of the physical properties of the materials is required. The discussion that follows focuses on the regional and local geologic setting, the identification of principal hydrogeologic units, and the physical characteristics of those units.

Many studies have contributed to our current understanding of the hydrogeologic framework of the study area. Previous geologic investigations and (or) mapping of Pleistocene deposits include those by Easterbrook (1963, 1966a, 1966b, 1969, 1971, 1973, and 1976), Armstrong (1956, 1960, 1976, 1977a, 1977b, and 1981), Armstrong and Hicock (1976), Armstrong and others (1965), and Cameron (1989). Studies of Eocene sedimentary bedrock include those of Daly (1912) and Johnson (1984a, 1984b, and 1991). Discussion of hydrogeologic conditions in the area is included in Newcombe and others (1949), Washington Division of Water Resources (1960), Halstead (1986), Kohut (1987) and Kohut and others (1989), Creahan and Kelsey (1988), Johanson (1988), Lindsay (1988), and Kahle (1990).

Regional Geologic Setting

The Fraser and Nooksack Lowlands represent the landward extension of a geological depression known as the Georgia Basin. The Georgia Basin is a large, elongate sedimentary trough that developed in response to tectonic activity beginning in Late Mesozoic time (England, 1991). This tectonic activity resulted in basin development (the Georgia Basin) in some areas, and mountain building (the Coast and Cascade Ranges) in others. As the Coast and Cascade Ranges were uplifted, they also underwent rapid weathering and erosion. This in turn resulted in enormous quantities of sediment being deposited in the Georgia Basin in fluvial, deltaic, and marine environments. Significant quantities of plant and other organic matter were deposited along with the sediment.

Post-depositional geologic activity resulted in the lithification and consolidation of sediments into sandstone, mudstone, and conglomerate; and the transformation of organic debris into hydrocarbon deposits including coal. Locally the sedimentary formations have been described as the Huntingdon Formation (Daly, 1912) and the Chuckanut Formation (McLellan, 1927), both of which are Eocene in age. Post-depositional deformation resulted in folding and faulting of the sedimentary rock units, producing an irregular bedrock surface topography. Pleistocene glaciers subsequently eroded and smoothed this bedrock surface prior to depositing a variable thickness of glacial sediment across the study area and much of the Puget Lowlands. It is these glacial sediments that comprise the principal aquifers of the study area.

Local Geologic Setting

Test drilling for coal and gas and geophysical surveys indicate that bedrock is beneath 1,000 to 2,000 feet of Pleistocene deposits throughout much of the Fraser-Nooksack Lowlands (Vonheeder, 1975). The depth to bedrock, in the study area, which is equal to the thickness of overlying unconsolidated sediments, is shown in figure 7. Surface exposures of the sedimentary bedrock formations are limited to the southeastern portion of the field area.

The most commonly occurring bedrock unit exposed in the field area is the Huntingdon Formation, which overlays the slightly older Chuckanut Formation. Although the Huntingdon Formation is more commonly exposed at land surface, it is actually a relatively thin unit. As described by Johnson (1984a, 1984b, and 1991), the Chuckanut Formation is composed primarily of sandstone, mudstone, and conglomerate with local coal seams. The unit was originally deposited in a nonmarine environment as a thick sequence of alluvial strata. Easterbrook (1973) concluded that the Huntingdon and Chuckanut Formations are lithologically similar, and that the only differences between them are (1) an erosional unconformity that separates them in geologic time, and (2) a greater amount of post depositional deformation in the Chuckanut Formation than in the Huntingdon. Together, these formations approach a combined thickness nearing 20,000 feet and represent one of the thickest nonmarine sedimentary sequences in North America (Johnson, 1991).

During the Pleistocene Epoch, most of the bedrock in the study area was covered by thick unconsolidated deposits as a result of repeated advances and retreats of continental glaciers. Little is known about the oldest and deepest of these deposits in the study area because they are not exposed at land surface and descriptive drilling information is scarce. Deposits of the last major glaciation are, however, either exposed at land surface or they have been penetrated extensively during drilling. The deposits of this final glaciation, known as the Fraser Glaciation, comprise most of the hydrogeologic units identified during this study.

The Fraser Glaciation began approximately 20,000 years ago and had a 10,000-year duration (Easterbrook, 1963, 1969). Three phases of this glaciation, from oldest to youngest are, the Vashon Stade, the Everson Interstade, and the Sumas Stade. Glacial deposits from each of these phases are present within the study area.

During the Vashon Stade, from 18,000 to 13,500 years ago, two units were deposited locally. The oldest, the Esperance Sand Member, is cross-bedded sand and gravel outwash that was deposited from meltwater streams emanating from the advancing Vashon Glacier. Vashon till, the younger of the two units, is a compact and poorly sorted mixture of cobbles, pebbles, and sand in a silt and clay matrix deposited beneath the ice of the advancing Vashon Glacier (Easterbrook, 1963, 1969). Within the study area, these deposits have a limited surficial exposure, but likely occur at depth below the Everson and Sumas deposits. Vashon deposits (Qv) only occur at land surface along the flanks of Sumas Mountain, in the eastern part of the study area (plate 2).

Overlying the Vashon Stade deposits are deposits of the Everson Interstade that occurred from 13,500 to 11,000 years ago. As the Vashon Glacier retreated from its terminus in southern Puget Sound, it thinned, allowing marine water to reenter the basin and float the ice. Everson interglacial deposits (Qe) were deposited as debris fell from the floating and melting glacial ice and was deposited in marine water. In the study area, deposits of the Everson Interstade are typically represented by glaciomarine drift, an unsorted mixture of pebbly silt and clay with some coarse-grained lenses, deposited in marine water (Easterbrook, 1963, 1969). Everson-age deposits are mapped at land surface in the northwestern Boundary Uplands, in the rolling hills in the south-central part of the study area, and in the lineated topography region northwest of Everson (plate 2). In the southern part of the study area, a relatively thick interlayer of stratified sand with some clay and gravel occurs within the glaciomarine drift. According to Easterbrook (1973), this interlayer, called the Deming Sand, was deposited during the Everson Interstade on flood plains and beaches when sea level dropped relative to the land. The Deming Sand has not been recognized elsewhere in the study area.

Following deposition of the Everson glaciomarine drift, glacial ice readvanced a short distance southward into northern Washington and deposited the Sumas Drift (Easterbrook, 1963, 1966a, 1966b, 1969, 1971, 1974, 1976d; Armstrong, 1977, 1981; Armstrong and others, 1965). The final phase of the Fraser Glaciation, known as the Sumas Stade, occurred from 11,000 to 10,000 years ago. During that time, the main glacial terminus was just north of the present-day International border with a lobe extending southward into Whatcom County at Sumas. Sumas outwash (Qso) was deposited on top of Everson glaciomarine drift by meltwater streams carrying sand and gravel southward and southwestward. The resulting outwash plain extends from north of the International border southward to Lynden, and southwestward from Sumas to Everson and Ferndale (plate 2). The outwash grades from gravel and cobble near the border to sand with occasional clay lenses near Lynden.

A morainal ridge and hummocky topography, composed of ice-contact deposits (Qsic), mark the maximum extent of the Sumas lobe (plate 2). The deposits are a poorly sorted mixture of till and outwash with varying proportions of boulders, cobbles, pebbles, silt, and clay. Ice-marginal ponding resulted in localized deposits of lacustrine silt and clay within the Qsic. Just west of Sumas, Wash., ice-contact deposits are located on top of Sumas-age advance outwash sand and gravel. This sequence is similar to that found in the Fraser Lowland north of the International border where moraine and ice-marginal debris overlie advance outwash or glaciomarine drift (Armstrong and others, 1965; Armstrong, 1981).

During the last 10,000 years (Holocene Epoch), the Nooksack River has incised a wide channel through Sumas Stade deposits, forming the nearly flat alluvial floodplain of the present Nooksack River Valley. Within the study area, Nooksack River alluvium grades from gravel in the upstream reaches near Cedarville to sand and silt in the downstream reaches near Lynden. Other fluvial deposits in the study area include alluvium of the Sumas River and of Bertrand, Johnson, and Fishtrap Creeks. At the same time that the modern Nooksack River was incising through Sumas Stade deposits, peat (Qp), composed of plant remains, was accumulating in former outwash channels and other low-lying depressions in the Sumas outwash. Peat-filled depressions in the study area are numerous and include Wiser and L'Axton Lakes and Pangborn Bog (plate 2).

During the late Holocene, a shallow lake occupied much of the Sumas Valley floor, covering it with a relatively thin lacustrine silt and clay deposit (Armstrong, 1976; Cameron, 1989). The area most recently occupied by the lake is the northeastern, or Canadian, part of the Sumas Valley floor. Historical records show that the lake, known as Lake Sumas, existed just north of the border in British Columbia prior to being drained in the 1920's for land reclamation (Klassen, 1980). Sand and gravel found beneath the fine-grained layer is thought to be alluvium deposited by a northward-flowing Nooksack River, or a greatly enlarged Sumas River, following deglaciation of the area (Cameron, 1989).

For the purposes of this study, the Holocene clastic deposits were subdivided into two geologic units--coarse-grained alluvium (Qcal), which includes sand, gravel, and cobbles, and fine-grained alluvium (Qfal), which includes clay and silt. Peat, although Holocene in age, was mapped as a separate geologic unit because it is composed mostly of organic material. The coarse-grained deposits dominate much of the Nooksack River channel, but fine-grained deposits become more prominent in downstream reaches. Fine-grained deposits also dominate most of the Sumas Valley floor (plate 2).

Principal Hydrogeologic Units

In this study, hydrogeologic units were distinguished primarily by their water-bearing characteristics and the geographic extent of the geologic deposit(s) comprising them. Two principle types of hydrogeologic units, aquifers and confining units, were recognized. It is especially important to keep in mind the heterogeneity of the unconsolidated sediments involved in the study area. As a result, the general occurrence and movement of ground water may be influenced locally by small-scale variations in lithology.

Four hydrogeologic units were delineated in the study area. They are, in order of increasing geologic age (1) the Sumas aquifer; (2) the Everson-Vashon unit; (3) the Vashon aquifer; and (4) the bedrock aquifer. The lithologic and hydrologic characteristics of these units are summarized in figure 8.

Sumas Aquifer

The Sumas aquifer is the most productive and most widely used source of ground water in the study area; 413 of the inventoried wells are completed within this unit. The aquifer is composed largely of Sumas stratified sand and gravel outwash (Qso), but also includes alluvium of the Nooksack and Sumas Rivers (Qcal and Qfal), ice-contact deposits (Qsic), lacustrine silt and clay in the Sumas Valley (Qfal), and peat (Qp). The Sumas aquifer is commonly referred to as the Abbotsford aquifer in the lower mainland of British Columbia. On a regional basis, the Sumas aquifer is included with the Fraser aquifer of Vaccaro and others (J. Vaccaro, USGS, written commun., 1993), which includes recessional outwash of the Fraser Glaciation throughout the Puget Sound Lowlands.

Although most of the Sumas aquifer is unconfined, it becomes confined in the Sumas Valley where it is overlain by lacustrine silt and clay. In fact, several wells in the valley flow as a result of artesian conditions that develop during the wet winter months. The hummocky topography along the northwestern margin of the Sumas Valley is a transition zone in the aquifer--with unconfined conditions in the outwash plain on the west and confined conditions in the Sumas Valley floor on the east. Clay lenses within the otherwise coarse-grained outwash can locally perch or confine ground water, as well.

The geometry of the Sumas aquifer is illustrated on the lithologic sections (plate 2) and on the Sumas aquifer thickness map (fig. 9). All surficial coarse-grained materials shown on the sections are part of the Sumas aquifer, although, lenses of clay and deposits of peat can be found locally within the unit. The Sumas aquifer covers nearly all of the study area (see fig. 9) except the northwestern and south-central highlands, along the eastern margin of the study area at the base of Sumas Mountain, and in the lineated topography area northwest of Everson. As illustrated in figure 9, the unit is commonly about 40 to 80 feet thick, but maximum thicknesses exceed 240 feet near Abbotsford. The unit's minimum thickness is along the Nooksack River channel south of Lynden--where the river has eroded all but about 15 feet of the sand and gravel outwash.

Everson-Vashon Unit

The Everson-Vashon unit is composed of (1) thick accumulations of Everson-age glaciomarine drift consisting of unsorted pebbly clay and sandy silt with locally occurring coarse-grained lenses and (2) relatively thin and (or) discontinuous deposits of sand or till encountered at considerable depth. Some of the coarse-grained material encountered deep within the Everson-Vashon unit may be Vashon-age Esperance Sand rather than coarse-grained lenses within the glaciomarine drift. Distinguishing between the two types of coarse-grained deposits, however, was not possible because of their similar lithologies, discontinuous nature, and a paucity of deep-drilling information. Till, which was recorded on several drillers' logs as being directly beneath the glaciomarine drift, is probably Vashon in age. This till was included with the Everson-Vashon unit because of its hydrologic similarities with the fine-grained glaciomarine drift.

Although the bulk of this unit is composed of confining fine-grained material, locally, numerous wells within the unit tap coarse-grained material under confined conditions. Such is the case in the northwestern and south-central highlands where domestic and some public supply wells tap the unit. The productive zones of the Everson-Vashon unit in the south-central part of the field area are believed to be the Deming Sand--the relatively thick (30 feet) interlayer within the glaciomarine drift. The other productive zones are probably small lenses within the glaciomarine drift or, if at considerable depth, the Esperance Sand. One hundred of the inventoried wells are completed in the Everson-Vashon unit.

The glaciomarine drift of the Everson-Vashon unit underlies nearly all of the Sumas aquifer and is found at land surface only in the northwestern and south-central highlands and in the lineated topography area northwest of Everson. As shown in figure 10, the top of the unit ranges from 600 feet above sea level to approximately 120 feet below sea level. The thickness of the Everson-Vashon unit is largely unknown because few wells penetrate it entirely. According to available drilling records, a typical thickness of the unit ranges from 100 to 200 feet.

Water quality in this unit is quite variable. Some deep wells in this unit, located in the central and northern parts of the study area, have been abandoned or destroyed due to poor water quality. Well owners have reported objectionable saltiness in these wells.

Vashon Aquifer

The Vashon aquifer consists of a small band of surficially exposed Vashon-age glacial deposits located in the eastern part of the study area along the flanks of Sumas Mountain. Although Vashon-age deposits were included with the Everson-Vashon unit for most of the study area, they were recognized as a separate hydrogeologic unit in this particular area because of their surficial exposure and greater thickness. Additionally, the Vashon-age deposits included with the Everson-Vashon unit were often encountered well below present-day sea level, whereas the deposits of the Vashon aquifer crop out at altitudes often greater than 200 feet above present-day sea level. The Vashon aquifer consists of poorly sorted till and gravel deposits that yield variable quantities of water. All of the 10 inventoried wells completed in this unit exist under confined conditions. The thickness of this unit is mostly unknown but probably does not exceed 200 feet.

Bedrock Aquifer

The bedrock aquifer consists of sandstone, mudstone, conglomerate, and coal of the Huntingdon and Chuckanut Formations. Although this unit is not highly productive, it yields usuable quantities of water locally. Water yield is controlled chiefly by secondary fracture permeability and, as such, is somewhat unpredictable. Most of the 23 inventoried wells that tap this unit are located in the southeastern part of the study area where bedrock is shallow. Data are largely insufficient to determine if the water occurs under unconfined or confined conditions. Where the bedrock is exposed at or near land surface, the ground water is likely to occur under unconfined conditions; where the bedrock is covered by a significant thickness of glaciomarine drift or till, the ground water is likely to be confined.

Hydraulic Characteristics of Hydrogeologic Units

An estimate of the magnitude and distribution of horizontal hydraulic conductivity of each hydrogeologic unit is helpful in understanding the discharge and availability of ground water within the unit. Hydraulic conductivity is a measure of a hydrogeologic unit's permeability, that is, its ability to transmit water; it is defined as the volume of water that will move in unit time through a unit cross-sectional area under a unit hydraulic gradient. For unconsolidated materials, hydraulic conductivity depends on the size, shape, and arrangement of the particles. Because these characteristics are highly variable within the glacial deposits of the study area, hydraulic conductivity values can also be expected to be highly variable. Hydraulic conductivity data were statistically summarized so that medians and ranges between hydrogeologic units could be determined. A summary of hydraulic-conductivity data by hydrogeologic unit is presented in table _. Individual values of hydraulic conductivity can be found in appendix _.

With the exception of the Everson-Vashon unit, the hydraulic conductivities are as expected. The median hydraulic conductivities for the Sumas and Vashon aquifers are 1,960 and 391 gal/day/ft^2 (gallons per day per foot squared), respectively (table _). The median hydraulic conductivity of the Sumas aquifer is the largest of any unit in the study area and its maximum observed value of 58,200 gal/day/ft^2 is four times larger than the maximum of any other unit.

The median hydraulic conductivity of 602 gal/day/ft^2 for the Everson-Vashon unit is somewhat surprising because it is, for the most part, a confining bed. The lowest median hydraulic conductivity (4.13 gal/day/ft^2) was found in the bedrock aquifer. Because ground water occurs primarily in the fractures of bedrock, this would imply that the bedrock aquifer generally is not fractured enough in the study area to produce large quantities of water.

The unexpectedly large median hydraulic conductivity of the Everson-Vashon unit is likely due to the presence of zones or lenses of coarse-grained material, as described previously. It is reasonable to expect that successful wells were completed in these more productive parts of the unit, and that wells completed in less-permeable zones have either been subsequently abandoned or may not have produced enough water for a pump test to be practical. As a result, the data are biased toward the more productive zones in the unit and are not representative of the unit as a whole. This bias probably occurs for all of the units in varying amounts, depending upon the heterogeneity of the unit, and, as a result, all of the median hydraulic conductivity values may be high. Because the Everson-Vashon unit is probably the most heterogeneous of the units, the bias is probably the highest for it. An examination of the minimum hydraulic conductivities for the hydrogeologic units illustrates that there are indeed poorly producing wells in each unit. Also, the range of hydraulic conductivities is at least three orders of magnitude for most units, indicating a substantial amount of heterogeneity.

Laboratory derived values of horizontal hydraulic conductivity for clayey silt of the Everson glaciomarine drift ranged from 0.02 to 2.12 gal/day/ft^2 according to a site assessment of the Cedarville Landfill, which is located in the southeastern part of the study area (Harding Lawson Associates, 1990). Hydraulic conductivity values for sand lenses within the glaciomarine drift were several orders of magnitude higher, again illustrating the heterogeneity of the deposit. Values of vertical hydraulic conductivity for the clayey silt were four orders of magnitude smaller than the horizontal hydraulic conductivity values for the same material. Such differences between horizontal and vertical hydraulic conductivities are commonly observed.

Horizontal hydraulic conductivity values for the Sumas aquifer were plotted to determine if an areal pattern of lower or higher values exists. Although both high and low values are found throughout the unit, a weak geographic trend exists with high values near the International border and lower values toward the southwestern part of the study area. This trend is probably due to decreasing grain size in the Sumas outwash plain, discussed earlier. In support of this theory, high hydraulic conductivity values are noticeably absent on the southern margins of the Sumas outwash plain south of the Nooksack River. Another apparent trend, a north-south band of generally high values, exists in the easternmost part of the study area in the alluvial valleys occupied by the Sumas River and the upper reaches of the Nooksack River. This area is characterized by well-sorted coarse-grained material. Much of the lower mainland of British Columbia and the Nooksack River flood plain west of Everson had no specific capacity data available. This lack of data precluded the construction of a map of horizontal hydraulic conductivity for the Sumas aquifer.

Ground-Water Flow System

The ground-water flow system describes the movement of water within the ground-water system, which includes the movement of water into and out of the ground-water system as well as the movement of water within and between individual hydrogeologic units. The general movement of ground water is from recharge areas in the uplands, to discharge areas at lower altitudes. The route traveled by ground water, referred to as the ground-water flow path, can range from local flow paths that are generally short and shallow to regional flow paths that cover great distance and go deep into the ground-water system. With respect to water quality, the flow system is important because ground water continually interacts chemically with the geologic material that makes up the aquifers.

Information on the ground-water flow system was derived primarily from water-level data from wells throughout the study area. These data were used to construct the water-level contour map shown on plate 3. Difference in water levels in closely spaced wells of different depths provided limited information on the vertical direction of ground-water movement. Seasonal variations in ground-water levels were determined from monthly water-level measurements. A vertical two-dimensional flow model, constructed as part of the Puget Sound Regional Aquifer study, provided information on the rate of ground-water movement along a flow path from the Abbotsford Airport to the Nooksack River at Lynden.

Water-Level Distribution and Movement of Ground Water

Water-level data, mostly from the Sumas aquifer and partly from the Everson-Vashon unit, were combined so that a continuous water-level map could be drawn for most of the study area. Water levels measured in wells within the Everson-Vashon unit, where it is exposed around the upland margins of the Sumas aquifer, were included in the construction of this map. Even though confined conditions exist within the productive coarse-grained lenses of the Everson-Vashon unit, water levels measured in wells in the upland margins represent the unit's water table--analogous to the water table of the Sumas aquifer. Ground water within the Everson-Vashon unit is believed to flow laterally from the uplands into the Sumas aquifer.

The water-level contours shown on plate 3 reflect regional water-table conditions in all areas except parts of the Sumas Valley, where the fine-grained alluvium--lacustrine silt and clay--overlying much of the valley floor have created confined conditions. In the Sumas Valley, there is widespread occurrence of water levels higher than the top of the Sumas aquifer, resulting in numerous wells being under artesian and even flowing conditions.

The general direction of ground-water flow can be inferred from the contours on plate 3, which show the configuration of water levels throughout the study area. The movement of ground water is generally perpendicular to the contours. The general pattern of ground-water flow in the study area is toward the Nooksack or Sumas Rivers, which are the primary ground-water discharge areas. Smaller scale flow patterns can be seen near creeks that also act as ground-water discharge areas. On a local scale, which is not readily apparent on plate 3, ground water can flow toward drainage ditches and buried tile drains. This type of flow, however, occurs on a small scale as compared to the regional ground-water flow directions.

Hydraulic gradient is the difference in water-level altitude between two locations and is an expression of the driving force that enables the movement of ground water. Lateral hydraulic gradients determined from the water-level contours shown on plate 3 are commonly 15 feet per mile, but range from about 5 to 100 feet per mile, within the Sumas aquifer. In the Everson-Vashon unit, lateral hydraulic gradients are often about 35 feet per mile, but range from 10 to 100 feet per mile. The lower hydraulic conductivity of the Everson-Vashon unit, discussed in a previous section of this report, requires larger hydraulic gradients to move similar quantities of ground water. Topography also plays a large role in variations of hydraulic gradients and is the primary cause of the variations observed within each unit.

Water-Level Fluctuations

Fluctuations of water levels in wells within the study area are caused largely by changing recharge/discharge relations. Precipitation is the main source of ground-water recharge, and the bulk of recharge occurs during the period November to April. In general, high precipitation leads to higher recharge, which in turn leads to higher ground-water levels. The opposite is generally true with low precipitation--lower recharge leading to lower ground-water levels.

The relation between precipitation and ground-water levels can be seen in figure 11, which compares average monthly precipitation (fig. 11a) to ground-water levels (fig. 11d) in well 40N/04E-05D01 from 1945 to 1976. During that period, the mean-monthly precipitation was 3.96 inches. The actual monthly precipitation compared to the 31-year average is the monthly precipitation departure (fig. 11b), and a running total of the monthly departures results in cumulative precipitation departure (fig. 11c) from the mean precipitation rate. The cumulative precipitation departure curve shows significant precipitation deficits during 1949, 1952, 1958, 1963, 1970, and

1973. Water levels were noticably lower during the months following low-precipitation periods, except for 1963 where water-level data are incomplete. Corresponding high water table periods are not as noticable following periods of precipitation excess, possibly because higher ground-water levels lead to higher discharge rates, thereby preventing large rises of the water table.

Water-level fluctuations are shown in the hydrographs plotted on plate 3 and summarized in table 2. The largest seasonal fluctuations, which can be as much as 14 feet per year, were observed in shallow water-table wells. Within the Sumas aquifer, observed seasonal variations in water-table wells ranged from 4 to 12 feet, with most wells experiencing about 7 feet of water-level variation. Smaller seasonal variations were observed in wells tapping confined or bedrock hydrogeologic units.

Long-term (greater than 10 years) water-level data are available for only a few wells, most of which are located in the Canadian portion of the study area. In general, the water-table altitude appears to be stable with respect to long-term trends.

Recharge and Discharge

The ground-water system of the LENS area is a dynamic one in which ground water is constantly being added or removed from hydrogeologic units of different hydrologic characteristics. Quantitative estimates of recharge throughout the study area are beyond the scope of this study. However, characterization of the factors that control recharge and discharge processes in the context with the physical features found in the study area should provide insight on how these processes affect ground-water supplies in the study area.

Recharge to the ground-water system of the study area is due largely to infiltration of precipitation. Smaller amounts of recharge are derived from losing reaches of streams and other waterways, irrigation of croplands and lawns, and leachate from septic systems. Recharge occurs to some degree over all of the LENS area with the possible exceptions of areas of perennial ground-water discharge, and impervious surfaces such as asphalt and concrete.

The principal hydrologic factors that control recharge are (1) precipitation, which varies in both space and time; (2) surficial geology and topography, which is spacially variable; and (3) evapotranspiration, which is temporally variable. Thus the rate of recharge also varies in both space and time, and some areas can, at different times of the year, either recharge or discharge water from the ground-water system. Variations in precipitation within the study area are shown in figure 4. Computed potential evapotranspiration (WSB 12) for the Clearbrook weather station ranges from 0.5 inches per month in January to 4.4 inches per month in July. Easterbrook (1973) lists percolation rates for the Sumas outwash as 0.37 to 17.8 minutes per inch and for the Everson glaciomarine drift as 80 to 280 minutes per inch. These percolation rates are useful as indicators of rates of recharge--rapid recharge occurs in the coarse-grained outwash and slow recharge occurs in the fine-grained glaciomarine drift.

Ground-water discharge occurs as seepage to rivers, lakes, and streams; spring flow, transpiration by plants, evaporation, artificial drainage, and withdrawals from wells. The area where ground water discharges is smaller than the area in which recharge occurs. Ground-water discharge areas are generally immediately adjacent to the receiving surface-water body. Additional ground-water discharge occurs in low-lying marsh and bog areas, such as near Pangborn, Green, Fountain, and Wiser Lakes. Most of the marshy and boggy areas have been artificially drained using either surface drainage ditches or buried tile drain. Flow in these drainage systems occurs primarily during the wet winter and early spring, and will stop once the water table has declined below the level of the drain. When the water table drops below the level of the drainage feature, excess infiltration will recharge the ground-water system.

Conceptual Model of the Ground-Water System

This section of the report presents a simplified conceptual model of the study area's ground-water system, focusing on topics particularly relevant to the subsequent section on water quality. A conceptual model of the ground-water system in the LENS and adjoining area is shown in figure 12. The LENS area can be characterized as a broad expanse of glacial deposits filling a topographic depression that is bounded by uplands on all sides, except where the channels of the Nooksack and Sumas Rivers allow the area to drain. The area is generally low lying, within several hundred feet of sea level; consequently, deep wells often draw ground water from altitudes below sea level.

The ground-water system within the LENS area is comprised of a sequence of glacial deposits that overlie bedrock. The bedrock is composed of fractured consolidated continental sediments that form a low-yielding aquifer. The glacial deposits consist primarily of either fine-grained, low permeability sediments or coarse-grained permeable sediments. The oldest glacial sediments in the study area, which are generally found at depths below sea level, are undifferentiated Vashon and pre-Vashon deposits. Generally, they are not an important source of ground water. Overlying these sediments is the predominately fine-grained, low-permeability Everson glaciomarine drift that underlies virtually all of the study area. The glaciomarine drift acts as a confining unit except where lenses of more permeable sands produce sufficient water for low-yield wells. Surficially exposed glacial outwash comprises the most extensively used aquifer in the study area. Interspersed within the surficial outwash are localized lenses of fine-grained sediment that creates localized zones of confined conditions. The outwash is absent from much of the upland areas that occur along the boundaries of the study area. In these areas, the glaciomarine drift is an important source of ground water where the more permeable outwash is not present.

Precipitation falls on the area and infiltrates past the plant root zone becoming recharge to the ground-water system. Ground water in the upland areas such as the Cascade Range and Boundary Uplands, moves vertically downward and laterally to discharge points. At depth, ground-water flow is mostly lateral, toward the Nooksack River, where the flow is mostly upward.

The Nooksack River is the regional ground-water discharge zone within the study area. Local ground-water discharge also occurs, generally along streams, in low-lying boggy areas, and in areas that have been artificially drained. Ground water withdrawn from wells and springs for domestic and irrigation purposes is a form of artificial discharge.

The movement of ground water within the fine-grained glacial deposits is slow. In several areas within the fine-grained deposits, seawater that was trapped within these sediments during deposition has not been completely flushed. By comparison, ground-water movement within the coarse-grained glacial outwash is rapid.

QUALITY OF GROUND-WATER

Water quality refers to the chemical and biological characteristics of water. Because water is an excellent solvent, all natural waters contain some level of dissolved materials. Chemical analysis of waters are the primary gauge of water quality. Water quality parameters examined in this study include numerous chemical species dissolved in water and general physical properties such as temperature and electrical conductance.

The quality of ground waters in large part reflect the water quality of the recharge source, the surrounding aquifer material along the flow path within the aquifer (described in the previous section) and the length of time ground water has been in contact with the aquifer material. While the interactions of ground water with aquifer material can be complex and site specific, several general patterns of changing water quality are apparent. There is a tendency for the overall concentration of many constituents to increase with increased contact with soil and rock particles resulting in large concentrations along flow paths. On the other hand, there are some water-quality constituents such as oxygen and hydrogen that react with aquifer material and are removed from ground water resulting in declining concentration along the flow path. A more detailed discussion on factors afecting water quality are provided by Johnston (1988).

Ground water within the study area originates largely as precipitation or deep percolation from irrigation. Water infiltrates through and reacts with the soil and unsaturated zone before entering the ground-water system. The chemistry of rain water is dilute, however all the common water-quality constituents found in ground waters of the study area are present in small concentrations in precipitation samples collected within the Puget Sound region and adjoining National Atmospheric Deposition Program (1991) (Laird and others, 1986). Irrigation is believed to make up only a small fraction of the recharge water, however because the source of most irrigation water is ground water, the chemistry of irrigation water is more concentrated and may have a larger impact on ground-water quality than precipitation.

In this section, the quality of the ground water in the study area is described on the basis of the results of chemical analyses of water samples. Water samples collected for this study include 308 reconnaisance samples and 125 samples collected for detailed chemical analysis. Additional data from other agencies has also been included where appropriate. Chemical concentrations and characteristics are discussed and related to geographic area and hydrogeologic unit. Areal distribution of nitrate, chloride, and iron are discussed. Temporal variations of nitrate and other constituents are also discussed. The subsequent chapter will address potential sources of nitrate in ground water.

It should be noted that for many constituents, some concentrations may be reported as "less than" (<) a given value, where the value given is the detection limit of the analytical method. For example, the concentrations of many organic compounds are reported at <0.2 μg/L (micrograms per liter) where the detection limit is 0.2 μg/L. The correct interpretation of such concentrations is that the constituent was not detected at or above that particular concentration. The constituent could be present at a lower concentration, such as 0.1 μg/L, or it may not be present at all, but that is impossible to tell with the analytical method used.

General Water Quality

Most of the data that describe the quality of the ground water are presented statistically in summary tables. Table __ presents the minimum, median, and maximum values of the common constituents determined for each of the hydrogeologic units; table __ shows median values for each of the common constituents by hydrogeologic unit. Similar summary tables are presented for other constituents and chemicals, as needed for the discussion. Relative cumulative frequency and diagrams are used to show the distribution of sample concentrations. All supporting basic data are presented in appendix __.

The distribution of nitrate and chloride concentrations within the Sumas aquifer and Everson-Vashon unit was analyzed and divided into four concentration classes; natural background, slightly elevated, moderately elevated, and significantly elevated. The range of background concentrations was estimated from water-quality data obtained from wells in nonagricultural and sparsely populated areas. Concentrations above U.S. Environmental Protection Agency's (EPA) drinking water guidelines were considered significantly elevated. The ranges of concentrations for the slightly and moderately elevated concentration classes were determined from distribution of the data.

Because nearly all of the sampled wells in the Sumas aquifer are located in areas that are either developed or used for agricultural purposes, water-quality data from wells located outside the study area were used to estimate the range of natural background concentrations in a shallow, highly permeable aquifer. Data from 28 wells tapping a glacial aquifer with similar hydrogeologic properties and located in a non-agricultural and sparsely populated part of Thurston County were used to estimate the range of natural background concentrations of nitrate and chloride in a shallow-permeable unconfined aquifer in glacial outwash deposits of the Puget Sound. Water-quality samples from these wells are believed to be unaffected by land-use activities, however, because most of the wells were installed as domestic water sources for homes with accompanying septic systems, there is some potential for some elevated concentrations resulting from the land-use activities. The range of nitrate and chloride concentrations in these wells was from less than 0.1 to 2.0 mg/L for nitrate and 1.8 to 3.6 mg/L for chloride. For this study, the estimate of the upper range of background concentrations is assumed to be 3.0 mg/L for nitrate and 4.0 mg/L for chloride.

Specific Conductance, Dissolved Solids, pH, and Dissolved Oxygen

Specific conductance samples were collected during the well inventory as a reconnaissance of ground-water quality throughout the study area. Specific conductance is a general indicator of the magnitude of dissolved material in water. The presence in water of dissolved species that possess electrical charge impart the capacity for conducting electrical current. As the concentration of charged dissolved species increases, so does the electrical conductance. Because of this relation, electrical conductance is a good indication of the level of dissolved material in solution. The electrical conductance of solutions also will vary with temperature; consequently, measurements of electrical conductance are reported at a standard temperature of 25°C, which is referred to as specific electrical conductance, commonly shortened to just specific conductance. The unit of measurement for specific conductance is microsiemens per centimeter (µs/cm), which is equivalent to the older unit of micromhos per centimeter.

The values of the 308 reconnaissance samples analyzed for specific conductance without regard to the hydrogeologic unit from which the ground water was obtained ranged from 70 to 4,025, and had a median of 258. For comparison, median values of specific conductance observed in the 12 Puget Sound counties in 1983 ranged from 113 to 950 (Turney, 1984). After hydrogeologic units had been assigned to wells based on lithologic data, median values of specific conductance within the four hydrogeologic units were Qso 233, Qev 309, Qv 430, and Thc 753 (table ____). These data suggest that there is a trend toward increased dissolved material within older hydrogeologic units.

Dissolved Solids

The concentration of dissolved solids is the total concentration of all the minerals dissolved in the water. The major components of dissolved solids depend on many factors, but usually include calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, nitrate, and silica. Other constituents, such as carbonate and fluoride, or metals such as iron and manganese, are also components, but are rarely found in large enough concentrations to make a significant difference in comparison with the major components.

Dissolved-solids concentrations ranged from 28 to 1,140 mg/L, with a median concentration of 112 mg/L, and the concentrations tended to be larger in the lower units. The median concentration in Qso was 93 mg/L, and there was a general increase to Tb, where the median concentration was 128 mg/L. Some of this variation is undoubtedly due to different types of aquifer material and water, but likely some is due to increased residence time of water in the lower units. Water that has been in the ground for a longer time generally has had the opportunity to dissolve more minerals than water with a shorter residence time.

The pH is a measure of the acidity or basicity of a substance and is actually a measure of the concentration of hydrogen ion. In water, pH is gauged on a scale from 0 to 14. A pH of 7.0 is considered neutral and is the pH of pure water at $25^{o}C$; smaller values are acidic and larger values are basic. The scale is logarithmic; therefore, a pH of 6.0 indicates that a water is 10 times as acidic as water with a pH of 7.0. The EPA has established a secondary drinking water standard range for pH of 6.5 to 8.5. Most ground waters within the Puget Sound region have pH values ranging from about 6.0 to

8.5. A common reaction of ground water with the encompassing aquifer material is the consumption of hydrogen ion, which causes the ground water to become more basic.

The pH values of all samples collected as part of this study ranged from 5.8 to 8.8 (table __) and the median was 6.9. The median pH by aquifer increased steadily from 6.5 in Qso to 8.5 in Th and TKc (table _). The variation in pH values is natural and due largely to alterations of the chemical composition of ground water by chemical reactions of the ground water with minerals in the aquifer material.

Dissolved-oxygen concentrations are useful in determining the types of chemical reactions that can occur in water. Small dissolved-oxygen concentrations indicate that a chemically reducing reaction can occur, and large concentrations indicate that a chemically oxidizing reaction can occur. Nitrate in the oxidized form of nitrogen generally is not present in ground waters devoid of dissolved oxygen.

Normally, the only source of oxygen is ground water from atmospheric gas that is dissolved in recharge water. Oxygen will react with organic water which is common in several of the hydrogeologic units of the LENS area.

Dissolved-oxygen concentrations ranged from 0.0 to 12.9 mg/L, and the overall median concentration was 2.8 mg/L. Median concentrations varied considerably by units, being largest in Qso (4.3 mg/L) and smallest in TKb (0.1 mg/L) as shown in table 7. Ground water from all hydrogeologic units had dissolved-oxygen concentrations at or near 0.0 mg/L; however, only the Qso had dissolved-oxygen concentrations above 7.0 mg/L. Much of this variation is natural and is due to reactions between the water and minerals or the water and organic matter.

Hydrogen ions are commonly consumed in reactions with rock matrix of the aquifer resulting in larger pH values in ground water with larger flow paths or longer contact time with aquifer matrix.

Depth	Nest A	Nest B	Nest C
15-25	6.1	6.1	6.3
35	6.2	6.2	6.3
55	7.2	7.1	6.9
75	7.9	7.8	7.6

This pattern can be explained as the result of carbon dioxide from the plant root zones and the atmosphere being dissolved into recharge water and excreting carbonic acid, which is subsequently consumed by reaction with aquifer material along the ground-water flow path. Ground water from long flow paths such as those in the bedrock aquifer will have much less acidity than ground waters near recharge areas. Acidity in the Th and TKc (median pH 8.5) is only one percent of acidity in the Qso (median pH 6.5).

Major Ions

The dissolved material in ground water can be composed of numerous chemical species, however, in general over 95 percent of all the dissolved solids is composed of 8 to 10 individual chemical species that are collectively referred to as the major ions. Ions possess either positive or negative electrical charge; cations are positive charges and anions are negatively charged. Major cations normally present in ground water are calcium, magnesium, sodium, and potassium; major anions are bicarbonate, chloride, sulfate, fluoride, and in some ground waters including many from the LENS area, nitrate is present in large enough concentration to be considered a major anion. Silica, which is an uncharged molecule, is included in discussions of major ions because it is the only uncharged major component of dissolved matter in ground waters.

The concentration observed in ground-water samples from the LENS area are plotted on cumulative frequency distribution plots (plate 6) and summarized in tables ______, which contain the median concentration of ions by individual hydrogeologic unit. The cumulative frequency distribution plots the entire range of sample values and shows the percentage of samples that are equal to or less than a particular value. For example, the maximum concentration will plot at 100 percent and median value at 50 percent. Samples are plotted by hydrogeologic unit to show variation in water chemistry by hydrogeologic unit. The frequency distribution plots also show relative contribution of individual ions, major cations, and anions. For all ions except Cl and NO_3, the number of samples is 126; the number of chloride and nitrate samples is ____ and ____, respectively.

Examination of plate 6 and table ____ indicates that calcium and sodium are the predominant cations. The calcium concentration is larger in ground water from the Sumas aquifer while sodium has the larger concentration in ground waters from the Everson-Vashon unit and the bedrock aquifer, and to a lesser degree the Vashon aquifer. In the Sumas aquifer the median calcium concentration was 22 mg/L followed by magnesium (6.9 mg/L) and sodium (6.0 mg/L). This concentration is typical of ground water in the Puget Sound region that is derived from unconsolidated deposit located away from coastal areas (Turney, 1986). The high sodium ground waters from the Everson-Vashon unit and the bedrock aquifer show simularities to ground waters affected by seawater (Turney, 1986; and Dion and Sumioka, 1989).

Bicarbonate is the predominant anion except in several cases where exceptionally large chloride concentrations occur. Nearly all of the ground-water samples with the concentration of bicarbonate smaller than the overall median concentration of 79 mg/L are in ground waters from the Sumas auifer, the larger bicarbonate concentrations are found in ground water from the bedrock aquifer and the Everson-Vashon unit.

The concentration of nitrate and chloride ions shows a large range covering these and four orders of magnitude, respectively. The large number of nitrate samples plotted at 0.1 mg/L reflect an analytical reporting level for analysis less than the detection limit.

The hardness of ground water in the LENS area is classified predominately as soft to moderately hard, following the scheme of Hem (1989).

Description	Hardness range (milligrams per liter of $CaCO_3$)	Number of samples	Percentage of samples
Soft	0-60	229	64
Moderately hard	61-120	108	30
Hard	121-180	10	3
Very hard	Greater than 180	12	3
		359	100

Hardness is a function of calcium and magnesium concentrations; and it is interesting to note that the ground water from the bedrock aquifer has the lowest hardness. The most familiar effect of increased hardness is a decreased production of soap lather and encrusting deposits produced when water is heated.

Trace Elements

A reconnaissance of trace element concentrations in ground water was conducted using existing data and analyses of additional water samples. Over all, concentrations of most trace elements are generally small in ground water from glacial deposits; however, larger concentrations of some trace elements are present in ground waters from the bedrock aquifer. Iron and manganese, which are present in large concentrations at many locations within the study area, are discussed in a separate section.

The trace element concentration data for water samples collected during this investigation, plus current and historic trace element data from wells sampled by the British Columbia Ministry of Environment, are present in tables __ and __. The data included in table __ contain analyses with varying detection levels. All of the detection levels are below EPA's reference levels with the exception of two historical analyses for arsenic, which had detection levels of 250 µg/L. Excluding the two samples with a detection level of 250 µg/L, the median and maximum arsenic concentrations of the remaining 25 samples are <1 µg/L and 6 µg/L, respectively. The sample with the arsenic concentration of 6 µg/L was from a well in the Vashon aquifer that is believed to produce ground water containing some residual seawater, which would indicate long residence time within the aquifer. Arsenic has been found at concentrations of 6 and 12 µg/L in ground water from older glacial deposits in East King County (Gary Turney, USGS, written commun., 1993).

With the exception of zinc, which can often be an artifact of plumbing within a well, barium is the most ubiquitous trace element found in ground-water samples collected for this study. In those samples, barium concentrations ranged from 4 to 1,100 µg/L with a median concentration of 12 µg/L. The larger barium concentrations were generally found in wells believed to be tapping ground water with longer flow paths; such as wells with the bedrock aquifer or well 40N/4E-09N03, which is the confined portion of the Sumas aquifer.

Zinc and copper were present in most samples, and the concentrations were variable. This is not surprising because most wells sampled were domestic wells that can contain copper and galvanized pipes from which copper and zinc can be readily leached, especially if the water is slightly acidic or low in dissolved-solids concentrations, as in much of the ground water in the LENS area. Concentrations of copper and zinc were all significantly below applicable drinking water reference levels.

Strontium was present in all six samples for which it was analyzed. Strontium is a common replacement element for calcium in rock-forming minerals and its presence in ground water is common, although concentrations are generally less than 200 µg/L (Skougstad and Horn, 1963).

The remaining trace elements that were analyzed for were rarely present, and if present, were at concentrations that were not significant in terms of drinking water standards. Silver was present in nine samples at concentrations of 1 to 2 µg/L. Molybdenum was detected in three samples between 10 to 40 µg/L. Cadmium, lead, and lithium were detected in two samples and chromium and selenium were detected in only one sample. Vanadium, cobalt, and beryllium were not detected.

Additional data on trace element concentrations were found in Ericson (1990), Harding Lawson Associates (1992), Washington Department of Ecology (Unpublished data, Dave Garland, written commun., 1992), and the Washington Department of Health drinking water data base. Ericson's data are for six wells near Bertrand Creek and are consistent with those presented here, with the exception of a single lead concentration of 50 µg/L, which was not detected in the follow-up sample. The data in the HLA report are site specific and deal exclusively with the area around the Cederville Landfill. Some of the monitoring wells within the Cederville Landfill are reported to contain large concentrations of some trace elements; however, the large concentrations were not seen in monitoring wells downgradient of the landfill.

Organic Compounds

Organic chemicals have been detected in at least 30 wells within the study area. Although the concentrations of most organic compounds in ground water are generally small with respect to drinking water guidelines, concentrations of the most commonly detected compounds, 1,2-dichloropropane and ethylene dibromide, generally exceeded drinking water guidelines. The presence of synthetic organic compounds in ground waters of the Sumas aquifer confirms the aquifer's vulnerability and that parts of the aquifer have already been contaminated by anthropogenic activities.

A reconnaissance for the presence of organic compounds in ground waters of the Sumas aquifer was conducted using existing data and the analyses of 24 water samples collected for this study. Existing data that is available is generally focused on three subareas within the LENS study area and much of the analyses are for a limited group of organic compounds. The 24 water samples collected for this study were collected from wells located throughout the study area and were analyzed for 63 organic compounds. These samples were collected to provide a broad view of the presence of organic chemicals in ground waters of the Sumas aquifer. The location of the wells sampled for organic compounds are shown in figure 13.

The water samples for this study were analyzed for selected compounds from 3 classes of organic chemicals, including 41 volatile organic compounds, 12 triazine or nitrogen containing herbicides, and 10 carbonate insecticides or metabolites. The volatile organic compound scan includes the soil fumigant dibromomethane commonly referred to as ethylene dibromide or EDB, 1,2-dichloropropane, 1,3-dichloropropene, and 1,2-dibromochloropropane.

Of the 24 wells for which samples were collected, organic compounds were detected in ground water from 3 wells. A total of five compounds were detected; four volatile organics including EDB and 1,2-DCP and one carbonate insecticide, oxamyl. The concentrations of these five compounds within ground water from the three wells are shown below:

	EDB 1,2-di-bromo-ethane µg/L	1,2-DCP 1,2-di-chloro-propane µg/L	1,3-di-chloro-propane µg/L	1,2,3-tri-chloro-propane µg/L	Oxamyl µg/L
39N/02E-01P02	<0.2	1.6	<0.2	<0.2	<0.5
	<.2	2.8	<.2	<.2	<.5
40N/02E-27B01	.3	5.6	.2	1.4	<.5
	.3	5.6	.2	1.2	<.5
0926.009.1.1.2-7	<.2	<.2	<.2	<.2	.5

Previous studies have detected organic compounds in at least 40 wells. Most of the studies focus on the presence of EDB in ground water of two areas near Lynden (see fig. 13). EDB was detected in at least eight different wells within these areas. Ericson (1990) sampled 27 wells within the subarea west of Lynden for the presence of more than 40 different organic compounds that are used in agricultural application. Ericson (1990) detected five organic compounds including nine occurrences of 1,2-dichloropropane, two occurrences of EDB and prometon, and single occurrences of carbofuran and dibromochloropropane. Environment Canada has been sampling ground water from the Abbotsford aquifer (Sumas aquifer) for the presence of pesticides since

1984. The results of their sampling through 1990 (Liebscher and others, 1992) includes the occurrence of 11 different organic compounds detected in at least 30 different wells. The most commonly found compound is 1,2-DCP, which was detected in 27 wells followed by atrizine in 13 wells and dinoseb and simizine in 11 wells each and diazinon in 7 wells.

Table __ summarizes all synthetic organic compounds that have been detected in ground waters from the LENS area.

Most of the compounds listed in table __ are associated with agricultural activity; however, general compounds including diazinon and prometon are also associated with products sold for home use. Many of the detected compounds, including EDB, 1,2-DCP, dinoseb, and alachlor are not currently registered for use as pesticides in either the United States or Canada, although 1,2-DCP may be present at low concentrations as an inactive ingredient in fumigants composed of 1,3-dichloropropene. The presence of these compounds, particularly EDB, in recent ground-water samples is believed to represent historical use. Time series analyses consisting of six to eight analyses of EDB over the period of April 1984 to September 1988 in two wells near Lynden by Sweet-Edwards showed a consistent pattern of decreasing EDB concentrations.

Distribution of Nitrate and other Nitrogen Compounds

Nitrate is one of several forms of nitrogen that are present in ground waters of the LENS area. Nitrate is of concern because elevated concentration and the associated implication of ground-water contamination are common in several parts of the study area. This section of the report describes the distribution of nitrate and other forms of nitrogen in ground water of the study area, the relation between nitrate and the ground-water flow system, and temporal variations of nitrate concentration in ground water. Although potential sources of nitrate are mentioned in this discussion of the distribution of nitrate and other nitrogen species, a more detailed evaluation of potential nitrate sources is given in a latter section, a brief discussion of the different forms of nitrogen and the chemical transformation between nitrogen forms is presented in the supplemental data and information section.

Nitrate, the most oxidized form of nitrogen, is the most common form of nitrogen found in ground waters of the study area. Other forms of nitrogen include ammonia, organic nitrogen, and nitrite. Nitrite, which is chemically unstable, was rarely found in ground waters above its detection level of 0.01 mg/L. Ammonia and organic nitrogen were present in small concentrations in some ground waters.

The concentration of nitrate in ground waters of the study area is variable, observed concentrations range from less than 0.1 mg/L to 43 mg/L and have been reported as high as 98 mg/L (Ericson, 1992). The nitrate concentrations in 19 percent of the wells sampled equalled or exceeded the primary drinking water guideline of 10 mg/L established by both the EPA and Canada Health and Welfare. Throughout the Puget Sound Region, Turney (1986) reported nitrate concentrations exceeding 10 mg/L in less than 3 percent of __ wells sampled in 1981.

The distribution of nitrate in ground waters of the study area is shown on plate 4 and represents concentrations of 568 samples collected from 386 wells between March 1990 and December 1992. Most of the nitrate concentrations on plate 4 are from single samples collected during the well inventory period, March 1990 to August 1990. If two or more samples were collected from the same well, such as the monthly observation wells, the concentration plotted on plate 4 is the arithmetic mean of the individual samples.

The hydrogeologic unit of the well from which the sample was taken is shown on plate 4. Of the four hydrogeologic units, the largest nitrate concentrations, as well as the largest range in concentrations, were found in the Sumas aquifer (see tables 6 through 9). Ground waters with nitrate concentrations below 0.1 mg/L were observed in all hydrogeologic units except the bedrock aquifer for which only six samples were available. Of the 60 wells that had nitrate concentrations that equalled or exceeded 10 mg/L, 59 of those wells produced water from the Sumas aquifer.

Nitrate concentrations have been divided into four concentration classes; less than 0.1 mg/L, indicating little or no nitrate present; 0.1 to 3.9 mg/L, the expected range of naturally occurring nitrate concentrations; 4.0 to 9.9 mg/L, nitrate present at concentrations less than the drinking water maximum contaminant level but above expected range of naturally occurring nitrate in ground water; and equal or greater than 10 mg/L, the maximum contaminant level in drinking water. Listed below for each of the four hydrogeologic units are the number of samples and the percentage of wells sampled with nitrate concentrations in each of the nitrate concentration classes.

	Sumas aquifer	Everson Interglacial confining unit	Vashon Drift	Tertiary Bedrock Aquifer
Less than 0.1 mg/L	28(10)	49(62)	(50)	(0)
0.1 to 3.9 mg/L	75(33)	25(35)	(25)	(85)
4.0 to 9.9 mg/L	76(33)	4(2)	(0)	(15)
greater than 10 mg/L	59(27)	1(1)	(25)	(0)
Total number of samples	236	100	4	(6)

Because there are no large areas within the study area that are undeveloped for either agriculture or residential use, data for determining the range of naturally occurring nitrate level were obtained from undeveloped areas of southwestern Thurston and eastern King Counties, with similar geologic setting (N. Dion, written commun., 1993; G. Turney, USGS, written commun., 1993).

The areal distribution of nitrate concentrations divided into four concentration classes is shown in figure 14. Wells with nitrate concentrations less than 0.1 mg/L and between 0.1 mg/L and 2.9 mg/L are found throughout the study area, but are concentrated in southern and northwestern portions of the study area where the Sumas aquifer is absent and the Everson-Vashon unit is exposed at the surface. The median nitrate concentration in the Everson unit is less than 2.1 mg/L. Almost without exception the wells in the large concentration classes are located within the Sumas aquifer; however within the Sumas aquifer, wells with large and small nitrate concentrations are unevenly distributed. Four areas with large nitrate concentrations are particularly noticeable. The largest of these is the transboundary area between the Aldergrove crossing and the town of Sumas. Within this area more than 25 wells had nitrate concentrations greater than 10 mg/L including the well with the largest nitrate concentration of 43 mg/L. Other areas where nitrate concentrations in ground water were commonly larger than 10 mg/L are the lower Bertrand Creek area, the Wiser Lake area, and the West Smith Road area. The area east of Lynden near the Mayfield area, which includes the Mayfield EDB study area of Black and Vetch, had nitrate concentrations that routinely were between 3 and 10 mg/L with several wells having concentrations greater than 10 mg/L. Large concentrations of NO_3 are noticeably absent from the Sumas Valley area, the Everson area, and the area northwest of Lynden.

The concentration of nitrate in ground water and the depth below land surface show a weak inverse relation. Figure 15 is a plot of nitrate concentrations and the depth of the open interval of the well from which the sample was taken. Small nitrate concentrations less than 1 mg/L are found at all depth, however large concentrations, particularly concentrations that exceed 10 mg/L, are in much greater numbers in the shallow wells. The pattern of generally decreasing nitrate concentration with depth is also seen in water samples from three sets of nested piezometers located near the Abbotsford Airport. The nitrate concentrations in these wells are shown below.

Nitrate concentration in piezometer near Abbotsford Airport

Depth	Site A	Site B	Site C
20 to 25	18	11.	5.9
35	21	19.	5.5
55	6.9	2.7	4.6
75	1.2	2.0	5.0

The distribution of nitrate with depth is related to the presence of both a source of nitrates at the surface, vertical ground-water flow, and the presence or absence of clay or silt layers that retard downward movement and can create localized zones of anoxic conditions where denitrification can occur. Denitrifing bacteria have been identified in ground water from the piezometer located near the Abbotsford Airport (Rodney Zimmerman, British Columbia Ministry of Environment, written commun., 1992), and nitrous oxide (N_2O) was found in gas samples from lower piezometers.

Variation in Nitrate Concentration

Concentrations of nitrate in ground waters of the LENS area vary with time. The largest variations were observed in the Sumas aquifer, and within this unit, variations are larger near the water table and decrease with depth.

Short-term variation, 12 to 24 months, can be large with nitrate concentrations in some wells increasing or decreasing by as much as 25 mg/L. In shallow wells, changing NO_3 concentrations do not show well developed patterns of seasonal variability, however, many wells exhibit increasing nitrate concentrations during the fall and winter periods, which suggests a seasonal response. The large degree of short-term variability in nitrate concentrations results in difficulties in distinguishing long-term trends without repeated sampling. Over the long term, the regional average nitrate concentration in the Sumas aquifer appears to be changing little, while within individual wells nitrate concentrations may remain static or may be significantly increasing or decreasing. However, some long-term records and the comparison of recent data to data from earlier studies suggest a slight trend toward increasing nitrate concentrations.

During the course of this study, short-term variations in nitrate concentrations were observed in 29 wells that were sampled 10 to 12 times per year, for a period of at least 12 months. Time series plots of the nitrate and chloride concentrations in these wells are shown on plates 4 and 5. Additional nitrate monitoring data from 15 wells, which were sampled at least twice yearly, were also used to assess temporal variation. Regional nitrate data from this study were also compared to data from earlier nitrate studies conducted in 1972 and 1988.

The fluctuation of nitrate concentrations observed in well water samples results largely from variability in the rate that nitrate enters the ground-water flow path that is intersected by the well. Other factors such as the rate of ground-water flow and the rate of biochemical reactions can also cause nitrate concentrations to fluctuate; however, in the LENS area these factors are believed to be less important. Variation in the source of nitrates entering the ground-water system results from variability in the availability of nitrate and variability in the timing of major recharge events. Nitrate enters the ground-water system largely as a dissolved component in waters that recharge the ground-water system. Nitrates are incorporated into the recharge water from a variety of land use practices including application of inorganic fertilizers, land application of barnyard manures, storage of manures, septic tank effluent, and domestic application of fertilizer to lawns and gardens. The application of inorganic fertilizers to crops and lawns and the application of manure to croplands are episodic events that occur infrequently throughout the year and that require major recharge events to flush nitrates below the root zone. Thus, for nitrates from land application of fertilizers and manures, they enter the ground-water system as a pulse that is subsequently diluted by mixing that results from advection and dispersion as ground water moves along its flow path.

Short-Term Variability of Nitrates in Hydrogeologic Units

Because nitrate concentrations in the water samples collected during well inventory indicated that only the Sumas aquifer contained ground water with extensive areas with nitrate concentrations above background levels, emphasis was placed on determining the variability of nitrate concentrations in the Sumas aquifer. Short-term temporal variability in the other hydrogeologic units is expected to be small.

Data on short-term variability in nitrate concentration is summarized in table z and figure 16. The range of variation in nitrate concentration in 39 wells tapping the Sumas aquifer exceeded 5 mg/L in 62 percent of the wells, and exceeded 10 mg/L in 36 percent of the wells. The maximum range of variability was observed in a shallow piezometer located within a grassland pasture that received regular applications of dairy manure. Nitrate variations were less than 3 mg/L in 24 percent of the Sumas wells that had multiple samples.

The range of variation in nitrate concentration is generally larger in wells that have larger average nitrate concentrations. Data from table z is plotted in figure 16 to show variability and the relation of the average nitrate concentration to the standard deviation and coefficient of variance. Figure 16 is a plot of the mean nitrate concentration and the standard deviation, which is an expression of the variability of the individual nitrate concentrations around the mean concentration. The plot shows that as the mean concentration increases, the standard deviation, or variability about the mean also increases. However, as shown in figure 16, the range of variation expressed by the coefficient of variance is similar at all concentration levels. Within the shallow water-table part of the Sumas aquifer, variations in nitrate concentrations do not follow a consistent pattern among all wells; however, there is a tendancy for many of the shallow wells to exhibit seasonal patterns of increasing nitrate concentrations in the fall and early winter followed by declining nitrate concentrations in late spring and summer. Nitrate concentrations are increasing during October to January in 7 of 11 time-series plots shown on plate 3 for shallow (less than 40 feet) wells in the water-table part of the Sumas aquifer; in 4 of the 7 wells, which show increasing nitrate concentrations in the fall and winter, declining nitrate concentrations occurred between April and August. A similar pattern can be seen in long-term records of nitrate concentrations in well 39N/03E-10L01; during October through January, nitrate concentrations are increasing more often than not. The long-term record of nitrate concentrations for pumped samples from well 29/2-10L show a similar pattern of an imperfect trend of increasing nitrate concentrations during fall and winter with decreasing nitrate concentrations during the spring and summer. The longest observed fluctuation in nitrate concentrations was between 2.5-99 mg/L, which occurred in a water-table piezometer (40/2E-05M05) located in a field used to grow grass feed, and one at which dairy manures were reportedly applied approximately every 30 days. Between February 1990 and April 1993, 18 samples were collected at intermittent intervals. The time-series plot of nitrate concentrations for these samples is shown on part of figure 18. Samples obtained during the fall and winter of 1990 and 1992 show rapidly increasing nitrate concentrations. Unfortunately, no samples were collected from this well during the similar period of 1991; however, the concentrations observed in the summer of 1991 and spring of 1992 are not inconsistent with the possibility that a large concentration may have been present at some time during the fall of 1991.

The 1990 and 1992 periods of rapidly rising nitrate concentrations observed in well 40N/03E-05M05 coincide with the onset of the fall rains and the period when precipitation exceeds potential evapotranspiration so deep percolation and ground-water recharge can occur. Unless extensive irrigation occurs, the preceding summer month is the period when the rate of evapotranspiration is at its highest level, and the amount of precipitation is at its lowest level. Deep percolation of water completely through the soil profile and onto the ground-water system probably does not occur during this period. Mobile ions in soil water such as nitrate and chloride may be moved deeper into the soil profile during summer rains or irrigation events, but unless the moisture capacity of the entire soil column is reached, the movement of water and ions below the soil profile will not occur. Thus, in the fall, the first slug of water to completely pass through the soil profile and onto the shallow ground-water system will also carry dissolved ions and will flush mobile ions such as nitrate and chloride out of the soil profile and into the ground-water system, resulting in larger concentrations near the water table at this time.

The fall period is also a time in which the temperature within parts of the soil profile are still warm enough that nitrifying bacteria can continue to convert nitrogen from the ammonia and organic nitrogen forms to the nitrate form. However, the utilization of nitrate by plants is declining during this time as most perennial plants shift to a dormant phase and winter crops, if present, may not be well established. The result is that during the fall there may be significant quantities of nitrate made available within the soil profile and because they are not used by plants, will be leached to the ground-water system.

The first slug of recharge waters to reach the water table in the fall will carry a large load of nitrate and other dissolved species. Subsequent recharge occurring later in the winter and spring may not encounter as much dissolved matter available for leaching within the soil profile. The varying concentrations of dissolved matter in recharge water will lead to varying concentrations in ground water, mixing and dispersion will occur as ground water moves along its flow path, and for wells at great distances from the recharge location, such as the Sumas City Municipal wells and most Sumas wells located in the Sumas Valley, the variability in nitrate concentration will tend to be much smaller.

Less variability should be seen in shallow wells that are affected by recharge from septic tanks and dairy lagoons because these sources generally operate year round and tend to supply recharge to the ground-water system on a year-round basis. Variability will still be present in the concentration constituents in ground waters affected by these sources because of the seasonability of precipitation and possible temperature cycles that may effect the bacterial community that converts ammonia and organic nitrogen to nitrate.

As expected, the seasonal variability in nitrate concentrations in the Everson-Vashon unit and the Vashon aquifer was generally small. In these wells, the nitrate concentrations never exceeded the analytical detection limit of 0.1 mg/L. Two wells in the Everson-Vashon unit yielded ground water with detectable nitrate concentrations that averaged 4.3 and 6.9 mg/L. Nitrate concentrations in these wells varied from 1.1 to 1.4 mg/L with a coefficient of variance of 9.9 percent and from 5.0 to 10.0 mg/L with a coefficient of variance of 20 percent (see table Z). Variability in the chloride concentration can provide some information regarding temperature variation in water quality for those wells in which the nitrate concentrations never exceed the analytical detection limit. In the two wells in the Everson-Vashon unit, chloride concentrations varied minimally between 2 to 5 mg/L and 52 to 54 mg/L. However, in the well in the Vashon aquifer, water-quality parameters other than nitrate concentrations were changing dramatically. The chloride concentration rose steadily from 640 mg/L to 890 mg/L and specific conductance rose from 2,100 to 2,800 between August 1990 and December 1991.

Long-Term Temporal Variations of Nitrate Concentrations

The long-term trend in nitrate concentrations in ground water is location dependent with areas of both increasing and decreasing nitrate concentrations. Data available to this study generally show more cases of increasing nitrate concentrations than decreasing nitrate concentrations. The data used to evaluate long-term trends include time-concentration plots for individual wells and data from previous studies that included a spatial survey of nitrate concentrations in ground water.

Time-concentration plots of nitrate concentrations in 21 individual wells are shown in figure 18. Individual wells can show periods of increasing and decreasing nitrate concentrations. Apparent seasonal patterns can be seen in several wells. The majority of these wells are near the Abbotsford Airport where nitrate concentrations have been reported to be increasing. Of the 22 locations shown on figure 18, 9 show clear patterns of increasing nitrate concentrations, 4 show decreasing nitrate trends, and 8 show little or no change. Some wells show a reversal in the trend of nitrate concentrations. The nitrate concentration in well 092G.009.1.2.3-31 appeared to be decreasing between 1976 and 1979 and then remained near the lower concentration through

1981. A single sample collected in late 1989 shows a return to the higher levels of early 1986. The BCME nested piezometers at sites B and C show a pattern of decreasing nitrate concentrations in the shallow piezometer and a concurrent increase in nitrate concentrations in the deeper piezometers. The upper piezometer of site B also shows increasing nitrate concentrations during 1989 and 1990 followed by steadily decreasing nitrate concentrations.

The nitrate concentrations in the wells and spring of the town of Sumas show little change between 1989 and 1992. There does appear to be a slight increase that is more noticeable if the yearly mean concentrations are compared.

The time-concentration plot for well 39N/03E-10L01 shows the nitrate concentrations of pumped water samples of the well monitored and reported by Dr. Flora (Flora, 1983; and C. Flora, _____, written commun., 1991) of Western Washington University. Weekly samples taken in 1976 and 1981-86 both show evidence of seasonal patterns and periods of generally increasing and decreasing nitrate concentrations. Monthly samples obtained from that well during 1991 have generally smaller concentrations than observed in the early 1980's.

Previous studies that included areal surveys of nitrate concentrations in ground waters in the LENS area include Obbert, 1973; Kwong, 1986; Kohut and others, 1990; Ericson, 1991; and Liebscher and others, 1992. The studies by Kwong, Kohut and others, and Liebscher and others are confined to the Canadian part of the study area, the same area in which most of the time-concentration plots shown in plate 4 are located. All of those studies indicate increasing nitrate concentrations in ground water in the Canadian part of the study area. The studies by Obbert and Ericson include data from the Whatcom County part of the study area. Nitrate concentrations from those studies will be compared to data from this study.

Obbert (1973) conducted a survey of nitrate concentrations in ground waters in western Whatcom County. Twenty-one of the 48 ground-water samples collected by Obbert were located within the LENS study area. The median concentration of all Obbert's ground-water nitrate data was 2.5 mg/L, while the median nitrate concentration of Obbert's sites that are located within the LENS area is 3.7 mg/L.

A comparison of the distribution of nitrate concentrations in the LENS area as sampled by Obbert (1973) with similar concentrations found in the Sumas wells sampled for this study are shown in box-plot form in figure ___.

Chloride

The concentrations of chloride in ground water vary within individual hydrogeologic units; within the 346 wells sampled for chloride during this study, concentrations ranged from 0.3 to 2,800 mg/L. In 82 percent (285) of sampled wells, chloride concentrations were larger than the estimated range of natural background chloride concentrations, and exceeded the secondary drinking water standard in 3.5 percent (12) of the sampled wells. The spatial distribution of chloride in the Sumas aquifer indicates that slightly elevated chloride concentrations occur throughout most of the aquifer, while most wells in the Everson-Vashon unit are within the range of natural background concentrations. In addition to precipitation, two sources contribute to chloride concentrations in ground waters of the study area. Land-use activities are a source of much of the chloride concentrations in ground waters with concentrations between 4 and 20 mg/L. Connate sea water, trapped during the last glacial episode is the source of chloride in most ground water with concentrations larger than 20 mg/L.

Chloride is soluble and a common constituent of natural waters, and because of its extremely limited involvement in chemical reactions and adsorbtion to aquifer materials or soil particles, chloride is also considered to be a good tracer in ground-water systems. Chloride is not, however, a common constituent of geologic materials within the Whatcom Basin, and except for sea water and brine solutions, the concentration of chloride in natural waters is generally small. Chloride is a significant component in domestic sewage and animal manures, both of which have been documented as sources of chloride in ground-water systems. Irrigation with shallow ground water will also tend to increase the level of chloride concentration within the shallow ground water due to evapoconcentration of conservative water-quality constituents like chloride. Chloride is also a component of some fertilizers applied to crops. At concentrations above 250 mg/L, chloride imparts a salty taste to water, which is the level set by the EPA as a secondary drinking water standard.

The concentrations of chloride in ground waters of the LENS study area are variable, concentrations observed in water samples from 346 wells sampled for this project range from 0.3 to 2,800 mg/L with a median value of 8.8 mg/L. While some samples from all hydrogeologic units had chloride concentrations below 2 mg/L, the larger chloride concentrations were unevenly distributed throughout the hydrogeologic units of the LENS study area.

The areal distribution of chloride in ground water from the four hydrogeologic units of the study area are shown on plate 4 along with time series plots of chloride concentrations collected at monthly observation wells. Chloride concentrations in the Vashon and bedrock aquifers were generally large, while chloride concentrations in the Sumas aquifer and the Everson-Vashon unit were generally smaller but covered a wide range.

The largest chloride concentration (2,800 mg/L) was observed in a well tapping the Everson-Vashon unit, while the largest seasonal variation of 6.8 to 20 mg/L was observed in the Sumas aquifer. The largest net change in chloride concentration was observed in the monthly observation well 39N/04-03P1, where the chloride concentration rose steadily from 640 to 840 mg/L. The variable chloride concentrations within the four hydrogeologic units reflect in large part differences in the hydrologic and water-quality characteristics of each unit. Chloride concentrations within the Qso and Qev are generally smaller than concentrations in the Qvt and Thk. Median chloride concentrations within the four geohydrolgic units are Qso, 8.8 mg/L; Qev, 7.7 mg/L; Qv, 182 mg/L; and Thk, 37 mg/L.

Within the Puget Sound area, elevated chloride concentrations occurring near the coast line generally are attributed to sea-water intrusion, while large chloride concentrations found further inland have been attributed to older marine sediments (Van Denburgh and Santos, 1965) or conate sea water. The range of median chloride concentration observed in the 12 Puget Sound counties is 1.8 to 86 mg/L (Turney, 1983).

Background concentrations of chloride in ground water derived solely from precipitation recharge were less than 4 mg/L in the Sumas aquifer and less than 7 mg/L in the Everson-Vashon unit. Most ground waters with greater than 25 mg/L chloride were found to have large bromide concentrations indicating mixing with connate sea water. In the Sumas aquifer most of the chloride concentrations are above background concentrations falling in the range of 4 to 20 mg/L, and are associated with the ground waters with elevated nitrate concentrations. The source of chloride in these ground waters is believed to be land-use activities, most probably the application of dairy manures or septic systems.

Frequency distribution plots, which show the range and distribution of chloride concentrations within individual hydrogeologic units, are shown on plate 5. The observed chloride concentrations were divided into four ranges of concentrations; background, slightly, moderately, and significantly elevated concentrations. The estimated range of background chloride concentrations in the Sumas aquifer is from 0 to 4 mg/L and was based on data from undeveloped areas of Thurston and east King Counties, because there are few undeveloped areas within the LENS area. The estimated range of background chloride concentrations in the Everson-Vashon unit, and the Vashon and bedrock aquifers was from 0 to 7 mg/L and was based on the frequency distribution of chloride in the Everson-Vashon unit. These ranges are similar to the range determined by Gilliom and Patmont (1982). Chloride concentrations above background levels and below 25 mg/L were considered slightly elevated, while concentrations between 25 mg/L and 250 mg/L were considered moderately elevated. Chloride concentrations above 250 mg/L, the EPA secondary drinking water standard, were considered significantly elevated. The distribution of observed chloride concentrations is tabulated below and plotted on plate 5.

Chloride concentrations in _____ wells tapping the Sumas aquifer ranged from 0.3 to ____ mg/L, with a median concentration of _____ mg/L. _____ percent of the wells sampled had chloride concentrations in the range of background concentrations. The chloride concentration in the majority of wells sampled (___ percent) fell within the range of slightly elevated chloride concentrations. In general, ground waters that contain background levels of chloride had small specific conductance values indicating low levels of dissolved material and _____ concentration also contained background levels of nitrates. These wells were distributed _____ the aquifer.

Groundwater and hydrocarbon exploration activities within the study area have reported large concentrations of chloride in some ground waters. The source of the large chloride concentrations is generally attributed to sea water. Like chloride, bromide is a conservative water-quality constituent that is generally present in uncontaminated ground water in small concentrations but is present in significant amounts in sea water; consequently in ground waters containing a significant fraction of sea-water, not only will the concentration of chloride be large but the ratio of bromide to chloride should remain relatively constant. Bromide was measured in ground-water samples to determine if the elevated chlorides reported in ground waters of the study area were the result of sea water present within the ground-water system. It should be noted that bromide can also be present in ground water as a result of land-use activities. The largest single use of bromide is as the gasoline additives ethelene dibromide (Hem, 1989), however EDB has also been used as a soil fumigant in part of the study area.

The concentrations of bromide and chloride in ground-water samples are plotted in figure __a, along with the present day bromide-chloride concentration in sea water and a line showing how sea water concentrations would vary upon dilution. The plot of bromide and chloride concentrations in ground water of the LENS study area produces a line similar to the sea water dilution line, indicating that many of the samples, particularly those with large chloride concentrations, may contain significant fractions of sea water. Two samples had large bromide concentrations but had relatively small chloride concentrations and plotted well away from the sea-water dilution pattern. The sample from well 40N/02E-23D01 is located in an area where EDB is reported to have been applied as a soil fumigant (Black and Veach, 1986), the other well, 40N/03E-31P03 is located where residential housing is the predominant land use.

The background concentration of bromide in ground water can be determined from the normal-probability plot of bromide concentrations shown in figure __b. Bromide concentrations from the study area define a two-stage curve with a sharp break in bromide concentrations occuring between 0.04 to 0.06 mg/L. Ground-water samples with bromide concentrations below 0.04 mg/L are interpreted to have little or no sea-water component, while ground waters with greater than 0.06 mg/L bromide and proportionally large chloride concentrations probably contain varying, but significant amounts of sea water. Samples from wells in the Everson-Vashon unit and the bedrock aquifer make up most of the sample points ploting on the upper portion of the chloride-bromide line. Bromide concentrations between 0.04 to 0.06 mg/L correspond to chloride concentrations of 15 to 25 mg/L, and indicate that for most wells in the Everson-Vashon unit and the Vashon and bedrock aquifers, wells with more than 25 mg/L chloride probably contain a significant fraction of sea water. The percentage of wells sampled with chloride concentrations larger than 25 mg/L in the Sumas aquifer, the Everson-Vashon unit, and the Vashon and bedrock aquifers are 9, 26, 62, 57, respectively.

Large chloride concentrations have been reported in ground water throughout the study area, although often the only data available is from a driller's log indicating "salty water". The location and altitude (if reported) of reported instances of "salty ground water" are plotted on figure __ with the location and altitude of ground-water samples with chloride concentrations larger than 250 mg/L. In all instances where wells within the study area penetrated the silty-clayey Everson-Vashon unit, highly saline ground water was found. The Everson-Vashon unit is extensive and considering that many of the Everson-Vashon wells contain ground water with some degree of reminant sea water, it is not likely that the productive unit beneath the Everson-Vashon unit will contain zones of fresh water. It should be noted that the Aldergrove test well located in the upland area several miles northwest of the study area which probably taps the hydrogeologic unit beneath the Everson-Vashon unit does yield large quantities of relatively fresh ground water. The upland location of the Aldergrove test well is in an area of downward flow and ground waters beneath the Everson-Vashon unit can be recharged slowly from precipitaion. The LENS study area is a shallow basin, and ground-water flow in the deeper unit near the central part of the basin will be upwards. Static water-level reports from the Greenwood test well also indicate upward flow (Carr and Associates, 1985). In the unlikely event that an exploration well drilled in the central portion of the study area were to encounter relatively fresh ground waters, it is quite probable that extensive pumping of the well would cause salt-water encroachment into the well's capture zone. The extensive nature of the Everson-Vashon unit limited recharge to this deeper unit to upland areas where recharge must pass through this relatively impermeable unit. It is unlikely that large quantities of fresh water will be found below the Everson-Vashon unit at locations other than beneath upland areas.

Chloride in ground waters of the LENS area are derived from three principle sources: chloride in precipitation that recharges the entire ground-water system; land-use activities such as septic tank effluent, spreading and handling of barnyard manures, and application of fertilizers locally that increase the level of chloride in ground-water recharge; and sea water trapped within hydrogeologic units during earlier geologic times. For the Sumas aquifer, it is unlikely that the aquifer was ever inundated by sea water, however, the aquifer is generally exposed at the surface and highly permeable, which would lead to relatively rapid flushing of any sea water that might have been present. These same characteristics however also result in the Sumas aquifer being susceptible to land-use activities that can contribute chloride to the ground-water system.

SUMMARY AND CONCLUSIONS

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American Public Health Association, 1979 (page 32)

American Public Health Association, 1989 (page 30)

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Table __.--Summary of values and concentrations of water-quality constituents in ground waters from the Everson-Vashon confining unit

[Concentrations in milligrams per liter (mg/L) unless otherwise noted; Spec. Cond. = Specific Conductance; µS/cm, microsiemens per centimeter at 25 degrees Celsius; D = dissolved, T = total, SAR = Sodium Absorbtion Ratio, MBAS = Methylene Blue Active Substances]

Name	Samples	Mean	Median	Minimum	Maximum	25th percentile	75th percentile
Temperature	28	24.568	10.850	9.10	228.00	10.32	12.25
Spec. Cond., field	83	618.477	309.000	99.00	10,100.00	244.00	547.50
Spec. Cond., lab	20	1,197.450	480.000	198.00	9,950.00	296.25	1,072.50
pH, field	27	7.651	8.000	.30	8.90	7.10	8.49
pH, lab	19	8.053	8.100	6.60	8.80	7.70	8.60
Dissolved oxygen	26	1.254	.200	0.	6.40	.10	1.52
Hardness as $CaCO_3$	19	129.055	68.378	10.20	1,008.63	27.70	121.10
Calcium, dissolved	19	22.921	16.000	2.00	140.00	4.00	27.00
Magnesium, dissolved	19	17.432	7.000	.90	160.00	4.30	12.00
Sodium, dissolved	19	220.805	98.000	4.70	1,800.00	33.00	230.00
Percent sodium	19	63.589	77.350	11.33	97.15	34.85	88.58
SAR	19	10.106	5.158	.23	31.34	1.36	14.14
Potassium, dissolved	19	6.821	3.800	1.00	44.00	2.90	5.90
Alkalinity	19	212.211	191.000	47.00	444.00	132.00	299.00
Sulfate, dissolved	22	44.300	2.675	.10	620.00	.17	11.25
Chloride, dissolved	86	97.517	7.700	.80	2,800.00	4.75	31.92
Fluoride, dissolved	22	.380	.300	.10	1.10	.18	.52
Silica, dissolved	19	20.316	19.000	13.00	31.00	16.00	23.00
T dissolved solids	14	904.954	252.479	135.67	5,630.06	172.94	1,279.90
Iron, dissolved	25	193.931	80.000	3.00	960.00	32.00	265.00
Manganese, dissolved	19	87.263	17.000	1.00	360.00	6.00	140.00
^{15}N Isotope	0	--	--	--	--	--	--
Ammonia-N, dissolved	22	.279	.150	.01	1.20	.01	.47
Ammonia-N, total	7	.344	.305	.02	.76	.28	.41
Nitrite-N, dissolved	22	.010	.010	.01	.01	.01	.01
Nitrite-N, total	7	.010	.010	.01	.01	.01	.01
Ammonia + organic-N, D	21	.467	.400	0.	1.30	.20	.60
Ammonia + organic-N, T	7	.446	.400	.20	.93	.20	.50
Nitrate + nitrite-N, D	81	.679	.100	.07	10.00	.10	.25
Nitrate + nitrite-N, T	22	13.097	.050	.05	[illegible]	.05	1.42
Phosphate -PO_4, D	22	.458	.260	.01	2.30	.01	.81
Phosphate -PO_4,T	7	.719	.730	.01	1.81	.14	1.16
Dissolved organic carbon	12	1.425	.650	.30	6.80	.35	1.95
MBAS	7	.056	.070	.01	.12	.01	.08
Boron, dissolved	15	227.333	120.000	10.00	890.00	30.00	360.00
Bromide, dissolved	10	.383	.030	.01	1.90	.02	.49

PRELIMINARY SUBJECT TO REVISIONS

Table__.--Comparison of median values of water-quality constituents in ground waters from four hydrogeologic units.

[The number of samples from each hydrogeologic unit is variable (see tables __-__ for data regarding sample distribution within each hydrogeologic unit); D = dissolved, T = total, Spec. Cond. = Specific Conductance, SAR = Sodium Absorbtion Ratio]

Water-quality constituent	Hydrogeologic units			
	Sumas	Everson/ Vashon	Vashon	Chuckanut
Temperature	10.2000	10.8500	9.600	11.50
Spec. Cond., field	233.0000	309.0000	430.500	753.00
Spec. Cond., lab	231.0000	480.0000	1,189.000	1,375.00
pH, field	6.5300	8.0000	8.270	8.37
pH, lab	6.7000	8.1000	7.850	8.3
Dissolved oxygen	4.0500	.2000	.400	.1
Hardness as $CaCO_3$	85.5150	68.3780	127.488	26.09
Calcium, dissolved	22.0000	16.0000	35.000	9.90
Magnesium, dissolved	6.4500	7.0000	12.000	.66
Sodium, dissolved	5.9500	98.0000	188.100	220.00
Percent sodium	13.4485	77.3500	47.496	94.69
SAR	.2895	5.1580	6.303	23.85
Potassium, dissolved	1.3500	3.8000	2.200	1.20
Alkalinity	45.0000	191.0000	75.000	226.00
Sulfate, dissolved	15.0000	2.6750	5.050	1.30
Chloride, dissolved	8.8500	7.7000	182.900	37.30
Fluoride, dissolved	.1000	.3000	.200	.35
Silica, dissolved	19.0000	19.0000	17.000	9.9
TDS;T dissolved solids	146.7390	252.4799	132.321	566.95
Iron, dissolved	26.0000	80.0000	54.500	48.00
Manganese, dissolved	8.0000	17.0000	20.000	13.00
Ammonia-N, dissolved	.0200	.1500	.030	.33
Ammonia-N, total	.0100	.3055	.161	.14
Nitrite-N, dissolved	.0100	.0100	.010	.01
Nitrite-N, total	.0100	.0100	.010	.01
Ammonia + organic-N, D	.3000	.4000	.400	.70
Ammonia + organic-N, T	.2000	.4000	.420	.50
Nitrate + Nitrite-N, D	3.8000	.1000	.100	.10
Nitrate + Nitrite-N, T	3.7000	.0500	.075	.05
Phosphate-PO_4, dissolved	.0100	.2600	.020	.01
Phosphate-PO_4, total	.0100	.7300	.088	.03
Dissolved organic carbon	.7000	.6500	1.700	1.20
Boron, dissolved	20.0000	120.0000	30.000	65.00
Bromide, dissolved	.0300	.0300	.010	1.10

PRELIMINARY SUBJECT TO REVISIONS

Table __.--Summary of values and concentrations of water-quality constituents in ground waters from the Vashon geohydrologic unit

[Concentrations in milligrams per liter (mg/L) unless otherwise noted; Spec. Cond. = Specific Conductance; µS/cm, microsiemens per centimeter at 25 degrees Celsius; D = dissolved, T = total, SAR = Sodium Absorbtion Ratio, MBAS = Methylene Blue Active Substances]

Name	Samples	Mean	Median	Minimum	Maximum	25th percentile	75th percentile
Temperature	3	9.37	9.60	8.10	10.40	8.10	10.40
Spec. Cond., field	8	651.00	430.50	1.00	1,533.00	218.62	1,211.88
Spec. Cond., lab	4	1,219.00	1,189.00	208.00	2,290.00	210.50	2,257.50
pH, field	3	7.79	8.27	6.50	8.60	6.50	8.60
pH, lab	4	7.72	7.85	6.90	8.30	7.05	8.28
Dissolved oxygen	3	2.44	.40	.11	6.80	.11	6.80
Hardness as $CaCO_3$	4	128.97	127.49	90.13	170.79	92.29	167.15
Calcium, dissolved	4	32.25	35.00	13.00	46.00	16.75	45.00
Magnesium, dissolved	4	11.75	12.00	7.00	16.00	7.75	15.50
Sodium, dissolved	4	194.90	188.10	3.40	400.00	4.10	392.50
Percent sodium	4	46.54	47.50	6.87	84.30	8.36	83.77
SAR	4	6.67	6.30	.15	13.93	.18	13.53
Potassium, dissolved	4	2.57	2.20	1.20	4.70	1.22	4.30
Alkalinity	4	75.50	75.00	57.00	95.00	60.00	91.50
Sulfate, dissolved	4	7.80	5.05	.10	21.00	.32	18.02
Chloride, dissolved	8	273.55	182.90	1.70	749.50	12.95	577.50
Fluoride, dissolved	4	.24	.20	.10	.45	.10	.41
Silica, dissolved	4	17.50	17.00	15.00	21.00	15.25	20.25
T dissolved solids	2	132.32	132.32	127.29	137.35	127.29	137.35
Iron, dissolved	4	77.50	54.50	11.00	190.00	15.50	162.50
Manganese, dissolved	4	32.75	20.00	1.00	90.00	5.75	72.50
^{15}N Isotope	0	--	--	--	--	--	--
Ammonia-N, dissolved	3	.10	.03	.01	.25	.01	.25
Ammonia-N, total	1	.16	.16	.16	.16	.16	.16
Nitrite-N, dissolved	3	.01	.01	.01	.01	.01	.01
Nitrite-N, total	1	.01	.01	.01	.01	.01	.01
Ammonia + organic-N, D	3	.33	.40	.20	.40	.20	.40
Ammonia + organic-N, T	1	.42	.42	.42	.42	.42	.42
Nitrate + nitrite-N, D	8	.86	.10	.08	6.20	.10	.10
Nitrate + nitrite-N, T	4	1.30	.08	.05	5.00	.05	3.78
Phosphate -PO_4, D	3	.02	.02	.01	.03	.01	.03
Phosphate -PO_4, T	1	.09	.09	.09	.09	.09	.09
Dissolved organic carbon	1	1.70	1.70	1.70	1.70	1.70	1.70
MBAS	1	.06	.06	.06	.06	.06	.06
Boron, dissolved	1	30.00	30.00	30.00	30.00	30.00	30.00
Bromide, dissolved	1	.01	.01	.01	.01	.01	.01

PRELIMINARY SUBJECT TO REVISIONS

Table __.--Summary of values and concentrations of water-quality constituents in ground waters from the Sumas-Abbotsford aquifer

[Concentrations in milligrams per liter (mg/L) unless otherwise noted; Spec. Cond. = Specific Conductance; µS/cm, microsiemens per centimeter at 25 degrees Celsius; D = dissolved, T = total, SAR = Sodium Absorbtion Ratio, MBAS = Methylene Blue Active Substances]

Name	Samples	Mean	Median	Minimum	Maximum	25th percentile	75th percentile
Temperature	79	10.278	10.2000	0.	13.600	9.6000	11.0000
Spec. Cond., field	203	246.049	233.0000	50.000	1,766.000	161.0000	289.0000
Spec. Cond., lab	101	264.089	231.0000	72.000	1,220.000	167.5000	293.5000
pH, field	78	6.717	6.5300	5.600	12.500	6.2150	6.8925
pH, lab	96	6.803	6.7000	5.800	8.700	6.4000	7.1000
Dissolved oxygen	74	6.830	4.0500	0.	196.000	1.5875	6.8775
Hardness as $CaCO_3$	96	97.635	85.5150	27.205	395.391	59.1815	116.5332
Calcium, dissolved	96	24.046	22.0000	6.500	94.000	14.2500	30.7500
Magnesium, dissolved	96	9.122	6.4500	1.800	51.000	4.7000	9.4000
Sodium, dissolved	96	8.947	5.9500	3.100	61.000	4.7000	8.7000
Percent sodium	96	15.715	13.4485	5.952	42.495	10.5497	19.2990
SAR	96	.400	.2895	.142	3.124	.2282	.4022
Potassium, dissolved	96	4.157	1.3500	.500	110.000	.9000	2.5750
Alkalinity	96	64.268	45.0000	1.000	559.000	26.0000	69.7500
Sulfate, dissolved	100	18.041	15.0000	.100	120.000	7.3250	24.0000
Chloride, dissolved	228	13.092	8.8500	.300	210.000	5.6187	13.3667
Fluoride, dissolved	100	.126	.1000	.100	.400	.1000	.1000
Silica, dissolved	96	21.390	19.0000	8.700	53.000	16.0000	24.0000
T dissolved solids	93	169.030	146.7390	53.387	759.588	108.8490	189.7875
Iron, dissolved	117	2,061.788	26.0000	3.000	36,000.000	7.5000	135.0000
Manganese, dissolved	96	161.552	8.0000	1.000	3,500.000	2.0000	106.7500
^{15}N Isotope	22	6.727	7.0500	1.500	12.500	4.0250	9.0250
Ammonia-N, dissolved	96	1.107	.0200	.010	63.000	.0100	.0575
Ammonia-N, total	65	1.300	.0100	.010	46.000	.0100	.0300
Nitrite-N, dissolved	96	.016	.0100	.010	.370	.0100	.0100
Nitrite-N, total	65	.023	.0100	.010	.335	.0100	.0100
Ammonia + organic-N, D	95	1.473	.3000	0.	63.000	.2000	.6000
Ammonia + organic-N, T	39	2.598	.2000	.200	50.000	.2000	.5125
Nitrate + nitrite-N, D	230	5.632	3.8000	.050	32.000	.5982	8.7596
Nitrate + nitrite-N,T	108	6.052	3.7000	.050	43.000	.4425	9.7500
Phosphate -PO_4, D	81	.102	.0100	.010	3.300	.0100	.0100
Phosphate -PO_4,T	65	.013	.0100	.010	.135	.0100	.0104
Dissolved organic carbon	71	1.990	.7000	.200	39.000	.5000	1.2000
MBAS	56	.064	.0500	.010	.190	.0200	.1000
Boron, dissolved	59	22.373	20.0000	10.000	120.000	10.0000	30.0000
Bromide, dissolved	33	.153	.0300	.010	3.100	.0100	.0400

PRELIMINARY SUBJECT TO REVISIONS

Table X.--Summary of concentrations of trace elements

[Concentrations in micrograms per liter. All are dissolved concentraions; --, no U.S. Environmental Protection Agency (USEPA) drinking water standard; H = HLA; E = Erickson, 1990; G = Garland, unpublished data, 1992; D = DSHS files]

Element	Number of wells with analysis reported	Number of wells with elements detected	Number of wells elements not detected in analysis	Concentrations Minimum	Concentrations Median	Concentrations Maximum	USEPA drinking water reference *µg/L	Number of wells exceeding standard	Number of wells sampled below reference level	Source of additional data
Arsenic	27	4	23	<1	<1	**6	50	0	27	H,E
Barium	36	30	6	4	20	1,100	2,000	0	36	H
Beryllium	6	0	6	<0.5	<0.5	<2	4	0	6	
Cadmium	36	2	34	<1	<5	<10	5	0	36	H,E
Chromium	36	2	34	<1	<6	<10	100	0	36	H,E
Cobalt	20	0	18	<3	<72	<100	--	0	20	
Copper	36	22	14	1	33	190	1,300b	0	36	H,E
Lead	36	2	34	<1	<40	<100	15b	0	36	H,E
Lithium	6	2	4	<4	9	18	--	0	6	
Mercury	18	0	18	<0.1	<0.1	<0.1	2	0	18	H,E
Molybdenum	19	3	15	<10	<10	40	--	0	19	
Nickel	19	0	19	<10	<10	<50	100	0	19	H,E
Selenium	18	1	17	<1	<1	1	50	0	18	E
Silver	24	9	15	<1	<1	<3	100a	0	24	
Strontium	6	6	0	120	447	1,700	--	0	6	
Vanadium	19	0	19	<6	<5	<18	--	0	19	
Zinc	36	32	5	<3	62	240	5,000a	0	36	H,E

* Primary drinking water standard, unless noted, a = second

** Two well reported non-detects at 250 µg/L, not included in concentration range

PRELIMINARY SUBJECT TO REVISIONS

Table Y.--Concentration of trace elements in well water samples from portions of the Lower Nooksack River Basin

Local well number	Date	Geo-hydro-logic unit code	Agency ana-lyzing sample (code number)	Arsenic, dis-solved (µg/L as As)	Barium, dis-solved (µg/L as Ba)	Beryl-lium, dis-solved (µg/L as Be)	Cad-mium, dis-solved (µg/L as Cd)	Chro-mium, dis-solved (µg/L as Cr)	Cobalt dis-solved (µg/L as Co)	Copper dis-solved (µg/L as Cu)
39N/02E-01P02	08-29-90	SUMS	USGS	<1	41	--	<1	<1	--	40
39N/02E-10F01	08-28-90	SUMS	USGS	<1	38	--	<1	<1	--	2
39N/02E-12K03	08-29-90	SUMS	USGS	<1	20	--	<1	<1	--	4
39N/02E-14M01	08-28-90	SUMS	USGS	1	54	--	<1	<1	--	2
	08-28-90		USGS	1	54	--	<1	<1	--	2
39N/02E-27F03	08-28-90	SUMS	USGS	<1	10	--	<1	<1	--	11
39N/03E-02B02	08-28-90	SUMS	USGS	1	55	--	<1	<1	--	15
39N/03E-08C02	08-30-90	SUMS	USGS	<1	10	--	<1	<1	--	10
39N/03E-13E01	04-23-91	CCKN	USGS	--	93	<0.5	<1	<5	<3	190
39N/03E-26J01	04-25-91	CCKN	USGS	--	1,100	<2	<3	<20	<9	<30
39N/04E-03P01	08-31-90	VSHN	USGS	6	200	--	<1	<1	--	1
39N/04E-19M01	04-25-91	CCKN	USGS	--	46	<0.5	1	<5	<3	<10
39N/04E-30D01	04-26-91	EVRS	USGS	--	44	<0.5	<1	<5	<3	<10
40N/02E-27B01	08-30-90	EVRS	USGS	<1	4	--	<1	<1	--	160
40N/03E-03B01	08-30-90	SUMS	USGS	<1	9	--	<1	<1	--	13
40N/03E-05N02	08-29-90	SUMS	USGS	<1	6	--	<1	<1	--	3
40N/03E-16A02	08-27-90	SUMS	USGS	<1	6	--	<1	<1	--	34
40N/03E-32M01	08-29-90	SUMS	USGS	<1	5	--	<1	<1	--	28
40N/04E-05P02	08-29-90	SUMS	USGS	<1	13	--	<1	2	--	6
40N/04E-09N03	08-28-90	SUMS	USGS	<1	390	--	3	<1	--	2
40N/04E-20F01	08-30-90	SUMS	USGS	<1	76	--	<1	<1	--	1
41N/04E-31J02	08-31-90	SUMS	USGS	<1	7	--	<1	<1	--	68
41N/04E-32Q01	04-30-91	SUMS	USGS	--	8	<0.5	<1	<5	<3	20
41N/04E-33H04	05-01-91	SUMS	USGS	--	20	<0.5	<1	<5	<3	<10
092G.008.2.2.2-15	03-04-87	SUMS	BCME	<1	10	--	<10	<10	<100	50
092G.008.2.4.4-11	03-04-87	SUMS	BCME	<1	60	--	<10	<10	<100	<10
092G.009.1.1.1-07	06-13-90	SUMS	BCME	--	<10	--	<10	<10	<100	<10
092G.009.1.1.2-11	06-09-87	SUMS	BCME	--	10	--	<10	<10	<100	<10
	06-09-90	SUMS	BCME	--	<10	--	<10	<10	<100	<10
092G.009.1.1.2-12	06-09-87	SUMS	BCME	--	<10	--	<10	<10	<100	<10
092G.009.1.1.2-13	06-01-88	SUMS	BCME	--	<10	--	<10	<10	<100	<10
092G.009.1.2.3-10	10-27-88	SUMS	BCME	<1	10	--	<10	<10	<100	<10
092G.009.1.3.3-08	09-28-88	SUMS	BCME	<1	40	--	<10	<10	<100	<10
092G.009.2.1.1-37	07-29-84	SUMS	BCME	*<250	--	--	<10	<10	<100	<10
092G.009.2.1.2-24	07-29-84	SUMS	BCME	*<250	--	--	<10	<10	<100	<10
092G.009.2.1.3-47	10-20-88	SUMS	BCME	<1	80	--	<10	<10	<100	20
092G.009.2.1.4-20	10-20-88	SUMS	BCME	<1	<10	--	<10	<10	<100	90
092G.009.2.1.4-23	10-20-88	SUMS	BCME	<1	<10	--	<10	<10	<100	20
39N/02E-01P02	<1	--	<0.1	--	--	<1	<1	--	--	6
39N/02E-10F01	<1	--	<0.1	--	--	<1	<1	--	--	43
39N/02E-12K03	<1	--	<0.1	--	--	<1	<1	--	--	10
39N/02E-14M01	<1	--	<0.1	--	--	<1	<1	--	--	170
	<1	--	<0.1	--	--	<1	1	--	--	160
39N/02E-27F03	<1	--	<0.1	--	--	<1	1	--	--	7

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Table Y.--Concentration of trace elements in well water samples from portions of the Lower Nooksack River Basin--continued

Local well number	Date	Geo-hydro-logic unit code	Agency ana-lyzing sample (code number)	Arsenic, dis-solved (µg/L as As)	Barium, dis-solved (µg/L as Ba)	Beryl-lium, dis-solved (µg/L as Be)	Cad-mium, dis-solved (µg/L as Cd)	Chro-mium, dis-solved (µg/L as Cr)	Cobalt dis-solved (µg/L as Co)	Copper dis-solved (µg/L as Cu)
39N/03E-02B02	<1	--	<0.1	--	--	<1	<1	--	--	46
39N/03E-08C02	<1	--	<0.1	--	--	<1	<1	--	--	10
39N/03E-13E01	<10	<4	--	<10	<10	--	<1	270	<6	130
39N/03E-26J01	<30	18	--	<30	<30	--	<3	1700	<18	150
39N/04E-03P01	<1	--	<0.1	--	--	<1	<1	--	--	180
39N/04E-19M01	<10	<4	--	40	<10	--	2	240	<6	85
39N/04E-30D01	<10	<4	--	20	<10	--	<1	230	<6	7
40N/02E-27B01	<1	--	<0.1	--	--	<1	<1	--	--	11
40N/03E-03B01	<1	--	<0.1	--	--	<1	<1	--	--	240
40N/03E-05N02	<1	--	<0.1	--	--	1	1	--	--	26
40N/03E-16A02	1	--	<0.1	--	--	<1	1	--	--	7
40N/03E-32M01	<1	--	<0.1	--	--	<1	<1	--	--	36
40N/04E-05P02	<1	--	<0.1	--	--	<1	2	--	--	18
40N/04E-09N03	1	--	<0.1	--	--	<1	1	--	--	48
40N/04E-20F01	<1	--	<0.1	--	--	<1	1	--	--	45
41N/04E-31J02	<1	--	<0.1	--	--	<1	1	--	--	68
41N/04E-32Q01	<10	<4	--	<10	<10	--	<1	120	<6	14
41N/04E-33H04	<10	4	--	<10	<10	--	<1	120	<6	<3
092G.008.2.2.2-15	<100	--	--	<10	<50	--	--	--	<10	20
092G.008.2.4.4-11	<100	--	--	<10	<50	--	--	--	<10	20
092G.009.1.1.1-07	<100	--	--	<10	<50	--	--	--	<10	20
092G.009.1.1.2-11	<100	--	--	<10	<50	--	--	--	<10	<10
092G.009.1.1.2-12	<100	--	--	<10	<50	--	--	--	<10	<10
092G.009.1.1.2-13	<100	--	--	<10	<50	--	--	--	<10	110
092G.009.1.2.3-10	<100	--	--	<10	<50	--	--	--	<10	30
092G.009.1.3.3-08	<100	--	--	10	<50	--	--	--	<10	100
092G.009.2.1.1-37	<100	--	--	<10	<50	--	--	--	<10	<10
092G.009.2.1.2-24	<100	--	--	<10	<50	--	--	--	<10	<10
092G.009.2.1.3-47	<100	--	--	<10	<50	--	--	--	<10	130
092G.009.2.1.4-20	<100	--	--	<10	<50	--	--	--	<10	140
092G.009.2.1.4-23	<100	--	--	<10	<50	--	--	--	<10	90

* Data not included in determining range of arsenic concentration.

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Table Z.--Temporal variability of nitrate concentrations in ground waters with multiple observations per year

[G, USGS; F, Flora, written communications; S, City of Sumas; C, Environment Canada; B, British Columbia Ministry of Environment; W, Washington State Department of Ecology]

Well number	Geologic unit	Depth (feet)	Period of record	Number of obser-vations	Data source	Range of nitrate concen-tration	Mini-mum concen-tration	Maxi-mum concen-tration	Average concen-tration	Standard deviation	Coeffi-cient of variation (percent)
39N/02E-01P02	SUMS	34	8/90-10/91	12	U	2.9	5.3	14	8.5	2.3	26
39N/02E-10F01	SUMS	20	8/90-10/91	14	U	13	1.6	15	7.7	4.0	52
39N/02E-27F03	SUMS	44	10/90-10/91	14	U	12	1.6	14	12	2.8	25
39N/03E-01C01	SUMS	49	10/90-10/91	12	U	.1	.26	.37	.30	.03	9.7
39N/03E-10L01	SUMS	35	81-86	237	F	8.9	.27	9.2	2.8	1.4	51
39N/03E-10L01	SUMS	35	10/90-10/91	11	U	2.7	.14	2.8	1.4	.98	70
39N/03E-19N01	EVRS	62	10/90-10/91	10	U	.3	1.1	1.4	1.3	.12	9.9
39N/03E-26P02	EVRS	155	10/90-10/91	11	U	0	<.1	<.1	--	--	--
39N/04E-03P01	VSHN	117	3/90-9/91	12	U	0	<.1	<.1	--	--	--
40N/02E-03C01	EVRS	100	11/90-9/91	10	U	0	<.1	<.1	--	--	--
40N/02E-27B01	SUMS	41	7/90-9/91	13	U	5.7	6.3	12	8.2	2.7	33
40N/03E-03B01	SUMS	29	7/90-12/91	15	U	5.2	5.8	11	7.54	2.52	33
40N/03E-5M05	SUMS	12	2/90-4/93	18	W	96	2.5	99	34	33	96
40N/03E-5N01	SUMS	18	1/90-5/92	7	W	4.4	.2	4.6	1.7	1.6	92
40N/03E-5N02	SUMS	24	1/90-8/92	11	W	1.6	.8	2.4	1.2	.71	59
40N/03E-16H02	SUMS	29	7/90-9/91	13	U	12	2.7	15	10	4.0	40
40N/03E-32M01	SUMS	26	8/90-9/91	15	U	4.1	8.9	13	11	1.0	9.1
40N/03E-20F01	SUMS	18	11/90-12/91	12	U	1.4	<.1	1.5	.54	.51	95
41N/03E-32Q1	SUMS	25	6/90-7/91	5	W	26	16	43	24	13	54
41N/04E-31J02	SUMS	80	10/90-9/91	13	U	11.1	2.9	14	11	3.0	28
41N/04E-33H01	SUMS	58	12/88-11/91	34	S	3.3	1.7	5	2.2	.5	22
41N/04E-33H01S	--	--	12/88-11/91	33	S	3.5	3.9	7.4	5.4	.65	12
41N/04E-33H02	SUMS	58	12/88-11/91	35	S	3.8	4	7.8	5.5	.8	15
41N/04E-33H03	SUMS	58	12/88-11/91	35	S	3.6	4.6	8.2	6.1	.7	13

Table Z.--Temporal variability of nitrate concentrations in ground waters with multiple observations per year--Continued

Well number	Geologic unit	Depth (feet)	Period of record	Number of obser-vations	Data source	Range of nitrate concen-tration	Mini-mum concen-tration	Maxi-mum concen-tration	Average concen-tration	Standard deviation	Coeffi-cient of variation (percent)
41N/04E-33H04	SUMS	69	12/88-11/91	35	S	2.7	3.7	6.4	5.2	0.58	11
092G.009.1.1.1-06	SUMS	20	6/88-6/90	13	B	24	10	41	20.3	8.6	42
092G.009.1.1.1-06	SUMS	35	6/88-6/90	12	B	17	17	34	20	4.8	24
092G.009.1.1.1-07	SUMS	55	6/88-6/90	13	B	5.7	6.3	12	8.4	2.0	24
092G.009.1.1.1-07	SUMS	75	6/88-6/90	13	B	1.8	2.3	4.1	3.2	.6	18
092G.009.1.1.2-11	SUMS	25	6/88-6/90	13	B	19	4.0	23	12	5.2	43
092G.009.1.1.2-11	SUMS	35	6/88-6/90	13	B	10	13	23	18	3.2	18
092G.009.1.1.2-12	SUMS	55	6/88-6/90	13	B	8.2	3.8	12	7.5	2.6	35
092G.009.1.1.2-12	SUMS	75	6/88-6/90	13	B	5.0	.2	5.2	2.4	1.8	75
092G.009.1.1.4-18	SUMS	25	6/88-6/90	12	B	7	3.3	11	4.9	1.9	39
092G.009.1.1.4-18	SUMS	35	6/88-6/90	12	B	2.4	3.5	5.9	4.6	0.8	18
092G.009.1.1.4-19	SUMS	55	6/88-6/90	12	B	1.1	4.3	5.6	5.0	.41	8.0
092G.009.1.1.4-19	SUMS	75	6/88-6/90	12	B	1.45	5.5	6.95	6.6	1.2	19.
092G.009.1.2.4-34	EVRS	163	3/73-5/92	40	E	5.0	5.0	10	6.9	1.4	20
092G.009.1.2.3-39	SUMS	81	--	40	E	7.0	11	18	15	1.6	11
092G.008.2.2.2-99	SUMS	25	1/90-5/91	22	E	25	2.6	28	12.2	5.1	42
092G.009.1.1.2-99	SUMS	25	1/90-8/92	22	E	11	6.7	18	11.0	3.2	29
092G.009.1.2.1-99	SUMS	58	11/89-8/92	22	E	22	5.3	27	17.02	5.6	33
092G.009.1.2.1-99	SUMS	96	1/90-8/92	21	E	11	18.3	29	25.26	4.0	16
092G.009.1.1.1-99	SUMS	29	11/82-8/92	22	E	9	16	25	20.28	3.25	16
092G.009.1.1.4-99	SUMS	30	11/89-8/92	21	E	6.4	8.6	15	11.59	1.84	16

Table __.--Summary of values and concentrations of water-quality constituents in ground waters from the Huntingdon-Chuckanut geohydrologic unit

[Concentrations in milligrams per liter (mg/L) unless otherwise noted; Spec. Cond. = Specific Conductance; µS/cm, microsiemens per centimeter at 25 degrees Celsius; D = dissolved, T = total, SAR = Sodium Absorbtion Ratio]

Name	Samples	Mean	Median	Minimum	Maximum	25th percentile	75th percentile
Temperature	8	174.96	11.50	10.10	1,032.00	10.42	227.89
Spec. Cond., field	14	936.59	753.00	88.00	4,025.00	250.07	1,057.88
Spec. Cond., lab	6	1,734.00	1,375.00	360.00	4,200.00	745.50	2,715.00
pH, field	7	8.41	8.37	7.70	9.20	7.80	9.10
pH, lab	5	8.20	8.30	7.60	8.60	7.90	8.45
Dissolved oxygen	7	.10	.10	0.	.30	0.	.20
Hardness as $CaCO_3$	5	55.86	26.09	12.71	195.04	13.45	113.17
Calcium, dissolved	5	18.10	9.90	4.00	61.00	4.30	36.00
Magnesium, dissolved	5	2.41	.66	.24	9.70	.41	5.28
Sodium, dissolved	5	327.40	220.00	67.00	760.00	138.50	570.00
Percent sodium	5	92.19	94.69	82.01	98.25	85.64	97.49
SAR	5	23.78	23.85	5.24	46.39	12.06	35.46
Potassium, dissolved	5	1.96	1.20	.80	5.30	.85	3.45
Alkalinity	5	305.60	226.00	146.00	605.00	162.50	488.50
Sulfate, dissolved	6	14.52	1.30	.10	79.00	.32	23.50
Chloride, dissolved	14	213.87	37.30	1.40	1,205.67	15.10	210.62
Fluoride, dissolved	6	.34	.35	.10	.50	.21	.50
Silica, dissolved	5	10.14	9.90	7.60	13.00	8.40	12.00
T dissolved solids	4	906.92	566.95	207.83	2,285.95	293.76	1,860.05
Iron, dissolved	5	347.60	48.00	5.00	1,500.00	10.00	835.00
Manganese, dissolved	5	47.80	13.00	6.00	110.00	8.50	104.50
^{15}N Isotope	0	--	--	--	--	--	--
Ammonia-N, dissolved	5	.63	.33	.01	2.00	.01	1.40
Ammonia-N, total	3	.16	.14	.13	.20	.13	.20
Nitrite-N, dissolved	5	.01	.01	.01	.01	.01	.01
Nitrite-N, total	3	.01	.01	.01	.01	.01	.01
Ammonia + organic-N, D	5	.94	.70	.20	2.40	.30	1.70
Ammonia + organic-N, T	3	.53	.50	.20	.90	.20	.90
Nitrate + nitrite-N, D	14	.25	.10	.08	1.60	.09	.18
Nitrate + nitrite-N, T	5	.07	.05	.05	.16	.05	.10
Phosphate -PO_4, D	5	.02	.01	.01	.04	.01	.04
Phosphate -PO_4, T	3	.07	.03	.01	.18	.01	.18
Dissolved organic carbon	2	1.20	1.20	1.00	1.40	1.00	1.40
Boron, dissolved	4	125.00	65.00	60.00	310.00	60.00	30.00
Bromide, dissolved	3	1.37	1.10	.41	2.60	.41	.01

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Table __.--Well, water level, and hydrogeologic data

Local well number	Latitude	Longitude	Ground water site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
092G.008.1.2.1-02	490040	1223215	W	W	S	EVRS	30	109	6	230	USGS	19900605	33.03
092G.008.1.2.1-03	490034	1223202	W	W	H	EVRS	30	99		220	USGS	19900605	41.10
092G.008.1.2.2-01	490034	1223129	W	W	H	EVRS	30	39		205	USGS	19900605	4.19
092G.008.1.2.3-10	490124	1223214	W	W	R	EVRS	30	230	8	250	USGS	19900605	56.2
092G.008.1.2.3-99	490124	1223211	W	W						247	USGS	19900605	1.40
092G.008.1.4.1-07	490214	1223139	W	W	H	EVRS	30	51	6	275	USGS	19900606	30.90
092G.008.1.4.2-01	490150	1223024	W	U	U			395	6	300	USGS		
092G.008.1.4.2-08	490156	1223122	W	W	H	EVRS	30	153	6	251	USGS	19900606	33.32
092G.008.1.4.2-15	490153	1223018	W	W	S	EVRS	30	342		300	USGS		
092G.008.1.4.4-03	490248	1223052	W	W	H	EVRS	30	81		305	USGS	19900606	56.16
092G.008.2.1.1-02	490023	1222926	W	W	H	EVRS	30	164	6	164	USGS	19900607	12.40
092G.008.2.1.1-04	490036	1222932	W	W	H	EVRS	30	68		180	USGS	19900607	13.19
092G.008.2.1.2-03	490017	1222736	W	W	H	EVRS	30	39	6	180	USGS	19900607	10.26
092G.008.2.1.2-04	490017	1222821	W	W	P	SUMS	10	52	8	154	USGS	19900607	13.92
092G.008.2.1.3-08	490100	1222929	W	U	U	EVRS	30	302	6	240	USGS	19900608	74.86
092G.008.2.1.4-01	490052	1222808	W	W		EVRS	30	102	8	291	USGS	19900607	45.24
092G.008.2.1.4-09	490106	1222750	W	W	H	SUMS	14	96	6	295	USGS	19900607	54.34
092G.008.2.2.1-03	490022	1222644	W	W	H	SUMS	14	100	6	150	USGS	19900611	4.43
092G.008.2.2.1-04	490012	1222636	W	W	H	EVRS	31	160	6	150	USGS	19900612	5.65
092G.008.2.2.2-10	490043	1222405	W	W	H	EVRS	30	220	6	152	USGS	19900612	39.33
092G.008.2.2.2-11	490043	1222405	W	U		SUMS	10	50	6	152	USGS	19900612	9.99
092G.008.2.2.2-12	490036	1222406	W	W	U	SUMS	10	80		152	USGS	19900612	9.44
092G.008.2.2.2-15	490011	1222432	W	W	S	SUMS	10	70	6	148	USGS	19900612	11.24
092G.008.2.2.2-99	490042	1222410	W	O		SUMS	10	26		150	USGS	19900618	8.46
092G.008.2.2.3-03	490053	1222600	W	W	H	SUMS	10	60	6	210	USGS	19900611	35.53
092G.008.2.2.4-16	490102	1222437	W	W	I	EVRS	30	98	6	170	USGS	19900612	2.47
092G.008.2.3.1-11	490212	1222837	W	W	H			44		305	USGS	19900608	19.39
092G.008.2.3.1-12	490154	1222842	W	W		EVRS	30	50		300	USGS	19900608	13.66
092G.008.2.3.2-10	490155	1222738	W	W		SUMS	10	85		362	USGS	19900608	32.54
092G.008.2.3.2-16	490157	1222739	W	W	H	EVRS	30	164	6	358	USGS	19900608	57.58
092G.008.2.3.3-09	490247	1222932	W	W	H	EVRS	30	73		298	USGS	19900608	12.84
092G.008.2.3.3-14	490246	1222938	W	W	H	EVRS	30	175		298	USGS	19900608	2.18
092G.008.2.3.4-03	490244	1222800	W	W				25			USGS		
092G.008.2.3.4-04	490241	1222749	W	W				125		315	USGS		
092G.008.2.3.4-99	490245	1222738	W	U				180		305	USGS	19900608	13.0
092G.008.2.4.1-18	490151	1222557	W	W	H	SUMS	14	110		325	USGS	19900608	58.42
092G.008.2.4.1-19	490148	1222534	W	W	H	SUMS	14	118		325	USGS	19900611	81.92
092G.008.2.4.1-99	490150	1222559	W	O		SUMS	14	85	6	326	USGS	19881027	57.85
											BCME	19881128	49.87
											BCME	19881129	49.60
											BCME	19881229	46.85
											BCME	19890130	43.96
											BCME	19890227	51.23
											BCME	19890331	51.70
											BCME	19890415	49.10
											BCME	19890428	49.99
											BCME	19890525	54.79
											BCME	19890629	56.13
											BCME	19890730	58.33
											BCME	19890731	58.31
											BCME	19890823	58.88
											BCME	19890924	59.61
											BCME	19890925	59.56
											BCME	19891026	60.12
											BCME	19891127	52.25

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
											BCME	19891128	52.17
											BCME	19891227	51.89
											BCME	19900125	53.26
											BCME	19900226	48.43
											BCME	19900228	48.85
											BCME	19900330	53.24
											BCME	19900424	56.42
											BCME	19900528	58.01
											BCME	19900608	57.35
											BCME	19900630	57.22
											BCME	19900703	57.28
											BCME	19900802	58.81
											BCME	19900903	59.99
											BCME	19900904	60.03
											BCME	19901005	60.85
											BCME	19901106	60.80
											BCME	19901206	49.74
											BCME	19910107	51.50
											BCME	19910114	52.59
											BCME	19910211	52.55
											BCME	19910306	52.74
											BCME	19910405	54.82
											BCME	19910502	55.22
											BCME	19910603	57.54
											BCME	19910604	57.61
											BCME	19910704	58.86
											BCME	19910805	60.42
											BCME	19910807	60.48
											BCME	19910905	61.08
											BCME	19911004	61.21
092G.008.2.4.2-13	490136	1222404	W	W	H	SUMS	10	110		321	USGS	19900612	76.58
092G.008.2.4.2-14	490209	1222420	W	W	H	EVRS	30	129		330	USGS	19900612	105.69
092G.008.2.4.2-99	490141	1222513	W	W	Q			135		210	USGS		
092G.008.2.4.3-14	490219	1222645	W	W	I	SUMS	14	61		360	USGS	19900619	47.62
092G.008.2.4.4-10	490250	1222408	W	U				110	10	345	USGS		
092G.008.2.4.4-12	490223	1222352	W	W	H	EVRS	30	175		270	USGS	19900612	140.58
092G.008.2.4.4-18	490253	1222405	W	W	I	SUMS	10	96	8	340	USGS	19900613	70.03
092G.008.3.1.4-66	490348	1223331	W	O		SUMS	10	73		308	USGS	19900608	57.21
092G.008.4.2.1-31	490311	1222647	W	W	I			85		390	USGS	19900611	14.75
092G.008.4.2.2-22	490310	1222516	W	W	H			132		412	USGS		
092G.008.4.2.2-27	490338	1222430	W	W	H	EVRS	30	127		400	USGS	19900613	106.89
092G.009.1.1.1-06	490031	1222253	W	O		SUMS	10	20		160	USGS	19900611	9.36
092G.009.1.1.1-06	490031	1222253	W	O		SUMS	10	35		160	USGS	19900611	9.36
092G.009.1.1.1-07	490030	1222253	W	O		SUMS	10	55		160	USGS	19900611	9.42
092G.009.1.1.1-07	490030	1222253	W	O		SUMS	10	75		160	USGS	19900611	9.42
092G.009.1.1.1-99	490009	1222331	W	O		SUMS	10	29		151	USGS	19900618	6.69
092G.009.1.1.2-11	490031	1222215	W	O		SUMS	10	25	2	168	USGS	19900611	11.60
092G.009.1.1.2-11	490031	1222215	W	O		SUMS	10	35	2	168	USGS	19900611	11.60
092G.009.1.1.2-12	490030	1222215	W	O		SUMS	10	55	2	168	USGS	19900611	11.56
092G.009.1.1.2-12	490030	1222215	W	O		SUMS	10	75	2	168	USGS	19900611	11.71
092G.009.1.1.2-29	490011	1222133	W	W	I	SUMS	10	48	8	166	USGS	19900615	14.54
092G.009.1.1.2-99	490020	1222132	W	O		SUMS	10	25		167	USGS	19891115	13.22
											BCME	19891215	10.79
											BCME	19900115	10.00
											BCME	19900215	7.94

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Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
											BCME	19900315	7.54
											BCME	19900415	8.92
											BCME	19900515	10.00
											BCME	19900615	10.63
											BCME	19900618	6.3
											BCME	19900715	11.74
											BCME	19900815	13.35
											BCME	19900915	14.56
											BCME	19901015	15.29
											BCME	19901115	11.55
											BCME	19901215	7.84
											BCME	19910115	7.31
											BCME	19910215	7.02
											BCME	19910315	7.45
											BCME	19910415	8.23
											BCME	19910515	9.32
											BCME	19910615	10.66
											BCME	19910715	11.87
											BCME	19910815	13.45
											BCME	19910915	14.11
											BCME	19911015	14.73
											BCME	19911115	14.24
092G.009.1.1.4-10	490043	1222107	W	W	H	SUMS	10	41		180	USGS	19900614	10.02
092G.009.1.1.4-17	490128	1222112	W	W	H	SUMS	10	60		200	USGS	19900614	19.37
092G.009.1.1.4-18	490101	1222215	W	O		SUMS	10	25		170	USGS	19900611	10.24
092G.009.1.1.4-18	490101	1222215	W	O		SUMS	10	35		170	USGS	19900611	10.24
092G.009.1.1.4-19	490100	1222215	W	O		SUMS	10	55		170	USGS	19900611	10.31
092G.009.1.1.4-19	490100	1222215	W	O		SUMS	10	75		170	USGS	19900611	10.31
092G.009.1.1.4-99	490046	1222133	W	O		SUMS	10	30		180	USGS	19900618	17.3
092G.009.1.2.1-23	490042	1222007	W	W	I	SUMS	10	161		190	USGS	19891115	47.97
											BCME	19891215	46.33
											BCME	19900115	44.59
											BCME	19900215	43.44
											BCME	19900315	38.81
											BCME	19900415	38.48
											BCME	19900515	39.66
											BCME	19900615	41.17
											BCME	19900715	42.78
											BCME	19900815	44.49
											BCME	19900915	45.90
											BCME	19901015	46.98
											BCME	19901115	47.21
											BCME	19901215	43.01
											BCME	19910115	39.14
											BCME	19910215	38.25
											BCME	19910315	37.27
											BCME	19910415	37.60
											BCME	19910515	38.38
											BCME	19910615	39.99
											BCME	19910715	41.73
											BCME	19910815	43.73
											BCME	19910915	45.41
											BCME	19911015	46.33
											BCME	19911115	47.74
092G.009.1.2.1-99	490011	1221932	W	W		SUMS	10	96		220	USGS		

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Lati-tude	Longi-tude	GW site type	Site use	Wat-er use	Geo-logic unit	Litho-logic unit	Well depth	Well dia-meter	Alti-tude	Source of data	Water level date	Water level
092G.009.1.2.1-99	490022	1222012	W	O		SUMS	10	58		200	USGS	19900618	35.7
092G.009.1.2.2-32	490013	1221810	W	W	I	EVRS	30	160		140	USGS	19900618	35.11
092G.009.1.2.2-46	490023	1221857	W	W	I	SUMS	14	179		260	USGS	19900615	116.87
092G.009.1.2.3-10	490105	1222030	W	O		SUMS	10	63		180	USGS	19881031	46.55
											BCME	19881130	44.51
											BCME	19881231	41.29
											BCME	19890131	37.48
											BCME	19890228	37.32
											BCME	19890331	37.50
											BCME	19890430	35.84
											BCME	19890531	36.75
											BCME	19890630	38.18
											BCME	19890731	39.96
											BCME	19890831	41.14
											BCME	19890930	42.70
											BCME	19891031	43.92
											BCME	19891130	42.46
											BCME	19891231	40.13
											BCME	19900131	39.10
											BCME	19900228	34.80
											BCME	19900331	34.02
											BCME	19900430	35.04
											BCME	19900531	37.44
											BCME	19900614	37.55
											BCME	19900630	38.20
											BCME	19900731	39.95
											BCME	19900831	41.67
											BCME	19900930	43.00
											BCME	19901031	44.11
											BCME	19901130	39.82
											BCME	19901231	36.07
											BCME	19910131	34.27
											BCME	19910228	33.3
											BCME	19910331	33.37
											BCME	19910430	34.27
											BCME	19910531	35.65
											BCME	19910630	37.43
											BCME	19910731	39.84
											BCME	19910831	41.22
											BCME	19910930	42.30
092G.009.1.2.3-39	490043	1222002	W	W	I	SUMS	10	81		193	USGS	19900615	51.78
092G.009.1.2.3-59	490102	1222043	W	W	I	SUMS	10	84		175	USGS	19900614	27.02
092G.009.1.2.3-69	490133	1221934	W	W							USGS		
092G.009.1.2.3-69	490133	1221934	W	W	I	SUMS	10	175	8	225	USGS	19900618	69.11
092G.009.1.2.3-73A	490132	1222007	W	W	I			100		200	USGS	19900618	39.48
092G.009.1.2.3-99	490046	1221953	W	O		SUMS	10			200	USGS	19891115	58.29
											BCME	19891215	56.62
											BCME	19900115	54.91
											BCME	19900215	53.77
											BCME	19900315	49.11
											BCME	19900415	48.75
											BCME	19900515	49.34
											BCME	19900615	51.57
											BCME	19900715	53.21
											BCME	19900815	54.88

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Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Lati-tude	Longi-tude	GW site type	Site use	Wat-er use	Geo-logic unit	Litho-logic unit	Well depth	Well dia-meter	Alti-tude	Source of data	Water level date	Water level
											BCME	19900915	56.33
											BCME	19901015	57.37
											BCME	19901115	57.67
											BCME	19901215	53.50
											BCME	19910115	49.57
											BCME	19910215	48.61
											BCME	19910315	47.63
											BCME	19910415	47.99
											BCME	19910515	48.78
											BCME	19910615	50.35
											BCME	19910715	52.06
											BCME	19910815	54.09
											BCME	19910915	55.96
											BCME	19911015	56.72
											BCME	19911115	58.13
092G.009.1.2.4-31	490120	1221847	W	W	H	EVRS	30	163	6	215	USGS	19900619	91.20
092G.009.1.3.1-16	490205	1222331	W	U	U			140		210	USGS	19900613	38.20
092G.009.1.3.1-16A	490158	1222331	W	W	H			20		175	USGS	19900613	9.91
092G.009.1.3.2-40	490147	1222116	W	W	I	SUMS	10	55		200	USGS	19900614	17.63
092G.009.1.3.3-08	490230	1222248	W	O	U	SUMS	10	52	8	180	USGS	19881027	11.88
											BCME	19881128	7.06
											BCME	19881129	7.10
											BCME	19881229	7.35
											BCME	19890227	7.69
											BCME	19890331	6.75
											BCME	19890428	7.67
											BCME	19890525	9.07
											BCME	19890626	9.98
											BCME	19890628	10.15
											BCME	19890730	11.69
											BCME	19890731	11.66
											BCME	19890823	12.56
											BCME	19890924	13.53
											BCME	19890925	13.56
											BCME	19891026	14.20
											BCME	19891127	6.83
											BCME	19891128	6.94
											BCME	19891227	7.92
											BCME	19900125	6.30
											BCME	19900226	5.86
											BCME	19900227	5.87
											BCME	19900330	7.34
											BCME	19900427	8.65
											BCME	19900529	10.08
											BCME	19900613	8.19
											BCME	19900630	9.69
											BCME	19900703	9.86
											BCME	19900802	11.70
											BCME	19900903	13.09
											BCME	19900904	13.13
											BCME	19901005	13.73
											BCME	19901106	13.32
											BCME	19901206	4.77
											BCME	19910107	7.62
											BCME	19910111	7.77

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
											BCME	19910211	6.15
											BCME	19910308	6.28
											BCME	19910403	8.17
											BCME	19910502	8.70
											BCME	19910603	10.32
											BCME	19910606	10.44
											BCME	19910704	11.68
											BCME	19910805	13.26
											BCME	19910807	13.33
											BCME	19910905	13.16
											BCME	19911004	13.88
092G.009.1.3.3-20	490224	1222303	W	W	H	SUMS	10	49	6	183	USGS	19900613	13.87
092G.009.1.3.4-26	490233	1222156	W	W	H	SUMS	10	45		195	USGS	19900614	17.05
092G.009.1.3.4-34	490216	1222133	W	W	I	SUMS	10	85		195	USGS	19900614	30.42
092G.009.1.4.2-50	490157	1221853	W	W	H	SUMS	14	88		230	USGS		
092G.009.2.1.1-37	490036	1221641	W	O		SUMS	10	112		50	USGS	19900618	24.80
092G.009.2.1.1-38	490036	1221644	W	W	P	SUMS	14	133	12	50	USGS		
092G.009.2.1.2-24	490031	1221628	W	O		SUMS	10	119		45	USGS	19900618	18.63
092G.009.2.1.2-98	490033	1221628	W	W	P	SUMS	10				USGS		
092G.009.2.1.3-41	490058	1221632	W	O		SUMS	10	220		150	USGS	19881014	138.33
											BCME	19881027	138.21
											BCME	19881128	137.98
											BCME	19881129	137.96
											BCME	19881229	137.52
											BCME	19890116	136.97
											BCME	19890130	136.24
											BCME	19890204	136.15
											BCME	19890227	135.78
											BCME	19890304	135.84
											BCME	19890331	135.40
											BCME	19890428	134.99
											BCME	19890525	134.77
											BCME	19890526	134.74
											BCME	19890625	135.24
											BCME	19890628	135.25
											BCME	19890730	135.53
											BCME	19890731	135.51
											BCME	19890823	135.63
											BCME	19890924	135.94
											BCME	19890925	135.96
											BCME	19891026	136.36
											BCME	19891127	136.29
											BCME	19891227	136.45
											BCME	19900125	136.44
											BCME	19900226	135.84
											BCME	19900228	135.75
											BCME	19900330	134.99
											BCME	19900427	134.61
											BCME	19900527	135.06
											BCME	19900529	135.11
											BCME	19900618	135.08
											BCME	19900630	135.30
											BCME	19900703	135.38
											BCME	19900802	136.04
											BCME	19900904	136.79

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
											BCME	19900926	137.11
											BCME	19901005	136.98
											BCME	19901025	136.52
											BCME	19901106	136.48
											BCME	19901114	136.30
											BCME	19901128	136.21
											BCME	19901206	136.12
											BCME	19910105	135.32
											BCME	19910111	135.20
											BCME	19910211	134.55
											BCME	19910228	134.24
											BCME	19910403	133.85
											BCME	19910430	133.77
											BCME	19910530	133.93
											BCME	19910628	134.20
											BCME	19910727	134.65
											BCME	19910731	134.69
											BCME	19910830	135.53
											BCME	19910927	135.43
092G.009.2.1.3-47	49010	1221714	W	O		SUMS	10	87	6	175	USGS	19881014	63.91
											BCME	19881027	63.99
											BCME	19881128	63.96
											BCME	19881229	62.87
											BCME	19890130	60.75
											BCME	19890227	59.43
											BCME	19890331	58.84
											BCME	19890428	57.86
											BCME	19890524	57.71
											BCME	19890626	58.40
											BCME	19890730	59.60
											BCME	19890823	60.22
											BCME	19890924	61.04
											BCME	19891026	61.82
											BCME	19891127	62.29
											BCME	19891227	61.66
											BCME	19900125	60.97
											BCME	19900226	58.70
											BCME	19900228	58.86
											BCME	19900330	57.47
											BCME	19900427	56.97
											BCME	19900529	57.72
											BCME	19900618	58.62
											BCME	19900703	58.72
											BCME	19900802	59.90
											BCME	19900903	60.83
											BCME	19901005	61.66
											BCME	19901106	62.23
											BCME	19901206	61.56
											BCME	19910107	59.31
											BCME	19910111	59.10
											BCME	19910228	56.54
											BCME	19910401	56.02
											BCME	19910403	55.92
											BCME	19910430	56.35
											BCME	19910530	57.09

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Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
											BCME	19910628	57.85
											BCME	19910730	59.02
											BCME	19910731	59.06
											BCME	19910830	60.11
											BCME	19910927	60.87
092G.009.2.1.4-20	490123	1221621	W	O		SUMS	10	160	6	100	USGS	19900618	42.54
092G.009.2.1.4-23	490112	1221621	W	O				320		90	USGS	19900618	38.21
092G.009.2.1.4-98	490113	1221623	W	W	P	SUMS	10	265	18		USGS		
092G.009.2.1.4-98	490113	1221623	W	W	P			265	12		USGS		
092G.009.2.2.1-03	490010	1221439	W	W	I	SUMS	20	78	10	30	USGS	19900619	3.59
092G.009.2.2.3-11	490106	1221350	W	W	I	SUMS	20	65	8	32	USGS	19900619	5.16
092G.009.2.3.1-32	490140	1221735	W	W	H	SUMS	14	90		210	USGS	19900619	58.33
092G.009.3.1.2-20	490338	1222149	W	W	H	EVRS	30	157		375	USGS	19900614	84.80
092G.009.3.1.2-23	490310	1222137	W	U	U	SUMS	10	125		215	USGS	19900614	13.93
38N/03E-04E01	484848	1222628	W	T				200		308	USGS		
38N/04E-06D01	484902	1222102	W	W	H	EVRS	30	132		276	USGS		
38N/04E-06D01	484902	1222102	W	W	H			132		276	USGS	19900427	3.1
39N/02E-01N01	485335	1223015	W	W	H	SUMS	10	25	36	75	USGS	19900410	9.83
39N/02E-01P02	485337	1222948	W	W	H	SUMS	10	34	36	80	USGS	19900412	11.28
											USGS	19901018	15.11
											USGS	19901114	13.22
											USGS	19901218	10.43
											USGS	19910119	9.70
											USGS	19910220	9.89
											USGS	19910313	10.00
											USGS	19910325	10.66
											USGS	19910521	11.39
											USGS	19910626	12.65
											USGS	19910718	13.68
											USGS	19910823	14.75
											USGS	19910925	14.60
											USGS	19911023	14.90
39N/02E-01Q01	485340	1222927	W	W	I	SUMS	10	31	36	80	USGS	19900410	10.14
39N/02E-02A01	485412	1223040	W	U	U	SUMS	11	40	6	60	USGS	19900413	9.18
39N/02E-02H01	485408	1223040	W	W	I	SUMS	10	19	36	60	USGS	19900412	7.03
39N/02E-03G01	485358	1223207	W	W	H	SUMS	10	32		35	USGS	19900410	4.90
39N/02E-05B02	485419	1223449	W	T						60	USGS		
39N/02E-10F01	485316	1223226	W	W		SUMS	10	20	12	55	USGS	19900412	8.16
											USGS	19901016	11.91
											USGS	19901116	9.27
											USGS	19901218	6.78
											USGS	19910116	6.62
											USGS	19910220	6.23
											USGS	19910313	6.70
											USGS	19910425	7.46
											USGS	19910521	8.39
											USGS	19910626	9.45
											USGS	19910718	10.20
											USGS	19910823	11.96
											USGS	19910925	11.67
											USGS	19911023	11.84
39N/02E-10J01	485253	1223155	W	W	I	SUMS	11	21		75	USGS	19900411	5.07
39N/02E-10Q02	485239	1223216	W	U	U	SUMS	10	27	24	60	USGS	19900411	3.27
39N/02E-11B01	485328	1223102	W	W	H	SUMS	10	26	36	65	USGS	19900410	9.45
39N/02E-11B02	485322	1223102	W	T	U					71	USGS		

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
39N/02E-11M01	485258	1223141	W	W	H	SUMS	10	40			USGS	19900410	2.79
39N/02E-12H04	485305	1222921	W	W	I	SUMS	10	45		82	USGS	19900501	5.48
39N/02E-12K03	485258	1222939	W	W	H	SUMS	10	27		85	USGS	19900413	9.57
39N/02E-12Q01	485244	1222939	W	W	H	SUMS	10	44	6	80	USGS	19900413	2.68
39N/02E-13B01	485234	1222934	W	W	P			52	5	80	USGS	19900413	9.73
39N/02E-14L01	485202	1223106	W	W	H	SUMS	10	21	36	60	USGS	19900412	5.45
39N/02E-14M01	485209	1223125	W	W	H	SUMS	10	34		60	USGS	19900411	5.91
39N/02E-16A01	485229	1223305	W	U		SUMS	10	19	12	48	USGS	19900418	3.22
39N/02E-16H03	485223	1223305	W	W	H	SUMS	11	19	12	50	USGS	19900418	2.54
39N/02E-21K01	485117	1223328	W	U	U	SUMS	12	19	8	50	USGS	19900410	4.87
39N/02E-22D02	485138	1223246	W	W	H	SUMS	10	48	6	50	USGS	19900410	17.49
39N/02E-22K02	485112	1223215	W	W	H	SUMS	10	17	6	45	USGS	19900410	2.87
39N/02E-22K03	485106	1223221	W	W	H	SUMS	10	25	12	58	USGS	19900411	5.18
39N/02E-22L01	485118	1223226	W	Z	U			175		45	USGS		
39N/02E-23F01	485121	1223113	W	W	S	SUMS	10	20	12	61	USGS	19900412	2.40
39N/02E-23G02	485131	1223058	W	W	H	SUMS	10	10	36	50	USGS	19900410	2.63
39N/02E-23J01	485118	1223039	W	T				1060		75	USGS		
39N/02E-24B01	485144	1222938	W	T						68	USGS		
39N/02E-24C02	485137	1222954	W	W	H	SUMS	10	22	12	62	USGS	19900410	7.95
39N/02E-24F02	485130	1222948	W	T				846		70	USGS		
39N/02E-24K01	485118	1222931	W	T	U			380		90	USGS		
39N/02E-24N02	485055	1223009	W	W		SUMS	10	29	12	76	USGS	19900412	2.58
39N/02E-24Q01	485056	1222925	W	U	U	EVRS	30	59	6	110	USGS	19900411	4.66
39N/02E-24R02	485054	1222924	W	W	H	EVRS	30	41	6	134	USGS	19900421	19.56
39N/02E-25C01	485045	1222955	W	T				867		75	USGS		
39N/02E-26C01	485052	1223119	W	W	H	SUMS	12	30	36	70	USGS	19900418	5.91
39N/02E-26H01	485031	1223041	W	W	H	SUMS	12	14		110	USGS	19900418	6.46
39N/02E-26N01	485003	1223139	W	W	H	SUMS	12	24	36	92	USGS	19900412	3.34
39N/02E-27F03	485031	1223242	W	W	H	SUMS	12	44	6	106	USGS	19900411	15.00
											USGS	19901018	18.45
											USGS	19901114	18.18
											USGS	19901218	15.14
											USGS	19910116	13.77
											USGS	19910220	13.85
											USGS	19910314	13.76
											USGS	19910425	14.32
											USGS	19910521	15.08
											USGS	19910626	15.99
											USGS	19910717	16.70
											USGS	19910823	17.59
											USGS	19910925	18.15
											USGS	19911023	18.60
39N/02E-27F04	485034	1223227	W	W	H	SUMS	12	36		108	USGS	19900411	17.39
39N/02E-27J01	485024	1223145	W	W	H	SUMS	12	29	36	110	USGS	19900418	16.54
39N/02E-27K01	485023	1223219	W	W	H	SUMS	12	35	18	110	USGS	19900411	11.84
39N/02E-27N01	485005	1223255	W	W	H	SUMS	10	32	12	95	USGS	19900411	4.08
39N/02E-27P01	485009	1223238	W	T				923		100	USGS		
39N/02E-27Q04	485005	1223207	W	W	P	SUMS	10	22	36	95	USGS		
39N/02E-28J02	485015	1223316	W	W	H	SUMS	10	25	18	93	USGS	19900501	5.20
39N/02E-28J03	485022	1223314	W	W	H	SUMS	12	24	18	90	USGS	19900501	9.76
39N/03E-01C01	485420	1222153	W	W	H	SUMS	10	49	6	96	USGS	19900427	9.39
											USGS	19901018	14.27
											USGS	19901115	12.54
											USGS	19901217	7.67
											USGS	19910116	6.8

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Local well number	Lati-tude	Longi-tude	GW site type	Site use	Wat-er use	Geo-logic unit	Litho-logic unit	Well depth	Well dia-meter	Alti-tude	Source of data	Water level date	Water level
											USGS	19910220	7.48
											USGS	19910313	8.05
											USGS	19910422	9.57
											USGS	19910522	10.82
											USGS	19910625	12.16
											USGS	19910717	12.84
											USGS	19910822	13.67
											USGS	19910926	13.13
											USGS	19911023	14.63
39N/03E-01D01	485410	1222223	W	W	N	SUMS	10	39	36	100	USGS	19900320	13.21
39N/03E-01R01	485330	1222124	W	W	H	SUMS	12	46	6	120	USGS		
39N/03E-02A01	485411	1222235	W	W	H	SUMS	10	39		100	USGS	19900330	15.77
											USGS	19900319	6.42
39N/03E-02B02	485418	1222254	W	W	H			40		93	USGS	19900828	11.67
39N/03E-02B03	485413	1222259	X	T				180		93	USGS		
39N/03E-02K01	485353	1222254	W	U	U	SUMS	10	39		100	USGS	19900329	13.58
39N/03E-02N02	485330	1222330	W	W	H	SUMS	10	30		100	USGS		
39N/03E-02N03	485333	1222344	W	W	H	SUMS	10	36	6	95	USGS	19900320	15.02
39N/03E-02Q01	485332	1222258	W	W	H	SUMS	10	32		106	USGS		
39N/03E-03E01	485358	1222504	W	W	H	SUMS	10	43	6	100	USGS	19900320	20.38
39N/03E-03G01	485408	1222421	W	W	I	SUMS	10	24	36	80	USGS	19900411	4.32
39N/03E-03M01	485346	1222448	W	Z	U			262		95	USGS		
39N/03E-03R02	485332	1222357	W	W	I	SUMS	10	40		95	USGS	19900320	12.95
39N/03E-04B01	485422	1222530	W	W	I	SUMS	10	31	6	83	USGS	19900321	15.21
39N/03E-04M01	485346	1222618	W	W	I	SUMS	10	41		100	USGS	19900321	23.56
39N/03E-04M02	485346	1222619	W	W	H			37	6	100	USGS		
39N/03E-04M02	485346	1222619	W	W	H	SUMS	10	37	6	100	USGS	19900321	22.96
39N/03E-04P01	485338	1222557	W	W	I	SUMS	10	41		97	USGS	19900321	21.43
39N/03E-04R02	485334	1222509	W	W	I	SUMS	10	20	36	80	USGS	19900320	2.96
39N/03E-05L01	485354	1222712	W	W	H			38		83	USGS		
39N/03E-05L02	485356	1222713	W	W	H			38	6	83	USGS		
39N/03E-05L03	485357	1222715	W	W	H			38	6	83	USGS	19900321	14.83
39N/03E-05Q01	485333	1222657	W	W	H	SUMS	10	9		90	USGS		
39N/03E-05Q02	485334	1222658	W	W	I	SUMS	10	28	36	90	USGS	19900321	9.42
39N/03E-06K01	485402	1222816	W	T				3490		65	USGS		
39N/03E-06M01	485353	1222902	W	T				2000		75	USGS		
39N/03E-07A01	485324	1222808	W	W	I	SUMS	11	48		80	USGS		
39N/03E-07K01	485256	1222823	W	W	I	SUMS	10	26	36	80	USGS	19900322	2.57
39N/03E-07K02	485304	1222820	W	W	H	SUMS	10	24		83	USGS	19900322	3.57
39N/03E-07L01	485304	1222830	W	W	I	SUMS	10	30		83	USGS	19900322	2.07
39N/03E-08C01	485326	1222718	W	W	I	SUMS	10	26		92	USGS		
39N/03E-08C02	485330	1222726	W	W	H	SUMS	10	27		90	USGS	19900322	12.03
											USGS	19900830	15.40
39N/03E-08F02	485307	1222720	W	W	H	SUMS	10	20		85	USGS	19900322	5.98
39N/03E-09C01	485328	1222554	W	W	I	SUMS	10	25		82	USGS	19900323	4.89
39N/03E-09D02	485324	1222624	W	W	P	SUMS	10	38	8	95	USGS	19900323	15.76
39N/03E-09Q02	485241	1222534	W	W	H			20		95	USGS	19900329	7.63
39N/03E-10E01	485313	1222447	W	U	U	SUMS	10	40	6	90	USGS	19900327	9.58
39N/03E-10H02	485317	1222402	W	W	H	SUMS	10	47	6	97	USGS	19900329	19.89
39N/03E-10J04	485254	1222351	W	W	H	CCKN	40	160		117	USGS	19900329	2.39
39N/03E-10L01	485257	1222441	W	W	H	SUMS	10	35		96	USGS	19900430	12.17
											USGS	19901015	15.58
											USGS	19901116	13.73
											USGS	19901217	9.6
											USGS	19910116	8.68

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Lati-tude	Longi-tude	GW site type	Site use	Wat-er use	Geo-logic unit	Litho-logic unit	Well depth	Well dia-meter	Alti-tude	Source of data	Water level date	Water level
											USGS	19910221	9.80
											USGS	19910314	10.27
											USGS	19910522	13.12
											USGS	19910717	14.79
											USGS	19910823	15.58
											USGS	19910926	16.16
											USGS	19911024	16.81
39N/03E-10Q01	485239	1222409	W	Z	H			210		140	USGS		
39N/03E-10Q02	485245	1222422	W	W	H			28		100	USGS	19900323	11.7
39N/03E-10Q03	485245	1222424	W	U	U			120		105	USGS	19900323	
39N/03E-11A02	485326	1222236	W	W	H	SUMS	10	37	6	105	USGS	19900412	14.5
39N/03E-11M01	485253	1222337	W	W	H	CCKN	40	80		125	USGS		
39N/03E-11P01	485241	1222314	W	U	U	CCKN	40	101		150	USGS	19900328	7.19
39N/03E-12C01	485325	1222153	W	U	U	SUMS	12	37		117	USGS	19900327	23.54
39N/03E-12D02	485328	1222207	W	W	H	SUMS	12	43	6	115	USGS	19900409	23.16
39N/03E-12G01	485314	1222138	W	W	H	SUMS	10	48		125	USGS	19900327	27.84
39N/03E-12J02	485257	1222122	W	U	U	SUMS	12	50	6	130	USGS	19900412	32.28
39N/03E-12R03	485237	1222128	W	Z	U	SUMS	10	47	6	135	USGS		
39N/03E-13E01	485211	1222225	W	W	H	CCKN	40	100		145	USGS	19900412	7.83
39N/03E-13R01	485147	1222111	W	W	H	CCKN	40	120		210	USGS	19900327	19.05
39N/03E-13R02	485149	1222135	W	W	H	SUMS	12	20	36	142	USGS		
39N/03E-14A01	485230	1222248	W	W	I	CCKN	40	130		130	USGS		
39N/03E-15C02	485233	1222428	W	W	H	CCKN	40	115		122	USGS	19900328	10.18
39N/03E-15D02	485234	1222503	W	W	H	SUMS	10	35		97	USGS	19900329	13.13
39N/03E-15J01	485208	1222408	W	W	H	CCKN	40	72		180	USGS	19900328	7.82
39N/03E-15L01	485209	1222445	W	W	H	CCKN	40	99		150	USGS	19900328	17.46
39N/03E-16B02	485237	1222536	W	W	H	SUMS	10	23	12	95	USGS	19900329	8.63
39N/03E-16F01	485214	1222604	W	W	H	SUMS	10	28	36	100	USGS	19900411	14.02
39N/03E-16F02	485213	1222559	W	W	H	SUMS	10	37			USGS		
39N/03E-16L03	485203	1222608	W	W	I	SUMS	10	21	36	100	USGS	19900411	9.78
39N/03E-16N02	485149	1222620	W	T				140		98	USGS		
39N/03E-17R02	485151	1222631	W	U	U			40		100	USGS		
39N/03E-17R03	485148	1222640	W	W	H	SUMS	10	60	6	97	USGS	19900409	18.84
39N/03E-18Q01	485147	1222808	W	W	H	SUMS	10	21	36	90	USGS	19900411	5.61
39N/03E-19L01	485110	1222830	W	W	H	EVRS	30	54	6	140	USGS	19900328	23.33
39N/03E-19N01	485056	1222853	W	W	C	EVRS	30	62	6	141	USGS	19900328	27.62
											USGS	19901016	31.26
											USGS	19901116	29.27
											USGS	19901218	26.7
											USGS	19910116	26.69
											USGS	19910220	26.58
											USGS	19910313	26.68
											USGS	19910423	27.28
											USGS	19910521	28.44
											USGS	19910626	29.40
											USGS	19910717	29.89
											USGS	19910823	30.53
											USGS	19910926	30.92
											USGS	19911023	31.23
39N/03E-19Q01	485055	1222808	W	W	H	EVRS	30	97	6	181	USGS	19900409	72.65
39N/03E-20F02	485129	1222713	W	W	H	EVRS	30	40		141	USGS	19900329	15.42
39N/03E-20K01	485117	1222652	W	W	H	EVRS	30	45	6	153	USGS	19900329	33.58
39N/03E-20L01	485117	1222712	W	W	H	EVRS	30	51	6	150	USGS	19900329	39.55
39N/03E-20R01	485054	1222637	W	W	H	EVRS	31	287	6	220	USGS	19900421	122.98
39N/03E-21E01	485123	1222623	W	W	H	EVRS	30	40	6	140	USGS	19900407	11.01

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Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
39N/03E-21K01	485118	1222538	W	W	H	EVRS	31	158	6	190	USGS	19900420	96.96
39N/03E-21M01	485117	1222621	W	T						160	USGS		
39N/03E-22M01	485115	1222502	W	W	H	EVRS	30	163		210	USGS	19900322	105.77
39N/03E-23A01	485142	1222240	W	W	H	SUMS	10	32	6	165	USGS	19900323	11.39
39N/03E-23D01	485138	1222339	W	U	U	CCKN	40	185	6	165	USGS	19900322	19.28
											USGS	19901016	20.75
											USGS	19901116	20.09
											USGS	19901218	19.07
											USGS	19910117	19.08
											USGS	19910220	18.93
											USGS	19910313	18.85
											USGS	19910422	18.88
											USGS	19910522	19.13
											USGS	19910626	20.71
											USGS	19910717	19.80
											USGS	19910823	20.23
											USGS	19910926	20.25
											USGS	19911023	20.40
39N/03E-23E01	485131	1222333	W	W	H	SUMS	12	21	12	135	USGS	19900322	1.82
39N/03E-23J01	485109	1222238	W	W	H	CCKN	40	126	6	192	USGS	19900406	65.71
39N/03E-23M01	485113	1222338	W	W	H	EVRS	30	100	6	165	USGS	19900406	62.99
39N/03E-24B01	485136	1222136	W	W	H	SUMS	10	18	36	149	USGS	19900409	9.29
39N/03E-24D01	485134	1222227	W	T	U			100	6	169	USGS		
39N/03E-25A01	485046	1222113	W	W	H	EVRS	30	148	6	227	USGS	19900404	47.7
39N/03E-25E01	485025	1222215	W	W	H	EVRS	30	131	6	208	USGS	19900320	76.09
39N/03E-26D01	485043	1222343	W	W	H	EVRS	30	90	6	190	USGS	19900320	68.70
39N/03E-26E01	485029	1222342	W	W	H	EVRS	30	129		230	USGS	19900322	99.11
39N/03E-26J01	485020	1222247	W	W	H	CCKN	40	182		230	USGS	19900320	114.7
39N/03E-26P02	485005	1222311	W	W	P	EVRS	31	155	6	262	USGS	19901017	135.62
39N/03E-27A01	485041	1222406	W	W	H	EVRS	30	150		195	USGS	19900407	15.69
39N/03E-27H01	485038	1222353	W	U	U	EVRS	30	62		190	USGS	19900407	20.15
											USGS	19901016	21.92
											USGS	19901116	14.37
											USGS	19901218	17.13
											USGS	19910117	16.86
											USGS	19910220	17.76
											USGS	19910313	16.72
											USGS	19910422	17.15
											USGS	19910522	18.40
											USGS	19910625	19.40
											USGS	19910717	19.96
											USGS	19910823	20.82
											USGS	19910926	21.00
											USGS	19911023	21.14
39N/03E-27H02	485036	1222353	W	W	H	EVRS	30	98		218	USGS	19900420	79.95
39N/03E-28F01	485031	1222604	W	W	H	EVRS	30	286	6	225	USGS		
39N/03E-28J01	485023	1222518	W	W	H	EVRS	30	85	6	230	USGS	19900420	43.70
39N/03E-28Q02	485003	1222547	W	W	H	EVRS	31	180	6	290	USGS	19900404	158.70
39N/03E-28R01	485008	1222513	W	W	H	EVRS	31	199	6	270	USGS	19900420	148.96
39N/03E-29B01	485050	1222656	W	W		EVRS	30	97	6	180	USGS		
39N/03E-29C01	485044	1222719	W	W	H	EVRS	30	105	6	180	USGS	19900327	68.32
39N/03E-29D01	485043	1222734	W	W	H	EVRS	30	74		160	USGS	19900407	49.99
39N/03E-30A01	485044	1222758	W	W	H	EVRS	30	82		160	USGS	19900501	49.98
39N/03E-30B02	485052	1222818	W	W	H	EVRS	30	59	6	161	USGS	19900328	45.29
39N/03E-30D02	485050	1222847	W	W	H	EVRS	30	68	6	150	USGS	19900328	35.55

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Lati-tude	Longi-tude	GW site type	Site use	Wat-er use	Geo-logic unit	Litho-logic unit	Well depth	Well dia-meter	Alti-tude	Source of data	Water level date	Water level
39N/03E-30N01	485005	1222850	W	W	H	EVRS	30	131	6	190	USGS	19900328	72.39
39N/03E-30R01	485010	1222754	W	W	H	EVRS	30	217	6	302	USGS		
39N/03E-31B02	484959	1222818	W	T				1,990		250	USGS		
39N/03E-31Q02	484909	1222814	W	W	H	EVRS	30	215		282	USGS	19900403	177.26
39N/03E-31R02	484919	1222805	W	W	H	EVRS	30	214	6	310	USGS	19900407	199.69
39N/03E-31R03	484915	1222805	W	W	H	EVRS	30	232	6	305	USGS	19900407	194.53
39N/03E-32A02	484959	1222632	W	T				1,520		278	USGS		
39N/03E-32E01	484947	1222735	W	W	H	EVRS	30		6	330	USGS	19900330	220.52
39N/03E-32J01	484925	1222637	W	W	H	EVRS	31	218	6	310	USGS	19900420	186.14
39N/03E-32M01	484922	1222731	W	T				1,720		290	USGS		
39N/03E-33K01	484923	1222537	W	W	H	EVRS	30	198	6	325	USGS	19900330	192.49
39N/03E-33M01	484933	1222627	W	W	H	EVRS	30	205	6	318	USGS	19900330	193.37
39N/03E-33R01	484911	1222528	W	W	H	CCKN	40	270	6	310	USGS	19900403	170.8
39N/03E-34C01	484957	1222439	W	T	H			500		295	USGS		
39N/03E-34N01	484909	1222504	W	W	H	SUMS	10	20	12	303	USGS	19900330	4.66
39N/03E-34P02	484911	1222447	W	W	H	EVRS	31	198	6	310	USGS	19900403	173.93
39N/03E-34Q01	484913	1222418	W	W	H	EVRS	31	206	6	304	USGS	19900403	173.79
39N/03E-35L01	484931	1222328	W	W	H	EVRS	30	100		232	USGS	19900407	84.88
39N/03E-35R01	484908	1222249	W	W	H	EVRS	30	60		260	USGS		
39N/03E-36B01	484958	1222138	W	U	H	EVRS	30	166	8	305	USGS	19900323	141.82
											USGS	19901015	141.90
											USGS	19901116	142.06
											USGS	19901218	141.37
											USGS	19910117	141.98
											USGS	19910220	141.67
											USGS	19910313	141.44
											USGS	19910422	141.38
											USGS	19910522	142.42
											USGS	19910717	141.52
											USGS	19910823	141.60
											USGS	19910926	141.53
											USGS	19911023	141.53
39N/03E-36B03	484956	1222138	W	U	U	EVRS	30	31		315	USGS	19900323	12.97
											USGS	19901015	21.63
											USGS	19901116	15.48
											USGS	19901218	8.78
											USGS	19910117	8.54
											USGS	19910220	8.71
											USGS	19910313	9.91
											USGS	19910422	13.02
											USGS	19910522	17.15
											USGS	19910626	18.74
											USGS	19910717	19.66
											USGS	19910823	20.76
											USGS	19910926	21.19
											USGS	19911023	21.80
39N/03E-36L01	484922	1222154	W	W	H	EVRS	30	223	6	275	USGS	19900404	32.89
39N/03E-36P01	484908	1222213	W	W	H	EVRS	30	73	6	260	USGS	19900404	31.26
39N/03E-36P02	48490	1222158	W	W	H	EVRS	30	107	6	260	USGS		
39N/04E-03C01	485410	1221642	W	W	H	VSHN	50	37		150	USGS	19900522	16.73
39N/04E-03P01	485336	1221634	W	W	H	VSHN	50	117		370	USGS	19900522	45.41
											USGS	19900831	55.25
39N/04E-03P02	485337	1221634	W	U		CCKN	40	260		370	USGS	19900831	53.40
											USGS	19901016	53.77
											USGS	19901115	53.68

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Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
											USGS	19910117	55.13
											USGS	19910219	54.14
											USGS	19910315	54.01
											USGS	19910423	53.46
											USGS	19910522	53.20
											USGS	19910625	53.57
											USGS	19910717	54.72
											USGS	19910822	56.50
											USGS	19910925	58.50
											USGS	19911023	57.74
39N/04E-04H01	485355	1221719	W	W	H	SUMS	12	41		135	USGS	19900522	32.10
39N/04E-04Q01	485329	1221749	W	W	H	SUMS	12	74	6	140	USGS	19900523	29.10
39N/04E-04Q02	485332	1221748	W	W	I	SUMS	12	58		138	USGS	19900523	29.21
39N/04E-06D01	485411	1222051	X	T						100	USGS		
39N/04E-06E01	485404	1222104	W	W	H	SUMS	12	63	8	105	USGS	19900423	20.27
39N/04E-06E02	485407	1222050	W	W	I	SUMS	12	67	8	107	USGS		
39N/04E-08C02	485324	1221925	W	W	I	SUMS	15	46	8	107	USGS	19900522	9.91
39N/04E-10D01	485316	1221654	W	W	H	VSHN	50	51		260	USGS	19900522	10.83
39N/04E-10M01	485251	1221658	W	W	H	VSHN	50	44	6	260	USGS	19900522	8.04
39N/04E-16B01	485231	1221740	W	W	S	VSHN	50	57		145	USGS	19900524	35.10
39N/04E-16B02	485229	1221743	W	W	S	SUMS	10	77	6	130	USGS	19900524	35.38
39N/04E-16D01	485223	1221818	W	W	I	SUMS	15	26	36	125	USGS	19900524	23.98
39N/04E-16F01	485212	1221805	W	W	H	SUMS	15	22		130	USGS		
39N/04E-16H01	485217	1221731	W	W	H	VSHN	50	48	6	130	USGS	19900525	33.39
39N/04E-16L02	485209	1221811	W	W	H	SUMS	15	29		130	USGS		
39N/04E-16Q02	485154	1221736	W	W	H	SUMS	15	33	6	130	USGS	19900523	20.98
39N/04E-17C01	485224	1221918	W	W	H	SUMS	15	53	6	120	USGS	19900523	10.72
39N/04E-18E01	485209	1222104	W	U	U	CCKN	40	121	6	210	USGS		
39N/04E-18M01	485202	1222107	W	W	H	CCKN	40	154	6	190	USGS		
39N/04E-18Q01	485147	1222015	W	W	H			90	6	160	USGS	19900425	.68
39N/04E-18R01	485144	1221956	W	W	H	EVRS	30	28		125	USGS	19900425	10.0
39N/04E-19C01	485141	1222036	W	W	H	CCKN	40	167	6	230	USGS	19900424	56.42
39N/04E-19E01	485119	1222105	W	Z				242		215	USGS		
39N/04E-19E02	485122	1222049	W	W	H	CCKN	40	110	6	200	USGS	19900424	1.54
39N/04E-19F02	485122	1222042	W	W	H	CCKN	40	170	6	190	USGS	19900424	7.06
39N/04E-19M01	485110	1222106	W	W	H	CCKN	40	200	6	220	USGS	19900424	69.32
39N/04E-20H01	485118	1221840	W	W	H	SUMS	15	41	6	130	USGS	19900426	14.19
39N/04E-20L01	485104	1221925	W	W	H	SUMS	10	37		150	USGS	19900424	21.06
39N/04E-20M02	485105	1221940	W	W	H	SUMS	10	33		155	USGS	19900424	21.33
39N/04E-20M03	485105	1221946	W	U	U	SUMS	10	26	6	155	USGS	19900424	9.73
39N/04E-22F01	485125	1221642	W	W	H	VSHN	50	71	6	180	USGS	19900524	30.51
39N/04E-22L01	485117	1221654	W	W	H	SUMS	15	30		155	USGS	19900523	13.50
39N/04E-22N01	485103	1221702	W	W	H	SUMS	15	39		150	USGS	19900524	12.51
39N/04E-28F01	485032	1221758	W	W	H			52	6	160	USGS	19900425	23.6
39N/04E-28K02	485018	1221734	W	W	H			54	6	170	USGS	19900525	27.25
39N/04E-29A01	485040	1221839	W	U	U	CCKN	40	275		200	USGS		
39N/04E-29B01	485037	1221908	W	W	H					203	USGS		
39N/04E-29B01	485038	1221908	W	W	H	EVRS	10	79		203	USGS	19900426	69.09
39N/04E-29H01	485028	1221844	W	W	H	SUMS	12	20	5	205	USGS	19900425	3.42
39N/04E-29H02	485034	1221839	W	W	H	EVRS	30			200	USGS	19900425	66.68
39N/04E-29M01	485021	1221938	W	W	I	EVRS	30	30		200	USGS	19900426	2.63
39N/04E-29N01	485009	1221937	W	U	U	CCKN	40	610	6	210	USGS	19900426	5.88
39N/04E-30D01	485044	1222049	W	W	H	EVRS	30	99	6	185	USGS	19900426	28.01
39N/04E-30F01	485025	1222047	W	T	U					225	USGS		
39N/04E-30M01	485023	1222107	W	W	H			65			USGS	19900323	48.79

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
39N/04E-31B01	484948	1222029	W	W	H	EVRS	30	225	6	220	USGS		
39N/04E-31D01	484951	1222111	X	T	U			311		250	USGS		
39N/04E-31Q02	484907	1222014	W	W	H	EVRS	30	92		265	USGS		
39N/04E-32A01	484954	1221838	W	W	H	EVRS	30	71	6	270	USGS	19900425	23.81
39N/04E-32D01	484957	1221950	W	W	H			230	6	215	USGS		
39N/04E-32D01	484957	1221950	W	W	H			230	6	215	USGS		
39N/04E-32E01	484939	1221948	W	W	H	EVRS	30	139	5	230	USGS		
39N/04E-32F01	484932	1221921	W	W	H	CCKN	40	231	6	290	USGS		
39N/04E-32M01	484932	1221939	W	W	H	EVRS	30	101		265	USGS		
39N/04E-32N01	484916	1221947	W	W	H	EVRS	30	107		280	USGS	19900426	3.83
39N/04E-33E01	484943	1221829	W	W	H	EVRS	30	123		340	USGS		
39N/04E-34C02	484952	1221649	W	W	H	EVRS	31	146	6	300	USGS		
											USGS	19900425	142.88
40N/02E-01C01	485931	1222959	W	U	U	SUMS	10	40		125	USGS	19900814	4.56
40N/02E-01F02	485917	1222958	W	W	I	SUMS	10	28		121	USGS	19900814	4.3
40N/02E-01N01	485851	1223002	W	W	I	SUMS	10	21		115	USGS	19900816	5.77
40N/02E-02B01	485934	1223059	W	W	P	EVRS	31	149	8	180	USGS	19901218	48.8
											USGS	19910118	49.16
											USGS	19910220	48.82
											USGS	19910314	49.02
											USGS	19910423	49.20
											USGS	19910606	49.76
											USGS	19910625	50.02
											USGS	19910717	50.53
											USGS	19910822	51.01
											USGS	19910925	50.74
											USGS	19911023	50.85
40N/02E-02D01	485935	1223127	W	W	H	EVRS	31	138		220	USGS	19900810	70.44
40N/02E-02D02	485931	1223132	W	U	U			8		220	USGS	19900815	6.19
40N/02E-02D03	485931	1223132	T	Z	U			0		220	USGS		
40N/02E-02Q01	485854	1223048	W	W	I	SUMS	10	23	36	114	USGS	19900815	8.19
40N/02E-02Q02	485854	1223100	W	W	I	SUMS	10	23		115	USGS	19900830	8.67
40N/02E-03C01	485936	1223229	W	W	H	EVRS	30	100		240	USGS	19900810	50.52
											USGS	19901116	49.85
											USGS	19910220	48.93
											USGS	19910314	48.82
											USGS	19910521	49.18
											USGS	19910625	50.41
											USGS	19910717	49.90
											USGS	19910822	50.50
											USGS	19910925	50.10
											USGS	19911023	49.99
40N/02E-03K01	485903	1223207	W	W	P	EVRS	30	208	6	250	USGS		
40N/02E-04A02	485927	1223305	W	W	H	EVRS	30	51		237	USGS	19900810	41.55
40N/02E-09H01	485829	1223306	W	U	U	EVRS	30	80	6	200	USGS	19900816	61.45
40N/02E-10N02	485758	1223244	W	W	H	SUMS	10	38	6	107	USGS		
40N/02E-11G01	485827	1223052	W	W	I	SUMS	10	28	36	112	USGS	19900815	16.85
											USGS	19900816	6.93
40N/02E-11M01	485814	1223135	W	W	I	SUMS	13	19		107	USGS	19900815	5.42
40N/02E-12C01	485834	1222948	W	W	I	SUMS	10	26	36	112	USGS		
40N/02E-12L01	485820	1222959	W	W	I	SUMS	10	31	36	111	USGS	19900814	9.84
40N/02E-13H01	485734	1222912	W	W	I	SUMS	12	26	36	103	USGS		
40N/02E-13J02	485720	1222919	W	W	I	SUMS	10	40		100	USGS		
40N/02E-13J03	485720	1222920	W	W	I	SUMS	10	20		100	USGS	19900817	9.34
40N/02E-13J04	485721	1222920	W	O	U	SUMS	10	16	1	99	USGS	19910521	3.85

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
40N/02E-13J05	485719	1222920	W	O	U	SUMS	10	16	1	99	USGS	19910521	3.79
40N/02E-13J06	485719	1222918	W	O	U	SUMS	10	18	1	99	USGS	19910521	5.18
40N/02E-13J07	485719	1222917	W	O	U	SUMS	10	16	1	99	USGS	19910521	3.64
40N/02E-14P02	485706	1223108	W	W	H	SUMS	10	39	36	91	USGS	19900814	21.62
40N/02E-14R01	485704	1223039	W	W	T	SUMS	10	30	36	95	USGS		
40N/02E-15A01	485754	1223146	W	W	I	SUMS	10	12		106	USGS		
40N/02E-15C01	485748	1223233	W	W	I	SUMS	10			99	USGS		
40N/02E-15H01	485736	1223158	W	W	I	SUMS	10			97	USGS		
40N/02E-15H02	485736	1223148	W	W	U	SUMS	10	15		100	USGS		
40N/02E-15J01	485726	1223147	W	W	H	SUMS	10	24		95	USGS	19900816	9.26
40N/02E-15P01	485705	1223241	W	W	H	SUMS	10	24	36	90	USGS		
40N/02E-15Q01	485708	1223221	W	Z	U			26	36	90	USGS		
40N/02E-15R02	485709	1223147	W	W	H	SUMS	10	26		92	USGS		
40N/02E-16B02	485753	1223329	W	W	H	SUMS	10	20	30	105	USGS		
40N/02E-21A01	485658	1223312	W	W	H	SUMS	13	21		90	USGS		
40N/02E-21D01	485658	1223409	W	W	S	SUMS	10	18		88	USGS		
40N/02E-21J01	485629	1223305	W	W	H	SUMS	10	21		83	USGS	19900817	7.60
40N/02E-21J05	485632	1223317	W	W	H	SUMS	10	17		82	USGS		
40N/02E-21N02	485704	1223422	W	W	F	SUMS	10			71	USGS		
40N/02E-21R01	485611	1223308	W	W	H	SUMS	10	24		73	USGS	19900814	8.02
40N/02E-21R02	485611	1223314	W	W	I	SUMS	10	23		74	USGS		
40N/02E-21R03	485607	1223307	W	W	H	SUMS	10			74	USGS		
40N/02E-22E02	485638	1223301	W	W	H	SUMS	10	21	36	86	USGS	19900814	7.23
40N/02E-22N02	485614	1223301	W	W	H	SUMS	10			74	USGS		
40N/02E-22N07	485609	1223246	W	W	H	SUMS	10			74	USGS		
40N/02E-22R02	485608	1223201	W	W	H	SUMS	10	30	6	60	USGS	19900815	19.46
40N/02E-23A03	485650	1223043	W	W	H	SUMS	10	23		90	USGS		
40N/02E-23B02	485659	1223102	W	W	H	SUMS	10			92	USGS		
40N/02E-23C01	485701	1223121	W	W	H	SUMS	10	38	18	90	USGS	19900814	24.20
40N/02E-23D01	485659	1223126	W	W	H	SUMS	10	30		91	USGS	19900710	21.3
40N/02E-23D02	485700	1223134	W	W	H	SUMS	10	48	6	90	USGS	19900814	19.15
40N/02E-23D04	48565	1223133	W	W	H	SUMS	10			83	USGS		
40N/02E-23N01	485612	1223141	W	W	H	SUMS	10	34		75	USGS	19900816	18.1
40N/02E-23P01	485613	1223104	W	U	U	SUMS	10	29		77	USGS	19900816	13.03
40N/02E-23Q01	485612	1223047	W	W	I	SUMS	10	25	36	78	USGS	19900816	9.46
40N/02E-26A03	485602	1223034	W	W	P	SUMS	10	33	36	76	USGS	19900817	20.23
40N/02E-26A04	485555	1223024	W	W	I	SUMS	10	25		60	USGS		
40N/02E-26B02	485502	1223054	W	W	H	SUMS	10			65	USGS		
40N/02E-26C03	485602	1223107	W	W	H	SUMS	10			62	USGS		
40N/02E-26C04	485602	1223104	W	W	H	SUMS	10			65	USGS		
40N/02E-26D02	485559	1223128	W	W	I	SUMS	10			70	USGS		
40N/02E-26E01	485542	1223125	W	W	P	SUMS	10	35	10	73	USGS	19900817	21.89
40N/02E-27B01	485607	1223214	W	W	H	SUMS	10	41	18	65	USGS	19900815	25.56
											USGS	19901017	25.12
											USGS	19901114	22.21
											USGS	19901218	21.62
											USGS	19910118	21.24
											USGS	19910220	22.21
											USGS	19910314	22.84
											USGS	19910324	23.50
											USGS	19910521	23.95
											USGS	19910626	25.10
											USGS	19910718	24.95
											USGS	19910813	25.20
											USGS	19910925	25.53

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Lati-tude	Longi-tude	GW site type	Site use	Wat-er use	Geo-logic unit	Litho-logic unit	Well depth	Well dia-meter	Alti-tude	Source of data	Water level date	Water level
											USGS	19911023	25.48
40N/02E-27C01	485607	1223224	W	W	H	SUMS	10			74	USGS		
40N/02E-27D02	485558	1223248	W	W	H	SUMS	10			60	USGS		
40N/02E-27N02	485522	1223257	W	W	H	SUMS	10	26	36	65	USGS	19900817	14.82
40N/02E 28G01	485551	1223343	W	W	H	SUMS	10			65	USGS		
40N/02E-33B02	485506	1223324	W	W	P	SUMS	10	36	36	65	USGS		
40N/02E-35G01	485448	1223058	W	U	U	SUMS	15	18	36	35	USGS	19900816	8.60
40N/02E-36N01	485425	1223003	W	W	I	SUMS	10	44	36	68	USGS	19900501	12.92
40N/03E-01R01	485847	1222104	W	W	I	SUMS	10	26	36	119	USGS	19900622	11.66
40N/03E-02B01	485935	1222242	W	W	H	SUMS	10	25		157	USGS	19900706	12.59
40N/03E-02B03	485927	1222252	W	W	I	SUMS	10	59	8	153	USGS	19900706	11.37
40N/03E-02C01	485930	1222308	W	W	I	SUMS	10	24		152	USGS	19900709	11.99
40N/03E-02M02	485858	1222339	W	W	I	SUMS	10	57	8	141	USGS	19900725	8.37
40N/03E-02N01	485849	1222321	W	W	I	SUMS	10	20		134	USGS	19900725	10.75
40N/03E-03A02	485936	1222355	W	W	H	SUMS	10	26	6	147	USGS	19900710	10.88
40N/03E-03B01	485932	1222416	W	W	H	SUMS	10	29	6	144	USGS	19900712	9.95
											USGS	19900830	11.76
											USGS	19901018	11.76
											USGS	19901114	6.89
											USGS	19901218	4.04
											USGS	19910117	4.12
											USGS	19910220	4.15
											USGS	19910314	4.88
											USGS	19910423	6.19
											USGS	19910521	7.52
											USGS	19910625	8.70
											USGS	19910717	11.08
											USGS	19910821	11.78
											USGS	19910929	11.05
											USGS	19911023	11.42
40N/03E-03N02	485849	1222449	W	W	I	SUMS	12	23	36	128	USGS	19900709	7.26
40N/03E-03R02	485847	1222358	W	W	P	SUMS	10	73	8	135	USGS		
40N/03E-03R03	485847	1222355	W	W	P	SUMS	10	73	10	135	USGS	19900713	12.45
40N/03E-05E01	485915	1222728	W	W	I	SUMS	10	33		129	USGS	19900629	5.75
40N/03E-05E02	485919	1220007	W	W							USGS	19900629	4.40
40N/03E-05E02	485919	1222737	W	W	I	SUMS	10	30		131	USGS	19900629	4.40
40N/03E-05L01	485900	1222719	W	O	U	SUMS	10	18		125	USGS	19900725	11.8
40N/03E-05L02	485900	1222714	W	O	U	SUMS	10	13		125	USGS	19900725	9.87
40N/03E-05M03	485900	1222725	W	O	U	SUMS	10	14		126	USGS	1990072	10.4
40N/03E-05M04	485859	1222722	W	O	U	SUMS	10	14		126	USGS	1990075	10.0
40N/03E-05M05	485905	1222722	W	O	U	SUMS	10	12		127	USGS	19900725	9.15
40N/03E-05N01	485848	1222740	W	W	H	SUMS	10	18		123	USGS		
40N/03E-05N02	485848	1222727	W	W		SUMS	10			118	USGS	19900725	9.64
40N/03E-06B01	485930	1222819	W	W	I	SUMS	12	29		132	USGS	19900710	3.05
40N/03E-06C01	485934	1222826	W	W	I	SUMS	11	33		130	USGS	19900629	3.55
40N/03E-06M01	485909	1222900	W	U	U	EVRS	30	156	6	123	USGS	19900710	5.85
40N/03E-06M02	485907	1222900	W	W	I	SUMS	12	30		122	USGS	19900710	4.71
40N/03E-06N02	485852	1222855	W	W	I	SUMS	12	30		118	USGS	19900629	3.39
40N/03E-07A02	485835	1222743	W	W	H	SUMS	11	21		116	USGS	19900712	7.49
40N/03E-07J01	485809	1222745	W	W	I	SUMS	10	31		111	USGS	19900710	4.69
40N/03E-07M02	485810	1222844	W	W	I	SUMS	10	24		111	USGS	19900723	11.51
40N/03E-07M03	485810	1222849	W	W		SUMS	10	25	8	111	USGS		
40N/03E-08J01	485811	1222623	W	W	I	SUMS	11	26	36	113	USGS	19900720	4.61
40N/03E-08N03	485802	1222739	W	U	U	SUMS	10	24	36	112	USGS	19900725	6.13
40N/03E-09A04	485838	1222512	W	W	I	SUMS	12	27	36	123	USGS	19900712	7.94

Local well number	Lati-tude	Longi-tude	GW site type	Site use	Wat-er use	Geo-logic unit	Litho-logic unit	Well depth	Well dia-meter	Alti-tude	Source of data	Water level date	Water level
40N/03E-09D01	485837	1222612	W	W	I	SUMS	12	22	36	118	USGS	19900712	4.94
40N/03E-09G01	485830	1222523	W	W	S	SUMS	10	65	6	122	USGS	19900712	7.41
40N/03E-10C02	485839	1222425	W	W	D	SUMS	10	18		132	USGS	19910503	5.58
40N/03E-10K01	485816	1222418	W	W	H	SUMS	10	30	6	132	USGS	19900803	15.27
40N/03E-10R02	485752	1222346	W	W	H	SUMS	10	38		115	USGS	19900809	13.96
40N/03E-11E03	485818	1222340	W	W	H	SUMS	10	36		130	USGS	19900808	17.40
40N/03E-11E04	485818	1222336	W	W	H	SUMS	10	44	6	130	USGS	19900808	17.05
40N/03E-12A05	485841	1222106	W	W	I	SUMS	10	80	10	133	USGS	19900621	23.97
40N/03E-12H01	485824	1222105	W	T	U	SUMS	10	120	8	100	USGS		
40N/03E-13N01	485705	1222222	X	Z						85	USGS		
40N/03E-13Q01	485659	1222142	W	U	U			225		86	USGS		
40N/03E-14B01	485747	1222254	W	Z	U			265		95	USGS		
40N/03E-14B02	485748	1222255	W	U	H	EVRS	99	9		95	USGS	19900807	4.13
40N/03E-15B02	485750	1222407	W	Z				33	18	125	USGS		
40N/03E-15B03	485751	1222406	W	U	U	SUMS	10	30		125	USGS	19900807	24.06
40N/03E-16A02	485746	1222503	W	W	H	SUMS	10	29	12	117	USGS	19900723	11.60
											USGS	19900827	12.93
											USGS	19901017	13.24
											USGS	19901114	11.71
											USGS	19901217	6.45
											USGS	19910119	5.50
											USGS	19910221	5.78
											USGS	19910314	6.04
											USGS	19910423	7.18
											USGS	19910521	8.39
											USGS	19910625	9.64
											USGS	19910717	11.10
											USGS	19910822	12.42
											USGS	19910926	13.07
											USGS	19911023	13.07
40N/03E-16D01	485745	1222617	W	W	I	SUMS	10	27	36	111	USGS	19900808	10.71
40N/03E-16F01	485736	1222559	W	W	H	SUMS	10	21	12	106	USGS	19900723	5.07
40N/03E-16H03	485737	1222507	W	W	H	SUMS	10			114	USGS		
40N/03E-16H04	485737	1222509	W	W	I	SUMS	10	58	6	114	USGS	19900720	13.21
40N/03E-16H05	485727	1222520	W	W	P	SUMS	10	45		117	USGS	19900808	31.69
40N/03E-16H06	485727	1222508	W	W	I	SUMS	10	28		96	USGS	19900808	6.96
40N/03E-16K01	485719	1222536	W	W	H	SUMS	10	33		105	USGS		
40N/03E-16M01	485723	1222622	W	T	U			380		100	USGS		
40N/03E-16Q01	485706	1222533	W	W	I	SUMS	10	50	8	104	USGS	19900719	1.30
40N/03E-17E01	485734	1222733	W	W	I	SUMS	10	28	36	104	USGS	19900719	4.10
40N/03E-18E01	485737	1222857	W	W	I	SUMS	10	36	36	103	USGS	19900713	5.15
40N/03E-18G01	485738	1222818	W	W	I	SUMS	10	30	36	106	USGS	19900709	3.68
40N/03E-19A01	485659	1222756	W	W	I	SUMS	12	40	8	98	USGS	19900719	6.06
40N/03E-22C01	485654	1222431	W	U	U	SUMS	15	15		55	USGS	19900809	10.0
40N/03E-24E01	485643	1222222	W	W		EVRS	30	147		75	USGS	19911002	7.93
40N/03E-25F01	485545	1222159	W	W	I	SUMS	15	29	12	76	USGS	19900621	5.03
40N/03E-25J01	485538	1222107	W	W	I	SUMS	21	45	8	78	USGS		
40N/03E-26H01	485546	1222233	W	W	I	SUMS	15	24	36	70	USGS	19900622	6.93
40N/03E-31J	485948	1222751	W	W	H	SUMS	10	12		73	USGS		
40N/03E-31L01	485445	1222838	W	W	H	SUMS	10	30	18	62	USGS	19900424	16.66
40N/03E-31L02	485447	1222830	W	W	H	SUMS	10	19	6	61	USGS	19900424	10.4
40N/03E-31N02	485428	1222903	W	W	U	SUMS	10	53	6	80	USGS	19900424	26.42
40N/03E-31P03	485425	1222829	W	W	H	SUMS	10	36	18	75	USGS	19900424	23.81
40N/03E-31R	485430	1222749	W	W	H	SUMS	10	16		70	USGS	19910129	8.9
40N/03E-32G01	485453	1222706	W	T	U			442	4	77	USGS		

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
											USGS		
											USGS		
40N/03E-32K02	485438	1222658	W	W	H	SUMS	10			90	USGS		
40N/03E-32K02	485438	1222658	W	W	H	SUMS	10		6	90	USGS	19900425	23.8
40N/03E-32L	485443	1222711	W	W	H	SUMS	10	41		168	USGS	19910121	24.3
40N/03E-32L01	485445	1222712	W	W		SUMS	10	50	36	87	USGS	19900425	27.55
40N/03E-32M01	485444	1222728	W	W	H	SUMS	10	26	18	76	USGS	19900119	11.73
											USGS	19900427	12.93
											USGS	19901017	15.29
											USGS	19901116	13.86
											USGS	19901217	12.23
											USGS	19910119	11.73
											USGS	19910221	11.72
											USGS	19910313	11.91
											USGS	19910424	12.36
											USGS	19910521	12.80
											USGS	19910625	13.30
											USGS	19910718	12.80
											USGS	19910823	14.55
											USGS	19910926	14.94
											USGS	19911023	15.38
40N/03E-32M02	485438	1222735	W	W	H			23		73	USGS	19910129	8.6
40N/03E-32P01	485427	1222717	W	W	H	SUMS	10	40	6	85	USGS	19900424	17.77
40N/03E-32P02	485434	1222720	W	T				900		92	USGS		
40N/03E-32Q01	485428	1222658	W	W	H	SUMS	10	25	18	83	USGS	19900322	15.47
40N/03E-33F01	485450	1222555	W	W	U			29	12	76	USGS	19900424	17.27
40N/03E-33G01	485450	1222546	W	W	H	SUMS	10	28	12	74	USGS	19900427	19.16
40N/03E-33J02	485446	1222517	W	W	H	SUMS	10	33	6	65	USGS	19900425	10.54
40N/03E-34E01	485454	1222504	W	W	I	SUMS	11	18	30	58	USGS	19900425	5.53
40N/03E-34P01	485427	1222429	W	W	I	SUMS	10	34	36	80	USGS	19900320	9.34
40N/03E-34Q01	485434	1222425	X	T				256		80	USGS	19900825	19.03
40N/03E-35R01	485423	1222228	W	U	U	SUMS	10	23		108	USGS	19900425	18.96
40N/03E-35R02	485425	1222232	W	W	H	SUMS	10	51	6	105	USGS	19900425	20.34
40N/03E-36J01	485446	1222121	W	U	U	SUMS	10	30		90	USGS		
40N/03E-36J02	485445	1222123	W	W	P	SUMS	10	32	36	86	USGS	19900426	9.9
40N/03E-36J03	485446	1222117	W	W	P	SUMS	10	36		90	USGS	19900426	10.65
40N/03E-36Q01	485431	1222127	W	W	P	SUMS	10	45		105	USGS	19900426	18.2
40N/04E-01C01	485932	1221400	W	W	I	SUMS	22	119	8	44	USGS		
40N/04E-01K02	485900	1221350	W	W	I	SUMS	22	97	8	40	USGS	19900516	11.1
40N/04E-02L02	485907	1221524	W	W	I	SUMS	22	69	8	35	USGS	19900516	3.49
40N/04E-03J01	485856	1221558	W	W	I	SUMS	20	59	8	45	USGS	19900518	4.83
40N/04E-04D01	485934	1221812	W	W	H	SUMS	14	95	6	154	USGS	19900522	62.8
40N/04E-05D01	485935	1221938	W	U	U			61		183	USGS	19790523	56.65
40N/04E-05D02	485934	1221944	W	W	I	SUMS	10	80	8	181	USGS	19900518	45.03
40N/04E-05E01	485910	1221932	W	W	I	SUMS	10	34	8	95	USGS	19900516	4.16
40N/04E-05E02	485921	1221944	W	W	I	SUMS	10	77	8	162	USGS	19900516	29.40
40N/04E-05L01	485906	1221927	W	W	H	SUMS	10	38	6	100	USGS		
40N/04E-05N01	485846	1221935	W	W	H	SUMS	14	28	6	70	USGS	19900515	14.30
40N/04E-05N02	485853	1221946	W	W	H	SUMS	14	85	6	139	USGS	19900515	62.72
40N/04E-05P01	485848	1221913	W	W	H	SUMS	14	23	36	74	USGS	19900530	15.72
40N/04E-05P02	485850	1221914	W	W	H	SUMS	14	28	36	56	USGS	19900530	14.72
40N/04E-06B01	485935	1222017	W	W	H	SUMS	10	75	6	168	USGS	19900518	31.78
40N/04E-06B02	485935	1222023	W	W	I	SUMS	10	88	8	166	USGS	19900518	28.28
40N/04E-06G01	485911	1222021	W	W	H	SUMS	10	32	36	155	USGS	19900522	23.21
40N/04E-06G02	485910	1222022	W	U	U	SUMS	10	25	6	136	USGS	19900522	8.69

Local well number	Lati-tude	Longi-tude	GW site type	Site use	Wat-er use	Geo-logic unit	Litho-logic unit	Well depth	Well dia-meter	Alti-tude	Source of data	Water level date	Water level
40N/04E-07G01	485829	1222019	W	W	C	SUMS	10	78	8	110	USGS	19900522	2.39
40N/04E-07H04	485826	1221948	W	W	P	SUMS	14	89		74	USGS		
40N/04E-08A02	485839	1221839	W	W	I	SUMS	20	57	10	56	USGS	19900522	7.18
40N/04E-08L01	485811	1221913	W	W	I	SUMS	20	58	8	60	USGS	19900524	7.37
40N/04E-09B01	485830	1221732	W	W	I	SUMS	20	49	9	48	USGS	19900522	.89
											USGS	19910314	-.83
											USGS	19910626	.81
											USGS	19910717	1.77
											USGS	19910822	1.71
											USGS	19910925	1.17
											USGS	19911023	1.37
40N/04E-09N03	485759	1221819	W	W	I	SUMS	22	78	8	59	USG	19900524	7.5
											USGS	19900828	9.18
											USGS	19901017	8.43
											USGS	19901116	3.81
											USGS	19901218	3.52
											USGS	19910117	3.51
											USGS	19910221	3.91
											USGS	19910314	5.20
											USGS	19910425	6.24
											USGS	19910521	6.92
											USGS	19910626	7.46
											USGS	19910718	8.40
											USGS	19910822	8.51
											USGS	19910926	7.95
											USGS	19911023	8.24
40N/04E-09Q01	485755	1221746	W	W	I	SUMS	20	59	8	55	USGS	19900523	2.87
40N/04E-09Q02	485752	1221603	W	W	I	SUMS	22	78	8	45	USGS	19900518	6.36
40N/04E-10B01	485841	1221624	W	W	I	SUMS	20	50	9	46	USGS	19900523	5.25
40N/04E-10C01	485843	1221644	W	W	I	SUMS	20	60	8	44	USGS	19900524	3.38
40N/04E-10E02	485828	1221707	W	W	I	SUMS	21	38	10	46	USGS	19900523	2.36
40N/04E-10G01	485828	1221627	W	W	I	SUMS	22	69	8	47	USGS	19900530	8.74
40N/04E-10R03	485759	1221557	W	W	I	SUMS	20	63	8	52	USGS	19900523	5.79
40N/04E-11C01	485834	1221515	W	W	I	SUMS	15	21	36	43	USGS	19900523	3.77
40N/04E-12B01	485831	1221345	W	W	I	SUMS	22	107	8	50	USGS	19900530	12.81
40N/04E-12C01	485838	1221408	W	W	I	SUMS	22	104	8	45	USGS	19900530	5.59
40N/04E-15B01	485744	1221621	W	W	I	SUMS	20	25	36	56	USGS	19900523	5.08
40N/04E-15C01	485750	1221640	W	W	I	SUMS	22	82	8	55	USGS	19900607	4.65
40N/04E-15J01	485713	1221600	W	W	H			130		78	USGS	19900605	9.78
40N/04E-16A02	485742	1221723	W	U	U	SUMS	15	26	36	55	USGS	19900607	1.75
40N/04E-17B02	485748	1221857	W	W	I	SUMS	15	57	8	62	USGS		
											USGS	19900606	5.00
40N/04E-17G01	485731	1221900	W	W	I	SUMS	15	26	36	65	USGS	19900606	1.82
40N/04E-17N01	485704	1221929	W	W	I	SUMS	20	30	8	66	USGS	19900607	1.66
40N/04E-18R01	485659	1221958	W	W	I	SUMS	20	67	8	65	USGS	19900607	2.68
40N/04E-19G01	485648	1222017	W	Z	U	SUMS	20	57		70	USGS		
40N/04E-19G02	485648	1222018	W	Z	U			435		70	USGS		
40N/04E-19G03	485645	1222018	W	U	U	SUMS	20	40		70	USGS	19900712	5.15
40N/04E-19K01	485626	1222026	W	W	I	SUMS	20	57	10	70	USGS	19900614	4.13
40N/04E-20D01	485652	1221930	W	W	I	SUMS	20	57	8	69	USGS	19900607	4.94
40N/04E-20F01	485642	1221912	W	W	H	SUMS	15	18		72	USGS	19900607	3.94
											USGS	19900830	7.05
											USGS	19901017	6.74
											USGS	19901115	2.02
											USGS	19901217	1.15

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Lati-tude	Longi-tude	GW site type	Site use	Wat-er use	Geo-logic unit	Litho-logic unit	Well depth	Well dia-meter	Alti-tude	Source of data	Water level date	Water level
											USGS	19910117	1.22
											USGS	19910219	.95
											USGS	19910314	2.65
											USGS	19910423	3.57
											USGS	19910522	4.50
											USGS	19910625	5.05
											USGS	19910717	5.92
											USGS	19910822	6.24
											USGS	19910925	5.95
											USGS	19911023	6.36
40N/04E-21F01	485632	1221810	W	U	U	SUMS	10	55		130	USGS	19900607	47.25
40N/04E-22G01	485639	1221618	W	W	H	SUMS	10	42	6	150	USGS	19900621	18.02
40N/04E-22J01	485624	1221607	W	W	H	SUMS	10	56	6	176	USGS	19900608	28.14
40N/04E-22J02	485628	1221609	W	T				200		178	USGS		
40N/04E-22R01	485607	1221611	W	W	H	VSHN	50	60	6	178	USGS	19900608	33.11
40N/04E-23N01	485608	1221535	W	W	H	VSHN	50	82	6	360	USGS	19900606	56.72
40N/04E-27K01	485538	1221620	W	U	U	VSHN	50	62	6	210	USGS	19900615	22.2
40N/04E-28D02	485555	1221815	W	W	H	SUMS	10	67		130	USGS	19900613	33.86
40N/04E-28H01	485544	1221714	W	W	I	SUMS	10	36	8	115	USGS	19900614	.47
40N/04E-28R01	485515	1221722	X	T	S	SUMS	10	32	12	111	USGS	19900608	2.16
40N/04E-29H02	485542	1221833	W	W	H	SUMS	10	59	6	110	USGS	19900614	7.11
40N/04E-29R01	485515	1221846	W	W	I	SUMS	15	31	8	85	USGS	19900614	2.58
40N/04E-30D01	485601	1222102	W	W	I	SUMS	21	27	36	75	USGS		
											USGS		
											USGS	19900807	2.84
40N/04E-30E01	485553	1222103	W	W	I	SUMS	21	33	8	75	USGS	19900807	5.82
40N/04E-30G01	485546	1222026	W	W	I	SUMS	20	37	8	75	USGS	19900621	2.55
40N/04E-31R02	485429	1221959	W	W	I	SUMS	15	32	8	90	USGS	19900615	6.45
40N/04E-33A03	485505	1221718	W	W	I	SUMS	12	34	8	125	USGS		
40N/04E-33R01	485430	1221715	W	W	H	SUMS	10	62	6	125	USGS	19900614	33.87
40N/04E-34F01	485454	1221651	W	W	H	SUMS	10	51	36	160	USGS	19900614	36.
40N/04E-34P01	485433	1221648	W	W	C	SUMS	12	57		150	USGS	19900614	27.07
40N/05E-06D01	485932	1221253	W	W	I	SUMS	20	43	36	38	USGS	19900510	5.6
40N/05E-06K01	485907	1221214	W	O	Z	SUMS	23	7	30	32	USGS	19910702	4.3
40N/05E-06L02	485859	1221251	W	W	I	SUMS	22	74	8	37	USGS	19900510	6.95
40N/05E-06M01	485859	1221307	W	W	I	SUMS	22	90	8	38	USGS		
40N/05E-07K01	485806	1221229	W	W	H	SUMS	10	31	36	440	USGS	19900530	16.28
40N/05E-07K02	485808	1221224	W	W	H	SUMS	10	34	36	460	USGS	19900530	21.48
41N/02E-33J01	485958	1223301	W	W	H	EVRS	30	79	6	250	USGS	19900810	48.27
41N/02E-35P01	485939	1223106	W	W	H	EVRS	30	73		160	USGS	19900815	28.43
41N/02E-35Q02	485944	1223049	W	T	U			30		150	USGS		
41N/02E-36J01	485954	1222908	W	U	U	SUMS	12	24		129	USGS	19900814	6.29
41N/02E-36K01	485954	1222936	W	W	I	SUMS	10	29	36	129	USGS	19900814	7.80
41N/02E-36M01	485957	1223002	W	W	I	SUMS	10	30	36	134	USGS	19900814	24.5
41N/03E-31E01	490008	1222900	W	W	H	SUMS	10	30	6	141	USGS	19900629	7.02
41N/03E-31Q01	485944	1222820	W	W	I	SUMS	11	33		136	USGS	19900629	3.61
41N/03E-32Q01	485949	1222700	W	W	H	SUMS	10	25		137	USGS	19900725	9.85
41N/03E-33E01	490005	1222620	W	W	S	SUMS	10	43	6	146	USGS	19900629	8.70
41N/03E-33G01	490008	1222538	W	T				283		141	USGS		
41N/03E-34F01	490008	1222427	W	W	H	SUMS	10	22		146	USGS	19900705	9.79
41N/03E-34G01	490003	1222420	W	W	I	SUMS	10	38	8	141	USGS	19900705	3.73
41N/03E-34M01	490002	1222443	W	W	H	SUMS	10	20	36	141	USGS	19900705	4.60
41N/03E-34Q01	485938	1222404	W	W	H	SUMS	10	61	6	146	USGS	19900706	9.62
41N/03E-35L01	485957	1222304	W	W	H	SUMS	10	25	6	158	USGS		
41N/03E-36J01	485951	1222106	W	W	H	SUMS	10	37		163	USGS	19900706	26.3

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
41N/03E-36J02	485953	1222109	W	W	H	SUMS	10	92	6	162	USGS	19900607	25.00
41N/03E-36N01	485946	1222218	W	W	I	SUMS	10	26	36	159	USGS	19900706	12.48
41N/04E-31J01	485952	1221947	W	U	U	SUMS	10	59	6	175	USGS		
41N/04E-31J02	485955	1221949	W	W	H	SUMS	10	80	8	185	USGS	19900508	44.62
											USGS	19901018	50.31
											USGS	19901114	50.45
											USGS	19901218	46.4
											USGS	19910117	43.77
											USGS	19910219	43.54
											USGS	19910314	43.01
											USGS	19910423	43.39
											USGS	19910521	44.08
											USGS	19910625	45.28
											USGS	19910717	46.33
											USGS	19910822	46.89
											USGS	19910929	48.92
											USGS	19911023	49.79
41N/04E-31R01	485945	1221952	W	W	I	SUMS	10	71	8	174	USGS	19900509	33.37
41N/04E-31R02	485946	1221944	W	W	H	SUMS	10	77		169	USGS	19900509	33.63
41N/04E-32E01	490003	1221942	W	T				400		206	USGS		
41N/04E-32M01	485953	1221937	W	W	H	SUMS	10	95	8	189	USGS	19900510	49.81
41N/04E-32Q01	485948	1221853	W	W	H	SUMS	10	26		132	USGS	19900508	6.46
41N/04E-32R01	485944	1221838	W	W	H	SUMS	14	92	6	194	USGS	19900516	76.70
41N/04E-33H01	490004	1221717	W	W	P	SUMS	20	58		48	USGS		
41N/04E-33H01S	490003	1221715	S		U					46	USGS		
41N/04E-33H02	490003	1221718	W	W	P	SUMS	20	58	12	48	USGS		
41N/04E-33H03	490006	1221718	W	W	P	SUMS	20	58	12	49	USGS		
41N/04E-33H04	490005	1221716	W	W	P	SUMS	20	69		50	USGS		
41N/04E-33N02	485947	1221820	W	T		SUMS	14	87	6	119	USGS	19900508	18.91
											USGS	19901017	21.97
											USGS	19901114	21.95
											USGS	19901201	19.85
											USGS	19910117	18.14
											USGS	19910219	18.08
											USGS	19910315	18.06
											USGS	19910522	18.88
											USGS	19910626	19.43
											USGS	19910717	19.84
											USGS	19910821	20.53
											USGS	19910925	21.11
											USGS	19911023	21.69
41N/04E-33N03	485948	1221803	W	T	U	SUMS	14	76	6	86	USGS		
41N/04E-33N04	485946	1221803	W	T	U	SUMS	14	72	6	87	USGS		
											USGS		
41N/04E-33N05	485938	1221803	W	T	U	SUMS	14	73	6	109	USGS	19900508	22.86
											USGS	19901017	24.80
											USGS	19901114	24.72
											USGS	19901217	23.23
											USGS	19910117	21.98
											USGS	19910219	22.20
											USGS	19910315	22.22
											USGS	19910522	22.83
											USGS	19910626	23.21
											USGS	19910717	23.50
											USGS	19910821	23.92

Table __.--Well, water level, and hydrogeologic data--continued

Local well number	Latitude	Longitude	GW site type	Site use	Water use	Geologic unit	Lithologic unit	Well depth	Well diameter	Altitude	Source of data	Water level date	Water level
											USGS	19910925	24.31
											USGS	19911023	24.64
41N/04E-36H01	490004	1221309	W	T						35	USGS		
41N/04E-36L01	485954	1221343	W	W	I	SUMS	22	63	8	30	USGS	19900509	6.41
41N/05E-31M01	485959	1221247	W	W	I	SUMS	22	71	8	35	USGS	19900515	5.81
41N/05E-31N02	485942	1221252	W	W	I	SUMS	22	78	8	30	USGS	19900509	8.2
41N/05E-31P01	485944	1221226	W	W	I	SUMS	22	95	8	34	USGS	19900510	8.91
41N/05E-32L01	485953	1221059	W	W	I	SUMS	15	34	8	27	USGS	19900510	7.6
41N/05E-32L02	490000	1221108	X	Z			10			27	USGS		

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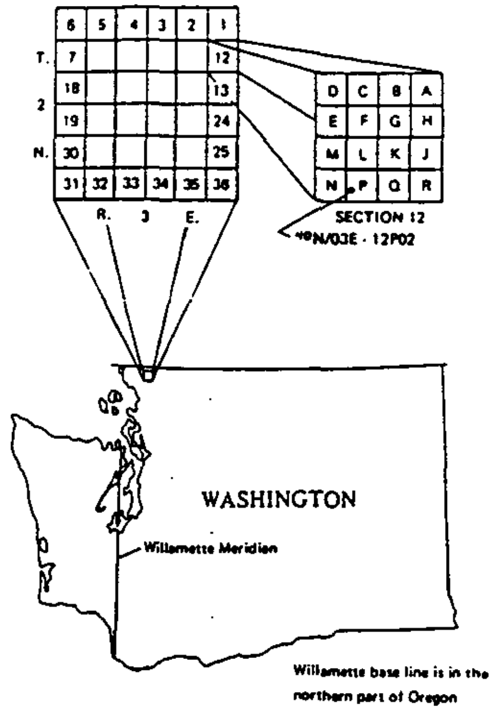
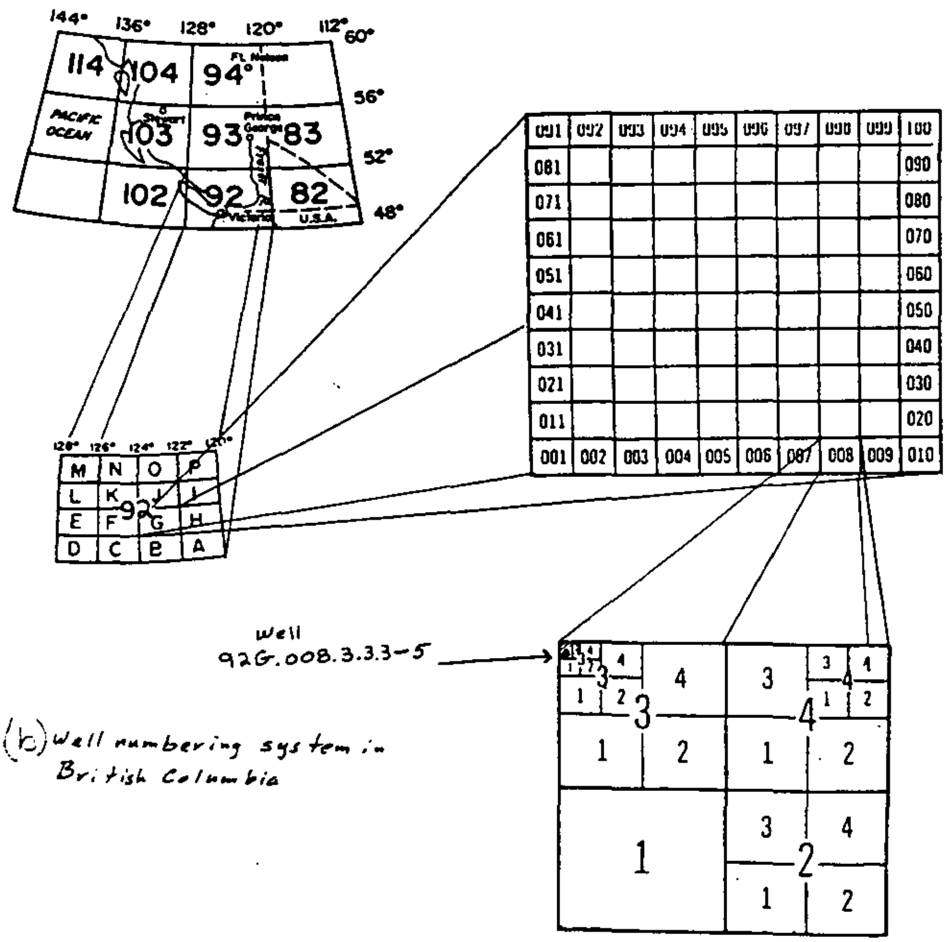


(a).--Well-numbering system in Washington.



(b) Well numbering system in British Columbia

FIGURE 1.--Well numbering systems in (a) Washington and (b) British Columbia

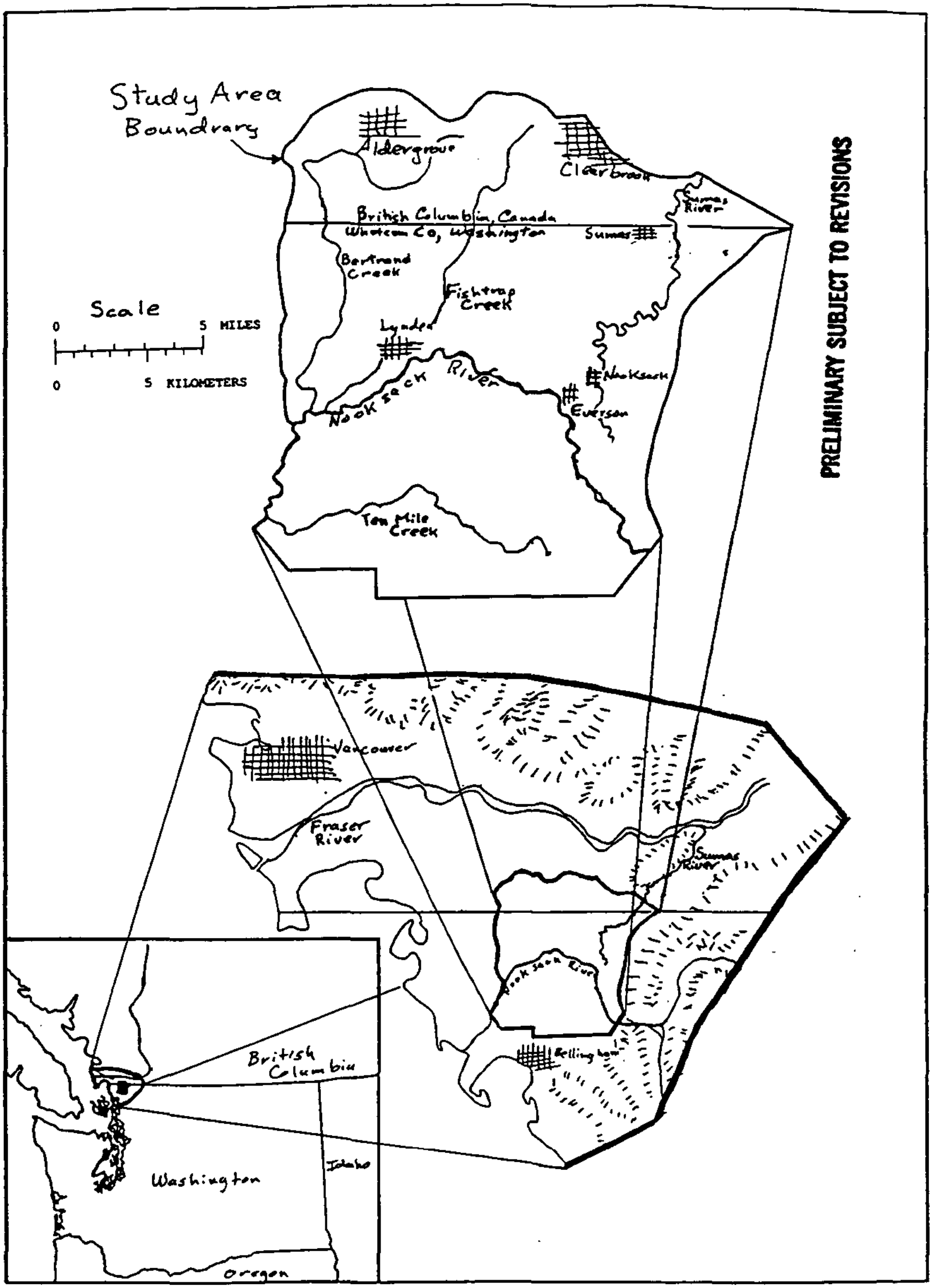


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FIGURE 2.--Location of study area

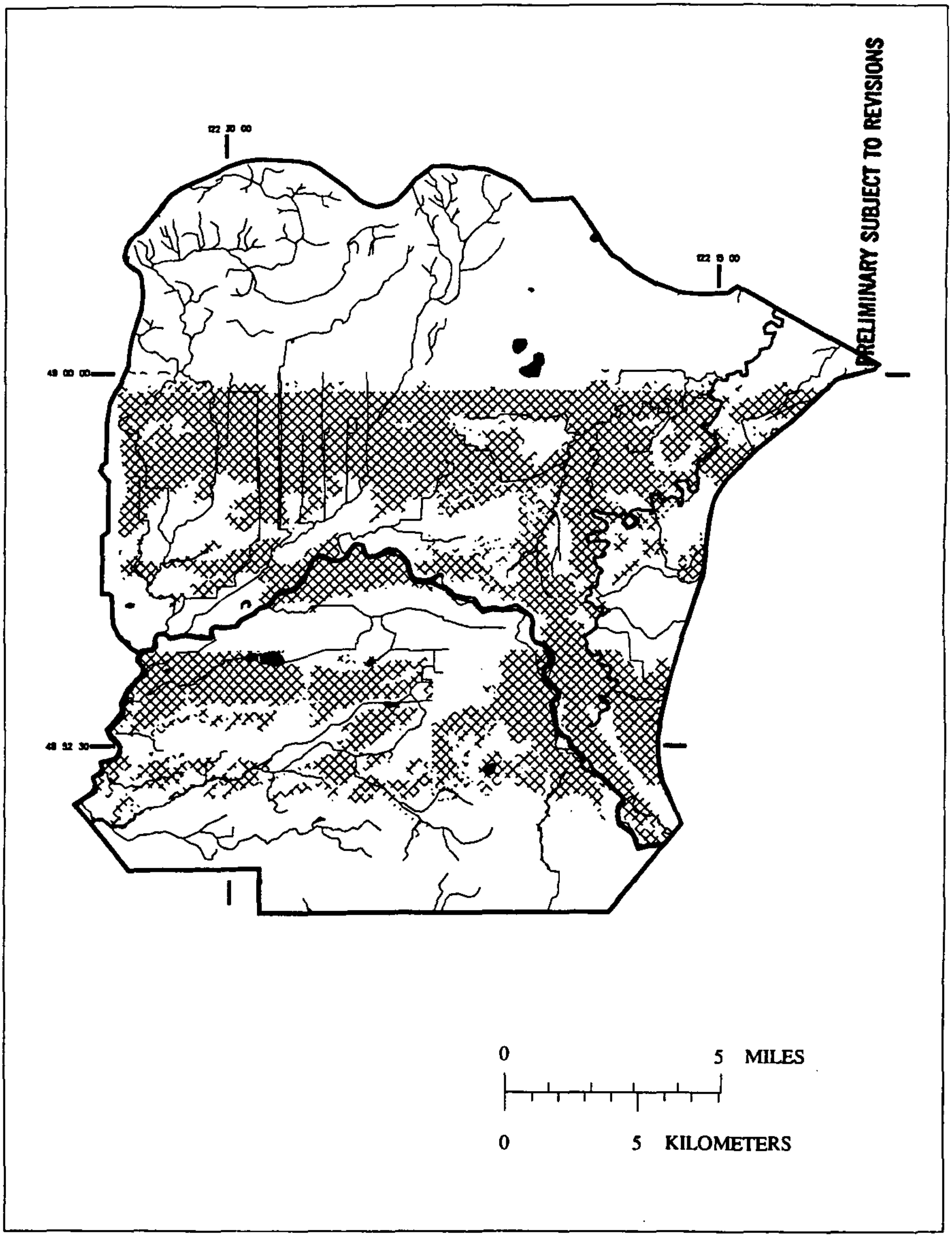

FIGURE 3.--Surface drainage features and drained soils; hachured areas indicate soils that are at least 85 percent artificially drained; bodies of water are shown in black

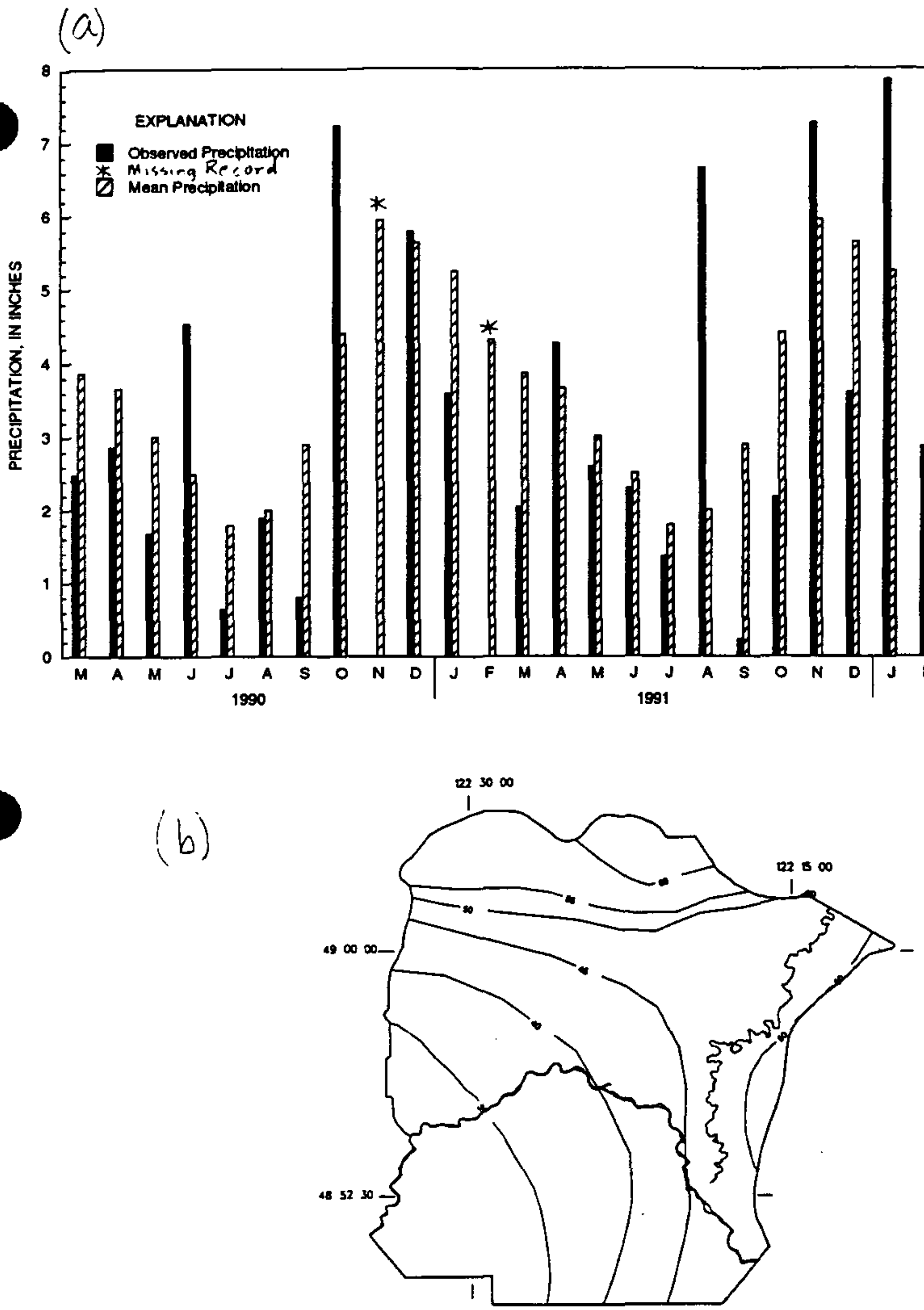

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FIGURE 4.--(a) Observed and mean-monthly precipitation at Clearbrook, Washington, and (b) annual precipitation in inches per year for the study area

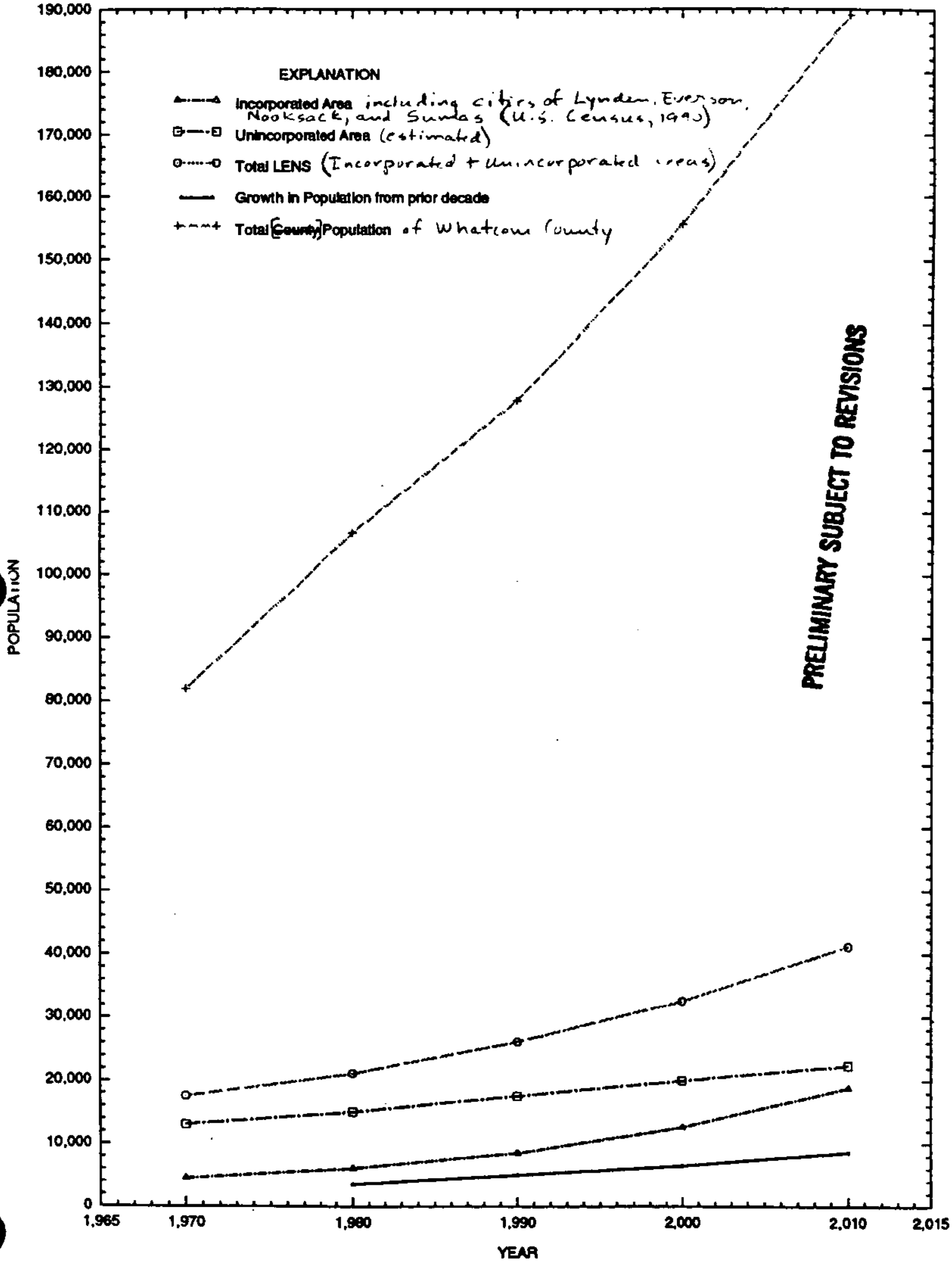

FIGURE 5.--Population trends in the LENS study area and Whatcom County

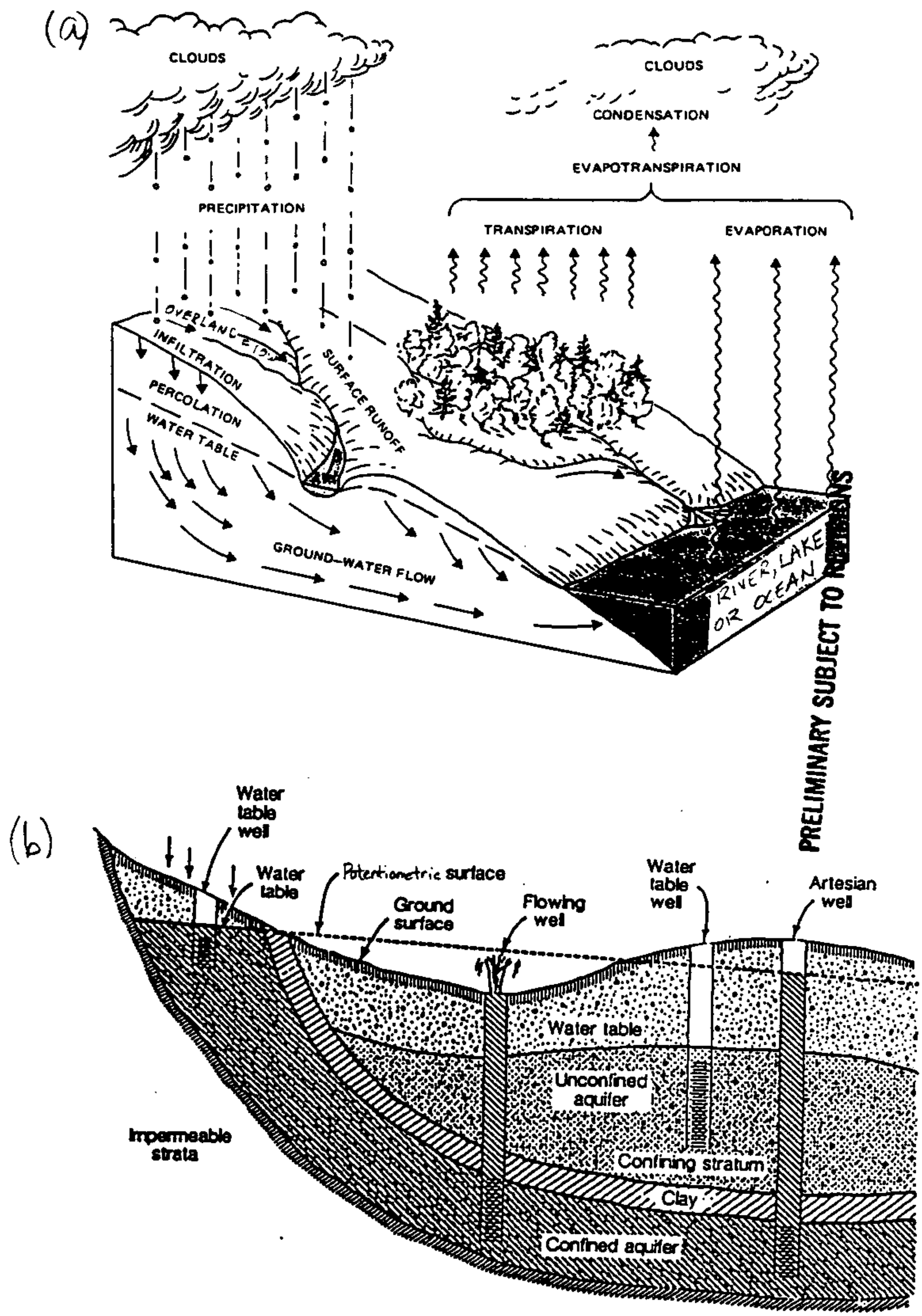

FIGURE 6.--(a) The hydrologic cycle and (b) the occurrence of ground water (Modified from Todd, 1980)

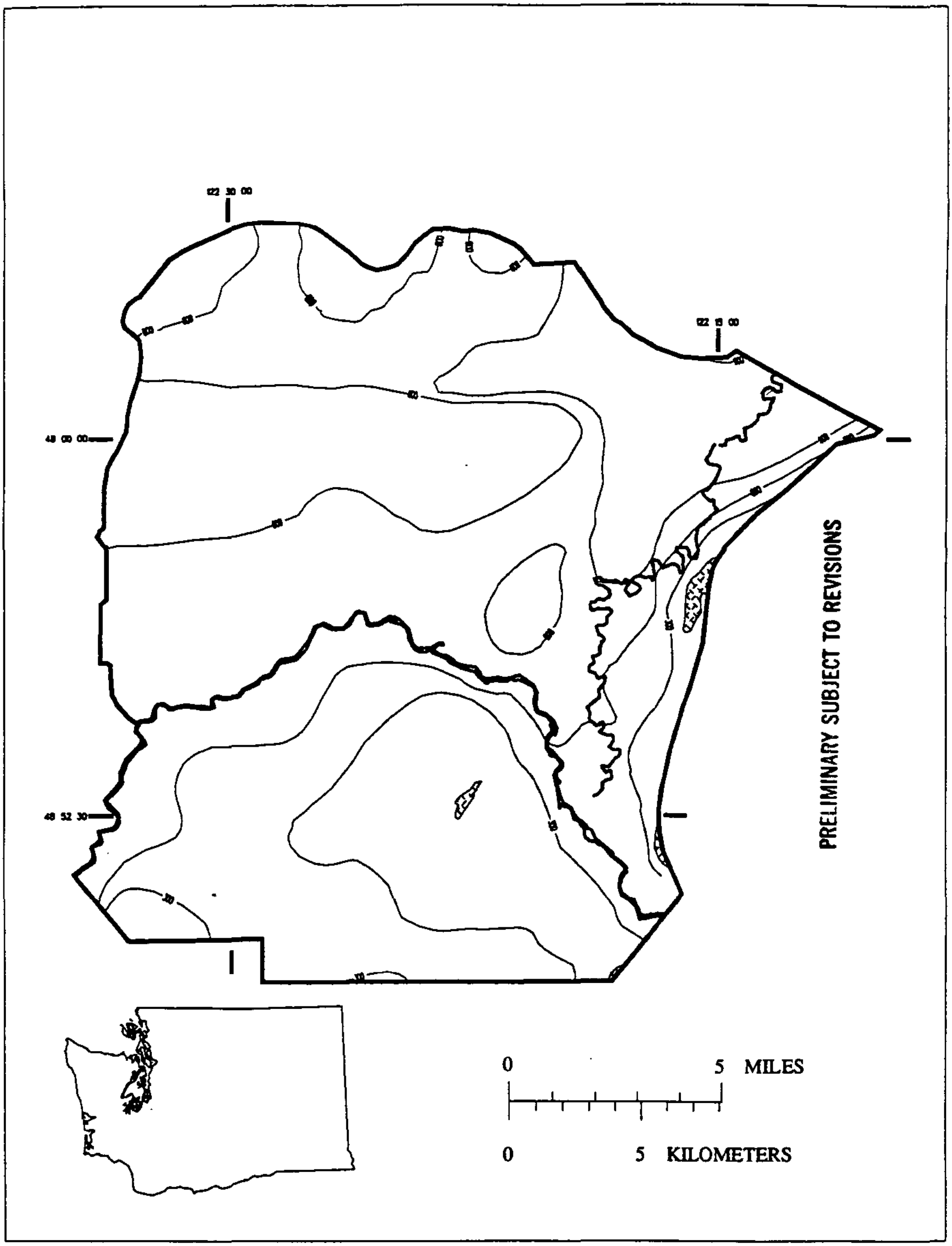

FIGURE 7.--Approximate depth to bedrock in the study area, in feet below below land surface

FIGURE 8.--Lithologic and hydrologic characteristics of hydrogeologic units; northern Whatcom County and southwestern mainland British Columbia.

Period	Epoch	Geologic unit	Hydrogeologic unit	Typical thickness (in feet)	Characteristics: Lithologic	Characteristics: Hydrologic	Characteristics: Water quality
Quaternary	Holocene	Qp Peat	Sumas aquifer	0-15 (unit total 40 - 80)	Stratified sand and gravel outwash with minor clay lenses. Outwash grades from pebble-cobble alluvium near Abbotsford to sand with fine-grained lenses southwest of Lynden. Unit includes Nooksack and Sumas River alluvium; till and ice-contact deposits; lacustrine and floodplain silt and clay; and peat	Highly productive unconfined aquifer. Unit exhibits a weak trend in hydraulic conductivity due to a lateral decrease in grain size. Lenses of clay, till, or peat cause locally confined or perched ground-water conditions. The unit is confined in much of the Sumas Valley by overlying lacustrine silt and clay and underlying clay presumed to be glaciomarine drift	
		Qalf Fine-grained alluvium		0-15			
		Qalg Coarse-grained alluvium		0-20			
	Pleistocene	Qso Sumas Outwash; Qsic Sumas ice-contact deposits		20-200; Qsic 20-60			
		Qe Everson interglacial deposits	Everson-Vashon unit	100 - 200	Glaciomarine drift consisting of unsorted pebbly-clay and sandy silt with occasional coarse-grained lenses as thick as 30 feet. Unit may include Vashon till and Esperance sand at its base	Generally a confining bed but coarse-grained lenses yield usable amounts of water to numerous wells. Salty water is present in some of the deepest wells within the unit	
		Qv Vashon Drift					
			Vashon aquifer	- -	Primarily till and gravel	Limited aerial extent, yields are variable	
Tertiary	Paleocene-miocene	Br Huntingdon and Chuckanut Fms.	Bedrock aquifer	- -	Sandstone, mudstone, and conglomerate with some coal bearing strata	Water yield controlled primarily by secondary fracture permeability. Water yield is low where the rocks are unfractured	

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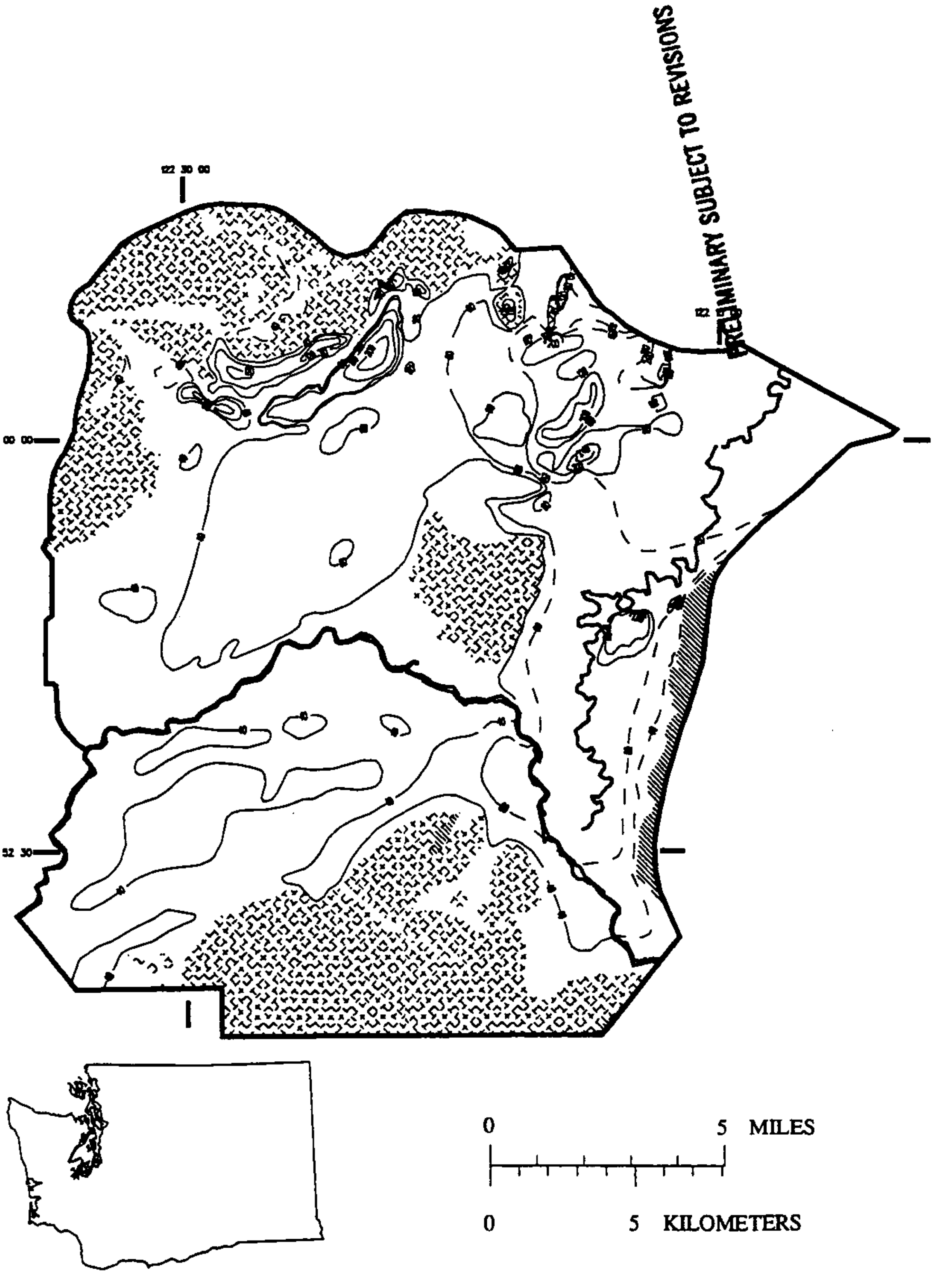

FIGURE 9.--Extent and approximate thickness of Sumas aquifer; contour interval equal to 40 feet; unshaded parts of the figure represent the Sumas aquifer, shaded parts represent other surficially exposed hydrogeologic units

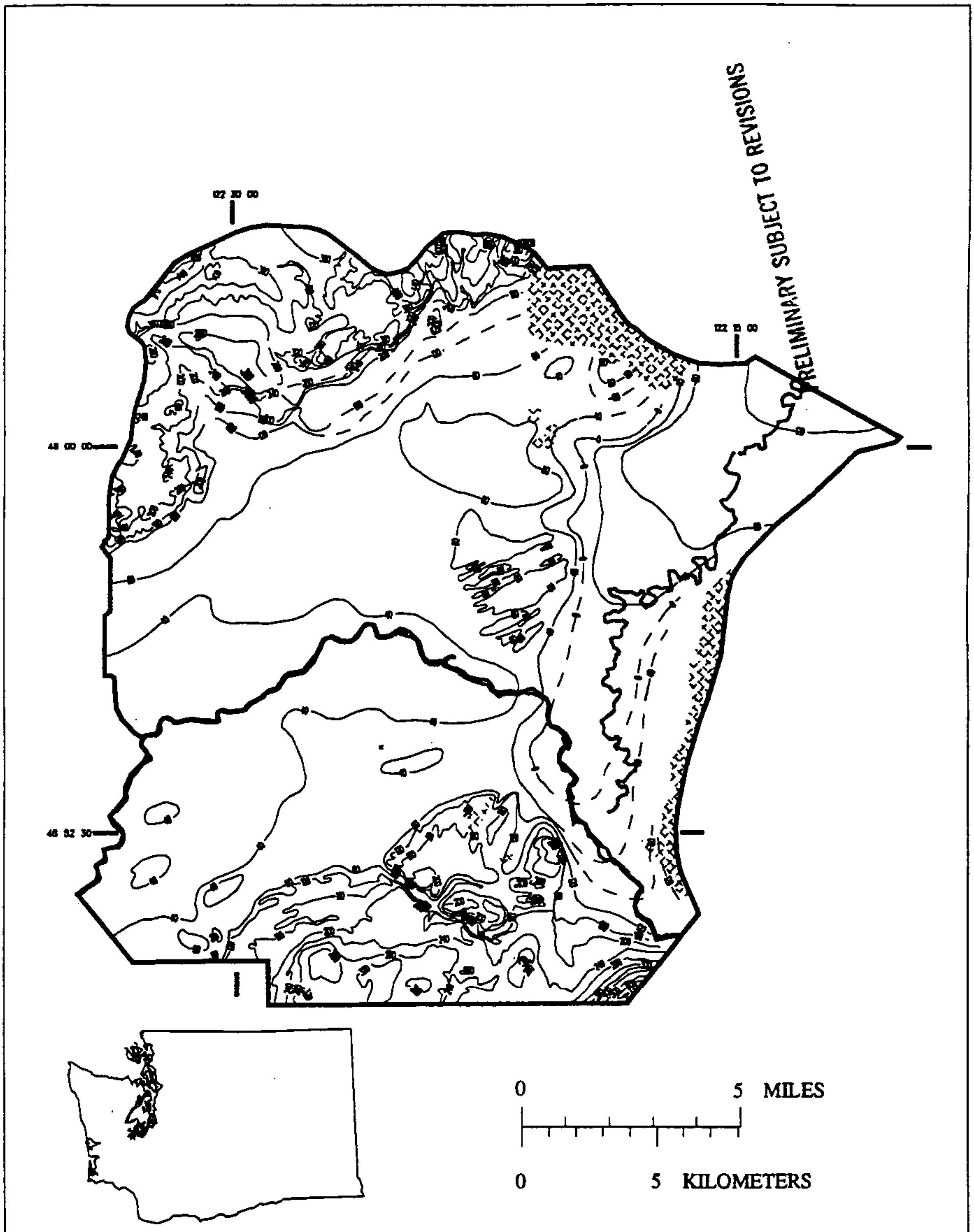

FIGURE 10.--Upper surface of Everson-Vashon confining unit; contours, in 40 foot intervals, represent the altitude of the unit in feet above or below (-) mean sea level; shading represents an absence of the unit or a lack of data

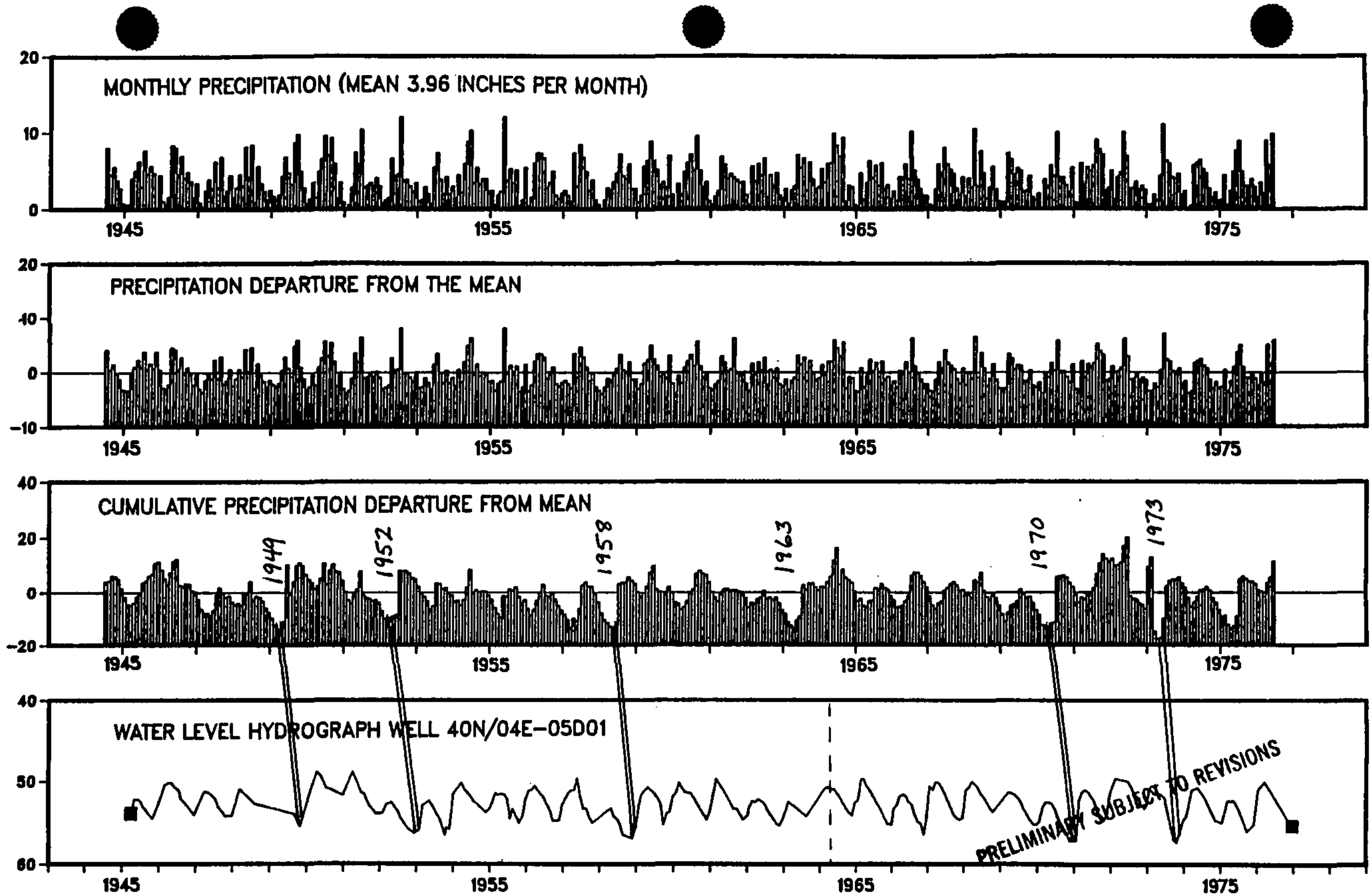

FIGURE 11.--(a) Monthly precipitation at Clearbrook, Wash., (b) precipitation departure from the mean, (c) cumulative precipitation departure from the mean, and (d) water-level hydrograph for well 40N/04E-05D01 near Clearbrook, Washington

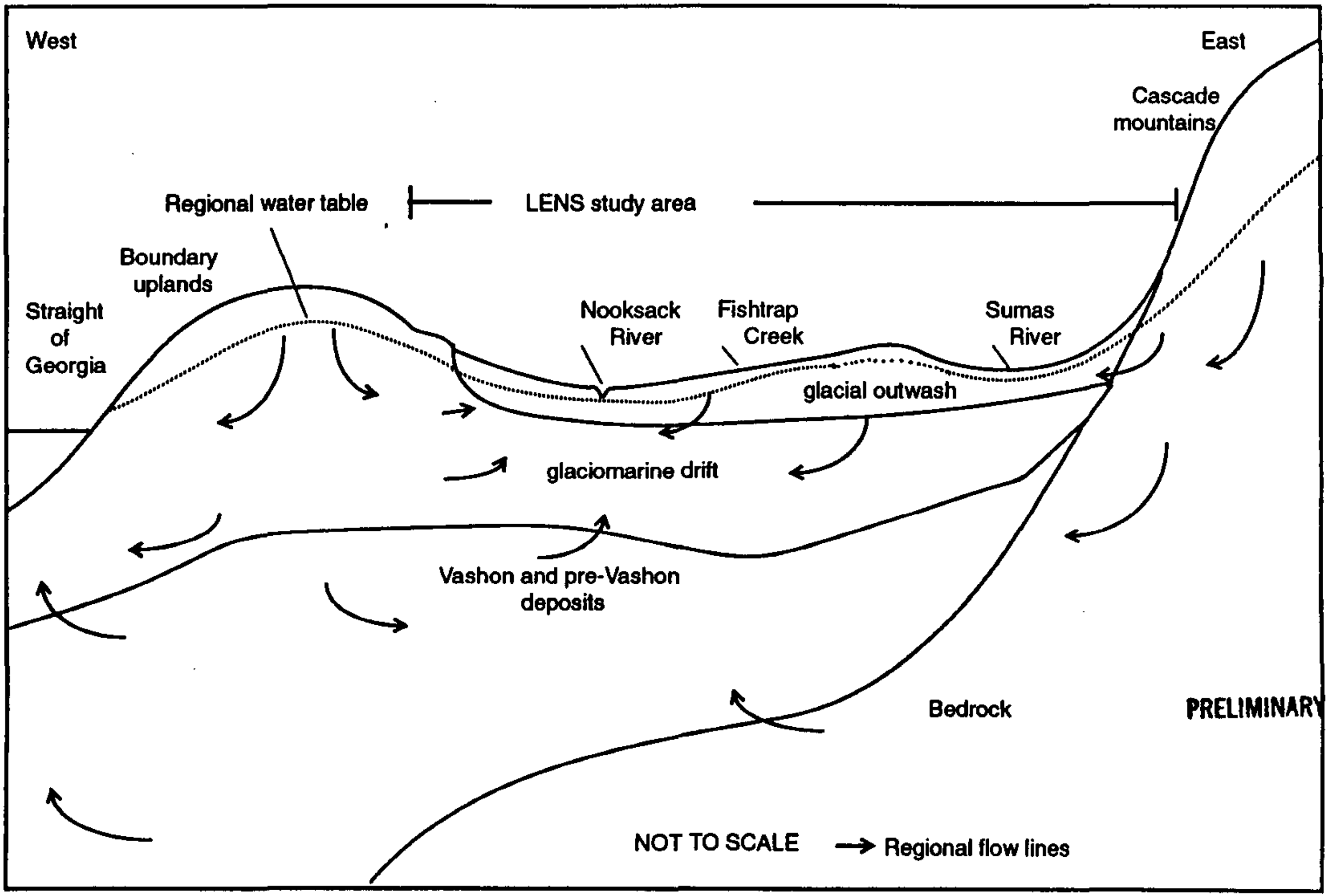

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FIGURE 12.--Conceptual model of ground-water flow system in study area

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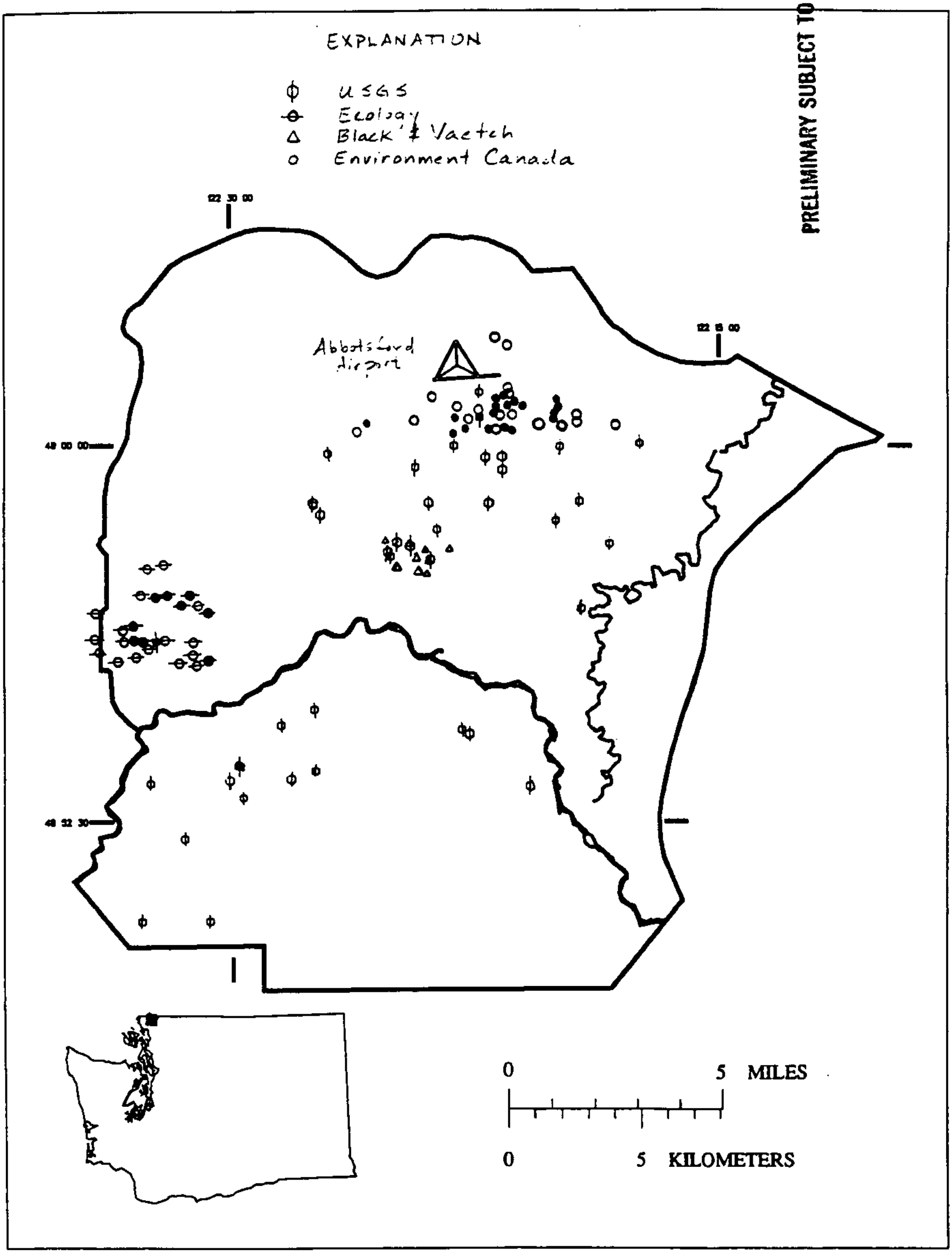

FIGURE 13.--Locations of wells sampled for pesticides and volatile organic compounds with source of data, shaded symbols indicate samples with detectable concentrations

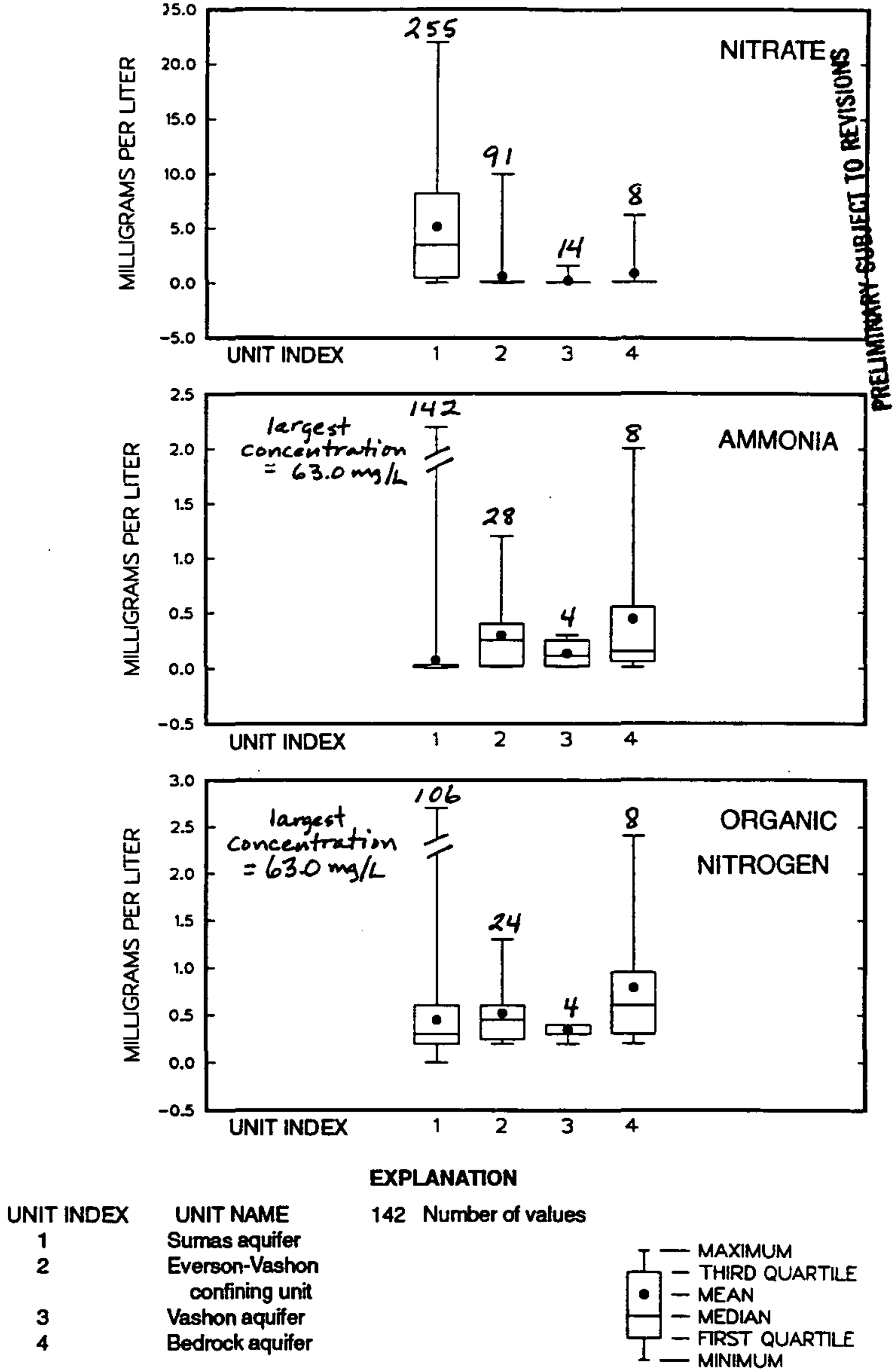

FIGURE 14.--Nitrate, ammonia, and organic nitrogen concentrations by hydrogeologic unit

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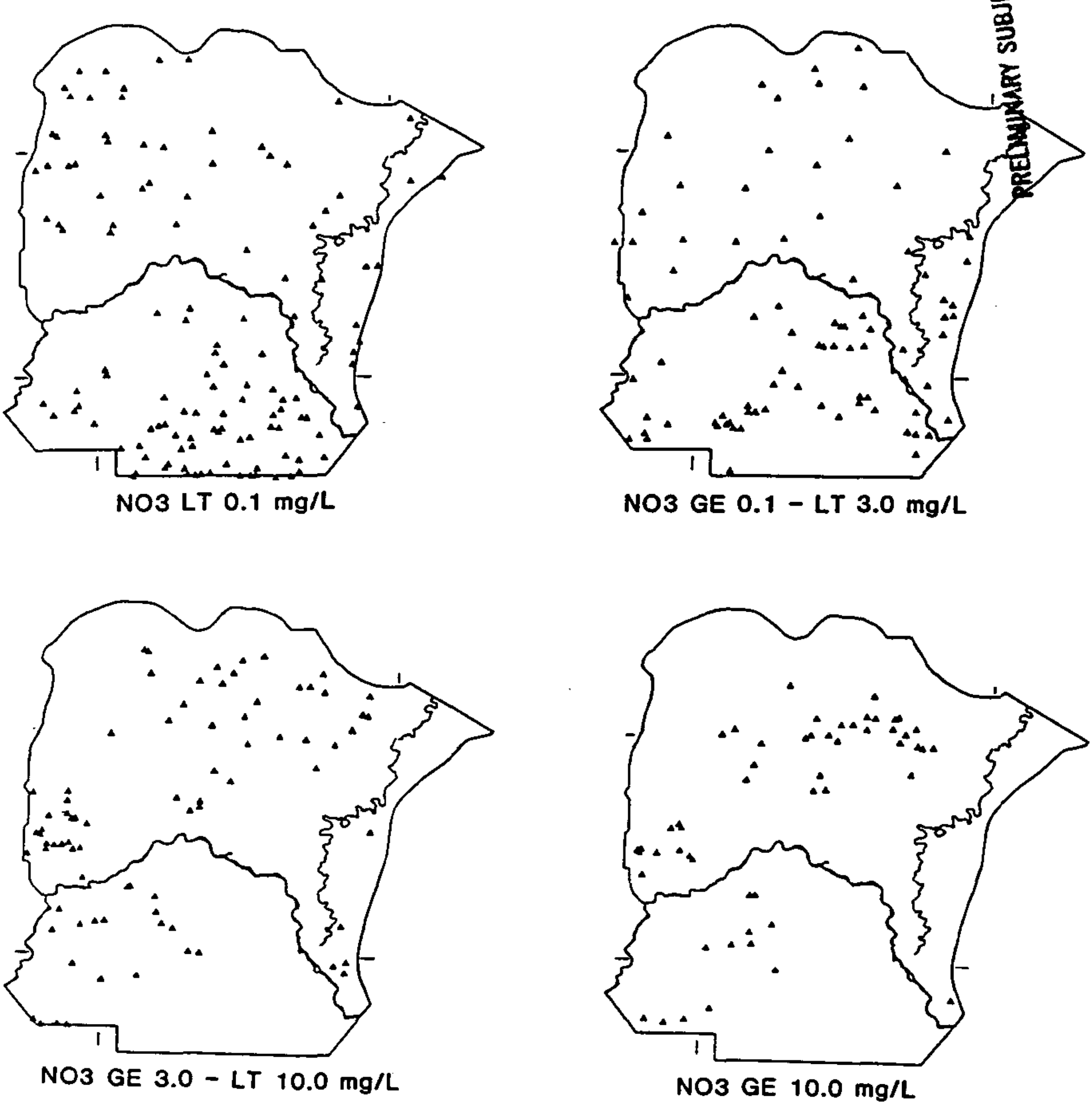

FIGURE 15.--Distribution of nitrate concentrations in ground water by concentration class

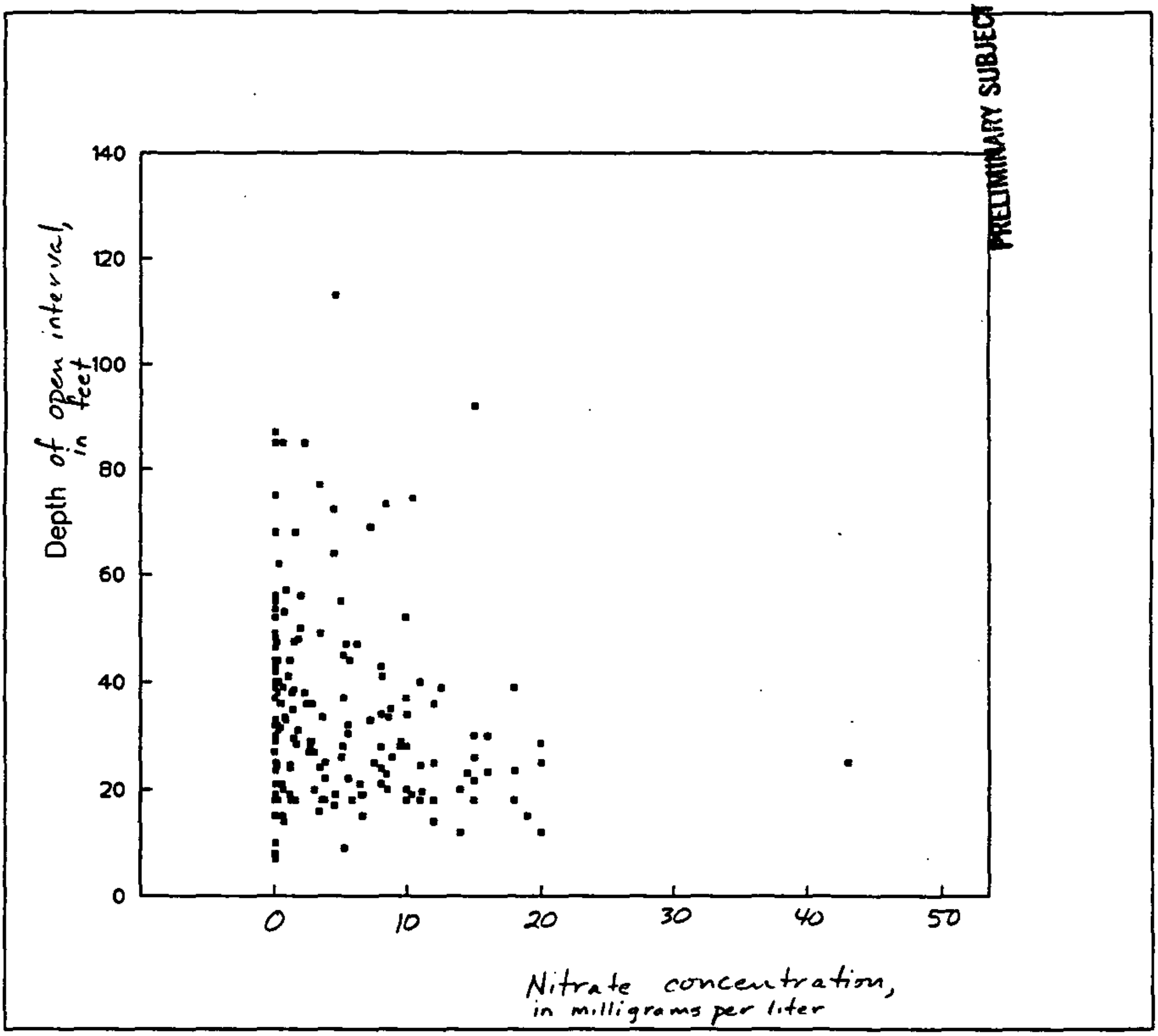

FIGURE 16.--Nitrate concentrations and altitudes of open intervals of sampled wells

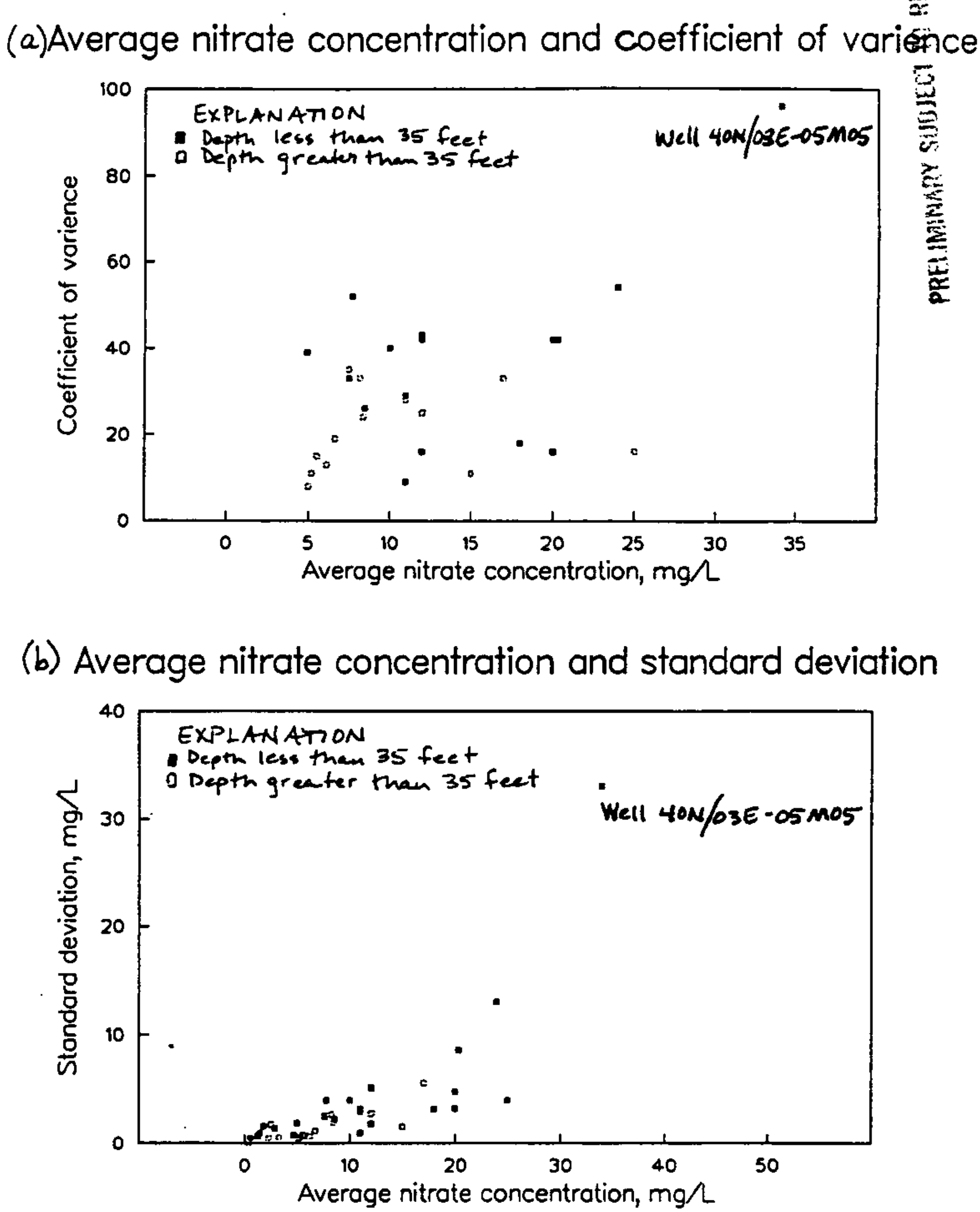

FIGURE 17.--Variability of nitrate concentrations in Sumas aquifer showing (a) average nitrate concentration and coefficient of varience and (b) average nitrate concentration and standard deviation

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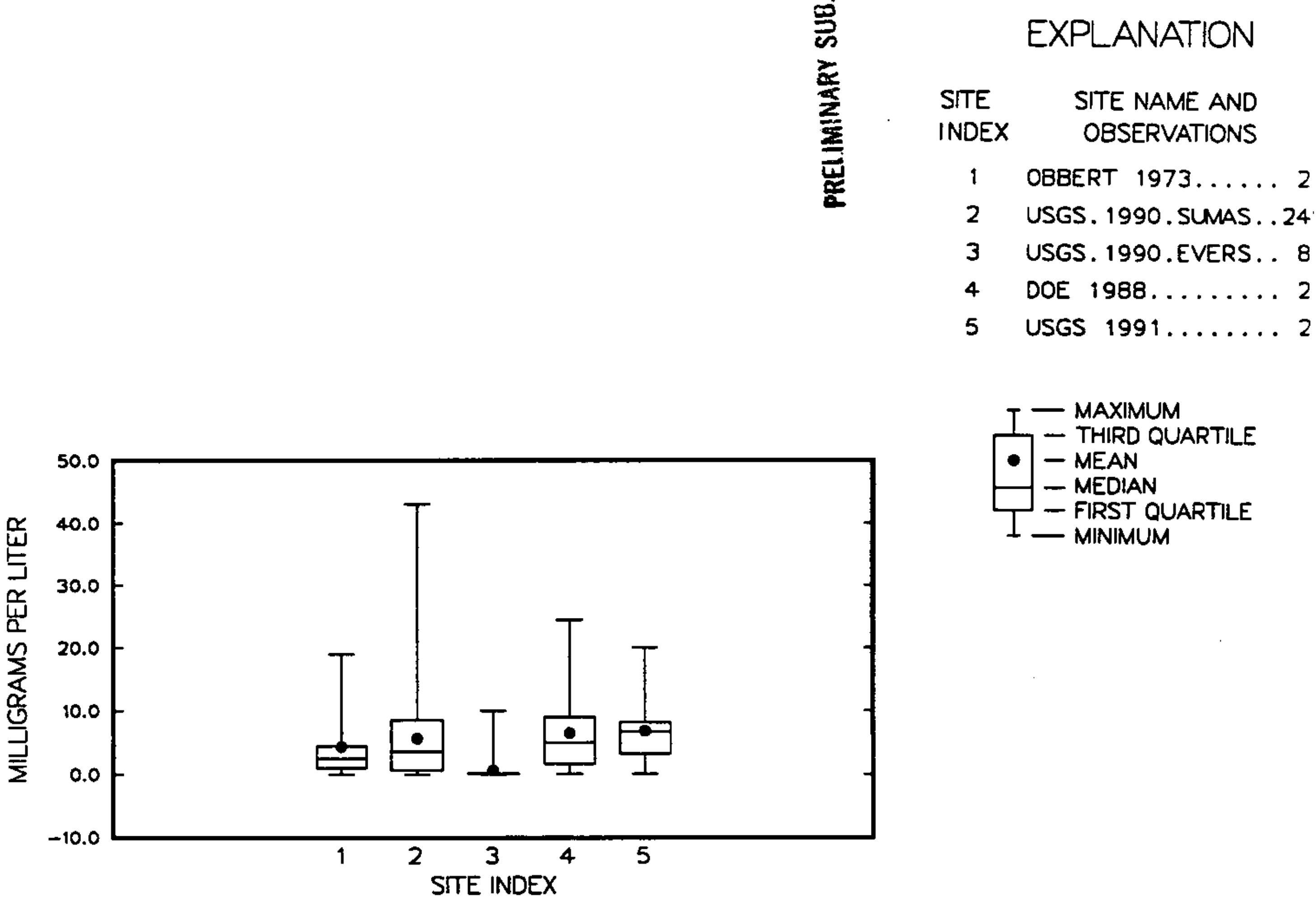


FIGURE 18.--Nitrate concentrations measured during current and previous studies

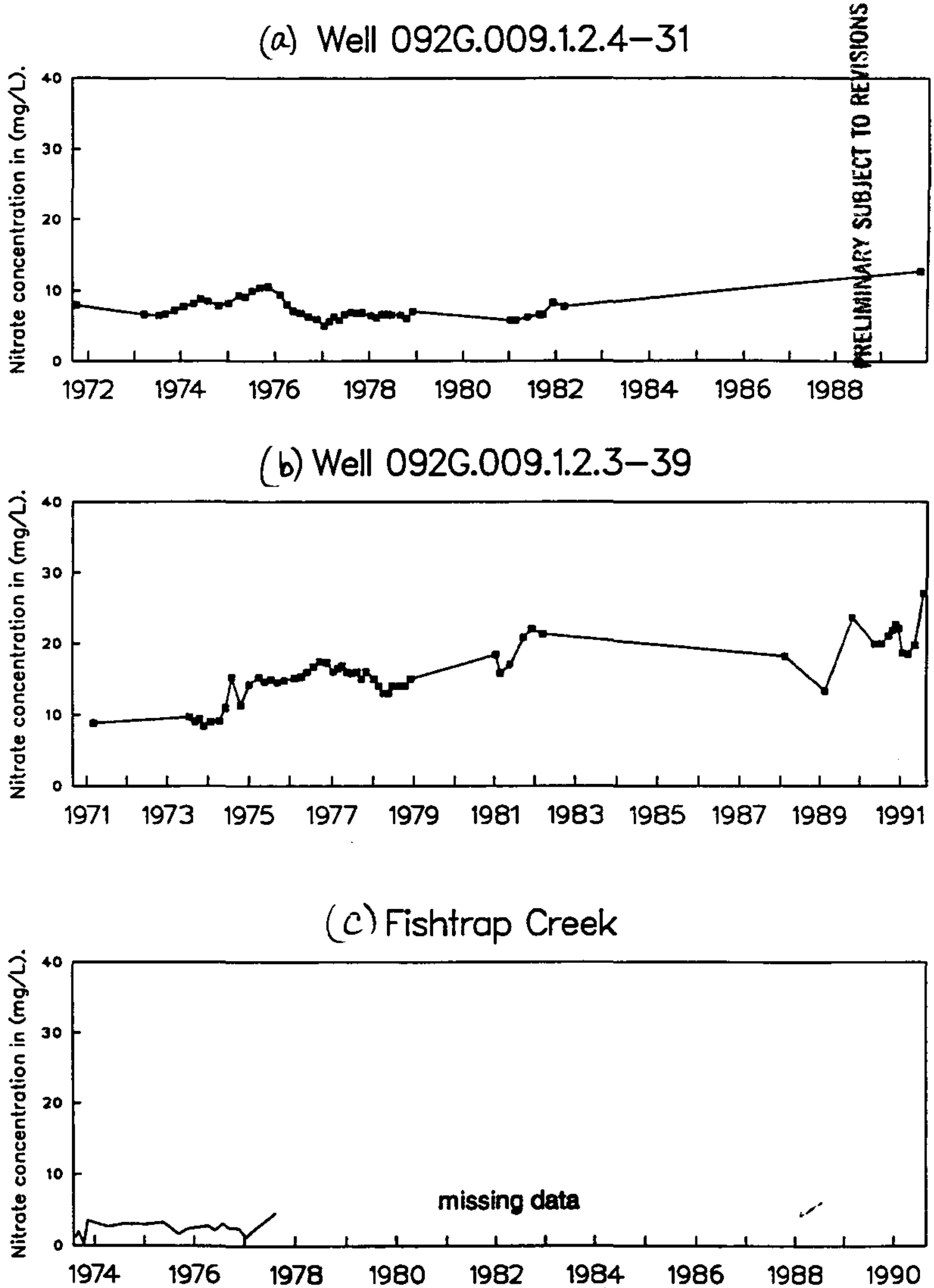


FIGURE 19.--Long-term variability of nitrate concentrations including (a) Well 092G.009.1.2.4-31, (b) Well 092G.009.1.2.3-39, (c) Fishtrap creek, (d) Piezometer site A, (e) Peizometer site B, (f) Piezometer site C, (g) Well 39N/03E-10L01, and (h) Sumas City wells and spring

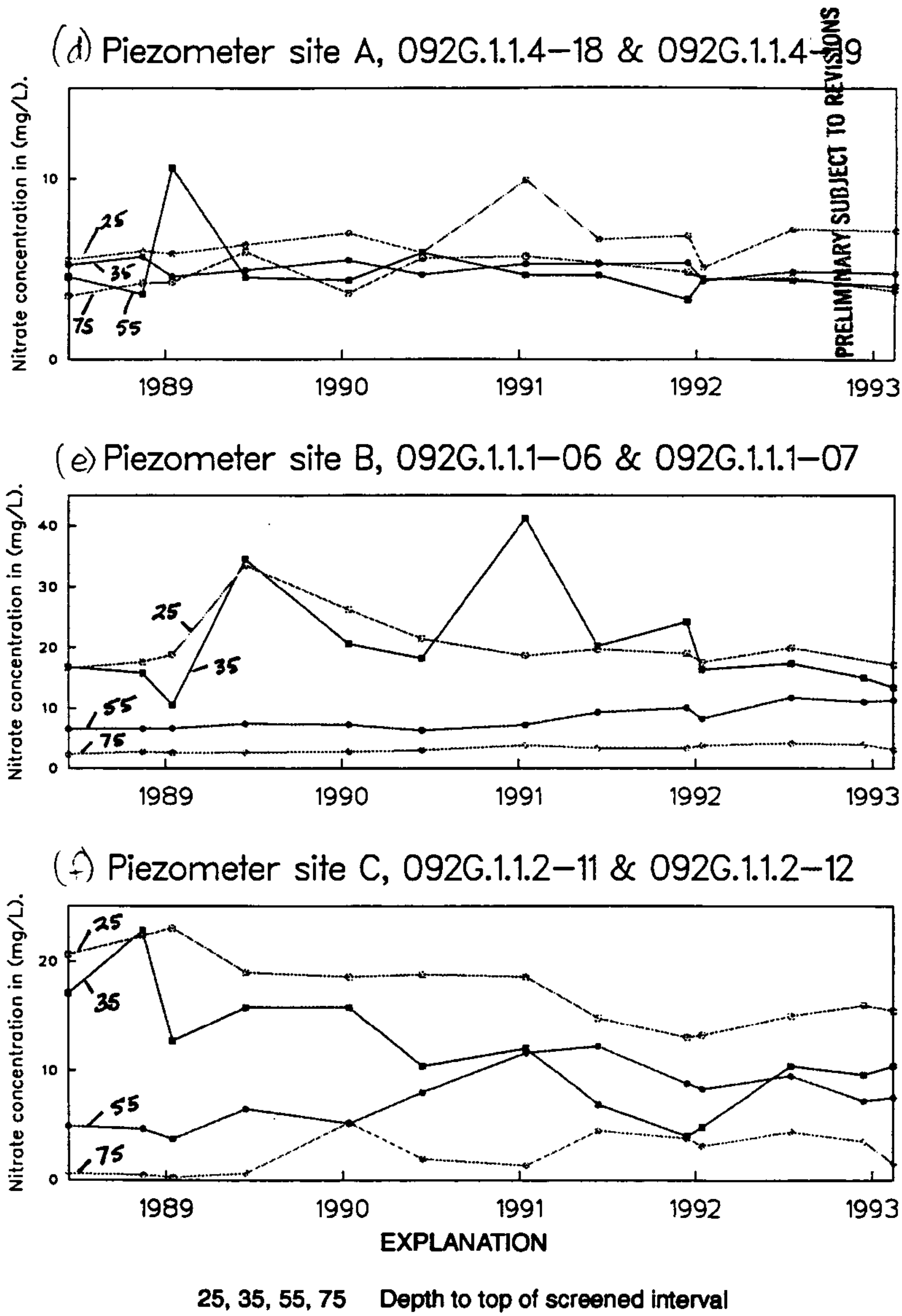


FIGURE 19.--cont.

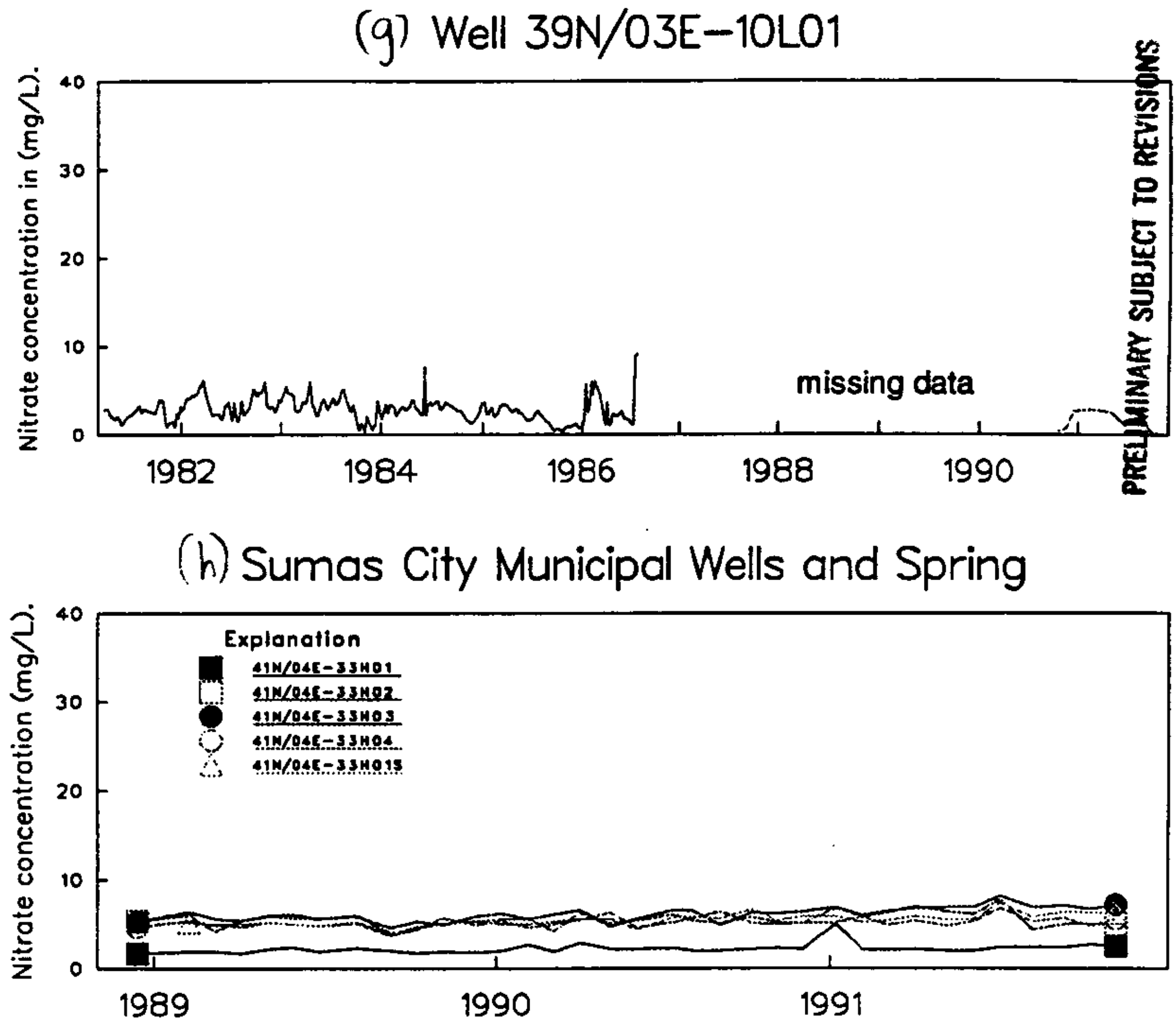


FIGURE 19.--cont.

★ to be replotted with hydrogeologic unit indicated

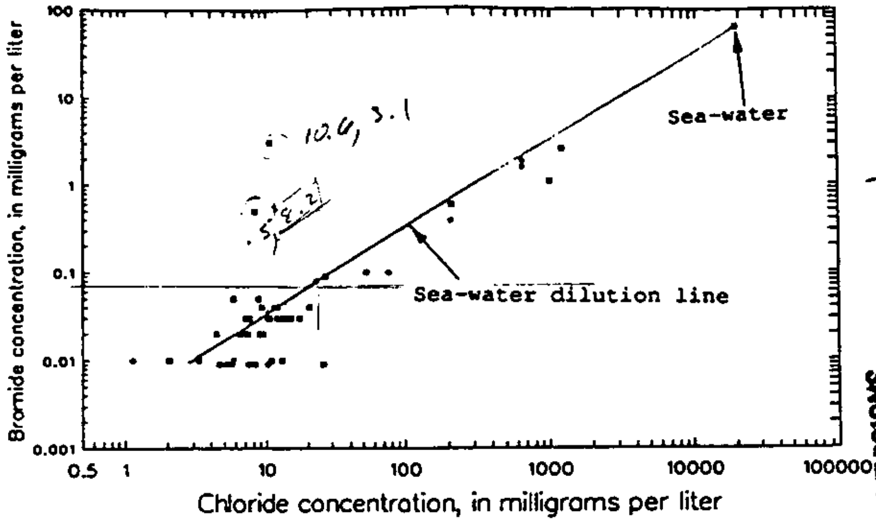


Figure 20a.--Plot of bromide and chloride concentrations in ground-waters from aquifers in the Fraser-Whatcom basin and in sea-water, with line showing sea-water dilution concentrations.

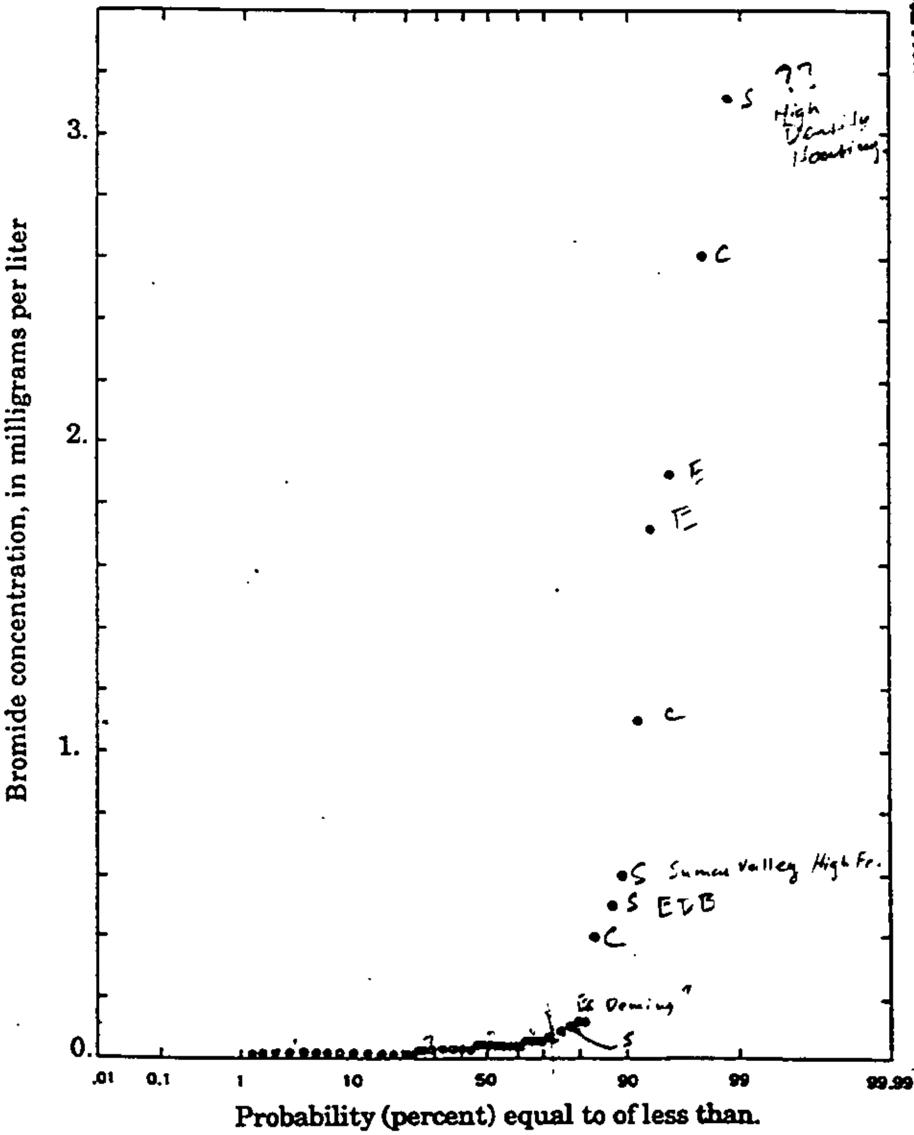


Figure 20b.--Normal probability plot of dissolved bromide concentrations in ground-waters from aquifers in the Fraser-Whatcom Basin.

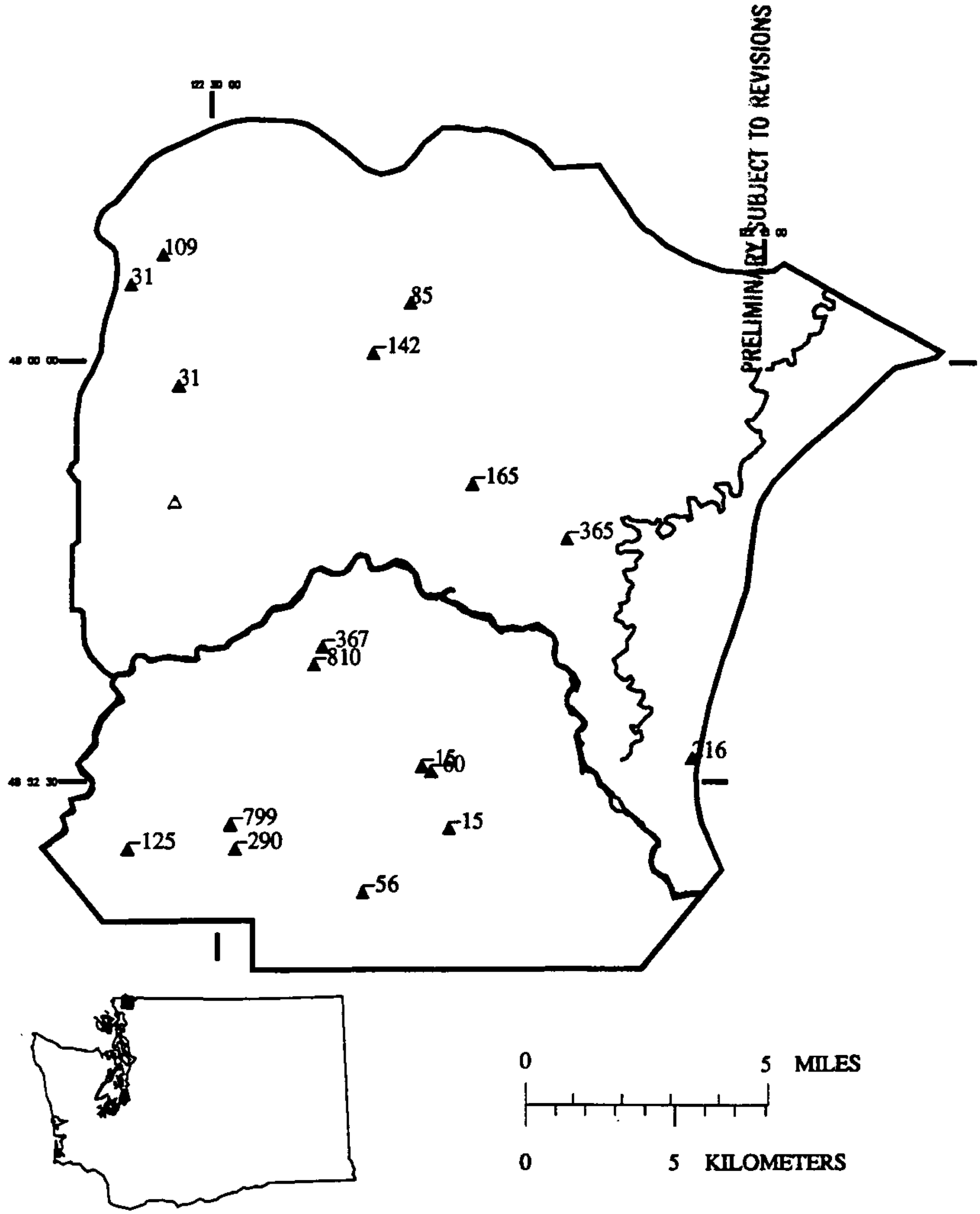


FIGURE 21.--Locations of wells with large chloride concentrations (greater than 250 mg/L or described as "salty water" by driller), showing altitude of open interval, in feet above or below (-) mean sea level

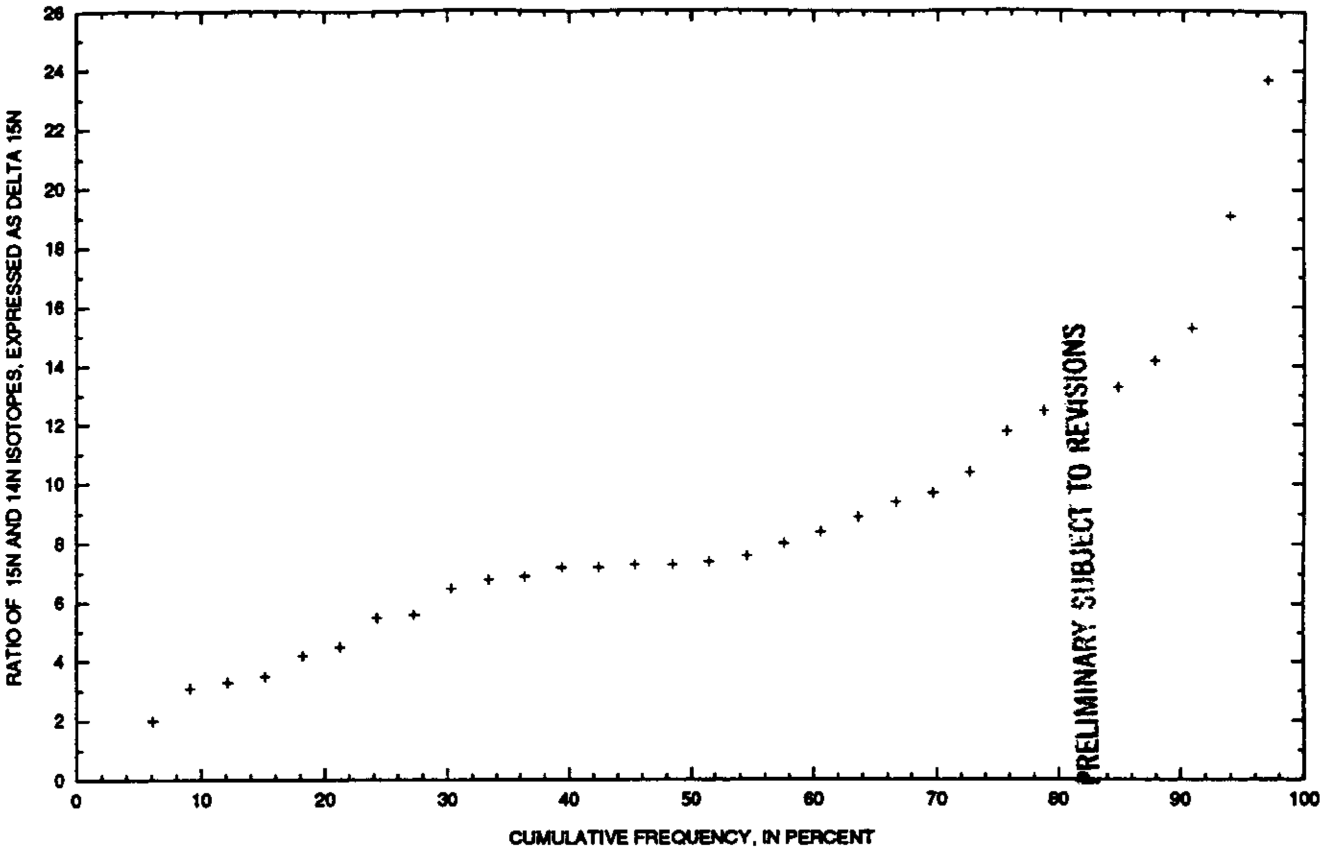


FIGURE 22.--Ratio of nitrogen isotopes in ground waters of the Sumas aquifer

Lithologic logs used in construction of hydrogeologic sections

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
AG 092G.008.1.4.2-01.	Altitude 300 feet.	Drilled, L Johnson, 1972	
Clay, brown	20	20	280
Clay, blue	17	37	263
Clay, blue, and sandy	122	159	141
Clay, blue, and silty	22	181	119
Till, clayey	19	200	100
Clay, blue, and stoney	93	293	7
Till	40	333	-33
Sand, water bearing, saltwater	1	334	-34
Clay and till	36	370	-70
Sand, water bearing, and saltwater	2	372	-72
Clay and pebbles	15	387	-87
Sand, fine, and silt	4	391	-91
Sand, compact	1	392	-92
Sand, water bearing	1	393	-93
Clay	2	395	-95
AJ 092G.008.1.4.4-03.	Altitude 320 feet.	Drilled by Linder's Well Drilling, 1980.	
Clay, brown	16	16	304
Clay, blue	74	90	230
Till	5	95	225
Sand, water bearing, and gravel	10	105	215
Sand, water bearing	12	117	203
AK 092G.008.2.1.1-02.	Altitude 165 feet.	Drilled by Linder's Well Drilling, 1986.	
Topsoil	6	6	159
Gravel, sandy, and clay	24	30	135
Sand, silty, and clay	30	60	105
Sand, silty, and some gravel	37	97	68
Sand and gravel	7	104	61
AL 092G.008.2.1.1-04.	Altitude 180 feet.	Drilled by John Beers Construction, 1984.	
Topsoil	3	3	177
Clay, stoney	15	18	162

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Gravel	1	19	161
Clay, stoney	33	52	128
Till	4	56	124
Sand	7	63	117
Silt, clay layers	5	68	112

AO 092G.008.2.1.3-08. Altitude 240 feet. Drilled 1986.

Sand	3	3	237
Clay, brown	11	14	226
Clay, blue	73	87	153
Till	3	90	150
Clay, stoney	8	98	142
Boulders	2	100	140
Clay, blue	30	130	110
Clay, blue, and layers of water bearing silt	68	198	42
Till	59	257	-17
Till with layers of water bearing silt	41	298	-58
Sand, water bearing, and gravel	4	302	-62

AZ 092G.008.2.2.4-16. Altitude 170 feet. Drilled by Linder's Well Drilling, 1985.

Sand	2	2	168
Clay	19	21	149
Sand, water bearing, and gravel	4	25	145
Clay, blue	25	50	120
Till with layers of silt, water bearing	37	87	83
Sand, water bearing, and gravel	10	97	73
Clay	1	98	72

BN 092G.008.2.4.2-14. Altitude 330 feet. Drilled by Valley Water, 1981.

Clay	2	2	328
Gravel	43	45	285
Till	5	50	280
Clay, sandy	5	55	275
Gravel	25	80	250

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Till	35	115	215
Sand, water bearing	14	129	201

BQ 092G.008.2.4.4-10. Altitude 350 feet. Drilled by Western Water Wells, 1960.

Boulders and gravel, with sand	35	35	315
Gravel, fine to medium, and sand	25	60	290
Sand, with some gravel	5	65	285
Sand, silty	33	98	252
Sand, fine to medium, and gravel	12	110	240
Sand, silty, and fine	21	131	219
Sand, silty, with saturated gravel	181	312	38
Sand	3	315	35
Clay, sandy, with some gravel	85	400	-50
Boulders	2	402	-52
Clay, stickey, with some gravel	196	598	-248
Sand, silty, and bearing water	3	601	-251
Clay, blue, with pebbles	74	675	-325

BW 092G.008.4.2.2-27. Altitude 400 feet. Drilled by Valley Water, 1981.

Clay, brown, and sandy	20	20	380
Clay, blue, and stoney	58	78	322
Gravel, dry	31	109	291
Sand, brown, water bearing	12	121	279
Sand, grey, water bearing	6	127	273

CE 092G.009.1.1.2-12. Altitude 167.6 feet. Drilled by Langley Water Wells, 1988.

Topsoil	7	7	160.6
Sand and gravel, with lenses of sand	68	75	92.6

CM 092G.009.1.1.4-19. Altitude 175 feet. Drilled by Langley Water Wells, 1988.

Topsoil	5	5	170
Sand and gravel, with lenses of sand	70	75	100

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
CQ 092G.009.1.2.1-99.	Altitude 225 feet.	Drilled 1988.	
Sand and gravel, red-brown	.91	.91	224.09
Sand, grey, very coarse	5.95	6.86	218.14
Sand, grey, fine to very coarse	4.11	10.97	214.03
Sand, very fine	3.51	14.48	210.52
Sand, coarse	.15	14.63	210.37
Sand, grey, fine to very coarse, some silt	2.59	17.22	207.78
Sand, grey, very fine, silty	.15	17.37	207.63
Sand, grey, coarse	1.98	19.35	205.65
Sand, grey, very fine	.92	20.27	204.73
Sand, grey, fine to very coarse	4.27	24.54	200.46
Sand and gravel, very fine to coarse, cobbles	.3	24.84	200.16
Sand, very fine to very coarse	1.37	26.21	198.79
Sand, greenish-grey, coarse	2.29	28.50	196.50
Sand and gravel, grey, very coarse	.76	29.26	195.74
DB 092G.009.1.2.4-31.	Altitude 225 feet.	Drilled by A & H, 1970.	
Soil	4	4	221
Gravel	77	81	144
Sand	11	92	133
Clay, blue	40	132	93
Sand and gravel	13	145	80
Sand	6	151	74
Sand and gravel	12	163	62
DI 092G.009.1.3.4-34.	Altitude 200 feet.	Drilled by Linder's Well Drilling, 1985.	
Unknown	36	36	164
Sand and gravel, water bearing	9	45	155
Sand, fine, water bearing	29	74	126
Sand and gravel, water bearing	10	84	116
DW 092G.009.3.1.2-20.	Altitude 375 feet.	Drilled by Valley Well Drilling, 1970.	
Topsoil	3	3	372

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, grey, hardpan, and till	21	24	351
Clay, blue, and sand	11	35	340
Clay, grey, and sand	15	50	325
Clay, blue	10	60	315
Clay, grey, and fine gravel	45	105	270
Sand, fine, and water	7	112	263
Clay, blue, fine gravel, and seepage	40	152	223

DX 092G.009.3.1.2-23. Altitude 215 feet. Drilled by Hi-land, 1974.

Gravel	32	32	183
Clay	93	125	90

DY 38N/03E-04E01. Altitude 310 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1981.

Topsoil	2	2	308
Clay, tan	13	15	295
Clay, grey	48	63	247
Clay, grey, gravel, and sand	35	98	212
Gravel, dry, and little clay	23	121	189
Sand, dry, and little clay	9	130	180
Sand, medium, and dry	19	149	161
Gravel, dry, and sand, course	13	162	148
Sand, little clay, and water	7	169	141
Sand, medium, and water	6	175	135
Sandstone, green	1	176	134
Sandstone, brown	14	190	120
Sandstone, grey	10	200	110

EA 38N/04E-06D01. Altitude 275 feet. Radke Well Drilling, 1974.

Topsoil	1	1	274
Hardpan	24	25	250
Clay, blue	82	107	168
Clay, black, and fine	3	110	165
Sand, fine, and clay strips	11	121	154
Sand, fine, clay strips, and water	11	132	143

Materials		Thickness (feet)	Depth (feet)	Altitude (feet)
EB	39N/02E-01N01.	Altitude 75 feet.	Drilled by Don Mulka, 1951.	
Topsoil		2	2	73
Sand		23	25	50
EC	39N/02E-01P02.	Altitude 80 feet.	Drilled by Snowden Well Digging, 1974.	
Sandy loam		2	2	78
Sand, coarse		24	26	54
Sand, fine		5	31	49
Sand, coarse		2.5	33.5	46.5
ED	39N/02E-01Q01.	Altitude 80 feet.	Drilled by G. A. Wetzel, 1951.	
Sandy loam		3	3	77
Sand		28	31	49
EA	39N/02E-05B02.	Altitude 60 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1981.	
Sand, brown		5	5	55
Sand and gravel, brown		10	15	45
Sand		20	35	25
Clay, silty		125	160	-100
Clay, silty, shells, and gravel		40	200	-140
Clay, silty, and gravel		175	375	-315
Sand and gravel with clay, silty		210	585	-525
Clay, silty, with sand and gravel		50	635	-575
Sand, clay, silty, and gravel		45	680	-620
Clay, silty, sand, and gravel		55	735	-675
Bedrock at bottom of hole				
EI	39N/02E-10F01.	Altitude 55 feet.	Drilled by B & C Well Drilling Inc., 1987.	
Topsoil		1	1	54
Gravel, sandy brown		7	8	47
Sand, gravel, and water		12	20	35
Clay and silt, fine		2	22	33

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
EM 39N/02E-11B02.	Altitude 70 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1981.	
Sand	15	15	55
Sand, grey, and water	20	35	35
Sand, fine and gravel, scattered	10	45	25
Sand, fine, grey, and clay	11	56	14
Clay, grey	9	65	5
Sand, grey, fine and clay	24	89	-19
Clay, grey	121	210	-140
Clay, grey and gravel, scattered clam shells	80	290	-220
Clay, grey, sandy	77	367	-297
Clay, grey, sand, coarse	53	420	-350
Clay, gravelly, grey, and boulders	55	475	-405
Clay, grey, hard, and sand	37	512	-442
Clay, grey, and cobble	8	520	-450
Sandstone	5	525	-455
EP 39N/02E-12K03.	Altitude 85 feet.	Drilled by B & C Well Drilling Inc., 1985.	
Topsoil, sandy	1	1	84
Sand, brown	8	9	76
Clay and brown sand mix	2	11	74
Sand, brown, and fine	16	27	58
EQ 39N/02E-12Q01.	Altitude 80 feet.	Drilled by Livermore & Son Inc., 1989.	
Topsoil	1	1	79
Loam, sandy, brown	4	5	75
Sand, blue, and fine	32	37	43
Sand, fine, and blue clay lenses	1	38	42
Sand and water	6	44	36
ER 39N/02E-13B01.	Altitude 80 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1987.	
Topsoil	1	1	79
Sand, brown, fine, dry	13	14	66
Sand, rusty-brown, fine, and water	9	23	57

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand, dirty grey, fine to medium and water	6	29	51
Sand, clean grey, fine to medium and water	18	47	33
Sand, dirty grey, fine, little clay, and water	5	52	28
Sand, dirty grey, fine, clay, and water	5	57	23

EW 39N/02E-21K01. Altitude 50 feet. Drilled by James L. Asplund, 1972.

Topsoil, sandy	3	3	47
Clay	1	4	46
Water bearing sand	15	19	31
Clay, blue at bottom of hole			

FA 39N/02E-22L01. Altitude 50 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1973.

Sandy loam, tan	9	9	41
Clay, grey	54	63	-13
Sand, fine, and clay with slight seepage	8	71	-21
Clay, blue, and sandy	69	140	-90
Sandstone	2	142	-92
Clay, grey, sandy, and hard	6	148	-98
Gravel and sand	2	150	-100
Sand, medium, and saltwater	10	160	-110
Clay and sand	15	175	-125

FB 39N/02E-23F01. Altitude 60 feet. Drilled by B & C Well Drilling Inc., 1987.

Hardpan	3	3	57
Sand, brown	7	10	50
Clay, grey	1	11	49
Sand, grey-black	9	20	40

FD 39N/02E-23J01. Altitude 80 feet. Drilled by Sprague & Henwood, G.J., Colo., 1959.

Sand	30	30	50

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand and gravel	5	35	45
Sand, grey, and medium	10	45	35
Sand and gravel	5	50	30
Clay, bluish-grey	60	110	-30
Sand, grey	5	115	-35
Clay, bluish-grey and sand, fine	25	140	-60
Sand and gravel	10	150	-70
Sand	25	175	-95
Sand, gravel, and boulders	15	190	-110
Gravel and boulders	20	210	-130
Sand and gravel	25	235	-155
Sand	55	290	-210
Sand and gravel	45	335	-255
Sand, medium	15	350	-270
Sand and gravel	15	365	-285
Sand, medium	30	395	-315
Sand and clay	5	400	-320
Sand, medium, gravel, and clay, bluish-grey	5	405	-325
Sand, fine, gravel, and clay, bluish-grey	5	410	-330
Sand, medium, gravel, and clay, bluish-grey	5	415	-335
Sand, gravel, clay, and coal	5	420	-340
Sandstone and shale	642	1062	-982

FE 39N/02E-24B01. Altitude 70 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1982.

Topsoil	1	1	69
Sand, brown	11	12	58
Sand, grey, and dark	5	17	53
Clay, grey	57	74	-4
Clay, grey, and gravel	7	81	-11
Sand, grey, with seeage	5	86	-16
Clay, grey	3	89	-19
Gravel; grey, and water	5	94	-24
Clay, brown	.5	94.5	-24.5
Clay, grey	7.5	102	-32
Clay, grey, and gravel	70	172	-102
Clay, grey, and some gravel	49	221	-151
Clay, grey, and gravel	21	242	-172

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Gravel, grey, sand, and water	8	250	-180
Gravel, grey, sand, clay sandstone and coal	17	267	-197
Gravel, grey, and clay sandstone	25	292	-222
Gravel, grey, and water	9	301	-231
Clay, grey, and gravel	27	328	-258
Gravel, grey, and water	59	387	-317
Clay, grey, and gravel	8	395	-325
Quartz rock, hard	46	441	-371
Gravel, grey, and clay	44	485	-415
Sand, grey, coarse, and gravel	45	530	-460

FH 39N/02E-24K01. Altitude 90 feet. Drilled by Whatcom County Wildcat Drilling Project.

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand, brown, and medium	10	10	80
Sand, brown, medium, and gravel lenses	28	38	52
Clay, silty, grey, and zones of sand and gravel	87	125	-35
Boulders	2	127	-37
Sand and gravel, grey	55	182	-92
Clay, silty, grey, with occasional sand and gravel	44	226	-136
Sand, fine to medium and gravel	9	235	-145
Sand and gravel, grey	5	240	-150
Sand, fine	10	250	-160
Sand and gravel, grey	70	320	-230
Sand, fine, gravel, and saltwater	35	355	-265
Sand, clay, very compact	25	380	-290
Bedrock at bottom of hole			

FO 39N/02E-26N01. Altitude 90 feet. Drilled by B & K Water Well Inc., 1980.

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Topsoil	2	2	88
Clay and sand, brown	4	6	84
Sand, brown, and gravel	18	24	66

FT 39N/02E-27N01. Altitude 100 feet. Drilled by B & K Water Well Inc., 1984.

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Topsoil, sandy loam	3	3	97
Gravel and some sand	29	32	68

FV 39N/02E-27P01. Altitude 100 feet. Drilled by Western Core Drilling, Inc., 1959.

Sand and gravel (undifferentiated deposits)	269	269	-169
Shale and sandstone	654	923	-823

FW 39N/02E-28J02. Altitude 90 feet. Drilled by B & K Water Well Inc., 1989.

Topsoil	2	2	88
Sand and gravel, brown	6	8	82
Sand, grey, and some gravel	17	25	65

FY 39N/03E-01C01. Altitude 95 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1985.

Topsoil	3	3	92
Gravel, dry	14	17	78
Gravel and seepage	8	25	70
Gravel and water	11	36	59
Gravel and dirty water	7	43	52
Sand and water	7	50	45
Clay, grey at 50 (bottom of hole)			

GA 39N/03E-01R01. Altitude 120 feet. Drilled by B & C Well Drilling, Inc., 1983.

Clay, gravely	18	18	102
Gravel, with sand	28	46	74

GD 39N/03E-02B03. Altitude 90 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1981.

Sand, brown, and gravel	2	2	88
Sand, brown, gravel, and water	33	35	55
Sand, grey, and gravel	3	38	52
Clay, grey	22	60	30

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, dark grey, and scattered gravel	5	65	25
Clay, lighter grey, and gravel	108	173	-83
Sandstone, grey, and coarse	27	200	-110

GJ 39N/03E-03J01. Altitude 80 feet. Drilled by Snowden Well Digging, 1978.

Gravel and loam	2	2	78
Gravel	3	5	75
Sand, medium	23	28	52

GK 39N/03E-03M01. Altitude 90 feet. Drilled by E.W. McClure, 1939.

Gravel, sandy	5	5	85
Sand, gravel, and boulders	5	10	80
Boulders, gravel, and sand	2	12	78
Gravel, hard	2	14	76
Gravel, slightly water bearing	1	15	75
Gravel, cemented	5	20	70
Gravel, sand, rock, and water bearing	1	21	69
Quicksand, dark	1	22	68
Clay, yellow	1	23	67
Quicksand, dark	42	65	25
Clay, blue	55	120	-30
Sand, silty, fine, and water	6	126	-36
Clay, grey, and water runoff	21	147	-57
Sand, fine	4	151	-61
Clay, grey	19	170	-80
Rock, hard	1	171	-81
Clay, grey, with gravel	9	180	-90
Shale	22	202	-112
Clay, gravel, and saltwater	1	203	-113
Shale, grey	10	213	-123
Shale, brown, and water	4	217	-127
Shale, grey	11	228	-138
Coal	4	232	-142
Sand and water	1	233	-143
Shale, sandy, light grey	7	240	-150
Sandstone	18	258	-168
Sandstone, smell of gas	2	260	-170

Lithologic logs used in construction of hydrogeologic sections--continued

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sandstone, hard	2	262	-172
GM 39N/03E-04B01.	Altitude 85 feet.	Drilled by Bezona Drill Co., 1981.	
Sand and gravel, brown	10	10	75
Sand, grey, and gravel	22	32	53
Clay, blue	10	42	43
Till, glacial, and hardpan	2	44	41
Sand, silt, gravel, and quicksand	2	46	39
Silt, fine, and quicksand	8	54	31
Clay, blue, soft	36	90	-5
GO 39N/03E-04M02.	Altitude 100 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1982.	
Topsoil	2	2	98
Sand, brown	10	12	88
Sand, brown, and gravel	8	20	80
Sand, brown, gravel, and water	12	32	68
Sand, brown	5	37	63
Clay, tan	1	38	62
Sand, brown, and fine	4	42	58
Silt, grey, fine, and sand	13	55	45
Clay, grey at bottom of hole			
HG 39N/03E-09D02.	Altitude 95 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1984.	
Topsoil	2	2	93
Sand, brown, and gravel	6	8	87
Sand, brown, gravel, and clay	19	27	68
Sand, brown, and fine	11	38	57
Clay, tan	2	40	55
HI 39N/03E-10E01.	Altitude 90 feet.	Drilled by Livermore & Son Inc., 1987.	
Topsoil	1	1	89
Sand and gravel, brown	17	18	82
Sand, blue, and fine	22	40	50

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, blue	1	41	49
Sand, fine, and clay seams	2	43	47
Clay, blue, and soft	5	48	42
HO 39N/03E-10Q03.	Altitude 105 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1989.	
Topsoil	1	1	104
Sand, brown, coarse, and gravel	21	22	83
Gravel, brown, sand, and water	1	23	82
Clay, brown	2	25	80
Clay, grey, and some gravel	8	33	72
Sandstone, grey	18	51	54
Coal	1	52	53
Sandstone, grey, and fine	13	65	40
Sandstone, grey, and coarse	14	79	26
Siltstone, grey	1	80	25
Sandstone, grey	22	102	3
Siltstone, grey	2	104	1
Sandstone, grey	6	110	-5
Siltstone, grey	1	111	-6
Sandstone, grey, green-brown, and hard	2	113	-8
Siltstone and sandstone, grey, layered	1	114	-9
Sandstone, grey	6	120	-15
Sandstone, grey, and saltwater	2	122	-17
HV 39N/03E-12J02.	Altitude 130 feet.	Drilled by B & C Well Drilling, Inc., 1979.	
Loam, sandy	7	7	123
Gravel, with hardpan	11	18	112
Sand, cemented, and gravel	17	35	95
Gravel, coarse, with sand and water	15	50	80
Clay, with gravel at bottom of hole			
HW 39N/03E-12R03.	Altitude 135 feet.	Drilled by B & C Well Drilling, Inc., 1979.	
Sand, fine	37	37	98
Sand, with gravel	10	47	88

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
HY 39N/03E-13R01.	Altitude 210 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1973.	
Topsoil	4	4	206
Clay	8	12	198
Shale, sandy	73	85	125
Sandstone	20	105	105
Water	15	120	90
IB 39N/03E-15C02.	Altitude 120 feet.	Radke Well Drilling, 1979.	
Topsoil	2	2	118
Gravel	2	4	116
Hardpan	25	29	91
Sandstone, hard	81	110	10
Sandstone, soft, water	1	111	9
Sandstone, hard	4	115	5
IE 39N/03E-15L01.	Altitude 150 feet.	Drilled by B & C Well Drilling, Inc., 1980.	
Clay	7	7	143
Siltstone	13	20	130
Sandstone	6	26	124
Siltstone	8	34	116
Siltstone and coal	7	41	109
Siltstone	27	68	82
Sandstone	7	75	75
Siltstone	24	99	51
IG 39N/03E-16F01.	Altitude 100 feet.	Drilled by Snowden Well Digging, 1974.	
Topsoil	2	2	98
Sand, brown	11	13	87
Sand and water	15	28	72
II 39N/03E-16L03.	Altitude 100 feet.	Drilled by Snowden Well Digging, 1977.	
Loan, sandy	3	3	97

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay and sand, layers	8	11	89
Gravel	10	21	79

IS 39N/03E-16N02. Altitude 100 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1982.

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand, brown	11	11	89
Sand, brown, and gravel	4	15	85
Sand, grey, and little clay, brown	18	33	67
Sand, gravel, brown, and water	3	36	64
Clay, brown, and gravel	1	37	63
Gravel, brown, and water	8	45	55
Gravel, brown, clay, and water	6	51	49
Clay, grey	1	52	48
Sand, grey, and water	7	59	41
Clay, grey	21	80	20
Clay, grey, and clam shells	16	96	4
Clay, grey	15	111	-11
Siltstone	5	116	-16
Sandstone	17	133	-33
Coal	2	135	-35
Sandstone	5	140	-40

IN 39N/03E-19L01. Altitude 140 feet. Drilled by Livermore & Son Inc., 1982.

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Topsoil	1	1	139
Hardpan	6	7	133
Clay, blue, and soft	16	23	117
Clay, blue, and sandy	9	32	108
Gravel, sand, and water	22	54	86

IR 39N/03E-20K01. Altitude 150 feet. Drilled by Star Drilling Service, 1986.

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, red	10	10	140
Hardpan	3	13	137
Clay, grey	11	24	126
Hardpan	18	42	108
Gravel with water	3	45	105
Clay, brown, at bottom of hole			

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
IS 39N/03E-20L01.	Altitude 150 feet.	Drilled by Star Drilling Service, 1986.	
Clay, red	7	7	143
Gravel	8	15	135
Clay, grey	12	27	123
Gravel, dry	1	28	122
Hardpan	21	49	101
Gravel with water	2	51	99
Sand, grey, and fine	1	52	98
IU 39N/03E-21E01.	Altitude 140 feet.	Drilled by Livermore & Son Inc., 1988.	
Topsoil	2	2	138
Sand, gravel, and hardpan	7	9	131
Sand, gravel, and clay, blue	13	22	118
Sand, gravel, little clay, and water	12	34	104
Sand, gravel, and water	6	40	100
Sand, gravel, and clay blue	3	43	97
IV 39N/03E-21K01.	Altitude 190 feet.	Drilled by Star Drilling Service, 1989.	
Clay, red	12	12	178
Clay, grey	58	70	120
Clay, grey, with stones	20	90	100
Sand, dry	30	120	70
Clay, hard, and gravel	17	137	53
Hardpan	19	156	34
Gravel with water	2	158	32
IW 39N/03E-21M01.	Altitude 160 feet.		
Clay, silty, and gravel, brown	10	10	150
Clay, silty, and gravel, grey	65	75	85
Gravel, sandy silty, grey	20	95	65
Sand, medium, brown, and water bearing	25	120	40
Sand and gravel, light brown	20	140	20
Silt, sandy with gravel	75	215	-55
Sand and gravel, water bearing	10	225	-65

Lithologic logs used in construction of hydrogeologic sections--continued

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand, silty with gravel, grey	5	230	-70
Sand, medium, and gravel, water bearing	30	260	-100
Sand, fine to medium	15	275	-115
Silt, sandy with gravel, grey	5	280	-120
Sand, grey, and fine	5	285	-125
Clay, grey, and silty	8	293	-133
Sand, grey, fine to medium	7	300	-140
Clay, silty, grey, and sandy	5	305	-145
Clay, silty, and sandy with gravel	15	320	-160
Sand, grey, and fine	10	330	-170
Sand, fine to coarse, gravel, grey, water	15	345	-185
Sand, fine to medium, and gravel, grey	5	350	-190
Gravel	25	375	-215
Gravel, with sand and bearing water	35	410	-250
Clay, sandy, with gravel, and till hard, and grey	40	450	-290
Bedrock at bottom of hole	10	460	-300

IX 39N/03E-22M01. Altitude 210 feet. Drilled by B & C Well Drilling, Inc., 1980.

Clay, brown	15	15	195
Clay, grey	38	53	157
Gravel, coarse	5	58	152
Clay, brown	9	67	143
Clay, grey	8	75	135
Clay, grey, and hardpan	16	91	119
Gravel, hardpan	10	101	109
Clay, hardpan	8	109	101
Hardpan with boulders	9	118	92
Gravel, grey, and hardpan	8	126	84
Clay, grey, and hardpan	12	138	72
Hardpan, with coarse gravel	7	145	65
Gravel cemented, and grey	9	154	56
Clay, grey, and sandy	3	157	53
Gravel, hardpan and grey	4	161	49
Sand, dark, water, and clay	2	163	47

JB 39N/03E-23J01. Altitude 190 feet. Drilled by Livermore & Son Inc., 1986.

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Topsoil	1	1	189
Sand, gravel, and hardpan	13	14	176
Sand, gravel, and little blue clay	33	47	143
Sand, gravel, and blue clay soft	23	70	120
Sand, gravel, and blue clay hard	9	79	111
Sand, and water	1	80	110
Sandstone	15	95	95
Sandstone, water	35	130	60

JC 39N/03E-23M01. Altitude 170 feet. Drilled by Star Drilling Service, 1984.

Clay, red	24	24	146
Clay, grey	6	30	140
Clay and sand	5	35	135
Clay and gravel	19	54	116
Clay, grey, and hard	16	70	100
Gravel, fine	1	71	99
Clay, grey	14	85	85
Sand cemented	10	95	75
Sand, fine	5	100	70
Hardpan at bottom of hole			

JF 39N/03E-25A01. Altitude 230 feet. Drilled by B & C Well Drilling, Inc., 1983.

Soil	2	2	228
Clay, with gravel, brown	25	27	203
Clay, blue, with gravel	112	139	91
Gravel with water	9	148	82

JK 39N/03E-26P02. Altitude 260 feet. Drilled by B & C Well Drilling Inc., 1978.

Topsoil	1	1	259
Clay, brown	9	10	250
Clay, blue	12	22	238
Quicksand	3	25	235
Sand and gravel	25	50	210
Clay, sandy, and gravel	14	64	196
Sand, with gravel	6	70	190

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, grey, sand, and gravel	39	109	151
Sand, brown, with clay	20	129	131
Gravel, sandy, with clay	9	138	122
Sand, gravel, and water	15	153	107
Clay, blue, and sandy	2	155	105

JO 39N/03E-28F01. Altitude 230 feet. Drilled by Bezona Well Service, 1987.

Clay, brown, and gravel	8	8	222
Clay, blue, and till	7	15	215
Hardpan and till	58	73	157
Hardpan and boulders	27	100	130
Clay, soft, and till	122	222	8
Hardpan	3	225	5
Gravel, layered, and silty	55	280	-50
Gravel and sand aquifer	6	286	-56

JP 39N/03E-28J01. Altitude 230 feet. Drilled by B & C Well Drilling Inc., 1977.

Topsoil	1	1	229
Clay, yellow	4	5	225
Sand, brown, and wet	6	11	219
Sand, blue, with clay	4	15	215
Clay, blue, with pebbles	51	66	164
Gravel and sand	4	70	160
Clay, blue, with gravel	4	74	156
Gravel, sandy, with water	10	84	146
Sand and clay, fine	1	85	145

JQ 39N/03E-28Q02. Altitude 290 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1977.

Sand, tan loam	3	3	287
Clay, grey, and gravel	57	60	230
Gravel, dry, clean	25	85	205
Clay, grey, and sandy	5	90	200
Clay, grey	20	110	180
Sand, grey, dry	10	120	170
Gravel, dry	20	140	150

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, grey, and sand	37	177	113
Sand, grey, and water	3	180	110
Sand, clay, brown, and water	4	184	106
Clay, brown, and gravel	1	185	105

JR 39N/03E-28R01. Altitude 270 feet. Drilled by B & C Well Drilling Inc., 1977.

Topsoil	5	5	265
Gravel, cemented, and boulders	11	16	254
Clay, grey, with gravel	4	20	250
Clay, brown, with gravel	15	35	235
Sand, brown, and clay	21	56	214
Clay, blue, with gravel	1	57	213
Clay, grey, with gravel	3	60	210
Clay, blue, and hard	10	70	200
Clay, brown, hard, with gravel	5	75	195
Sand, brown, and clay	14	89	181
Sand and clay, brown	7	96	174
Sand and gravel	26	122	148
Clay, brown, with gravel	2	124	146
Sand and gravel	3	127	143
Clay, brown, with sand and gravel	9	136	134
Sand, medium	11	147	123
Sand and blue clay	2	149	121
Sand and water	6	155	115
Silt	25	180	90
Clay, blue	12	192	78
Sand, gravel, and water	5	197	73
Clay, brown, with pebbles	2	199	71

JY 39N/03E-30N01. Altitude 190 feet. Drilled by Livermore & Son Inc., 1974.

Topsoil	1	1	189
Hardpan	8	9	181
Sand, gravel, and hardpan	6	15	175
Sand, gravel, and little blue clay	11	26	164
Sand, gravel, and little blue clay, soft	28	54	136
Sand, gravel, and little brown clay	6	60	130
Sand, and dry gravel	8	68	122

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand, dry gravel, and blue clay	23	91	99
Sand, gravel, coarse, and blue clay	35	126	64
Sand, gravel, and water	5	131	59
Sand, gravel, and blue clay at bottom of hole			
JZ 39N/03E-30R01.	Altitude 300 feet.	Drilled by B & C Well Drilling Inc., 1978.	
Topsoil	1	1	299
Clay, brown	8	9	291
Clay, brown, and grey	3	12	288
Clay, blue	6	18	282
Clay, brown, and gravel	11	29	271
Sand and gravel	61	90	210
Sand, gravel, and clay	10	100	200
Gravel, large	10	110	190
Sand, medium, with gravel	4	114	186
Sand, fine, with gravel	6	120	180
Gravel	27	147	153
Sand with gravel	19	166	134
Clay, grey, and sandy	8	174	126
Gravel	7	181	119
Sand, fine, with gravel	4	185	115
Sand, coarse, with gravel	5	190	110
Sand, medium, gravel, and water	13	203	97
Sand, fine, with gravel, and water	11	214	86
Sand, medium, gravel, and water	3	217	83
KA 39N/03E-31B02.	Altitude 250 feet.	Drilled by Sprague and Henwood, G.J., Colo., 1961.	
Soil	5	5	245
Boulders, gravel, clay, and sand	63	68	182
Gravel and sand	65	133	117
Gravel, boulders, sand, and clay	127	260	-10
Clay, blue-grey, and few boulders	110	370	-120
Clay, boulders, and sand	30	400	-150
Gravel and boulders	57	457	-207
Gravel	13	470	-220
Boulders	4	474	-224

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay	6	480	-230
Shale and sandstone	1512	1992	-1742
KE 39N/03E-32A02.	Altitude 280 feet.	Drilled by Sprague & Henwood, G.J., Colo., 1961.	
Alluvium	2	2	278
Clay	8	10	270
Sand, grey, with few boulders	85	95	185
Gravel	15	110	170
Sand, grey	10	120	160
Sand, gravel, with few boulders	100	220	60
Sand and gravel	5	225	55
Clay, grey	17	242	38
Clay and sand	58	300	-20
Clay mainly, with gravel	115	415	-135
Shale and sandstone	1102	1517	-1237
KG 39N/03E-32J01.	Altitude 310 feet.	Drilled by Bezona Well Service, 1986.	
Till, glacial, brown, and soft	16	16	294
Clay, blue, and till, soft	26	42	268
Till, glacial, and hardpan	23	65	245
Gravel, hard-packed, and till	23	88	222
Sand, loose, and gravel, alluvium	17	105	205
Gravel, coarse, loose, and alluvium	11	116	194
Sand and some gravel, alluvium	13	129	181
Clay, blue, and sandy	11	140	170
Sand, coarse, and alluvium	7	147	163
Gravel, coarse, and alluvium	23	170	140
Sand, coarse, and alluvium	7	177	133
Gravel, pea, and alluvium	8	185	125
Sand and gravel, aquifer	33	218	92
KI 39N/03E-33K01.	Altitude 330 feet.	Drilled by Star Drilling Service, 1985.	
Sand	3	3	327
Clay, red	6	9	321
Clay, grey	15	24	306

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Hardpan	22	46	284
Gravel and traces of water	.6	46.6	283.4
Hardpan	2.4	49	281
Clay, hard, and dry	18	67	263
Hardpan	48	115	215
Hardpan took water	18	133	197
Clay, brown, and sandy	22	155	175
Sand, cemented	21	176	154
Hardpan	20	196	134
Gravel with water	1	197	133
Sand, grey, and cemented	6	203	127

KJ 39N/03E-33M01 Altitude 320 feet. Drilled by B & C Well Drilling, Inc., 1987.

Clay, brown	10	10	310
Clay, grey	32	42	278
Gravel, with clay	100	142	178
Clay, fine, and sandy	14	156	164
Sand and gravel, with clay	24	180	140
Sand, brown, fine, and dry	11	191	129
Sand and gravel, with clay	6	197	123
Sand, with gravel and water	3	200	120
Sand, with water	5	205	115
Quicksand at bottom of hole			

KK 39N/03E-33R01. Altitude 310 feet. Drilled by B & C Well Drilling Inc., 1981.

Topsoil	4	4	306
Hardpan	2	6	304
Clay, blue	18	24	286
Gravel, dry	2	26	284
Clay, blue, with cobbles	13	39	271
Sand, coarse	2	41	269
Sand, coarse, with gravel, dry	15	56	254
Clay, blue	36	92	218
Gravel, dry	3	95	215
Clay, with rock	10	105	205
Sand, soupy	51	156	154
Gravel, fine	11	167	143

Lithologic logs used in construction of hydrogeologic sections--continued

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Gravel, with sand, dry	8	175	135
Clay, blue, with rock	9	184	126
Oil shale, dark brown	8	192	118
Oil shale, light brown	9	201	109
Shale, grey	24	225	85
Sandstone, white	7	232	78
Clay, grey, and dry	2	234	76
Oil shale, dark brown	15	249	61
Shale, grey	6	255	55
Clay, oil, grey, and blue	15	270	40

KL 39N/03E-34C01. Altitude 300 feet. Drilled by Hayes Well Drilling and Pumps, Inc., 1981.

Topsoil	1	1	299
Clay, brown	9	10	290
Clay, grey, and gravel	30	40	260
Gravel, grey, and clay	50	90	210
Sand, grey, dry	40	130	170
Gravel, grey, dry	9	139	161
Gravel, brown, dry	4	143	157
Sand and gravel, dry	7	150	150
Sand, grey, fine, dry	10	160	140
Sand, grey, coarse, dry	5	165	135
Gravel, grey, dry	10	175	125
Sand, fine, and seepage	4	179	121
Sand, grey, coarse, and water	19	198	102
Clay, grey	7	205	95
Clay, wood, and sand	28	233	67
Gravel, grey, and clay, hard	95	328	-28
Gravel, grey, and saltwater	15	343	-43
Sandstone, siltstone, and coal	157	500	-200

KR 39N/03E-36B01. Altitude 310 feet. Drilled by Livermore & Son Inc., 1970.

Fill	3	3	307
Hardpan	3	6	304
Boulder	4	10	300
Hardpan and gravel	3	13	297
Clay, blue, and gravel washes	4	17	293

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand and gravel washes, little clay	93	110	200
Clay, blue, and gravel, soft	14	124	186
Clay, blue, soft, and sandy	24	148	162
Sand, gravel, and blue clay hard	10	158	152
Sand, gravel, and water	8	166	144
Clay, blue at bottom of hole			

KY 39N/04E-03P02. Altitude 370 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1990.

Topsoil	3	3	367
Clay, brown	5	8	362
Clay, brown, and little gravel	3	11	359
Gravel, brown, and sand	16	27	343
Clay, brown, and gravel	4	31	339
Clay, grey	11	42	328
Clay, grey, and gravel	76	118	252
Gravel, grey, sand, and saltwater	21	139	231
Sandstone, grey, coarse	60	199	171
Sandstone, medium	16	215	155
Sandstone, coarse	45	260	110

LA 39N/04E-04Q01. Altitude 140 feet. Drilled by B & C Well Drilling Inc., 1981.

Clay, with gravel	14	14	126
Sand and gravel, silty	31	45	95
Pebble cobbles, and silty gravel	20	65	75
Gravel, sand, and silty	9	74	66

LC 39N/04E-06D01. Altitude 100 feet. Drilled 1982.

Sand, and gravel, grey	80	80	20
Sand, grey	37	117	-17
Clay, grey, silty, and seashells	13	130	-30
Clay, grey, silty, and gravel	107	237	-137
Sand, medium to coarse	5	242	-142
Clay, silty and grey	108	350	-250
Sand, grey, and minor silt	123	473	-373
Bedrock at bottom of hole			

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
LD 39N/04E-06E01.	Altitude 105 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1980.	
Topsoil	2	2	103
Gravel, brown, and clay	34	36	69
Gravel, brown, sand, and water	31	67	38
LF 39N/04E-08C02.	Altitude 105 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1977.	
Topsoil	2	2	103
Clay, brownish-grey	14	16	89
Gravel, fine and little sand	4	20	85
Gravel, large, and water	26	46	59
Gravel and less water at bottom of hole			
LQ 39N/04E-18E01.	Altitude 210 feet.	Radke Well Drilling, 1977.	
Topsoil	1	1	209
Hardpan	2	3	207
Sandstone	16	19	191
Rock, hard	42	61	149
Sandstone	13	74	136
Rock, hard	44	118	92
Sandstone, coal, and water	3	121	89
LR 39N/04E-18M01.	Altitude 190 feet.	Radke Well Drilling, 1974.	
Topsoil	2	2	188
Hardpan	1	3	187
Sandstone	52	55	135
Coal, trace	1	56	134
Sandstone	90	146	44
Sandstone, soft, and water	4	150	40
Sandstone, hard	6	156	34
LV 39N/04E-19E01.	Altitude 215 feet.	Drilled by Star Drilling Service, 1988.	
Clay, red	6	6	209

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sandstone, hard	27	33	182
Sandstone, soft	5	38	177
Sandstone, very soft	49	87	128
Shale, black, and soft	28	115	100
Sandstone, moderate	19	134	81
Sandstone, soft	53	187	28
Sandstone, very soft, and brown	2	189	26
Sandstone, moderate	18	207	8
Sandstone, hard	35	242	-27

LY 39N/04E-19M01. Altitude 220 feet. Radke Well Drilling, 1978.

Topsoil	1	1	219
Hardpan	18	19	201
Clay, blue	9	28	192
Hardpan	37	65	155
Sandstone, hard	130	195	25
Sandstone, soft, and water	1	196	24
Sandstone, hard	4	200	20

MB 39N/04E-20M02. Altitude 155 feet. Drilled by B & C Well Drilling, Inc., 1980.

Clay, brown, gravel, and silt	19	19	136
Sand, black with gravel	15	34	121
Clay, grey, and soft at bottom of hole			

MC 39N/04E-20M03. Altitude 155 feet. Radke Well Drilling, 1977.

Topsoil	1	1	154
Hardpan	8	9	146
Gravel coarse	4	13	142
Sand and gravel cemented	12	25	130
Sand, gravel, and water	1	26	129

MD 39N/04E-22F01. Altitude 180 feet. Drilled by Livermore & Son Inc., 1981.

Topsoil	1	1	179

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand, gravel, and hardpan	9	10	170
Loam, sandy	8	18	162
Sand, gravel, and clay, blue	7	25	155
Sand, gravel, and clay, brown	30	55	125
Sand, gravel, and clay, blue	23	78	102

ME 39N/04E-22L01. Altitude 160 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1973.

Loam, sandy, and brown	2	2	158
Clay, brown, sand, and gravel	16	18	142
Hardpan, grey, and gravelly	2	20	140
Sand, gravel, and silt, brown	4	24	136
Sand, gravel, and water	5	29	131
Gravel	1	30	130

MF 39N/04E-22N01. Altitude 150 feet. Drilled by Bezona Well Service, 1977.

Alluvial sand	5	5	145
Gravel, medium	33	38	112
Sand and gravel	1	39	111

MI 39N/04E-29A01. Altitude 200 feet. Drilled by Star Drilling Service, 1983.

Sand, fine, and clay	12	12	188
Sand, coarse	15	27	173
Silt, black, and water	10	37	163
Sand, black, and water	6	43	157
Clay, grey, and hard	14	57	143
Clay, wet, and soft	15	72	128
Hardpan, brown	20	92	108
Silt, fine, and mud	17	109	91
Gravel	1	110	90
Clay, grey, and wet	83	193	7
Clay, grey,	1	194	6
Sandstone, soft	64	258	-58
Sandstone and coal	8	266	-66
Sandstone, grey	9	275	-75

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
MQ 39N/04E-30F01.	Altitude 225 feet.	Drilled by Deer Creek Drilling Project.	
Clay, silty, with gravel and sand, brown	10	10	215
Clay, silty, with gravel and sand, and occasional boulders	55	65	160
Sand and gravel, with clay, grey	5	70	155
MS 39N/04E-31B01.	Altitude 220 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1982.	
Topsoil	2	2	218
Clay, tan	11	13	207
Sand, clay, grey, and gravel	85	98	122
Sand, grey, fine, and clamshells	2	100	120
Clay, dark grey	12	112	108
Clay, grey, and gravel	103	215	5
Gravel, dry, and little clay	6	221	-1
Rock, green	1.5	222.5	-2.5
Sand, coarse, little gravel, and water	2.5	225	-5
MT 39N/04E-31D01.	Altitude 250 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1981.	
Topsoil	2	2	248
Clay, brown	13	15	235
Clay, grey, and gravel scattered	101	116	134
Clay, grey, and gravel	34	150	100
Gravel and water	12	162	88
Gravel, clay, grey, and scattered boulders	63	225	25
Gravel and water	1	226	24
Sand, grey, hard	2	228	22
Gravel, little clay and scattered boulders	22	250	0
Clay, grey	4	254	-4
Clay, grey, and gravel	1	255	-5
Clay, grey	40	295	-45
Sand, coarse, little gravel, coal, and water	5	300	-50
Clay, grey	5	305	-55
Sandstone, grey	7	312	-62

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
MV 39N/04E-31Q02	Altitude 265 feet.	Drilled by B & C Well Drilling, Inc., 1979.	
Hardpan, brown	15	15	250
Clay, grey, and gravel	37	52	213
Hardpan, grey, and coarse	14	66	199
Clay, grey, and sandy	19	85	180
Sand with clay	4	89	176
Sand with gravel	3	92	173
Sand, brown, with gravel	55	147	118
Sand, grey, and fine	42	189	76
Sand, grey, with gravel	15	204	61
Sand, with gravel	8	212	53
Gravel, coarse, sandy, and with water	3	215	50
MX 39N/04E-32E01.	Altitude 230 feet.	Drilled by Dahlman Pump & Drilling Inc., 1984.	
Clay, brown	15	15	215
Clay, blue, and gravel	124	139	91
Sand, clay, and water	3	142	88
MY 39N/04E-32F01.	Altitude 290 feet.	Drilled by Bezona Well Service, 1990.	
Clay, brown, and hard	17	17	273
Clay, blue, and till	91	108	182
Glacial till, hard	7	115	175
Till, light, brown, and sandy	5	120	170
Shale, weathered, carbonaceous	8	128	162
Shale, grey	16	144	146
Sandstone, grey, and hard	36	180	110
Sandstone, coarse	18	198	92
Shale, grey	17	215	75
Shale, carbonaceous, water	10	225	65
Sandstone	6	231	59
NB 39N/03E-33E01.	Altitude 340 feet.	Drilled by G. Cowden, 1939.	
Hardpan	11	11	329
Clay, blue	109	120	220

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Gravel		3	123
NC 39N/04E-34C02.	Altitude 300 feet.	Drilled by Aut Hillard, 1946.	
Hardpan	22	22	278
Clay, blue	39	61	239
Gravel and sand	18	79	221
Clay, blue	15	94	206
Sand, fine, with clay, and some water	52	146	154
Bedrock at bottom of hole			
NF 40N/02E-01N01.	Altitude 115 feet.	Drilled by Snowden Well Digging, 1975.	
Clay loam	1	1	114
Gravel, sandy brown	4	5	110
Sand, coarse, and gravel	15	20	95
Clay	1	21	94
NG 40N/02E-02B01.	Altitude 180 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1983.	
Topsoil	1	1	179
Clay, brown, and gravel	6	7	173
Clay, brown, tan, and gravel	28	35	145
Clay, sandy, and brown and gravel	31	66	114
Sand, brown, fine, dirty	30	96	84
Siltstone, grey	13	109	71
Clay, grey	3	112	68
Clay, grey, and gravel	3	115	65
Gravel and sand, grey	1.5	116.5	63.5
Clay, grey, and gravel	6.5	123	57
Peat and wood	3	126	54
Clay, grey, hard	2.5	128.5	51.5
Clay, grey, and gravel	5.5	134	46
Gravel, grey, coarse, and water	13	147	33
Sand, grey, and water	4	151	29
Clay, grey	12	163	17
Clay, grey, and gravel, scattered	14	177	3
Clay, brown, hard	18	195	-15

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, grey, and clam shells	12	207	-27
Clay, grey, scattered gravel, and clam shells	25	232	-52
Clay, grey, and little gravel	92	324	-144
Gravel, grey, wood, and water	5	329	-149
Gravel, grey and clay	45	374	-194
Clay, grey, and little gravel, hard	6	380	-200
Gravel, grey, and clay	26	406	-226
Clay, grey, gravel, and wood	14	420	-240
Clay, brownish-grey, and gravel	1	421	-241
Gravel, grey, sand, and clay	22	443	-263
Sand, gravel, grey, and saltwater	17	460	-280

NH 40N/02E-02D01. Altitude 220 feet. Drilled by B & C Well Drilling Inc., 1979.

Clay, brown, and sandy	35	35	185
Clay, grey, soft	8	43	177
Clay, grey, hard	15	58	162
Coarse gravel with hard clay	7	65	155
Sand, gravel, and clay	17	82	138
Sand, yellow, very fine	5	87	133
Sand, gravel, and clay	6	93	127
Hardpan	14	107	113
Sand, grey, fine	14	121	99
Clay, grey, soft	6	127	93
Hardpan	6	133	87
Sand, and gravel	2	135	85
Gravel, and water	4	139	81
Sand	1	140	80

NK 40N/02E-02Q01. Altitude 115 feet. Dug 1952.

Gravel	15	15	100
Sand	7	22	93

NL 40N/02E-02Q02. Altitude 115 feet. Drilled 1982.

Sand, dirt, and clay	23	23	92

Lithologic logs used in construction of hydrogeologic sections--continued

Materials		Thickness (feet)	Depth (feet)	Altitude (feet)
NM	40N/02E-03C01.	Altitude 240 feet.	Drilled by B & C Well Drilling Inc., 1980.	
Soil		2	2	238
Clay, blue		82	84	156
Gravel and sand		.5	84.5	155.5
Hardpan		6.5	91	149
Sand, gravel and water		10	101	139
NN	40N/02E-03K01.	Altitude 250 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1981.	
Topsoil		1	1	249
Clay, brown, and gravel		12	13	237
Sand, grey with seepage		5	18	232
Clay, grey		31	49	201
Clay, sandy, and grey		11	60	190
Clay, grey		33	93	157
Clay, sandy, and grey		25	118	132
Sand, grey, and dry		6	124	126
Clay, grey, and sandy		32	156	94
Sand, grey, and dry		14	170	80
Clay, grey, and wood		7	177	73
Clay, grey		19	196	54
Sand, grey, medium, and water		13	209	41
Clay, grey		1	210	40
NV	40N/02E-13H01.	Altitude 100 feet.	Drilled by Don Mulka, 1961.	
Clay, loam		2	2	98
Clay		1	3	97
Sand		23	26	74
NW	40N/02E-13J02.	Altitude 100 feet.	Drilled by Snowden Well Digging.	
Sand		10	10	90
Gravel		5	15	85
Sand		25	40	60

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
OC 40N/02E-14P02.	Altitude 90 feet.	Drilled by Snowden Well Digging, 1981.	
Sand	2	2	88
Sand, gravel, and clay	8	10	80
Sand, hard	15	25	65
Sand, grey, and water	17	42	48
OD 40N/02E-14R01.	Altitude 100 feet.	Drilled by Herman Ellingson, 1966.	
Topsoil, brown	2	2	98
Sand, grey, and gravel, small	28	30	60
Clay, blue, sand, fine at 30 (bottom of hole)			
OJ 40N/02E-15P01.	Altitude 90 feet.	Drilled by Levy Rice, 1946.	
Topsoil	5	5	85
Sand	4	9	81
Sand, gravel, and waterbearing	15	24	66
OK 40N/02E-15Q01.	Altitude 90 feet.	Drilled by Don Mulka, 1954.	
Clay, red	5	5	85
Sand	19	26	64
ON 40N/02E-21A01.	Altitude 90 feet.	Drilled by Snowden Well Digging, 1974.	
Clay loam	1	1	89
Clay, hard	2	3	87
Bog iron	1	4	86
Sand, hard	4	8	82
Sand, grey	13	21	69
PD 40N/02E-23D02.	Altitude 90 feet.	Drilled by Livermore & Son Inc., 1989.	
Topsoil	1	1	89

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand, with thin clay seams and water	46	47	43
Sand, blue	1	48	42
Clay, blue	12	60	30
PJ 40N/02E-26A04.	Altitude 60 feet.	Drilled by Snowden Well Digging, 1980.	
Loam, sandy	1	1	59
Sand, coarse	22	23	37
Sand, fine	5	28	32
QA 40N/03E-02C01.	Altitude 153 feet.	Drilled by B & C Well Drilling, Inc., 1986.	
Topsoil, sandy	2	2	151
Gravel, sandy	11	13	140
Gravel, sandy, and water	11	24	129
Boulders at bottom of hole			
QB 40N/03E-02M02.	Altitude 141 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1986.	
Topsoil	2	2	139
Gravel, dry	2	4	137
Gravel, sand, and water	26	30	111
Sand, small gravel, and water	7	37	104
Sand, gravel, and water	20	57	84
QC 40N/03E-02N01.	Altitude 134 feet.	Drilled by Beck & Zwicker, 1946.	
Topsoil	3	3	132
Gravel, coarse, and rock	17	20	114
QF 40N/03E-03N02.	Altitude 129 feet.	Drilled by Al Towe Well Digging, 1982.	
Topsoil	2	2	127
Clay, hard	6	8	121
Sand, coarse, and gravel,fine	15	23	106

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
QG 40N/03E-03R02.	Altitude 135 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1986.	
Topsoil	2	2	133
Gravel, dry	8	10	125
Gravel, sand, and water	29	39	96
Sand, brown, and water	9	48	87
Sand, grey, gravel, and water	22	70	65
Sand, grey, trace of clay, and water	5	75	60
Clay, grey	2	77	58
QH 40N/03E-03R03.	Altitude 135 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1988.	
Topsoil	3	3	132
Gravel, brown, dry	12	15	120
Gravel, rusty brown	19	34	101
Sand, brown, little gravel, and water	22	56	79
Sand, red, grey, and water	17	73	62
Clay, grey at 73 (bottom of hole)			
QQ 40N/03E-05N01.	Altitude 123 feet.	Drilled by America Water Well, Inc., 1984.	
Topsoil, black	1	1	122
Sand, brown	2	3	120
Sand, brown, and gravel	3	6	117
Sand, blue, grey, gravel, and water	12	18	105
QR 40N/03E-05N02.	Altitude 117 feet.	Drilled 1980.	
Gravel	20	20	97
QU 39N/03E-06M01.	Altitude 80 feet.	Drilled by Sprague & Henwood, G.J., Colo., 1960.	
Sand, grey, and medium	65	65	15
Sand, grey, fine, and clay	85	150	-70
Clay and coarse-grained sand	25	175	-95
Clay	15	190	-110
Clay, grey	50	240	-160

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand and gravel	50	290	-210
Clay, grey	20	310	-230
Clay, grey, with fine sand	40	350	-270
Clay, grey	15	365	-285
Gravel	5	370	-290
Gravel and boulders	10	380	-300
Sand and gravel	50	430	-350
Gravel and cobbles	50	480	-400
Boulders	6	486	-406
Clay, blue, and little sand	49	535	-455
Sand, gravel, and clay	35	570	-490
Sandstone and shale	1430	2000	-1920

QV 40N/03E-06M01. Altitude 123 feet. Drilled by Tilley and Hillard, 1947.

Gravel	20	20	103
Sand, very fine	27	47	76
Clay, soft	68	115	8
Clay with gravel	7	122	1
Clay, hard	30	152	-29
Sand and water	4	156	-33

QW 40N/03E-06N02. Altitude 120 feet. Drilled by Snowden Well Digging, 1979.

Loam sandy	2	2	118
Clay, loam	3	5	115
Gravel	3	8	112
Sand, coarse	25.6	33.6	86.4

RA 40N/03E-07M03. Altitude 111 feet. Drilled by Hayes Well Drilling & Pumps Inc., 1979.

Topsoil	2	2	109
Sand, brown	8	10	101
Gravel and water	15	25	86
Sand, dirty grey, and little water	31	56	55
Clay, grey	24	80	31

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
RB 40N/03E-08J01.	Altitude 113 feet.	Drilled by Frank Otter, 1938.	
Loam, black	1	1	112
Clay	3	4	109
Sand, coarse	10	14	99
Gravel, coarse	12	26	87
RD 40N/03E-09A04.	Altitude 123 feet.	Drilled by B & K Water Wells, 1978.	
Topsoil	2	2	121
Clay, brown	6	8	115
Gravel, brown	12	20	103
Gravel and sand, blue	7	27	96
RE 40N/03E-09D01.	Altitude 118 feet.	Drilled by Dun Mulka, 1953.	
Loam	1	1	117
Clay	2	3	115
Sand and gravel	18	22	96
RF 40N/03E-09G01.	Altitude 123 feet.	Drilled by Livermore & Son, Inc., 1988.	
Road bed	2	2	121
Sand, gravel, and boulders	4	6	117
Sand and gravel	19	25	98
Sand gradually gets finer	40	65	58
Clay, blue and soft	5	70	53
RK 40N/03E-11E04.	Altitude 130 feet.	Drilled by B & C Well Drilling, Inc., 1984.	
Gravel and sand, fine	22	22	108
Gravel, pea	13	35	95
Gravel and sand, coarse	9	44	86
RM 40N/03E-12H01.	Altitude 100 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1982.	

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Topsoil	1	1	99
Gravel, brown, and little clay	11	12	88
Gravel, brown, sand, and water	13	25	75
Clay, grey, and sand seepage	27	52	48
Clay, grey	68	120	-20

RN 40N/03E-13N01. Altitude 90 feet. Drilled by B & C Well Drilling, Inc., 1984.

Clay, grey	160	160	-70
Clay, grey, and sand	10	170	-80
Sand, very fine, saline	5	175	-85

RO 40N/03E-13Q01. Altitude 85 feet. Drilled by M. Starkemburg, 1947.

Topsoil	2	2	83
Clay, blue	178	180	-95
Sand, coarse, gravel, and quicksand	45	225	-140

RP 40N/03E-14B01. Altitude 100 feet. Drilled by Radke Well Drilling, 1947.

Clay, hard blue and cobbles	260	260	-160
Sand	5	265	-165

RU 40N/03E-16D01. Altitude 110 feet. Drilled by Sumas Well Drill, 1963.

Clay, red, and loam	3	3	107
Sand	24	27	83

SB 40N/03E-16M01. Altitude 100 feet. Drilled 1984.

Clay, sandy topsoil, brown	7	7	93
Clay, brown	3	10	90
Sand, brown, and gravel	3	13	87
Gravel, grey, sand, and water	10	23	77
Sand, grey, and water	36	59	41
Clay, grey	210	269	-169

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, grey, and gravel	4	273	-173
Clay, grey	2	275	-175
Clay, grey, and gravel	49	324	-224
Gravel, grey, and water	21	345	-245
Clay, and gravel, grey	5	350	-250
Clay, sand, occasional gravel	30	380	-280

SC 40N/03E-16Q01. Altitude 105 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1988.

Topsoil	1	1	104
Sand, dry, and gravel	15	16	89
Sand, brown, and water	14	30	75
Sand, brown, dirty, and water	8	38	67
Sand, fine, grey, and water	12	50	55
Clay, grey	4	54	51

SE 40N/03E-18E01. Altitude 102 feet. Drilled by B & K Water Wells, 1979.

Topsoil	2	2	100
Sand and clay	4	6	96
Sand, grey, and gravel	30	36	66

SG 40N/03E-19A01. Altitude 99 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1989.

Topsoil	1	1	98
Clay, brown, and sand	9	10	89
Clay, grey, sand, and little gravel	4	14	85
Sand, grey, little gravel, and water	7	21	78
Sand, coarse, grey, gravel, and water	11	32	67
Sand and water	6	38	61
Clay, grey, sand, fine	2	40	59

SH 40N/03E-22C01. Altitude 54 feet. Drilled 1945.

Gravel	5	5	49
Clay, grey-blue	10	15	39

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
SI 40N/03E-24E01.	Altitude 75 feet.	Drilled by Star Drilling Service, 1990.	
Clay, red	11	11	64
Clay, grey	132	149	-74
Hardpan	1	150	-75
Gravel	.5	150.5	-75.5
SK 40N/03E-25J01.	Altitude 80 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1985.	
Topsoil	10	10	70
Clay, grey	7	17	63
Peat, dark brown	19.5	36.5	43.5
Sand and water	2	38.5	41.5
Gravel, grey, water, and clay, grey	6.5	45	35
SR 40N/03E-26H01.	Altitude 70 feet.	Drilled by Sumas Well Drill, 1954.	
Clay, loam	8	8	62
Sand	7	15	55
Gravel	9	24	46
SP 40N/03E-31N02.	Altitude 81 feet.	Drilled by Livermore & Son Inc., 1989.	
Sand, coarse	12	12	69
Sand, brown, and fine	32	44	37
Sand, blue, and fine	9	53	28
SS 40N/03E-32G01.	Altitude 75 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1985.	
Topsoil	2	2	73
Sand, brown, and dry	31	33	42
Gravel and sand	1	34	41
Clay, grey, and sandy	3	37	38
Clay, grey	78	115	-40
Clay, grey, and gravel	10	125	-50
Clay, grey, and scattered gravel	27	152	-77
Silt, grey, fine, sand, and saltwater	51	203	-128

Lithologic logs used in construction of hydrogeologic sections--continued

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand, fine, grey, and saltwater	102	305	-230
Clay, grey	48	353	-278
Sand, grey, and saltwater	7	360	-285
Gravel, grey, and clay	42	402	-327
Gravel and saltwater	5	407	-332
Gravel, grey, and clay	30	437	-362
Gravel, saltwater, and clay	5	442	-367
SW 40N/03E-32L01.	Altitude 87 feet.	Drilled by B & K Water Well Inc., 1989.	
Topsoil	2	2	85
Sand, brown, and coarse	24	26	61
Sand, brown, and fine	8	34	53
Clay, brown	6	40	47
Sand, grey, and fine	5	45	42
SZ 40N/03E-32P01.	Altitude 90 feet.	Drilled by Bezona Well Service, 1989.	
Soil, brown, and sandy	2	2	88
Sand, grey, and coarse	23	25	65
Clay, blue	15	40	50
TA 40N/03E-32P02.	Altitude 90 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1981.	
Topsoil	2	2	88
Sand, brown and coarse	15	17	73
Sand, brown, coarse and gravel	15	32	58
Clay, brown	2	34	56
Clay, grey	23	57	33
Sand, grey	14	71	19
Clay, grey	123	194	-104
Sand, grey, and water	13	207	-117
Clay, sandy grey	12	219	-129
Sand, grey, and water	23	242	-152
Clay, grey, and gravel	129	371	-281
Sand, grey, and water	2	373	-283
Gravel, some sand, and water	4	377	-287
Gravel and clay, grey	1	378	-288

Lithologic logs used in construction of hydrogeologic sections--continued

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Gravel, sand, and water	72	450	-360
Gravel, grey, and clay	43	493	-403
Clay, grey	24	517	-427
Clay, grey, and clam shells	40	557	-467
Clay, grey, and gravel	12	569	-479
Clay, grey	1	570	-480
Gravel and saltwater	4	574	-484
Clay, grey, and gravel	6	580	-490
Granite boulder	3	583	-493
Conglomerated gravel	117	700	-610

TB 40N/03E-32Q01. Altitude 85 feet. Drilled by B & K Water Well Inc., 1988.

Topsoil	2	2	83
Sand, grey, coarse	14	16	69
Clay, brown	1	17	68
Sand, grey, and gravel	8	25	60
Clay, blue at bottom of hole			

TG 40N/03E-34P01. Altitude 80 feet. Drilled by B & K Water Wells, 1988.

Topsoil	2	2	78
Sand, coarse	17	19	61
Sand and gravel	15	34	46
Clay, blue at bottom of hole			

TH 40N/03E-34Q01. Altitude 80 feet. Drilled by Hayes Well Drilling & Pumps, Inc.

Sand, fine to coarse	10	10	70
Sand and gravel, brown, fine to medium	5	15	65
Sand, grey, fine to medium	15	30	50
Silt, with sand, light grey	5	35	45
Clay, silty, with some gravel	100	135	-55
Sand, very fine, and bearing water	80	215	-135
Clay, silty, and occasional gravel	41	256	-176
Bedrock at bottom of hole			

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
TJ 40N/03E-35R02.	Altitude 105 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1988.	
Topsoil	3	3	102
Gravel, dry	32	35	70
Sand, medium, brown, and water	12	47	58
Sand, medium, grey, and water	5	52	53
Clay, grey at bottom of hole			
TK 40N/03E-36J01.	Altitude 90 feet.	Drilled 1936.	
Gravel, ashy, and grey	30	30	60
Subsoil, gravel, rusty, and gravel, ash-grey	3	33	57
TU 40N/04E-05D02.	Altitude 181.1 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1979.	
Topsoil	5	5	176.1
Sand and little gravel	5	10	171.1
Clay, sandy, and gravel	40	50	131.1
Gravel and water	31	81	100.1
Sand, dirty, and little water	14	95	86.1
TW 40N/04E-05E02.	Altitude 162.3 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1988.	
Topsoil	3	3	159.3
Gravel, brown, and dry	28	31	131.3
Gravel and water	9	40	122.3
Gravel, grey, sand, and water	31	71	91.3
Sand, grey, medium, gravel, and water	6	77	85.3
Sand, grey, medium, clay, and water at bottom of hole			
TZ 40N/04E-05N02.	Altitude 139.8 feet.	Drilled by B & C Well Drilling, Inc., 1979.	
Gravel with cobbles, sandy	17	17	122.8
Hardpan, brown	32	49	90.8
Hardpan, softer	14	63	76.8
Gravel, coarse	10	73	66.8

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand with gravel	7	80	59.8
Sand, coarse, with gravel	6	86	53.8
UG 40N/04E-07G01.	Altitude 110 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1988.	
Sand, brown, coarse, and gravel	2	2	108
Sand, brown	13	15	95
Sand, brown, and little clay	7	22	88
Sand, brown	12	34	76
Sand, brown, and water	5	39	71
Clay, coarse, brown, and sand	1	40	70
Sand, brown, and water	10	50	60
Sand, brown, coarse, gravel, and water	15	65	45
Gravel, brown, sand, coarse, and water	13	78	32
UH 40N/04E-07H04.	Altitude 75 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1987.	
Topsoil	4	4	71
Sand, brown, dry, gravel, and clay	6	10	65
Sand, brown, fine, and little gravel	4	14	61
Clay, brown	2	16	59
Gravel, brown, sand, and water	4	20	55
Sand, brown, medium, and water, dirty	16	36	39
Gravel, sand, and water	4	40	35
Clay, brown	1	41	34
Gravel, sand, and water	21	62	13
Sand, brown, and water	10	72	3
Sand, brown, gravel, and water	4	76	-1
Sand, gravel, greyish, and water	6	82	-7
Sand, coarse, and water	2	84	-9
Sand, coarse, gravel, and water	6	90	-15
Clay, grey at bottom of hole			
UI 40N/04E-08A02.	Altitude 55 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1980.	
Topsoil	3	3	52
Sand, brown, slit, and clay	22	25	30
Clay, grey, and some gravel	7	32	23

Lithologic logs used in construction of hydrogeologic sections--continued

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Gravel, grey, sand, clay, and water	3	35	20
Gravel, grey, sand, and water	22	57	-2
UK 40N/04E-09B01.	Altitude 50 feet.	Drilled by G.A. Bezona, 1962.	
Clay	10	10	40
Sandy muck, some water	10	20	30
Clay and gravel	13	33	17
Gravel, loose, and water	16	49	1
UR 40N/04E-10E02.	Altitude 45 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1971.	
Loam, sandy, tan	1	1	44
Clay, grey	3	4	41
Silt, grey, and clay seepage	2	6	39
Clay, grey, chunks of peat and wood	12	18	27
Silt, grey, clay, and wood	7	25	20
Sand, gravel, and water	13	38	7
US 40N/04E-10G01.	Altitude 45 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1979.	
Topsoil	3	3	42
Clay, sandy brown	3	6	39
Clay, grey	24	30	15
Gravel and water	15	45	0
Clay, grey, and gravel	10	55	-10
Gravel and water	14	69	-24
UU 40N/04E-11C01.	Altitude 45 feet.	Drilled by America Water Wells Inc., 1980.	
Topsoil	1	1	44
Sand and gravel	7	8	37
Sand, gravel, and water	13	21	24
Cemented graveled boulders at bottom of hole			
UV 40N/04E-12B01.	Altitude 60 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1980.	

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Topsoil	3	3	57
Sand, dry, and little wood	12	15	45
Sand, medium, and water	3	18	42
Sand, grey, medium, gravel, and water	7	25	35
Clay, grey	20	45	15
Gravel, sand, and little water, dirty	3	48	12
Clay, grey	7	55	5
Gravel, sand, and water	7	62	-2
Clay, grey	3	65	-5
Gravel, sand, and water	1	66	-6
Peat, clay, grey, and wood	9	75	-15
Gravel and water	7	82	-22
Clay, grey	8	90	-30
Gravel, sand, and water	12	102	-42
Sand, fine, and water	8	110	-50

VI 40N/04E-19K01. Altitude 70 feet. Drilled by Dahlman Pump & Drilling, Inc., 1982.

Topsoil	3	3	67
Clay, blue	32	35	35
Sand and gravel	15	50	20
Gravel and water	7	57	13

VO 40N/04E-22J02. Altitude 180 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1981.

Topsoil	1	1	179
Gravel, brown, dry and sand	36	37	143
Gravel, brown, sand, seepage	20	57	123
Gravel, brown, sand, and water	12	69	111
Clay, brown	2	71	109
Clay, grey, and soft	36.5	107.5	72.5
Sand, grey, coarse, little gravel, and water	1	108.5	71.5
Clay, grey, and little gravel	4.5	113	67
Clay, grey, and soft	6	119	61
Gravel, sand, and water	1	120	60
Sand, little gravel, shells, and water	3	123	57
Sand, grey, and clay, soft	4	127	53
Clay, grey	1	128	52

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, grey, and gravel, soft	2	130	50
Clay, grey, and soft	7	137	43
Clay, grey, and gravel	7	144	36
Clay, and gravel, grey	11	155	25
Sandstone	45	200	-20
VS 40N/04E-28D02.	Altitude 130 feet.	Drilled by B & C Well Drilling, Inc., 1980.	
Soil	1	1	129
Gravel, crusted	1	2	128
Gravel, dry, loose	39	41	89
Gravel, dirty	7	48	82
Hardpan	1	49	81
Gravel and water	19	68	62
Silt with sand and water	3	71	59
VX 40N/04E-30D01.	Altitude 75 feet.	Drilled by Herman Ellingson, 1962.	
Topsoil	2	2	73
Sand	6	8	67
Clay and peat	18	26	49
Gravel	1	27	48
VY 40N/04E-30E01.	Altitude 75 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1980.	
Topsoil	3	3	72
Clay, brown	7	10	65
Clay, grey	5	15	60
Peat and wood	5	20	55
Gravel, grey, and clay	5	25	50
Gravel, grey, and water	9	34	41
Clay, grey at bottom of hole			
WL 41N/02E-33J01.	Altitude 250 feet.	Drilled by Livermore and Son, Inc., 1989.	
Topsoil	2	2	248
Hardpan	6	8	242

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Sand, gravel, and hardpan	6	14	236
Sand and clay, blue	47	61	189
Sand, fine, and water	7	68	182
Sand and clay, blue	6	74	176
Sand, gravel, and water	5	79	171

WN 41N/02E-35Q02. Altitude 150 feet. Drilled by Hayes Well Drilling & Pumps, Inc., 1979.

Gravel, greyish-brown	15	15	135
Gravel, grey, and clay	8	23	127
Clay, grey, and gravel	37	60	90
Gravel, grey, and sand	35	95	55
Clay, grey, very hard	26	121	29
Gravel, grey, and clay	119	240	-90
Gravel, clean, grey	2	242	-92
Gravel, grey, and clay	18	260	-110
Gravel, clay, grey, and wood	3	263	-113
Gravel, grey and clay, and small layers of clay	51	314	-164
Clay, grey, hard	17	331	-181
Gravel, grey, and clay, dry	10	341	-191
Gravel, brownish-grey, and clay	4	345	-195
Gravel, grey, and clay	37	382	-232
Clay, grey, and gravel	16	398	-248
Gravel, grey, water wood, and clam shells	26	424	-274
Siltstone	76	500	-350

WO 41N/02E-36J01. Altitude 129 feet. Drilled by Snowden Well Digging, 1979.

Sandy loam	2	2	127
Sand, and clay, hard	3	5	124
Gravel	10	15	114
Sand, layers of hard and fine silt	13	28	101
Clay, blue at bottom of hole			

WP 41N/02E-36K01. Altitude 129 feet. Drilled by Herman Ellingson, 1962.

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Topsoil	3	3	126
Gravel, water bearing	26	29	100
WS 41N/03E-31Q01.	Altitude 135 feet.	Drilled by Snowden Well Digging, 1980.	
Peat, soil	4	4	131
Sand and clay	3	7	128
Sand and gravel	26	33	102
WT 41N/03E-32Q01.	Altitude 138 feet.	Drilled by A & K Driller, 1974.	
Topsoil	1	1	137
Sand, coarse, and gravel	29	30	108
WU 41N/03E-33E01.	Altitude 147 feet.	Drilled by Livermore & Son, Inc., 1987.	
Topsoil	3	3	144
Sand and gravel, dry	13	16	131
Sand and gravel	5	21	126
Sand and water	22	43	104
WV 41N/03E-33G01.	Altitude 141 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1981.	
Topsoil, sandy, and some gravel	2	2	139
Sand, brown, and gravel	13	15	126
Gravel, brown, sand, and water	8	23	118
Sand, brown, and water	62	85	56
Clay, grey, soft	150	235	-94
Sand, grey, coarse, and water	18	253	-112
Clay, grey	22	275	-134
Sand, gravel, and saltwater	8	283	-142
WY 41N/03E-34M01.	Altitude 140 feet.	Drilled by Harold Zwicker, 1954.	
Clay loam	3	3	137
Gravel and rock	17	20	120

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
WX 41N/03E-34G01.	Altitude 141 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1988.	
Topsoil	2	2	139
Clay, grey	1	3	138
Gravel, sand, and water	15	18	123
Sand, little gravel, and water	20	38	103
Sand, fine, and clay and water at bottom of hole			
XH 41N/03E-35L01.	Altitude 159 feet.	Drilled by B & C Well Drilling, Inc., 1988.	
Topsoil	2	2	157
Sand, and gravel	25	27	132
XC 41N/03E-36J02.	Altitude 160 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1987.	
Topsoil	1	1	159
Sand, brown, gravel, and wood	7	8	152
Gravel, brown	24	32	128
Gravel, brown, sand, and water	16	48	112
Gravel, rusty-brown, and water	11	59	101
Sand, greenish-grey, gravel, and water	20	79	81
Gravel, grey, sand, and water	13	92	68
Clay, grey at bottom of hole			
XD 41N/03E-36N01.	Altitude 159.17 feet.	Drilled by Don Mulka, 1956.	
Clay, red, loam	2	2	157.17
Gravel	24	26	133.17
XG 41N/04E-31R01.	Altitude 175 feet.	Drilled by Livermore and Son, Inc., 1951.	
Topsoil	3	3	172
Sand and gravel	35	38	137
Sand, fine, and water bearing	9	47	128
Sand and gravel, brown	13	60	115
Sand and gravel, blue	11	71	104

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
XI 41N/04E-32E01.	Altitude 205 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1981.	
Topsoil	3	3	202
Sand, brown, dry, and gravel	67	70	135
Sand, brown, gravel, and water	10	80	125
Gravel, brown, sand and water	23	103	102
Sand, brown, gravel, and water	27	130	75
Sand, brown, some gravel, and water	44	174	31
Gravel, grey, sand, and clay	10	184	21
Sand, grey, very little gravel, and water	29	213	-8
Clay, grey	21	234	-29
Sand, grey, fine, and water	106	340	-135
Clay, grey, with some sand	20	360	-155
Sand, grey, medium, some clay	40	400	-195
XJ 41N/04E-32M01.	Altitude 189.3 feet.	Drilled by Bezona Well Service, 1979.	
Gravel, silty, and topsoil	2	2	187.3
Gravel, sand, and alluvium	88	90	99.3
Gravel, coarse	5	95	94.3
XK 41N/04E-32Q01.	Altitude 132.2 feet.	Drilled 1970.	
Topsoil	6	6	126.2
Gravel	21	27	105.2
XL 41N/04E-32R01.	Altitude 195 feet.	Drilled by B & C Well Drilling, Inc., 1974.	
Topsoil	3	3	192
Gravel, cemented	7	10	185
Boulders	1	11	184
Gravel, cemented	12	23	172
Sand, with gravel	4	27	168
Clay, sandy	23	50	145
Gravel, cemented	15	65	130
Sand, with gravel	17	82	113
Sand and gravel with water	10	92	103

Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
XQ 41N/04E-33H04.	Altitude 50 feet.	Drilled by Kimple Well Drilling, 1971.	
Peat	30	30	20
Gravel, clayey	5	35	15
Gravel with chunks of clay and water	10	45	5
Gravel, coarse	11	56	-6
Sand, coarse	2	58	-8
Gravel, coarse	10	68	-18
XR 41N/04E-33N02.	Altitude 119.4 feet.		
Sand, brown, fine, and traces of clay, silt and gravel	32	32	87.4
Silt and traces of sand	22	54	65.4
Sand, dark brown and grey, and little gravel	50	104	15.4
Silt, grey	4	108	11.4
Sand, grey-brown, fine	91	199	-79.6
Clay, grey	1	200	-80.6
XT 41N/04E-33N04.	Altitude 87.5 feet.		
Sand brown, fine, and some slit, trace clay	23	23	64.5
Clay, grey, traces of fine sand, and silt	13	36	51.5
Sand, grey to brown, fine, trace clay, and little silt	6	42	45.5
Clay, grey, trace silt	12	54	33.5
Sand, grey-brown, and gravel	17.5	71.5	16
Clay, brown-grey, some sand	.5	72	15.5
XW 41N/04E-36L01.	Altitude 40 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1982.	
Topsoil	2	2	38
Gravel, small, brown	6	8	32
Clay, brown, and sand	4	12	28
Clay, grey, and some sand	6	18	22
Sand, grey, some gravel, and water	11	29	11

Lithologic logs used in construction of hydrogeologic sections--continued

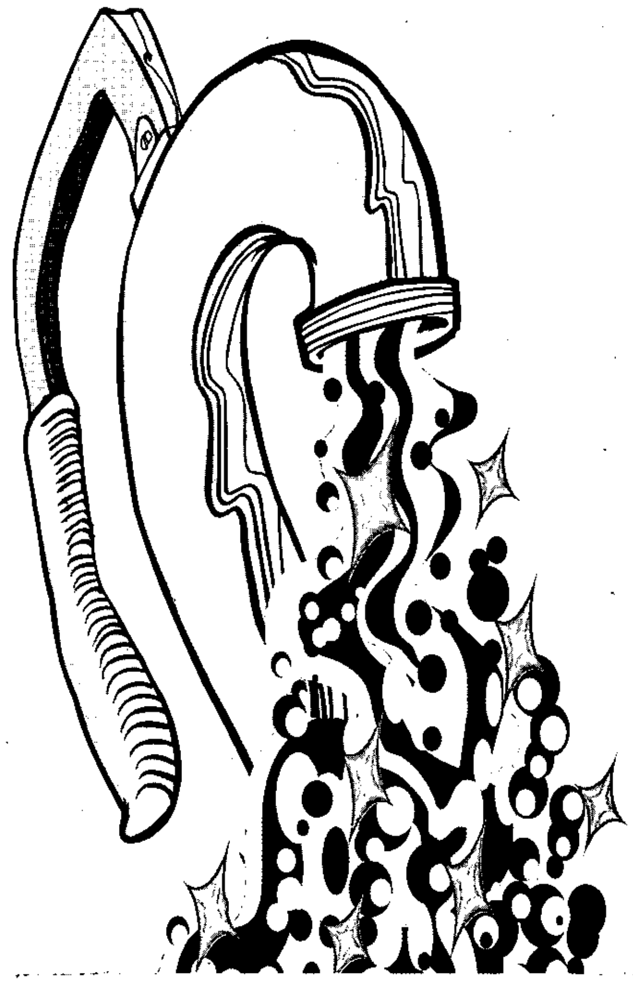
Materials	Thickness (feet)	Depth (feet)	Altitude (feet)
Clay, brown	2	31	9
Clay, grey	2	33	7
Sand, grey, some gravel, and water	4	37	3
Clay, grey	16	53	-13
Sand, grey, some gravel, and water	10	63	-23
Clay, grey, some sand, and lots of wood	5	68	-28
Sand, grey, fine, dirty, some wood, and water	15	83	-43
XX 41N/05E-31M01.	Altitude 40 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1979.	
Topsoil	3	3	37
Clay, tan, sandy	5	8	32
Clay, grey	26	34	6
Sand, medium, and water	8	42	-2
Clay, grey	10	52	-12
Sand, gravel, and water	20	72	-32
Clay, grey	2	74	-34
Sand, fine, dirty, wood, and water	4	78	-38
YB 41N/05E-32L02.	Altitude 20 feet.	Drilled by Hayes Well Drilling & Pumps, Inc., 1986.	
Topsoil	2	2	18
Clay, grey, and sand	23	25	-5
Sand and water	10	35	-15
Sand, dirty, wood, and water	7	42	-22
Sand, dirty, fine, grey, and wood	48	90	-70
Silt, grey, sand, clay, and wood	50	140	-120
Clay, grey	40	180	-160

APPENDIX B

Whatcom County
Health Department
509 Girard St. — P.O. Box 935, Bellingham, WA 98227-0935

ARE YOU

protecting your most valuable liquid asset?



Being careful with our water today will give us cleaner, safer water tomorrow.

For the future... for us all.

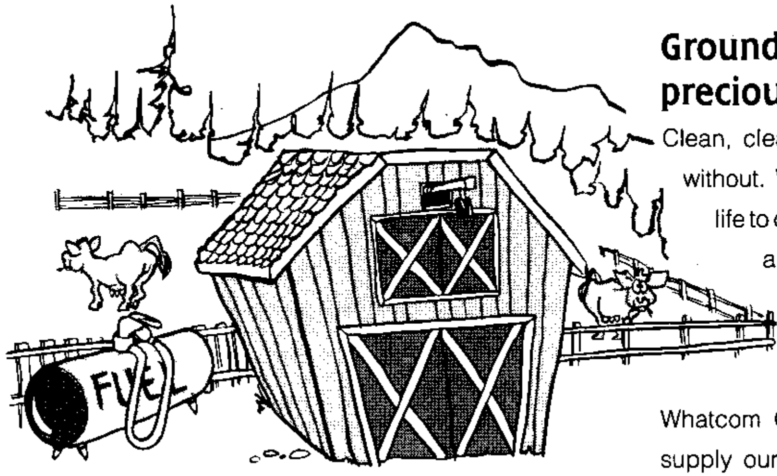
Remember — it is up to us to prevent the contamination of our local groundwater supply. By taking care of our most valuable liquid asset today, we will be ensuring clean, safe water for all of us ... for the future.

Test Results

Date	Site of Test	Type of Test	Results

It is important to test the water supplied by your well system to determine the safety of the water you use. To record your test results, use the form above.

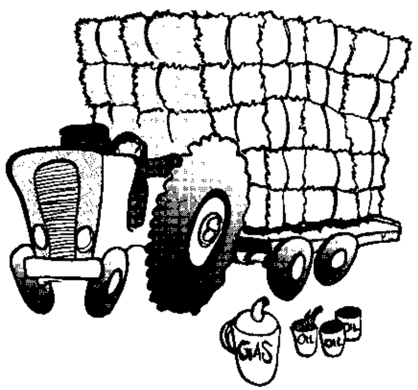
If you would like more information on how to test your groundwater, call the Whatcom County Health Department at 676-6724.



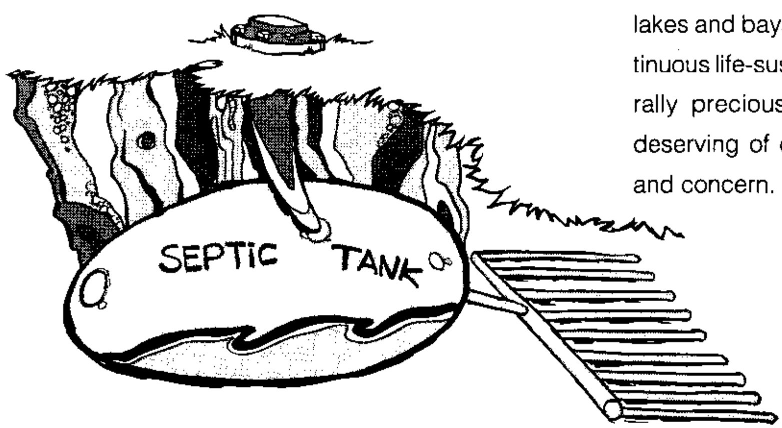
Groundwater – A naturally precious commodity

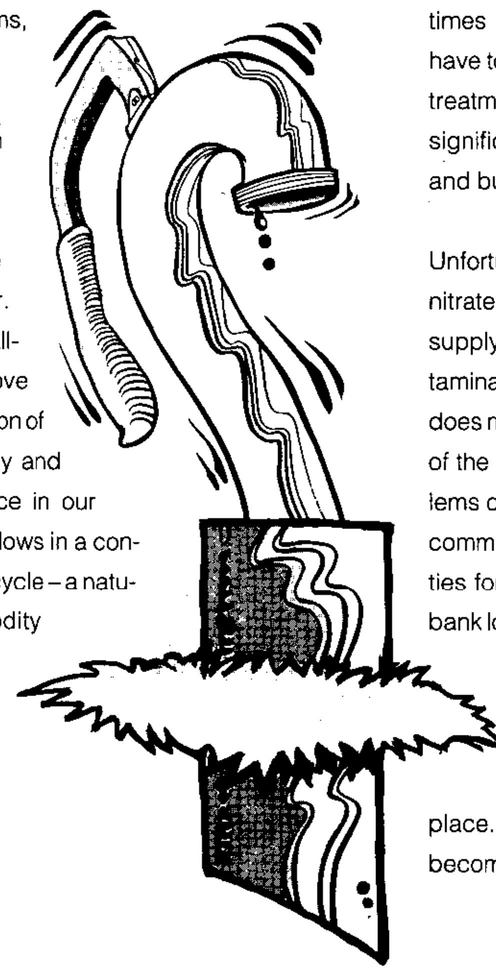
Clean, clear water. It's something we simply can't live without. We drink it, cook with it, and depend on it to give life to crops and other plants through irrigation. Without a clean, safe water supply, none of this would be possible.

One of the major sources of drinking water for Whatcom County is the groundwater we depend on to supply our well systems. Almost half the population of Whatcom County relies on groundwater. Not only is it essential for home, farm and industrial use, groundwater also supplies our streams, rivers, and lakes.



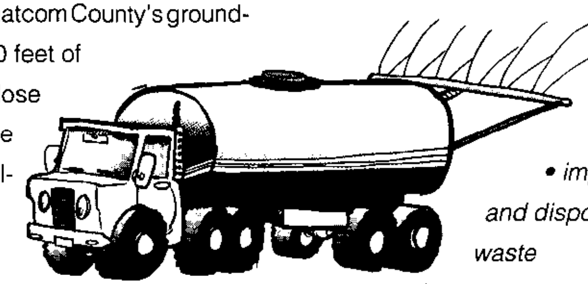
Groundwater exists in aquifers — geological formations of sand, rock, or gravel that are saturated with water. From rain and snow falling on the ground above the aquifer, to the creation of the groundwater supply and its eventual appearance in our lakes and bays, water flows in a continuous life-sustaining cycle – a naturally precious commodity deserving of our care and concern.





A natural resource becomes a source of concern

Many people believe that because groundwater remains hidden beneath the surface of the land, it is safe from contamination. But much of Whatcom County's groundwater supply lies within just 50 feet of ground level. Because of its close proximity to the surface of the ground, this water is highly vulnerable to contamination.



Once groundwater becomes contaminated, it becomes extremely difficult — and sometimes impossible — to clean. Some water systems may have to provide treatment for contaminated water, and this treatment, along with increased monitoring, can put a significant financial burden on public funds, homeowners, and businesses.

Unfortunately, recent studies show an elevated level of nitrate in some areas of Whatcom County's groundwater supply, indicating that groundwater is vulnerable to contamination from a variety of human sources. While there does not appear to be an immediate health concern to most of the population, there is potential for more serious problems down the road, impacting the long-term health of our community. Poor water quality has already created difficulties for some residents applying for building permits and bank loans. And in some areas, standards used to indicate groundwater is "safe to drink" are not being met.

The best way to deal with contaminated groundwater is to prevent it from happening in the first place. It's up to all of us to keep a vital natural resource from becoming a source of concern.

Keep it Clean – Avoid contamination at its source

Many of the sources of contamination endangering our groundwater come from what we consider to be daily activities. Some of the more serious causes include:

- *poorly maintained or designed septic systems*
- *improper animal waste handling and disposal of garbage and other solid waste*
- *incorrect use of agricultural and garden pesticides and fertilizers*
- *fuel storage tank leaks*
- *inadequate handling of storm water runoff*

We can control the damage done to groundwater by taking time to ensure careful use of the items listed above. For example:

If you have a septic system, be sure it is properly maintained and designed — don't use harsh cleansers or anything your system isn't meant to treat.

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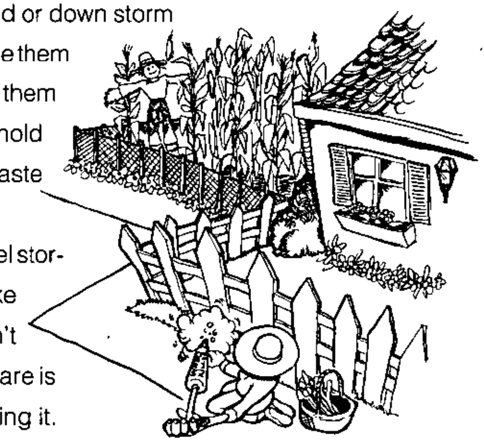

Whatcom County
Health Department
509 Girard St. — P.O. Box 935, Bellingham, WA 98227-0935

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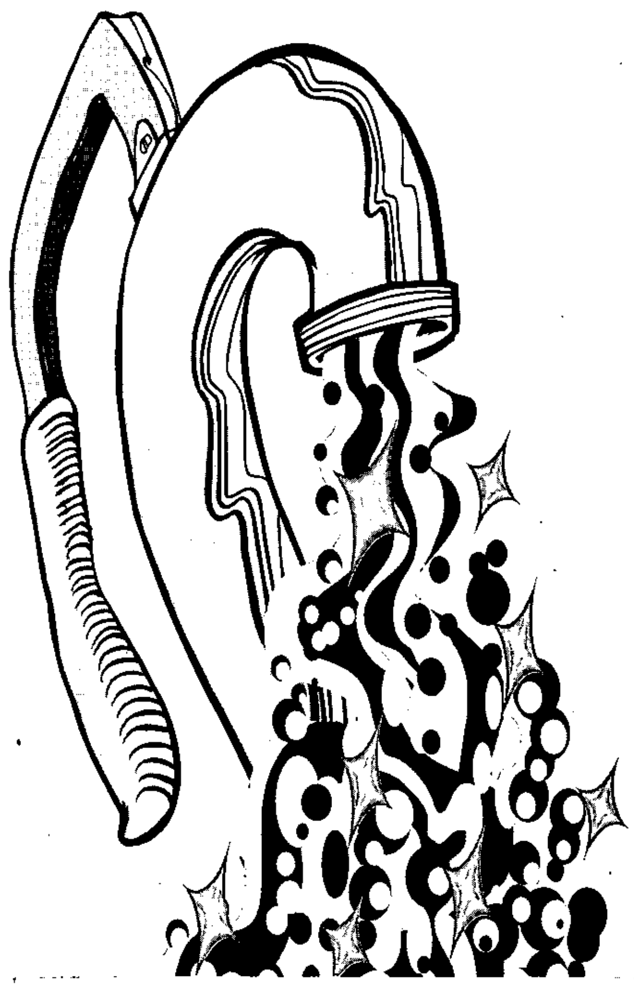
ARE YOU

protecting your most valuable liquid asset?



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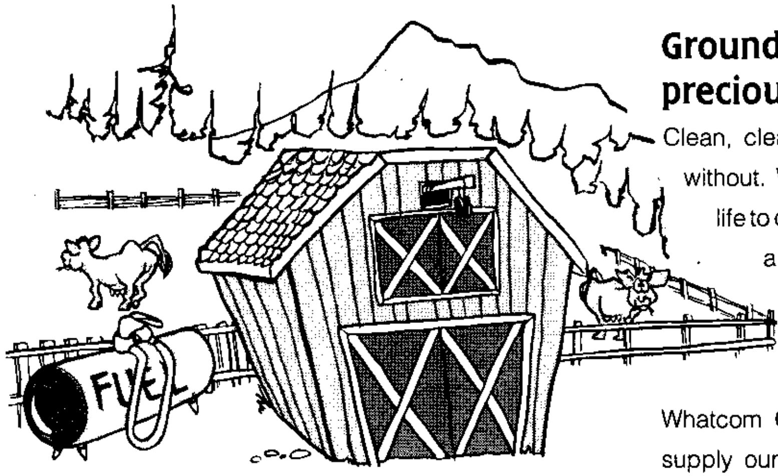

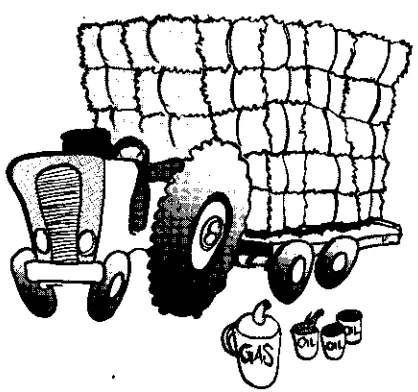

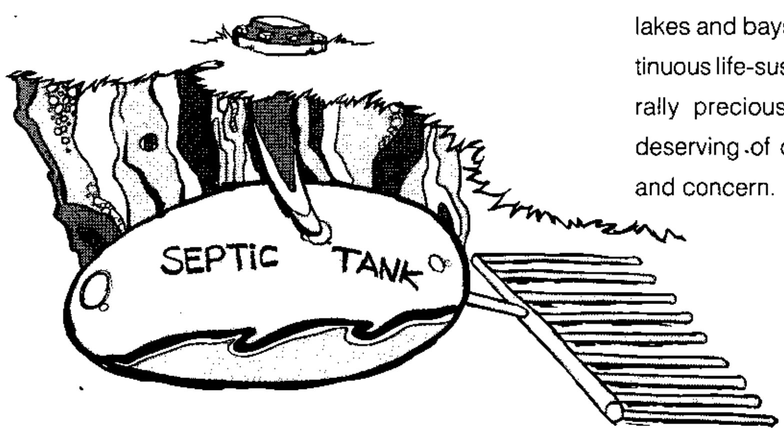

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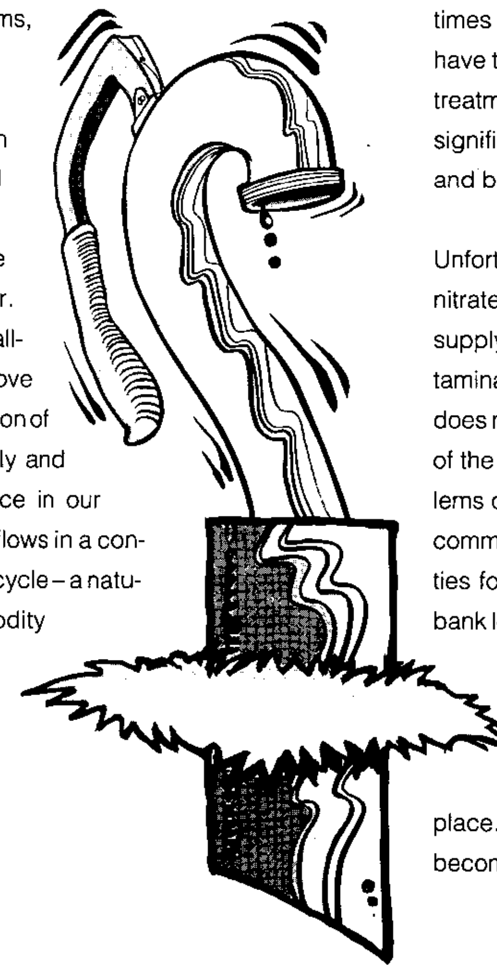

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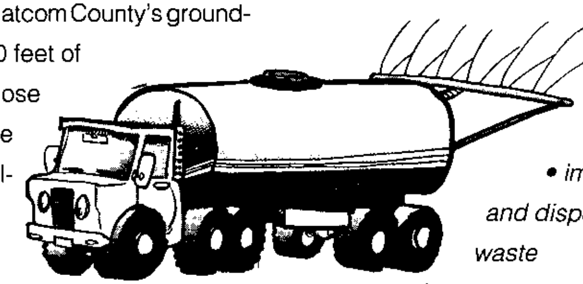

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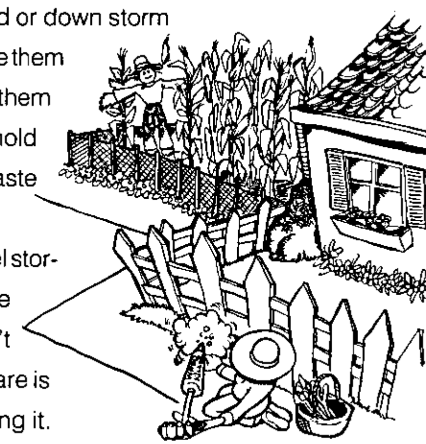

HOW TO TEST YOUR WELL WATER FOR NITRATES:

1) Use a clean glass or plastic container that holds at least two cups of water. Collect the sample just before bringing it to the test center.
2) Locate a faucet, valve or other access as close to your well as possible. Samples shouldn't be collected if the water has passed through any sort of treatment system. If the only access is from a faucet in the house, remove any aerators, filters, or treatment devices before you fill your bottle.
3) Let the water run 15 minutes to purge out water sitting in the well and pipes. Don't touch the inside of the bottle or cap, and don't allow dirt, dust, etc. to contaminate the bottle before or after filling.
4) With water running, rinse the container twice by filling, capping, and shaking it, then emptying the contents. Then fill the container and screw the cap on firmly.
5) Keep the sample cool during transport to the test center. You may put the container in a cooler with ice but do not freeze the sample.

Important: the results of your test will only be as good as the effort put into following these instructions.

For more information call 676-6724

CAN YOUR WELL WATER PASS THE TEST?

TEST YOUR WELL WATER FOR NITRATES

Thursday, July 15th and July 22nd

at the following locations:

- Sumas City Hall—433 Cherry
- Everson City Hall/Senior Center —111 West Main
- Lynden—NW Washington Fair Grounds office, 1775 Front Street

This testing is free of charge

Whatcom County Health Dept.
509 Girard Street
Bellingham, WA 98227
(206) 676-6724

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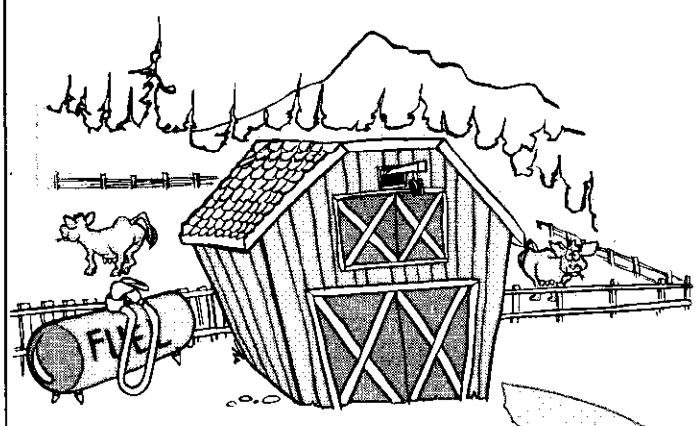
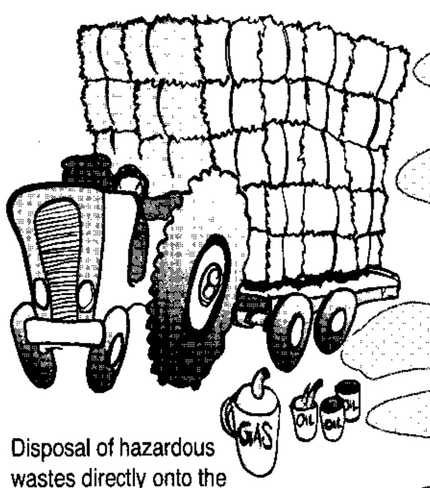
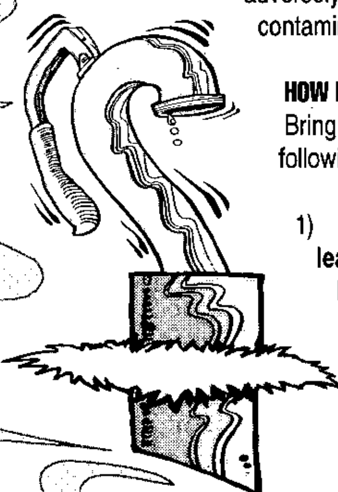
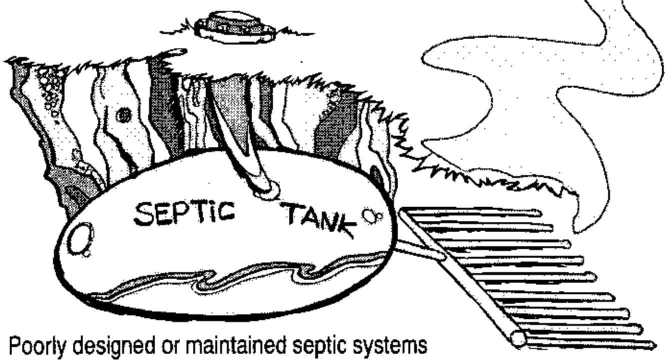


Improper animal waste handling practices and fuel storage tank leaks can affect the quality of your water



Disposal of hazardous wastes directly onto the ground can harm the groundwater supply





Poorly designed or maintained septic systems are a potential problem

Discover if the groundwater supplying your well makes the grade with free testing by the Whatcom County Health Department on:

Thursday, July 15th and
Thursday, July 22nd
at the following locations:

- ***Sumas City Hall****—433 Cherry*
- ***Everson City Hall/Senior Center****—111 West Main*
- ***Lynden****—NW Washington Fair Grounds office—1775 Front St.*

WHY IS IT IMPORTANT TO TEST FOR NITRATES?

Nitrate is a chemical that can be found naturally in drinking water. But when it occurs at higher concentrations, it can mean that other contaminants, bacteria, or viruses may be present as well.

High levels of nitrates can also indicate that groundwater is vulnerable to contamination from a variety of human sources. Poorly designed or maintained septic tanks, incorrect use of pesticides and fertilizers, leaking fuel tanks, and improper disposal of animal waste can adversely affect the quality of the water you drink—producing contaminants that can affect your health.

HOW DO I TEST MY WELL WATER FOR NITRATES?

Bring a sample of your well water to one of the testing sites, following these simple instructions:

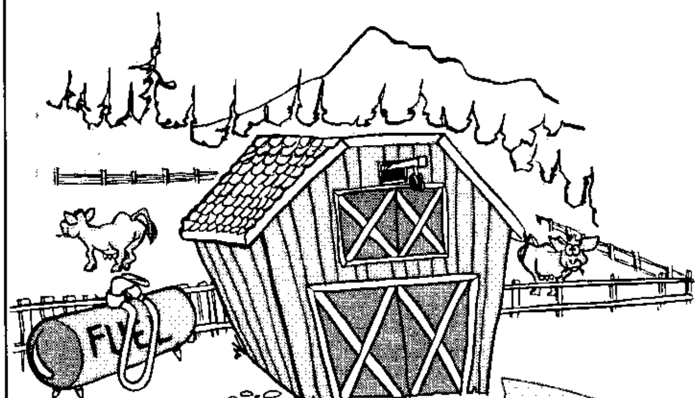
1) **Use a clean glass or plastic container that holds at least two cups of water**, collecting the sample just before bringing it to the test center. Your results will be more accurate if the sample is fresh.
2) **Locate a faucet**, valve, or other access to fill your container as close to your well as possible. Samples shouldn't be collected if the water has passed through any sort of treatment system. If your only access is from a faucet in the house, remove any aerators, filters, or treatment devices before you fill your bottle.
3) **Let the water run for 15 minutes in order to purge out water that has been sitting in the well and pipes**. Use the purge water for irrigation or other good use. Don't touch the inside of the bottle or cap, and be careful not to allow dirt, dust, etc. to contaminate the bottle before or after filling.
4) **With the water running, rinse the container twice by filling it**, capping it, shaking it, and emptying the contents. Finally, fill the container and screw the cap on firmly.
5) **Keep the sample cool during transport to the test center.** This can be done by putting the container in a cooler with ice. However, be careful not to freeze the sample.

Important: the results of your test will only be as good as the effort you put into following these instructions

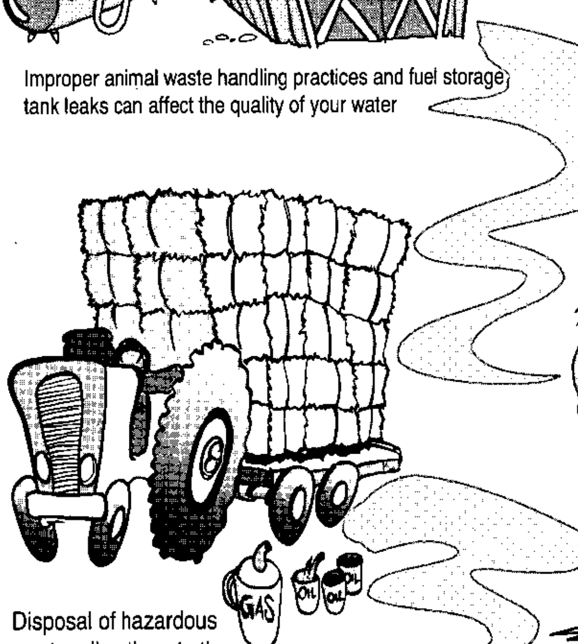
Whatcom County Health Department

Whatcom County Health Dept. • 509 Girard Street • Bellingham, WA 98227
(206) 676-6724

CAN YOUR WELL WATER PASS THE TEST?



Improper animal waste handling practices and fuel storage tank leaks can affect the quality of your water



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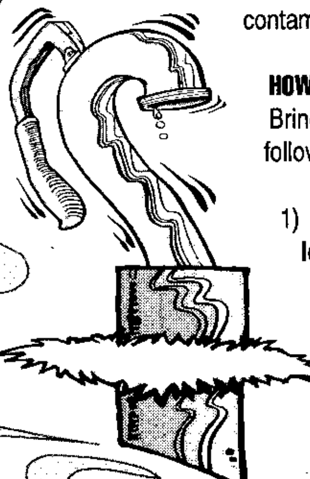

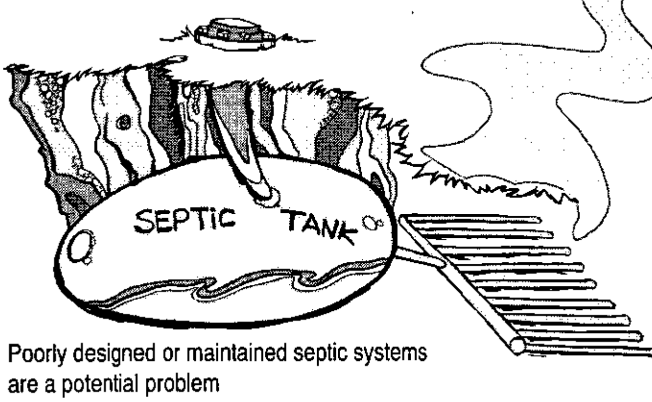

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UNDERSTANDING THE RESULTS

PART 1

WHAT DO THE RESULTS MEAN?

WHAT IS NITRATE?

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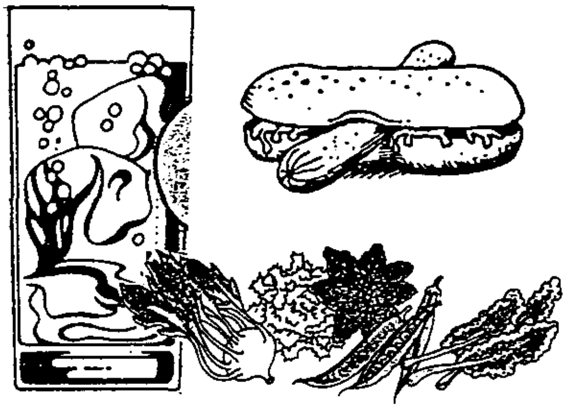
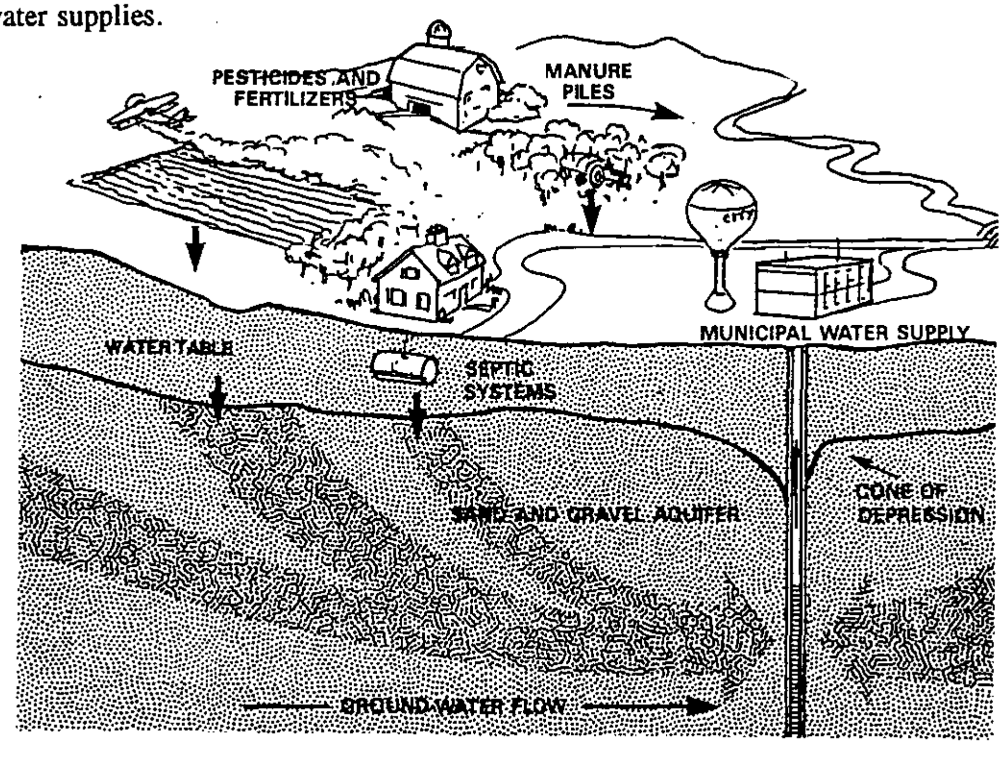


HOW CAN NITRATE GET INTO DRINKING WATER?

Nitrate can be found naturally in drinking water but when it occurs at higher concentrations it usually means that some kind of human activity is the cause. Nitrate in water is most often linked to septic systems, animal waste such as manure, and fertilizers. Nitrate from these sources can be carried by rainwater into the soil and eventually into the groundwater if care is not taken. This can be a particular problem in areas with sandy or gravelly soils (as is the case in much of the northern part of the county) or when wells are poorly designed and constructed, allowing surface water to "leak" into groundwater supplies.



WHAT DOES THE TEST NUMBER MEAN?

Natural levels of nitrate are generally less than 3 ppm. If your water sample is over 3 ppm, it means some kind of kind of human activity, such as septic systems or manure storage or spreading, may be impacting your well's water quality. If nitrate in your water is greater than 10 ppm, it exceeds what the State Department of Health considers to be "safe" levels. This safe level is referred to as a maximum contaminant level (MCL). If a sensitive individual consumes water with a nitrate level greater than 10 ppm, they may experience health problems. In addition, be sure to remember nitrate's special role as an indicator of water quality; when elevated nitrates are found, it is possible that other kinds of contaminants may also be present.

WHAT ARE THE HEALTH CONCERNS?

The nitrate standard is an acute standard. This means that there may be health effects occurring within a very short time if an individual consumes water with a nitrate level greater than the MCL. For nitrates, the sensitive populations are infants, individuals with reduced gastric acidity, individuals with a hereditary lack of methemoglobin reductase, and women who are pregnant. The primary acute illness caused by high nitrates is a blood disorder called methemoglobinemia or "blue baby disease". There have been no identified cases of methemoglobinemia to date in Whatcom County although 2,000 cases have been reported worldwide since 1945. Some studies have suggested a possible link between nitrate and cancer and birth defects. These suggestions, however, have not been confirmed.

Elevated nitrates also raise a "red flag" because they indicate other contaminants, such as bacteria, viruses, pesticides and other organic chemicals, may be present. Each of these could have an impact on public health.

PREVENTING NITRATE AND OTHER CONTAMINANTS FROM ENTERING DRINKING WATER

The best solution to high nitrates is to prevent them from getting into the groundwater in the first place. Refer to **PART 3 - *(under) Prevention***, for suggestions that can be followed to prevent nitrates and contaminants from entering groundwater.

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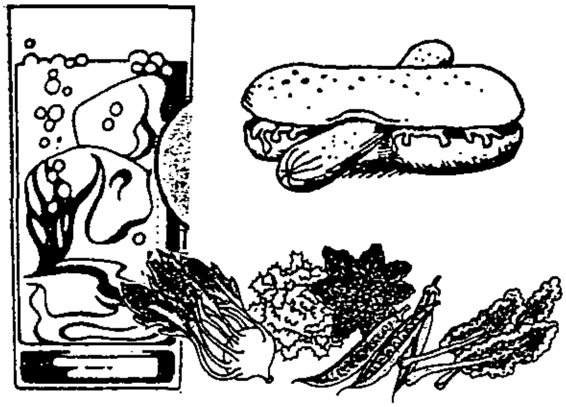

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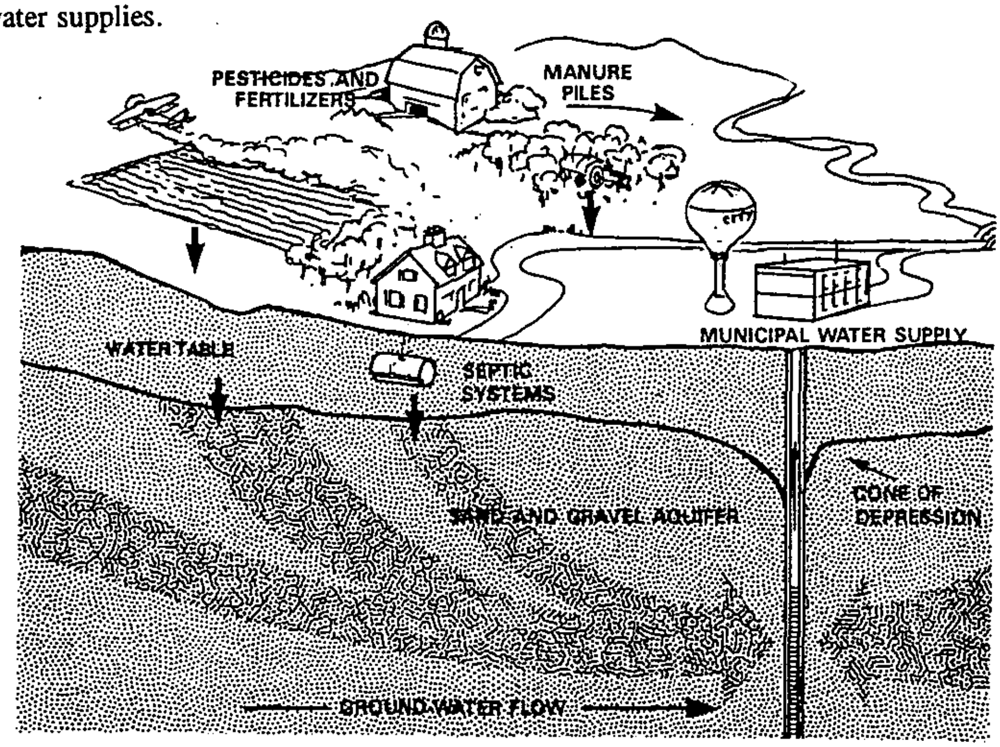

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UNDERSTANDING THE RESULTS

PART 2

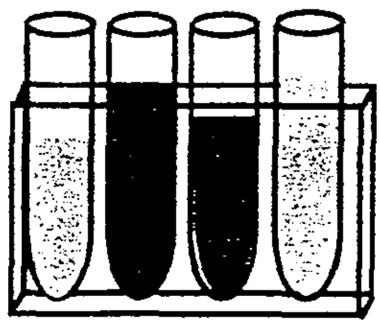
LIMITATIONS OF THE TEST AND HOW TO GET MORE ACCURATE INFORMATION

BEWARE! USE CAUTION WHEN INTERPRETING YOUR RESULTS!!!

Test results can vary with the testing procedures and time of year. Read on for more details!

TESTING PROCEDURES

Nitrates can be tested using a variety of different methods. Some of these methods will give more reliable and accurate results than others. The test method which was used to analyze your water today is capable of giving only fairly general results - ones that may vary about 10%, assuming you have collected the sample carefully. If you want to get better results you will need to use a certified laboratory.



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- Material Testing and Consulting Inc.
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- Washington State Dept. of Health
  (206) 361-2898
- Water Management Labs
  (206) 531-3121

TIME OF YEAR

Nitrate concentrations can fluctuate with the time of year. Some wells which have been tested range from near zero during some times of the year to over 10 mg/l at others. A recent study in the northern part of the county indicates that concentrations tend to be higher in the fall and early winter, and lower in the spring and summer. The graphs below show the seasonal fluctuation found in some wells in the county:

You may want to test your well for nitrates this fall or winter to get an idea of the range of nitrate concentrations which you may have in your well water.

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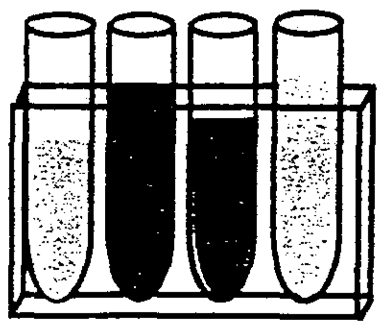

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UNDERSTANDING THE RESULTS

PART 3
WHAT TO DO IF YOUR TEST RESULTS EXCEEDS THE MCL - 10 MG/L

Do not panic!

CONFIRM YOUR TEST RESULTS

Remember, test results depend on the testing procedure and time of year. The test used today does not give really accurate results. It would be wise to get your water tested at a certified laboratory to be sure of the values. Refer to the list of certified labs in PART 1. They will be able to instruct you on what you will need to do.

SOLVING THE PROBLEM ...

In the Short Term ...

If you have children under the age of one year, the state Department of Health recommends using uncontaminated water in preparing their formula, juice and food becouse water is the most common source of nitrates for infants. Women who are pregnant, individuals with a hereditary lack of methemoglobin and people with reduced gastric acidity may also want to follow the same advice but they may also want to minimize intake of foods which contain high nitrate concentrations. Vegetables are generally are more common source of nitrates for most adults.

In the Long Run ...

Prevention

The best solution to high nitrates in water is to prevent them from entering groundwater in the first place. Look around your well for possible sources of nitrate - things such as septic systems, animal waste/manure, or fertilizer. Look also for other possible contaminants, such as pesticides and motor oil, because you do not want them entering the groundwater either. Make sure they are being handled correctly and that:

- septic systems are properly constructed, located and maintained (pumping is generally needed every 3 - 5 years)
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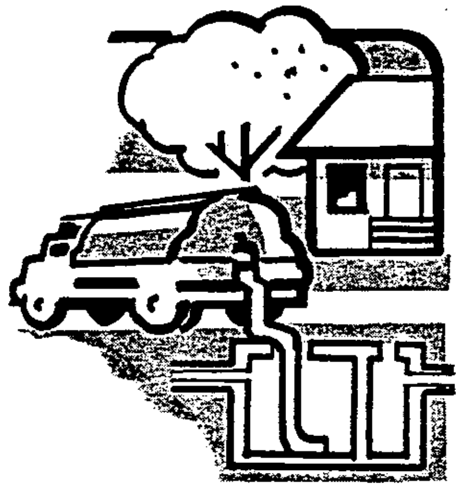

Contact the Whatcom County Health Department (676-6724) for advice on the proper maintenance for septic systems. The Soil Conservation Service, Conservation District or Cooperative Extension can help ensure that safe methods are being used to handle manure or fertilizers. The City of Bellingham can offer advice on safe disposal of household hazardous materials and pesticides (676-6850). The Cooperative Extension can provide advice on pesticide use (676-6736). ***It may take years for nitrate concentrations to decrease once the contamination source has been removed - have patience and remember, future generations will thank you for your efforts!***

Alternative Supplies

Alternative sources of water may offer a solution to high nitrates - some possibilities are listed below. Each of these options has both advantages and disadvantages; be sure to talk to the local Health Department to get more information.

- Blending water with high nitrates with water from a source which doesn't have high nitrates,
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- Connecting to another supply source such as a neighbors well or a local public water system

Treatment

Nitrate can be removed from water through various treatment methods including ion exchange and reverse osmosis. These methods are expensive to install and require frequent, careful maintenance

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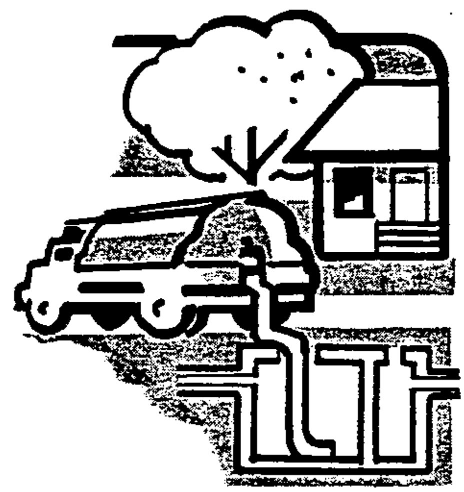

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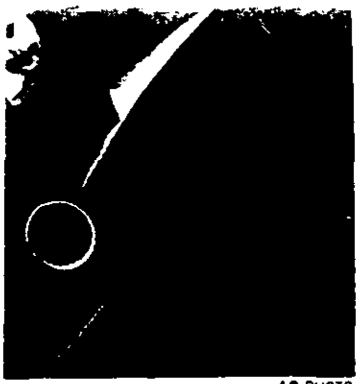

AP PHOTO

:e's funeral Saturday in Yorba
m left) son-in-law Ed Cox,
a Cox.

:r, Alexander Haig, C.G. "Bebe" ›ozo, H.R. Haldeman, Charles son and former ambassador lter Annenberg. Nixon resigned ;. 9, 1974, amidst impeachment

Milligan noted the Secret Service code name for Pat Nixon was "Starlight."

Former Sen. George McGovern, who was defeated by Richard Nixon in a bitter 1972 presidential campaign, said he admired Pat Nixon.

"I wanted to be here," said McGovern. "I've always admired Mrs. Nixon. She is one of the least pretentious public figures I've ever known. She had a lot of courage."

Pat Nixon, 81, who died Tuesday of lung cancer at her New Jersey home, was interred in the garden of the library, 35 miles southeast of Los Angeles.

The former president escorted his wife's body back to California Friday. The trip was made on the old Air Force One, a Boeing 707 that President Clinton provided for the occasion, the same plane Nixon flew on his historic trips to China and the former Soviet Union.

picted as a woman struggling against debilitating illnesses caused by the implants and a woman who needs mental help.

After the verdict, Mohney said she wondered how many other women will have to tell similar stories of leaking implants before juries hold implant makers accountable.

"In time, this will be proven as fact," she said.

Defense lawyers pointed to

TRYING TO CONSERVE WATER: Nooksack Environmental Alliance member Jay Taber, a leader of the Watershed Defense Fund, looks out over the Nooksack River near Nugents Corner.

Quotable

"Our problems are not industrial pollution problems. Our problems are runoff problems."

Fred Sears, alliance member

dying away to human development.

"We're doing what natural history took ...ions and billions of years to do, and ...e doing it in centuries," said Hugh ...wis, an alliance member with Washington Trout. "We can't help but be impacted."

■ Salmon restored to historic numbers.

The Nooksack River was one of the Northwest's most salmon-abundant rivers.

"And it doesn't produce anything now," Lewis said.

■ More education on the need to protect water.

Bierlink said farmers can agree with many of the environmental goals, but each interest group still must compete for water.

"We can't diminish the fact that individuals and individual interests play a role and they always will," he said. "We're never going to get away from competing interests on this river and it's naive to think otherwise.

"But these competing interests can be made to work together."

Tests reveal nitrates in wells

HOME: Nitrates not a concern in themselves; the problem is the path they take.

BY LEO MULLEN
THE BELLINGHAM HERALD

Possible ground-water polluters surround Dave and Nancy Nygren's home just east of Lynden.

Among them: a dairy, a raspberry farm, septic tanks and fertilized lawns.

Also, the source of their water is in Canada, too far away for the Nygrens to feel secure.

So the couple jumped at an offer from the Whatcom County Health Department to test their well water for nitrates.

The results: elevated, but not serious, nitrate levels.

"I anticipated it might be worse," Nancy Nygren said, "so I was pleasantly surprised."

The Nygrens are among 304 north county residents on one-home wells who brought water samples to Health Department checks in July. A $15,000 state grant covered the cursory tests.

About 40,000 county residents live on one-home wells.

Nearly half the tested homes showed elevated levels of nitrates, a chemical that in itself offers little health risk. Nitrates can cause a rare disease in infants a few months old.

But high nitrate levels suggest more harmful chemicals — such as pesticides — could take the same path to drinking water, said Dr. Frank James, the county's health officer.

"If nitrates can get there, anything can get there," he said.

Elevated levels of nitrates mean problems may lie close to a well, such as a faulty septic tank, a chemically treated rose garden or a hay field spread too thick with manure.

Health officials advised residents with unnaturally high nitrate levels to seek more exact tests and to look for clues to the problem within 100 feet of their wells.

"This is a screen and all we want to do is educate people," James said.

The Nygrens had tested their water before for other chemicals. None were found. They plan to seek more definitive nitrate testing.

The two don't want nitrates to be a problem if they try to sell their home.

Manure, fertilizer and failed septic tanks are considered the big three causes of elevated nitrates in county ground water. Health officials think natural peat bogs may be a fourth contributor.

Besides answering homeowner concerns, the samples offer a unique look at the county's nitrate problem, said Sue Blake, county water resource specialist.

In the past, the Health Department tracked nitrates through focused studies of specific locations and tests of public water systems and new wells tied to building permits, Blake said.

This was the first look at many one-home wells. The results showed nitrates to be more pervasive than James expected. Otherwise, the tests were too random and unscientific to draw broad conclusions, he said.

The department will continue to look for nitrate trends and is considering whether to offer similar tests in the south part of the county.

▼ Test results

Of 304 home wells in the county recently tested for nitrates:

- 154 showed natural nitrate levels.
- 97 showed unnaturally high levels.
- 53 showed excessive levels.

Certified laboratories in Western Washington that test for nitrates:

- AM Test, 885-1664.
- Avocet Environmental Testing, 734-9033.
- Lauck's Testing Labs Inc., 767-5060.
- Material Testing and Consulting Inc., 757-1400.
- State Department of Health, 361-2898.
- Water Management Labs, 531-3121.

Expect to pay about $20. The lab can usually send a container you can use to mail back a water sample.

Nitrates abundant, but poisioning rare

THE BELLINGHAM HERALD

Nitrates are in plenty of Whatcom County wells and hot dogs, too. Vegetables also are a major source of the chemical.

High nitrate doses only threaten infants in the first few months of life if they drink formula prepared with nitrate-contaminated water. Those children are susceptible to "blue baby disease," poisoning that turns a baby blue and causes breathing problems.

Doctors have diagnosed only 2,000 cases in 20 years for all of North America, making it quite rare, said Whatcom County Health Officer Dr. Frank James. None have been in this area.

The verdict is still out on whether nitrates pose a health threat when consumed in low doses over a lifetime, James said.

If you have an infant, use uncontaminated water for formula, juice and baby food. Tests can determine if water has high nitrate levels.

Pregnant women and people with a hereditary lack of methemoglobin or reduced gastric acidity also should avoid contaminated water.

Nitrates can be removed from water through expensive treatments such as reverse osmosis or ion exchange that require regular and careful maintenance.

Bottled water also is nitrate-free.

APPENDIX C

Lynden-Everson-Nooksack-Sumas (LENS) Groundwater Study Meeting

Date: March 13, 1991

Time: 3:00 P.M.

Location: Lynden City Hall (323 Front Street) Second Floor Meeting Room

AGENDA

1. Introductions of Meeting Participants

2. Opening Remarks-Shirley Van Zanten, Whatcom County Executive

3. Historical Perspective of the Study

   A. Need for the Study-City of Lynden Perspective-Egbert Maas, Mayor of Lynden

   B. Whatcom County Role-Diane Harper, Whatcom County Planning Department

4. Study Results to Date-Steve Cox, United States Geological Survey

5. Summarization of Canadian Groundwater Studies in the Border Region-Hugh Liebscher, Environment Canada

6. Group Discussion and Summary

Meeting Participants: Shirley Van Zanten, George Furguson, Egbert Maas, Terry Klimpel, Matt Lagerway, Keith Bode, Maxine Jones, Lawrence Silvis, Bob Mitchell, Dan Taylor, Hugh Liebscher, Steve Cox, Al Kohut, Craig Mapel, Tom Anderson, Diane Harper, Bill Peters, Larry Purcivall, Ed Regts, Sue Blake, Anne Atkeson, John Gillies, Cooperative Extension Representative

For additional information or questions contact Craig Mapel at (206) 676-6756

LENS GROUNDWATER MEETING, MARCH 13, 1991

Name	Affiliation	Address and Phone Number
Ron Bertrand	B.C. Ministry of Ag.	33832 South Fraser Way, Abbotsford, V2S 2C5
Diane Harper	County Planning Dept	401 Grand Ave, Bellingham WA 98225
[illegible]	District of Matsqui	[illegible] South Fraser Way [illegible] V2T-[illegible]
John Gillies	Soil Cons Ser	12975 Hannegan Lynden 354-2035
Terry Klimpel	City of Lynden	323 Front St. Lynden 354 5532
[illegible]	[illegible]	[illegible]
[illegible]	U.S. Geol Survey	[illegible] Pacific Ave [illegible]
Maxine Jones	City of Nooksack	204 W. Harrison St Nooksack 966-2552
Matt Lagerway	City of Everson	Box 315 Everson WA 966-3411
Keith Bode	LENS Aty	P.O. Box 680 Lynden 354-5021
George Ferguson	Dist. of Abbotsford	34194 Marshall Rd V2S 5E4
Bob Mitchell	City of Sumas	Box 189 Sumas 98295
Sue Blake	Whatcom Co	P.O. Box 935 Bellingham 98227
Anne Atkeson	Whatcom Co Health	" " " " 676-672[illegible]
[illegible]	Inst. Watershed Studies WWU	Western Wash University, Bellingham 676-[illegible]
Dick Mayer	Western Washington Univ	Bellingham 676-3974
Tom Anderson	Whatcom PUD	2011 Young St Bell 98226 733-5310
Don [illegible]	Whatcom PUD	" " "
Curt [illegible]	Lynden	300 East Grover
Henry Bierlink	W.C. Coop. Ext.	1000 N. Forest Bell, 98225 733-2531
Dan Taylor	W.C. Planning	401 Grand Ave B'ham 98225 676 6756
Leonora Ko	USDA - SCS	6975 Hannegan Rd, Lynden, WA 98264 354-2035
Chris Pharo	Environment Canada	224 West Esplanade, North Vancouver 604-666-63[illegible]
Bill Peters	B.C. Min. of Agric.	205-33780 Laurel St, Abbotsford B.C. V2S 1[illegible]
Hugh Liebscher	Environment Canada	224 W Esplanade, North Vancouver 604-666-0807
Egbert Maas	Mayor of Lynden	323 Front St 354-5026

LENS GROUNDWATER MEETING, MARCH 13, 1991

Name	Affiliation	Address and Phone Number

WHATCOM COUNTY

PLANNING DEPARTMENT
284 W. Kellogg Road, Suite B
Bellingham, Washington 98226

Scan: 769-6756 *Fax: 738-2525*
206/676-6756 *206/398-1310*

Lynden-Everson-Nooksack-Sumas (LENS) Groundwater Study Meeting
Technical Update and Overview

Date: June 26, 1991

Time: 1:00 P.M.

Location: Abbotsford Health Center 2391 Crescent Way, Abbotsford, British Columbia

AGENDA

1. **Introductions of Meeting Participants**

2. **Study Results-General Comments & Overview, Steve Cox, United States Geological Survey**

3. **Summarization of British Columbia Groundwater Study in the Airport Region-Al Kohut, British Columbia Ministry of Environment**

4. **Summarization of Canadian Groundwater Studies in the Border Region-Hugh Liebscher, Environment Canada**

5. **Group Discussion, Summary and "Where Do We Go From Here?"**

Invited Participants: Hugh Liebsher, Steve Cox, Al Kohut, Bill Peters, Ron Bertrand, Robin Busch, Marian Webb, William Culbertson, Sue Blake

For additional information or questions contact Craig Mapel at (206) 676-6756

LENS GROUNDWATER STUDY MEETING

ABBOTSFORD, BRITISH COLUMBIA, JUNE 26, 1991

NAME	AFFILIATION	ADDRESS
Al KOHUT	BC ENVIRONMENT	VICTORIA
M.L. WEBB	MHO UFV HUNIT	CHILLIWACK / [illegible]
[illegible]	[illegible]	[illegible]
W.S. PETERS	B.C. MIN. OF AGRIC.	ABBOTSFORD
[illegible]	BC ENVIRONMENT	SURREY
Rick Van Kleeck	B.C Min of AGRIC	ABBOTSFORD
[illegible]	SUSTAINABLE [illegible] GROUP	ABBOTSFORD
DALE [illegible]	BC MIN OF AGRIC	ABBOTSFORD
[illegible]	[illegible]	[illegible]
CRAIG MAPEL	W.C. Planning Dept.	Bellingham
Sue BlAKE	W.C. Water Resources Dept.	"

WHATCOM COUNTY

PLANNING DEPARTMENT
284 W. Kellogg Road, Suite B
Bellingham, Washington 98226

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206/676-6756 *206/398-1310*

Lynden-Everson-Nooksack-Sumas (LENS) Groundwater Study Meeting
Joint Canadian-Whatcom County Technical Update

Date: October 3, 1991

Time: 1:00 P.M.

Location: Abbotsford Health Center, 2391 Crescent Way, Abbotsford, British Columbia

AGENDA

1. Introductions of Meeting Participants

2. Study Results Update-General Comments & Overview, Steve Cox, United States Geological Survey

3. General Overview of Canadian Groundwater Studies and Results in the Abbotsford Area
   a. Hugh Liebscher, Environment Canada
   b. Rod Zimmerman, British Columbia Ministry of Environment

4. Overview of Groundwater Protection Issues in Whatcom County, Sue Blake, Whatcom County Water Resources Coordinator

5. Groundwater Contamination Concerns From a Public Health Standpoint, British Columbia Perspective, Dr. Webb, Medical Health Officer, Abbotsford Health Unit

6. Groundwater Contamination Concerns From A Public Health Standpoint, Whatcom County Perspective, Dr. Frank James, Director, Whatcom County Public Health Department

7. Washington State's Department of Ecology Role, Carol Jolly, Special Assistant to the Director, International Affairs, Department of Ecology

8. Agricultural Perspective on the Status of Groundwater Protection Legislation Measures, Ron Bertrand, British Columbia Ministry of Agriculture

9. Group Discussion

For additional information or questions contact Craig Mapel at (206) 676-6756.

JOINT CANADIAN-WHATCOM COUNTY LENS MEETING

ABBOTSFORD, BRITISH COLUMBIA, OCTOBER 3, 1991

NAME	AFFILIATION	ADDRESS / FAX
✓ Sue Blake	Whatcom County	
✓ Frank [illegible]	" "	509 Girard Bldg 98225
✓ Stephen Cox	U.S. Geological Survey	1201 Pacific Ave. Tacoma WA
[illegible]	BC Environment	10334 - 152 "A" St Surrey
[illegible]	[illegible]	[illegible]
Steve Chan	Simon Fraser H.U.	644 Poirier St Coquitlam
Bob [illegible]	Ministry of Health Victoria	1515 Blanchard [illegible] Victoria
✓ Anne Atkeson	Whatcom Co Health	PO BOX 935 Bellingham 98227
Alison Bell	Central Fraser Valley H.U.	11940 Haney Pl., Maple Ridge
Tim [illegible]	Central Fraser Valley H.U.	11940 Haney Pl. Maple Ridge BC
[illegible]	[illegible] H.U.	14265 - 56 Ave Surrey, B.C.
Larry Pericic	Ministry of Health	250 - 4259 Canada Way Burnaby BC
[illegible]	[illegible]	[illegible]
✓		
[illegible]	Whatcom Co Health	505 Girard B'ham FAX (206) 676-7646
✓ Hugh Liebscher	Envt. Canada	224 Esplanade N Van
X Leonora Vo	Soil Conservation Service	6975 Hannegan Rd, Lynden, WA 98264
X HENRY BIERLIUK	WSU Extension, District Mgt.	1000 N. Forest, Bellingham 98225
X John Gillies	USDA - SCS	6975 Hannegan Rd Lyn 98264 FAX 354 [illegible]
[illegible]	[illegible]	[illegible]
X Bill Peters	BCMAFF	205 - 33780 Laurel St, Abbotsford FAX 852-5428

JOINT CANADIAN-WHATCOM COUNTY LENS MEETING

ABBOTSFORD, BRITISH COLUMBIA, OCTOBER 3, 1991

NAME	AFFILIATION	ADDRESS
Ron Bertrand	B.C. Ministry of Ag. Fish Food	33832 South Fraser Way; Abbots.
[illegible]	" "	[illegible]
[illegible]	[illegible]	[illegible]
Tom Anderson	Whatcom [illegible]	201 [illegible] St [illegible] 98225
[illegible]	[illegible]	[illegible] Broughton [illegible]
U. TIN TUN	B.C. Min. of Health	2391 Crescent Way. Abb
DR. M. L. WEBB	B.C. Min. of Health	45470 MENHOLM RD. CHILLIWACK
[illegible]	[illegible] Dept of Ecology	[illegible]; Olympia, WA [illegible]

Craig - FYI
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Whatcom County Planning Dept

STATE OF WASHINGTON

DEPARTMENT OF ECOLOGY

Mail Stop PV-11 • Olympia, Washington 98504-8711 • (206) 459-6000

November 1, 1991

TO: Chris Gregoire
Hedia Adelsman
Terry Husseman
Mike Llewelyn
Cheryl Strange

FROM: Carol Jolly *Carol*

SUBJECT: Cross-Border Groundwater Condition

Attached is the summary of a meeting I attended earlier this month that was organized by the Whatcom County Planning Department.

As you'll see, the discussion identified a potentially significant problem of nitrate contamination of groundwater. The work being done by Whatcom County is funded by a Centennial Clean Water Fund grant; it is a ground water study of the Lynden, Everson, Nooksack, Sumas area. I expect to keep in touch with Craig Mapel, the Project Manager, and will let you know how the county staff and their Canadian counterparts progress on the information strategy cited.

Feel free to contact me if you need additional information.

cc: Bill Miller, WQFAP

Attachments

Summary of Groundwater Assessment Meeting
Abbotsford, B.C.

October 3, 1991

As part of an ongoing effort to keep regional governments informed, Whatcom County arranged a joint Canadian-County technical update session on groundwater conditions. A list of the attendees is attached; it reflects involvement by Canadian federal, provincial, and local officials from environmental, health and agricultural agencies.

The major issue discussed was the data from both sides of the border showing increasing nitrate levels. The general consensus was that the majority of the nitrates were the result of agricultural practices related to raspberry and poultry farms as well as to septic systems. Only one pesticide (1,2 dichloropropane) was considered to be of concern; it has been identified in Environment Canada Monitoring, but it is not known whether it occurs in Whatcom County groundwater. The attendees also agreed that most groundwater movement was from north to south (i.e., from B.C. to the U.S.).

Rod Zimmerman, of the B.C. Ministry of Environment's Ground Water Unit, noted that the Ministry is preparing the province's first ground water assessment and objectives document for the Abbotsford area. They do not expect this to be completed for 6 to 9 months. He also pointed out that the province does not have ground water protection legislation; as a result, the government can recommend, but cannot mandate, changes in practices thought to contribute to pollution.

Dr. Webb of the Abbotsford Health Unit said that his staff does warn mothers of newborns in the high nitrate areas how to avoid the danger of methemoglobinemia. He also noted that the Unit only has the authority to test or regulate septic systems that "malfunction," i.e., discharge sewage to the ground's surface. Dr. Frank James, Director of Whatcom County's Health Department, emphasized that while methemoglobinemia is not a major public health concern, the presence of nitrates can serve as an indicator of other pollutants.

Ron Bertrand from the B.C. Agriculture Ministry described that agency's work with poultry farmers to develop a Code of Practice and guidelines for manure management. He stressed the significant contribution poultry rearing makes to the province's and Abbotsford area's economy.

The group discussed the merits of a public information strategy to convey their findings and concerns to a broader audience. They agreed to meet again later in the month to begin formulating such a plan.

LENS Attendance List, October 3, 1991

Ir. Ron Bertrand
. C. Ministry of Health
3832 South Fraser Way
Abbotsford, BC V2S 2C5

Ms. Robin Busch
Ministry of Health
2391 Crescent Way
Abbotsford, BC V2S 3M1

Mr. Bill Rogers
Boundary Health Unit
14265 56 Avenue
Surrey, BC

Mr. Roland Guasparini
Central Fraser Valley Health Unit
11940 Haney Place
Maple Ridge, BC

Dr. Alison Bell
Central Valley Health Unit
11940 Haney Place
Maple Ridge, BC

Mr. Don Child
Ministry of Environment
10334 152 A Street
Surrey, BC V3R 7P8

Mr. Kevin Chipperfield
* Sustainable Poultry Farming Group
302-34252 Marshall Road
Abbotsford, BC V2S 1L9

Mr. Hugh Liebscher
* Environment Canada
224 West Esplanade
N. Vancouver, BC V6E 2M9

Dr. Frank James
* Whatcom County Health
P.O. Box 935
Bellingham, WA 98225

Mr. John Gillies
* Soil Conservation Service
6975 Hannegan Way
Lynden, WA 98264

Mr. Rick Bomhof
* District of Matsqui
200-32315 South Fraser Way
Clearbrook, BC V2T-1W7

Mr. U. Tin Tun
* BC Ministry of Health
2391 Crescent Way
Abbotsford, BC V2S 3M1

Mr. Larry Percival
* BC Ministry of Health
250-4259 Canada Way
Burnaby, BC

Mr. Steven Chan
* Simon Fraser Health Unit
644 Poirier Street
Coquitlam, BC

Mr. Al Kohut
BC Ministry of Environment
765 Broughton
Victoria, BC V8V 1X5

Mr. W. Wickens
* BC Ministry of Ag, Fish, Food
33780 Laurel Street
Abbotsford, BC V2S 1X4

Mr. David Sands
Greenzone Administrator
33832 South Fraser Way
Abbotsford, BC V2S2C5

Ms. Sue Blake
* Whatcom County Health Dept.
P. O. Box 935
Bellingham, Wa 98225

Mr. Dave Bader
* Health Department
509 Girard
Bellingham, WA 98225

Ms. Leonora Ko
* Soil Conservation Service
6975 Hannegan Way
Lynden, WA 98264

Dr. M. L. Webb
* Ministry of Health
45470 Menholm Road
Chilliwack, BC V2P 1M2

Mr. Tim Roark
* Central Valley Health Unit
11940 Haney Place
Maple Ridge, BC

Mr. William Koberston
* BC Ministry of Health
45470 Menholm Road
Chilliwack, BC

Mr. Robert Smith
* BC Ministry of Health
1515 Blanchard Street
Victoria, BC

Mr. Rod Zimmerman
* BC Ministry of Environment
765 Broughton
Victoria, BC V8V 1X5

Mr. Bill Peters
* BC Ministry of Agriculture
Room 205-33780 Laurel Street
Abbotsford, BC V2S 1X4

Dr. Chris Pharo
Environment Canada
224 West Esplanade
N. Vancouver, BC V6E 2M9

Ms. Anne Atkeson
* Whatcom County Health Dept.
P. O. Box 935
Bellingham, WA 98225

Mr. Henry Bierlink
* Whatcom County Extension Service
1000 North Forrest
Bellingham, WA 98225

* Mr. Tom Anderson
Whatcom County PUD
2011 Young Street
Bellingham, WA 98225

* Attended last Meeting

Ms. Debbie Kingsley
Whatcom County PUD
2011 Young Street
Bellingham, WA 98225

Ms. Carol Jolly
Washington Dept. of Ecology
PV-11
Olympia, WA 98509
Dear Ms. Jolly,

Dr. Peter Willing
Water Resources Consultant
2509 Sylvan
Bellingham, WA 98226

Mr. Craig Mapel
Whatcom County Planning
294 West Kellogg Road, Suite B
Bellingham, WA 98225

Mr. Terry Klimpel
City of Lynden
323 Front Street
Lynden, WA 98264

Mr. Lawrence SIlvis
City of Sumas
433 Cherry Street
Sumas, WA 98295

Ms. Maxine Jones, Mayor
City of Nooksack
204 West Harrison Street
Nooksack, Wa 98276

Mr. Matt Lagerway, Mayor
City of Everson
P.O. Box 315
Everson, WA 98247

Mr. Keith Bode
LENS Attorney
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Lynden, WA 98264

Mr. George Ferguson, Mayor
District of Abbotsford
34194 Marshall Road
Abbotsford, BC V2S 5E4

Mr. Bob Mitchell, Mayor
City of Sumas
P. O. Box 189
Sumas, WA 98295

Dr. Tom Storch
Institute of Watershed Studies
Western Washington University
Bellingham, WA 98225

Dr. Richard Mayer
Institute of Watershed Studies
Western Washington University
Bellingham, WA 98225

Mr. Egbert Maas, Mayor
City of Lynden
323 Front Street
Lynden, WA 98264

Mr. Bob Blackhall
10184 208 Street
R. R. 5
Langley, BC

WHATCOM COUNTY/BRITISH COLUMBIA GROUND WATER REPORTS

Date: July 23, 1992

Time: 2:00 p.m.

Location: Lynden City Hall (323 Front Street) Second Floor Meeting Room

AGENDA

1. **Opening Remarks - Sue Blake, Whatcom County Water Resource Protection Manager**

2. **Introduction of Meeting Participants**

3. **Study/Report Results**

   A. **LENS Study - Steve Cox, United States Geological Survey (45 - 60 minutes)**

   B. **Abbotsford Aquifer Report - Hugh Liebscher, Environment Canada (45 - 60 minutes)**

   C. **Fraser Valley Ground Water/Drinking Water Study - Al Kohut, B.C. Ministry of Environment (15 minutes)**

4. **Question and Answer Period**

5. **Next Step(s), Closing Remarks**

Potential Attendees: Tom Anderson/PUD, George Ferguson/ Mayor District of Abbotsford, John Giles/Soil Conservation Service, Dr. Frank James/Whatcom County Health Department, David Jennings & Ginny Stern/State Department of Health, Maxine Jones/Mayor Nooksack, Matt Lagerway/Mayor Everson, Craig MacConnell/Cooperative Extention, Egbert Maas/Mayor Lynden, Dr. Richard Mayer & Dr. Tom Storch/ Western Washington University, Bob Mitchell/Mayor Sumas, Dan Taylor/Whatcom County Planning Department, Shirley Van Zanten/County Executive, Dr. Webb/Ministry of Health, Peter Willing/Water Resource Consultant

Clearbrook well constant' level

Surface drainage prevents recharge to the extent it would theoretically seem possible

most of nitrate (highs) in summer outwash

- no inorganic fertilizer indication

LENS GROUNDWATER STUDY
AGENDA
April 1, 1993

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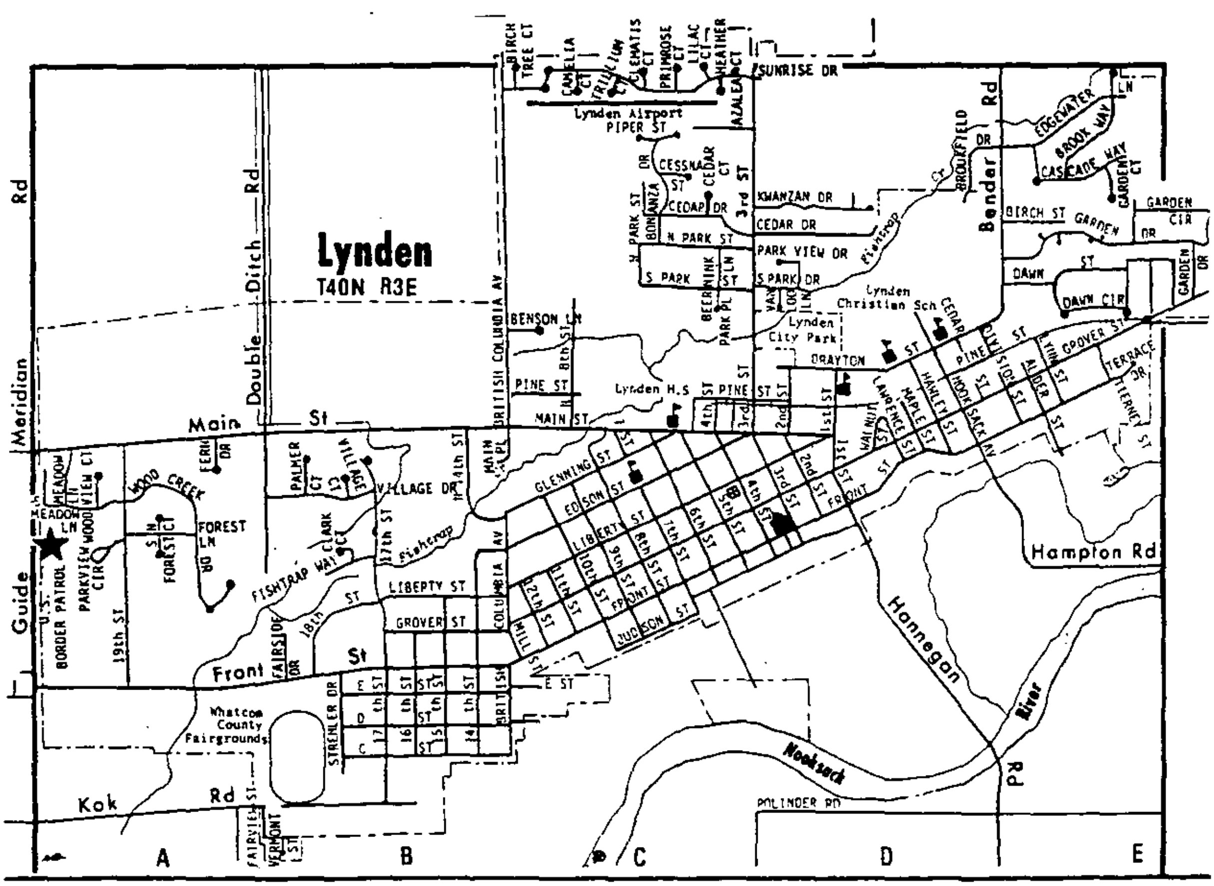
1. **Brief Update on Status of United States Geological Survey Report and International Task Force Efforts**

2. **Discussion of Education Program**
   (Sue Blake and State Health Department Representatives will outline some possible strategies for discussion)

3. **Additional Comments and Questions**

4. **Adjourn**



POSSIBLE EDUCATIONAL PROJECTS

1. Free Nitrate Screening and Educational Information

Following the general approach used in Clallam County, we could offer free nitrate screening for County residents that rely on ground water. HACH kits would be used as opposed to sending the samples into a lab - this would provide immediate on-site results. The results would not be as accurate but would be acceptable for determining if there were a problem. Results could be displayed on a large map of the County using color coded dots (or something). Map would be of a scale that results would be confidential (or participants could choose to not have their results included on map).

Educational materials would be provided to participants including information on health effects, limitations of the testing procedure and how to get more accurate information if needed, what ground water is, what individuals can do to protect it, and general information on the LENS study. Participants would also have an opportunity to sign up for possible participation in the Farm Assist program described below.

The "testing booth" could be set up at a central location on 2 or 3 separate dates (what locations and dates would be most convenient?) . In addition, it could be used again at community events such as the Lynden Fair.

2. Farm Assist

Farm Assist is a program developed in the mid-west that is used to help people in rural areas protect their ground water supplies. It is strictly educational in its orientation. Using the "packet" of lesson plans, residents, with the assistance of a volunteer trained in the program, cover a wide variety of topics pertinent to water quality protection.

The program is just beginning here in Washington State through the cooperative efforts of the Department of Health and the Thurston County Cooperative Extension (the Extension is modifying the program to reflect our situation in Western Washington). Whatcom County has been identified as a pilot area. A portion of the money could be used to buy the "Farm Assist" packets now which could be used later.

3. Pamphlet

Produce informational pamphlet that could be provided to various agencies and other centers for distribution to the public. It would focus on the LENS area and could cover the following areas:

- vulnerability of the aquifer
- potential sources of contamination

- general overview of water quality
- ways to protect water supplies - things individuals could do

4. Video

A 5 - 10 minute video could be developed that would focus on many of the issues discussed in previous sections (ways to protect groundwater, vulnerability of the aquifer, etc.). The video could be shown as a part of various presentations that may occur in the area, and at fairs such as the Lynden Fair. Another option would be to make a number of copies and make them available through various distribution points.

LENS GROUNDWATER STUDY

What Did We Learn? Where to From Here?

Where: *Lynden City Hall Council Chambers*
When: *10:00 a.m., December 3, 1993*
Who: *Participants in the LENS Study*

AGENDA

10:00 - 10:10:	Welcome and Introduction
10:10 - 10:30	Summary of Education Efforts Questions/Comments Sue Blake - Whatcom County Water Resources
10:30 - 11:30	Study Results (30 - 45 minutes) Questions and Comments Steve Cox - United States Geological Survey
11:30 - 11:50	Abbottsford/Sumas International Task Force Questions and Comments
11:50 - 12:00	Final Comments - Where to From Here?

APPENDIX D

Seattle Times 5/18/93

Sharing pollution, solutions across the border

B.C., Washington find common ground on the environment

by Eric Pryne SEATTLE-TIMES
Times staff reporter 5/18/93

LYNDEN, Whatcom County — This fast-growing farm town, five miles from Canada, went looking for a new water supply a few years ago. Mayor Egbert Maas says what Lynden got instead was a lesson:

Pollution doesn't stop at the border.

City officials found plenty of water when they drilled a well about 10 miles east of town. But when the lab tests came back, they learned they couldn't drink it: Too many nitrates.

They're mostly from Canada, Maas suspects: "They're having a much bigger impact on the aquifer than we are."

Canadian and U.S. government studies have since revealed widespread nitrate and pesticide contamination throughout the Abbotsford/Sumas Aquifer, the big underground reservoir that spills across the international border east of Lynden.

Scientists haven't pinned down the sources yet. But nitrates are associated with human wastes, animal wastes and fertilizers. The Canadian side is both more densely populated and more intensively farmed.

And water in the aquifer flows south, from Canada into the U.S.

"When we find contamination of ground water, it's a big deal," says Dr. Frank James, Whatcom County's health officer. "What it is is a warning placard about the size of Husky Stadium that says you've got to change your land-use practices."

> 'When we find contamination of ground water, it's a big deal. What it is is a warning placard about the size of Husky Stadium that says you've got to change your land-use practices.'
>
> **Dr. Frank James, Whatcom County health officer**

The Abbotsford/Sumas Aquifer is one of several environmental sore spots that straddle the border between British Columbia and Washington, sometimes straining relations.

The uproar in Western Washington over Victoria's reluctance to treat the sewage it pours into the Strait of Juan de Fuca is a prime example.

Such conflicts are nothing new. B.C. howled in the 1970s when Seattle City Light wanted to raise Ross Dam, flooding the Canadian Skagit Valley. Canadian and American fishermen have fought for years over who's catching whose salmon.

But the Abbotsford/Sumas Aquifer also illustrates a more recent development in relations between the state and province. Environmental agencies and environmental-

Please see **BORDER** on A 15

BORDER

continued from Page 1

ists on both sides of the border are talking and working with each other more closely than ever before.

Agreements have been signed. Joint projects have been started. Changes have been made.

■ Seattle-based People for Puget Sound and the Vancouver-based Save Georgia Strait Alliance agreed a year ago to work together to protect those interconnected seas. A report card grading sewage-treatment plants on both sides of the border is in the works.

■ An "environmental cooperation council" that former Gov. Booth Gardner and B.C. Premier Mike Harcourt established last May to address trans-boundary air and water-pollution concerns holds its second meeting Thursday in Sidney, B.C.

Victoria's sewage should take center stage. The Abbotsford/Sumas Aquifer also is on the agenda.

■ Two weeks later, environmentalists from both sides of the border will gather near Chilliwack, B.C., to kick off a campaign for an international park in the North Cascades.

The upcoming events reflect a growing awareness that what happens on one side of the 49th parallel affects the other, participants say.

One region, despite border

The boundary British and American diplomats drew 147 years ago pays no attention to seas, rivers, aquifers, wind, weather or wildlife. "I think there's recognition that this is indeed one region," says Laurie MacBride, executive director of the Save Georgia Strait Alliance.

In the Abbotsford/Sumas area, an international task force is forming to address the aquifer's problems. The B.C. government last year adopted new rules aimed at reducing nitrates, which can prevent blood cells from transporting oxygen and may cause cancer.

Lynden's unfortunate experience helped prod the B.C. government to pay more attention to the aquifer, says Geoff Hughes-Games, an agriculture-ministry soils specialist.

Mayor Maas likes what he sees across the border. "Now they are being much more cautious about how they handle things up there," he says. "They've been very responsive. This affects them as much as it affects us."

That sense of intertwined destiny prompted Gardner and Harcourt to sign the agreement a year ago that established the environmental cooperation council. It includes representatives from state, provincial and federal environmental agencies.

Carol Jolly, the state Department of Ecology's liaison to the council, says the accord had its roots in 1988, when the barge Nestucca sank off Grays Harbor, spilling oil that washed ashore on Vancouver Island.

It prompted formation of a task force that worked out a joint plan for spill response. What's more, Jolly says, it showed officials from both sides they could work together.

Tom Reese

Lynden Mayor Egbert Maas suspects that pollution from Canada is what ended his city's attem water from this new well when it was discovered the water contained too many nitrates.

Seattle Times 5-18-93 cont.

Seattle Times 5-18-93 cont.

Council sets priorities

Since its creation a year ag the cooperation council has iden- fied the Abbotsford/Sumas Aquif and Puget Sound/Georgia Bas water pollution as top priorities for joint attention, along with:

- **The Nooksack River.** At flood stage, the river leaps it banks in Whatcom County and spills into a tributary of the Sumas River, pouring into Canada's Fraser Valley.

In November 1990, high water from the Nooksack closed the Trans-Canada Highway.

- **Lake Roosevelt.** Scientists have found alarming concentrations of heavy metals and highly toxic dioxins and furans in fish and sediments from the 150-mile-long reservoir behind Grand Coulee Dam on the Columbia River.

A lead-zinc smelter and a pulp mill upriver in Canada are likely sources.

Some people near Northport, Stevens County, suspect the plume from the smelter in nearby Trail, B.C., may be making them sick. The state Health Department is investigating.

- **Air pollution.** Washington air-quality officials wonder if Vancouver's automobiles may be contributing to summer smog problems in the Puget Sound basin. Their counterparts in Canada are concerned about new U.S. cogeneration plants near the border that produce both steam and electricity.

In some places the cooperative venture has produced only paper so far. Elsewhere, officials in both nations say, significant environmental improvements have resulted.

Fuss over Lake Roosevelt

Lake Roosevelt may be the best example, Jolly says: "Before we started making a fuss, their attitude was, 'It's a big river.' "

"There's been significant improvement the last couple years," says Frank Ossiander of Kettle Falls, Stevens County, who heads Citizens for a Cleaner Columbia, an environmental group.

B.C. and Washington environmental officials first began meeting formally in 1991, when the Lake Roosevelt Water Quality Council, a U.S. intergovernmental group, invited Canadians to participate in their sessions.

Before then, B.C. officials didn't appreciate the impact the smelter and pulp mill might be having downstream, says Rick Crozier, the B.C. environment ministry's regional manager in Nelson, B.C.

"When they (U.S. officials) looked north, they saw a big black hole. When we looked south, we didn't understand."

The smelter now plans to stop dumping slag – toxic-waste rock – into the Columbia in mid-1995. The change might not have come so quickly, or at all, without new information and pressure from south of the border, Crozier says.

B.C. officials waited two days in 1991 before telling their outraged Washington counterparts about a major spill from the Trail sewer system, 12 miles from the border. It happened on the eve of the July 4 weekend, with visitors flocking to Lake Roosevelt.

The B.C. environment ministry has since agreed to alert the Department of Ecology of any spill as soon as it finds out.

Canadian and U.S. scientists also have agreed to coordinate [illegible] plans to share monitoring [illegible] and now notify each other when big new sources of pollutants are proposed within 60 miles of the border.

They may seem like simple, neighborly things to do – but they weren't being done before.

A political barrier

Despite the advances, however, the international boundary remains a significant barrier. "The border may be meaningless for ecological purposes," says Kathy Fletcher, executive director of People for Puget Sound, "but it has incredible meaning for how we might structure solutions."

Washington and B.C. have different political structures and traditions. Canadian environmentalists say they envy the U.S.' tougher [illegible] made. [illegible]

Environmental standards vary. British Columbia's ozone limit is more stringent than Washington's. Two pesticides found in the Abbotsford/Sumas Aquifer were detected in concentrations that violate U.S. drinking water limits. Canada has no standards for those compounds.

"Their aquifer maps stop right at the border," Sumas Mayor Bob Mitchell says of his Canadian neighbors. "Our flood maps stop right at the border.

"No one thinks of anyone else."

But that's beginning to change, says Lynden's Mayor Maas.

"We don't have, like East Berlin, a big wall," he says. "That border is less significant every day."

Vancouver Sun Oct 14, 1992

SYLVAIN SENEZ

: ACTION: Robyn
Ron Stewart

JVER theatregoers get the tonight to see the chief ve officer of a B.C. Crown w some fancy footwork on arallel" love of her life.

chief executive officer at the . of B.C., opens tonight in s Soar at the Waterfront artwright. It runs until Satur-

a legitimate dance com- yn, 37, in an interview over "Because of my lifestyle I itimate dance company. group of professional danc-

choreographer Robyn says cing professionally "most of it I've also had a career in put them together I've had professional dance life.

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good deal on a mountain

rcuse Dance Company had its fourth annual lottery usly disappeared" from he bike was replaced but it count into the red. the bike has generously half the proceeds of the back to the company. The 595. Make them an offer at p the non-profit company

ION

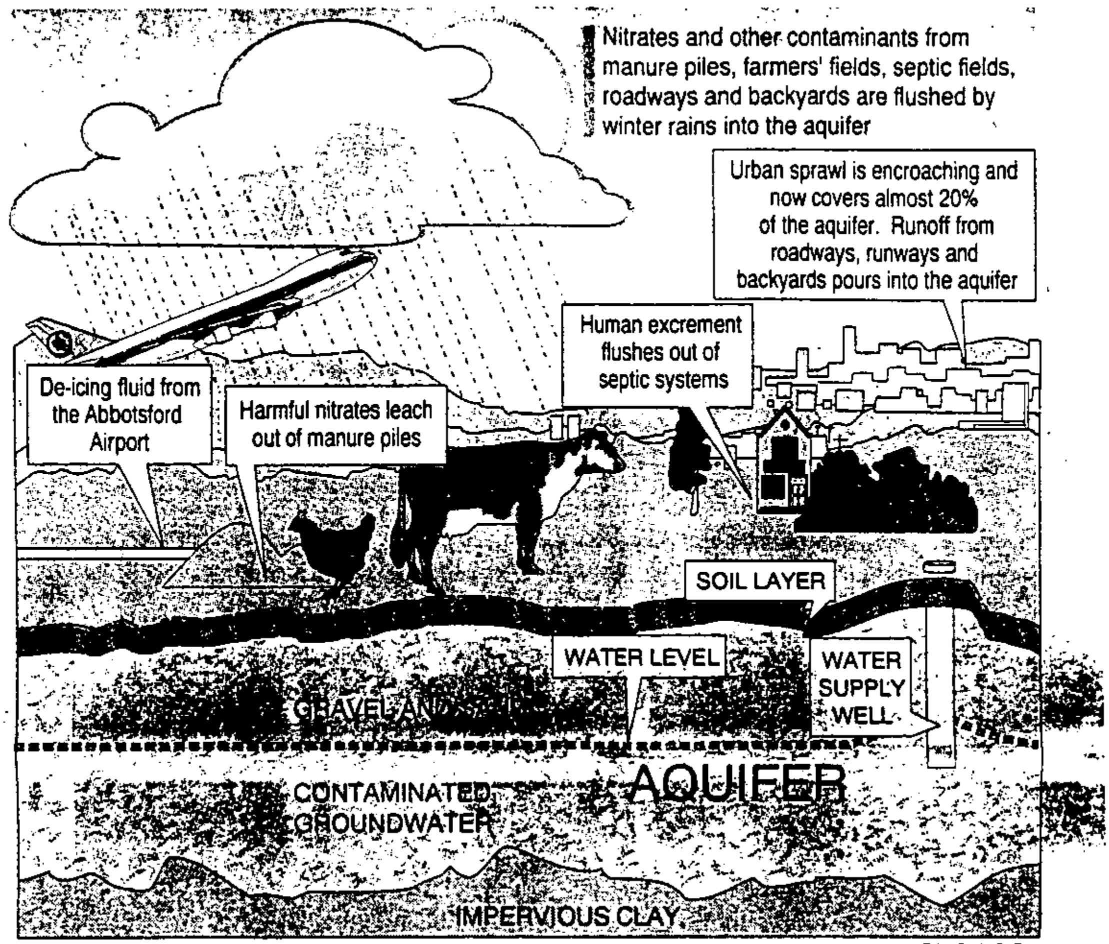
us of Vancouver Commu- lding a 25th anniversary 19 for graduates, past and employers, instructors college's computer infor- program. For more informa- Wuhrer at 324-5489.

ED

3) Vancouver is looking ed and first-time volun-

ow this year will be Eliza- ruited from First Night touch with Elizabeth call 9-9841 or 9842.

By ARCHIBALD ROLLO



DAVID MACLEAN

DRINKING WATER AT RISK

MARGARET MUNRO
Sun Science Reporter

ONE OF THE MOST daunting pollution problems in the Fraser Valley is about to return with the winter rain.

As the water pours down, it picks up pollutants and flushes them straight into the giant Abbotsford aquifer, which provides drinking water for thousands of people in the Fraser Valley and Whatcom county in northern Washington.

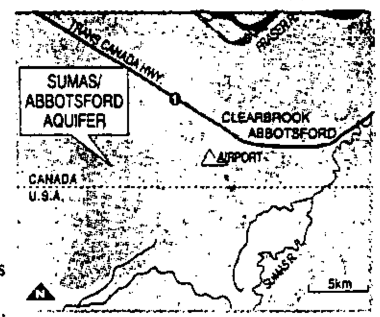
Contaminants from manure piles, farmers' fields, roadways, airport runways and backyards are washing into the aquifer, which scientists say acts like a giant sponge, soaking up water and pollution, particularly during the wet winter months.

While officials stress there is "no immediate concern for human health," there is deep concern about the health of the aquifer and the communities and industries it supplies with water.

"It is a critical concern," says Sheila Bull, who chairs the water committee for the Upper Fraser Valley district government.

Federal, provincial and municipal officials all say the costs could be enormous if the pollution isn't stopped:

- The communities of Abbotsford, Clearbrook and Sumas, and hundreds of farms and industries such as the multi-million-dollar Fraser Valley trout hatchery near Abbotsford, depend on the aquifer for water. Tapping into a new supply would cost hundreds of millions of dollars.
- B.C.'s $220-million-a-year poultry industry, fingered as the main source of pollution, could be forced to trim back operations or pay huge pollution fines if the flow of contaminants isn't checked.
- Canada could find itself embroiled in a costly international dispute with the U.S. because pollution from the Canadian half of the aquifer is flowing south into the American half.



SUN GRAPHICS

"It's a clear violation of the Boundary Waters Treaty," says Dr. Frank James, medical health officer in Whatcom county, pointing to the 1909 Canada-U.S. treaty that states: "Water flowing across the boundary shall not be polluted on either side to the injury of health and property on the other side."

James and his American colleagues freely admit that U.S. communities and farmers are also polluting the aquifer. And they say they are keen to cooperate with Canada on a

Please see WATER, B11

WATER

Continued from B1

cleanup.

But they want positive results. If the pollution does not stop flowing across the border they could start asking for compensation, either financial or in the form of a clean, clear source of drinking water.

"Someplace, we have got to find more water," says Egbert Maas, mayor of the Whatcom county town of Lynden, which is running out of water. The community wants to tap into the aquifer but U.S. health regulations won't allow it: "The water is no good,' says Maas.

The aquifer, a water-saturated bed of gravel and sand that covers a 200-square-kilometre area, straddles the Canada-U.S. border.

Since the sand was deposited in the valley thousands of years ago, it has been regularly recharged with rainwater. In the past few decades, it has also been recharged with pollutants.

Researchers — such as Environment Canada's Hugh Liebscher — who probe the cool, dark aquifer say the problem is that it is an "unconfined" aquifer, meaning there is no impervious layer separating the water from what goes on at the surface.

Chemical evidence of traditional — and sloppy — farming, urban sprawl, improperly designed septic fields, de-icing fluid from the Abbotsford airport are all found in the aquifer's depths.

The aquifer does gradually flush itself, but the process could take decades. And that's if the pollution were to stop tomorrow, which isn't likely.

Luckily for the Canadian communities of Abbotsford and Clearbrook, the water and the pollution in the aquifer flows in a southerly direction.

As a result, the water coming out of household taps in those communities still meets Canadian drinking water guidelines. South of Abbotsford, the pollution is much worse.

A recent Environment Canada study found that 60 per cent of 450 water samples taken from the aquifer had nitrate levels above the recommended level for drinking water. Many wells had nitrate levels several times the recommended level.

material in the manure degrades — a process that makes manure both a good fertilizer and a worrisome pollutant. The Environment Canada report says some farmers in the Abbotsford area have been applying up to twice as much manure as crops can absorb. The excess washes into the aquifer.

To reduce the flow, the provincial government in collaboration with the farming community has introduced a new code of agricultural practice: Manure can no longer be left uncovered on fields during the wet winter months. The code also spells out how much manure can be used to fertilize crops.

Officials are confident the code will reduce the pollution. But they say animal manure is only part of the problem. Human excrement also figures large in the nitrate equation. And health officials say the human contribution will be much harder to eliminate.

There are close to 500 septic fields on farms and homes on the Canadian side of the aquifer. Health inspectors suspect many of them are not treating or digesting the sewage properly, so that nitrates are being flushed into the aquifer.

"It's out of sight, out of mind," says Larry Percival, chief environmental health officer for the Upper Fraser Valley.

"What we need is to find out if the septic fields are failing downwards, which we suspect they are," adds medical health officer Dr. Bud Webb.

Until they can prove it and get regulations in place to control the problem, Percival says little can be done to reduce pollution from existing septic fields.

Then there is the runoff from roadways, runways and backyards that cover 20 per cent of the aquifer. The runoff is considered another major source of pollution.

Al Kohut, acting head of the ground water section for the provincial environment ministry, says "it's extremely critical" to consider the impact on ground water when planning new development. "Until now it's been more or less ignored in B.C.," he says.

Kohut and most of his government associates say they are optimistic the pollution problems in the aquifer can be solved. "Progress is slow," says Kohut. "But things are moving in the right direction."

Some observers are not so sure the aquifer can be saved.

Whatcom county medical health officer Dr. Frank James says cleaning up the aquifer will mean curbing and carefully controlling development and agricultural practices in both Whatcom county and the Fraser Valley.

"It's gonna be things that slow down an economy, there is no question about that," says James. "Things that are not going to be popular in tough economic times."

And if the pollution flowing into the aquifer isn't stopped? "There's going to be hell to pay," says James.

Pesticides with unappetizing names like Carbofuran, Atrazine, Endosulfan and Diazinon were also found in the well water.

The Environment Canada report says most were found in trace amounts well within the "acceptable" level set down by Health and Welfare.

But one pesticide, 1,2-dichloropropane, more commonly referred to as 1,2-DCP, was found at high levels even though it has not been used by Fraser Valley farmers since 1987. The persistent chemical clearly shows just how effective a sponge the aquifer is.

Another report on ground water problems in the Fraser Valley was released by the B.C. health ministry earlier this year. Like the Environment Canada report, it points to serious nitrate pollution problems, which it says is also common in smaller aquifers in the Brookswood and Hopington areas west of Abbotsford.

Both studies make it clear that the excessive nitrate levels have been recorded for years. And little was done to halt the pollution.

Dr. Ray Copes, an environmental health specialist with the health ministry, says the nitrate data was well enough known that action should have been taken years ago.

Another study is about to be added to the pile by the U.S. Geological Survey. It has analysed samples from 625 wells on the Abbotsford-Sumas aquifer, 72 of them in Canada. The study is being done for the Whatcom county communities of Sumas, Lynden, Everson and Nooksack, which all need new sources of drinking water if they are to continue growing.

"The largest growth issue in this area is water," says Lynden Mayor Egbert Maas. He says banks won't give homeowners financing and

Vancouver Sun, Oct. 19, 1993 cont.

B.C. pollution of aquifer travels to U.S.

by Geordie Wilson
Times South bureau

ABBOTSFORD, B.C. – Concerns about pollution slipping across international borders into the United States usually focus on Mexico.

But a Canadian report released Friday shows nitrates and pesticides from farms there have contaminated a shallow aquifer that flows south into Whatcom County.

More than a dozen water systems in the U.S. draw on the aquifer, known as the Abbotsford aquifer in Canada and the Sumas aquifer south of the border.

They supply drinking water to "hundreds, perhaps thousands of individuals," said Dr. Frank James, director of the Whatcom County Department of Health.

Twelve pesticides have been detected in the aquifer. None was found above Canadian drinking-water standards, but levels for three pesticides exceed U.S. standards.

Nitrates in the water exceed both U.S. and Canadian water standards.

James said the Canadian findings are not cause for alarm but should lead to changes in agricultural habits on both sides of the border.

"I don't think there's an immediate threat to anyone's health on this," James said. "What it does, it throws down the gauntlet. It gives notice that we've got to change our practices."

Vic Niemela, regional director of inland waters for Environment Canada, that nation's version of the U.S. Environmental Protection Agency, said the report recommends several minor changes in farming practices.

"One of the things we're looking at," he said, "is better manure handling, also avoiding application during winter time."

Extending from Sumas and Lynden to the Nooksack River, the Abbotsford/Sumas aquifer is shallow and not protected by an impermeable layer such as clay.

The land above the aquifer is farmed intensively for berries and vegetables on the Canadian side, less so on the U.S. side.

There have been few groundwater quality tests of the aquifer on the U.S. side, said Virginia Stern, a hydrogeologist with the state Department of Health. Even so, studies have found high nitrate levels and traces of two pesticides. No pesticides at levels above drinking-water standards have yet been found on the U.S. side of the border.

"The rate at which the contaminants might enter the U.S. we really don't know yet," said Stern.

Nitrate contamination is usually caused by either fertilizers or manure. It can be harmful to infants who drink contaminated water.

Several of the pesticides found in Canada are thought to cause cancer at high levels.

ATCOM COUNTY HEALTH DEPARTMENT

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FRANK E. JAMES, M.D.
Health Officer

FOR IMMEDIATE RELEASE

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Whatcom County Health Officer
676-6720

ABOTTSFORD/SUMAS AQUIFER GROUND WATER STUDY RESULTS RELEASED

Environment Canada has released a report detailing the results of ground water studies conducted on the Abbotsford Aquifer between 1955 and 1990. The report, Nitrate and Pesticide Contamination in the Abbotsford Aquifer, Southwestern British Columbia, documents ground water quality degradation that appears to be related to land-use activities. The Abbotsford Aquifer is a shallow aquifer which straddles the U.S./Canada border in Whatcom County. It is an important source of water for domestic, industrial, agricultural and commercial uses. The U. S. portion of the aquifer is known as the Sumas Aquifer and is bounded by the cities of Sumas and Lynden, and the Nooksack River. The direction of flow is southerly so that water on the Canadian side of the aquifer may cross into Washington State. The Abbotsford/Sumas aquifer is an unconfined aquifer; it has no 'confining' or impermeable layer between it and the surface of the ground and is usually open to infiltration.

Whatcom County, in cooperation with the United States Geological Survey, is nearing completion of a related ground water study. The LENS Ground Water Study takes in the 200 square mile area encompassing the cities of Lynden, Everson, Nooksack, Sumas and extends into the Abbotsford area of British Columbia. As with the Canadian study, results show water quality degradation that appears to be linked to human land-use practices.

Both the Canadian and U.S. studies monitored many wells for nitrate and pesticide concentrations. The results from the Canadian study showed a total of 12 different pesticides detected in ground water on the Canadian side of the aquifer. Three of these pesticides, 1,2 Dichloropropane, Simazine and Atrazine, were detected at concentrations exceeding U.S. Federal Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs). Pesticide monitoring in the LENS study was less extensive showing two of the 21well sampled with detectable pesticides.

Generally widespread nitrate contamination was found in both study areas. The Canadian study found areas with nitrate concentrations three times higher than Washington State Drinking Water Standards. In the South Matsqui area, approximately 60% of the samples exceeded Canadian drinking water standards. The LENS study similarly showed a number of areas with nitrate concentrations exceeding drinking water standards. The source of the nitrates is believed to correlate with land use including agricultural operations, poultry operations and on-site sewage systems. Although land use development on the Canadian side of the border is more intense, many of the same land uses can be found on the Washington side. Elevated nitrates also signal the potential for contamination from other pollutants.

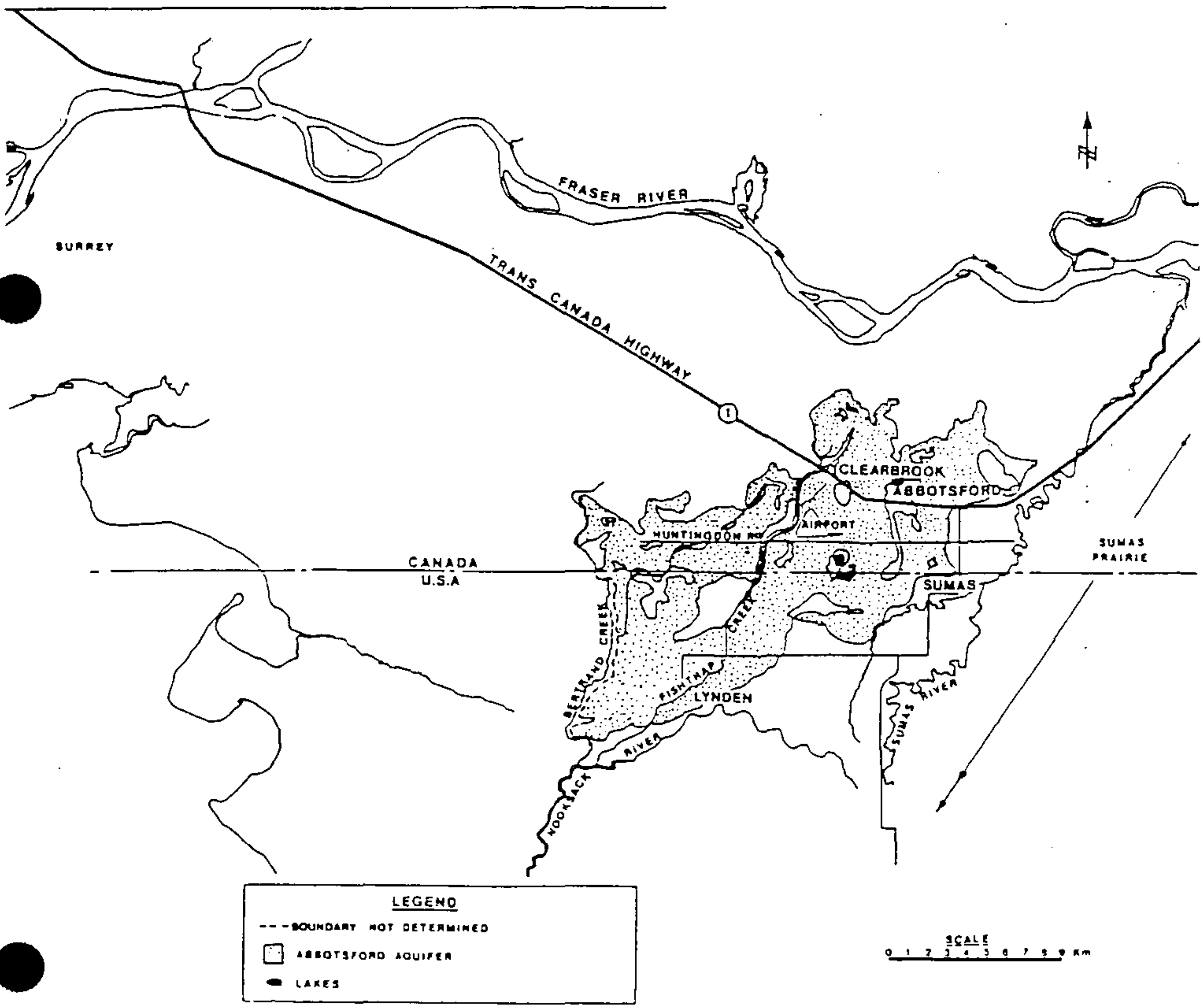
These studies highlight the vulnerability of many ground water based drinking water supplies to contamination. While results do not reveal any imminent health hazards, the ground water quality degradation trends identified, indicate the need to shift to a more pro-active pollution prevention approach to ground water contamination.

The Whatcom County Health Department is working with the Washington State Department of Health and Ecology to evaluate appropriate follow-up activities that can help reduce the current and future problems which these systems may experience. The Health Department also hopes to be working closely with both the state and Canadian Governments to ensure that efforts to control and prevent further degradation of the shared ground water resource are coordinated.

These studies provide an important impetus for local and state agencies in Washington and Canada to work together to develop a pro-active approach towards ground water protection.

It is important that we take the necessary steps to ensure drinking water supplies are protected now and into the future.

ABBOTSFORD AQUIFER - LOCATION MAP



Wells polluted in Abbotsford

By Ann Rees
Staff Reporter

New housing subdivisions are accelerating the contamination of private water supplies in Abbotsford.

Nitrates from septic fields are adding to the pollution caused by the use of manure as fertilizers, says a federal study to be released this week.

The Environment Canada report says nitrate levels in private wells in the Abbotsford aquifer are two to three times allowable limits.

The study did not sample municipal water supplies. Provincial and municipal authorities say their tests show the supply is safe.

Environment Canada hydrologist Hugh Liebscher, who wrote the report called Pesticides and Nitrates in the Abbotsford Aquifer, said it did "suggest that the nitrates are gradually increasing with time due to traditional land-use practices."

"The (nitrates) originated from septic effluent, manure stockpiling and soil enhancement" using high concentrations of poultry manure.

Liebscher refused to give details of his study. But U.S. authorities briefed in Lyoden, Wash., last week said they are concerned.

The aquifer straddles the border, with about 100 square kilometres on each side.

The study found nitrate readings as high as "20 and 30 parts per million," said Whatcom county environmental health specialist Anne Atkeson, who attended the meeting.

The Canadian and U.S. standards are a maximum of 10 parts per million.

"When you look at the dots on the map and take the border line out there's high (nitrate) levels on your side," said Atkeson. "As you go south it looks like it is coming from your direction."

The study also found one pesticide reading in excess of five parts per billion, the new U.S. standard. There is no Canadian standard.

Liebscher said an earlier provincial study identified 12 pesticides in the aquifer.

A group of Fraser Valley residents suffering from mysterious flu-like ailments and muscle weakness have blamed their symptoms on pesticides in the water.

But provincial hydrologist Al Kohut said provincial tests show the municipal wells, which supply most residents, have pesticide and nitrate levels far below the U.S. standard.

He said a provincial study found that about 20 per cent of about 50 private wells sampled had excessive nitrate levels.

Residents with contaminated wells have been warned that high nitrate levels pose a risk to infants under six months of age, who can develop an oxygen deficiency called blue-baby syndrome.

Only two cases have been reported over the past 20 years and both babies survived, said acting regional medical health officer Dr. Roland Guasparini.

Abbotsford health officials who have been briefed on the report failed to return calls.

7044A

Province of British Columbia

Ministry of Health and Ministry Responsible for Seniors

NEWS RELEASE

MINISTRY OF HEALTH, MINISTRY OF ENVIRONMENT, & MINISTRY OF AGRICULTURE

FOR IMMEDIATE RELEASE May 21, 1992
1992:094

FRASER VALLEY GROUNDWATER TESTING EXPANDED -- COMMUNITY ENVIRONMENTAL HEALTH COMMITTEE ESTABLISHED

VICTORIA -- The provincial government will expand its groundwater testing program in the Fraser Valley by adding a significant number of private wells and increasing tests of groundwater sources of public drinking water.

The expanded program, which will cost about $500,000 a year, is in response to the recommendations in a recent study of existing Fraser Valley groundwater quality data funded by the ministries of Health, Environment, and Agriculture that was released today.

"This report gives all three ministries a better overall understanding of the quality of groundwater in the Fraser Valley, and recommends certain measures to respond to this newly-assembled information," said Health Minister Elizabeth Cull.

Cull also announced approval in principle of a pilot project -- a Community Environmental Health Committee structured under the Upper Fraser Valley Union Board of Health in Abbotsford. The committee's role will be to help the local community identify and examine local environmental health issues, and to address public concerns about these issues.

"This new committee will act as a resource for the community -- to identify issues, develop and maintain a database of key environmental factors, and develop appropriate community-supported recommendations for action by all levels of government," said Cull.

The groundwater study collected and correlated existing water quality data provided by a variety of different agencies. It confirms that elevated levels of nitrates are present in several areas of the valley. A few of the samples showed traces of pesticides, although there is no evidence that current levels are above drinking water guidelines or that these levels pose any risk to human health.

... 2

Cull said the expanded water quality monitoring program actually exceeds the recommendations in the survey, which was carried out by the engineering firm Gartner Lee and jointly funded by the three ministries.

Environment Minister John Cashore said that a coordinated, inter-agency groundwater monitoring program will be established to incorporate the findings of the Gartner Lee study, and to evaluate existing and new groundwater quality and land use mapping information as it becomes available through the expanded monitoring program.

"As additional water quality data are received, they will be added to this new data base, which will be managed by my ministry with input from the ministries of Agriculture and Health. As our data base expands, the proposed monitoring program may be adjusted to reflect changes in our base-line information."

Cashore said he will soon be releasing a comprehensive discussion paper on water management, including groundwater regulations. The paper will outline certain basic criteria designed to protect groundwater resources from contamination.

Agriculture Minister Bill Barlee also supported the expanded groundwater monitoring program. He commented on the new Code of Agricultural Practice for Waste Management, developed jointly by the B.C. Federation of Agriculture and technical specialists from both the environment and agriculture ministries.

"This Code of Practice clearly defines agricultural practices which are acceptable, and those which are not," said Barlee. "The new code has been written into regulations under the Waste Management Act, and I encourage farmers to familiarize themselves with the details of the code, and to manage their operations within these guidelines."

The agriculture minister also noted several other industry-supported initiatives including environmental farm audits, grants to assist farm groups with technology transfer for environmentally sound waste management practices, and research and development of integrated pest management technologies to reduce the use of chemicals in crop production.

-30-

For further information, contact:
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Province of
British Columbia

NEWS RELEASE

Ministry of Environment, Lands and Parks
Ministry of Agriculture, Fisheries and Food

For Immediate Release

1992:ELP65

April 29, 1992

NEW ENVIRONMENTAL GUIDELINES FOR FARMERS

VICTORIA — A new Code of Agricultural Practice for Waste Management has been incorporated into a regulation under the provincial Waste Management Act, Environment Minister John Cashore and Agriculture Minister Bill Barlee announced today. The code was developed after three years of consultation between government and more than 17 farm groups.

"The regulation provides the environment ministry with controls over agricultural waste for the first time," said Cashore. "It has the full support of farming organizations, and it provides government with a tool to enforce the reduction of air, soil, surface and groundwater pollution resulting from agricultural waste."

"Developing and adopting this code simply would not have been possible without the excellent cooperation of the B.C. Federation of Agriculture, their membership and government specialists," said Barlee.

The new regulations govern the storage and spreading of manure, disposal of dead animals, exhaust from building ventilation systems, and the proximity of agricultural operations and livestock feeding areas to watercourses.

Actions under the new regulation will be coordinated by the Agricultural Environmental Protection Council, which includes representatives from the B.C. Federation of Agriculture, the Ministry of Environment, Lands and Parks, and the Ministry of Agriculture, Fisheries and Food.

The council will oversee 150 volunteer farm inspectors trained to investigate and resolve complaints at the farm level. Farmers who do not comply with the regulation could face fines.

(more)

The code will have a major impact on improving both ground and surface water quality in many areas of the province affected by intensive agricultural operations. (eg. groundwater in the Lower Fraser Valley)

"The onus will be first on the agriculture industry to enforce the code of practice among their peers," said Barlee. "Only if that process fails will the regulatory force of the Waste Management Act be brought into effect."

Copies of the Code of Agricultural Practice for Waste Management have been distributed to local governments and farm organizations. Copies are also available from the Ministry of Agriculture, Fisheries and Food's district offices and the Ministry of Environment, Lands and Parks regional offices.

- 30 -

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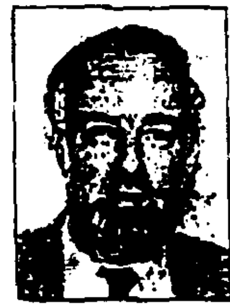
Groundwater Contamination from Agricultural Sources in the Lower Fraser Valley, BC

R Allan Dakin PEng



Citizen groups in the Lower Fraser Valley have recently expressed concern that construction of a proposed underground gas storage facility may cause contamination of their groundwater supplies. Ironically, in the opinion of many experts presenting evidence at recent commission hearings (Anderson 1990), the possibility of contamination from this proposed activity is very remote, and certainly much less so than little publicized contamination of groundwater which has resulted from ongoing agricultural practices utilized by local farmers. Principal agricultural sources of this contamination are animal wastes, which have either been stockpiled or spread on land, and pesticides.

The Environment Committee of the Association of Professional Engineers and Geoscientists of British Columbia have been aware of these problems for many years, and have submitted two briefs to former BC Ministers of Environment. These statements, are entitled "Pollution from Agricultural Resource" and "Preservation of Groundwater Quality", and were submitted in 1981 and 1985, respectively. Very few of the many recommendations contained in these briefs have been instituted, and the problems cited are becoming more apparent.

Background

Groundwater contamination, particularly high nitrate and pesticide concentrations resulting from agricultural activities, is widespread in the USA (Bouwer, 1990) and Europe (Vrba, 1985). This form of contamination has recently been the subject of extensive surveys in many countries, but only limited studies have been carried out in Canada.

Not so much as a decade ago, it was generally believed that pesticides (including insecticides, herbicides, fungicides, nematicides, etc) would not move from the ground surface down to the water table. In recent years, it has been found that significant quantities of pesticides are moving down into the aquifers, and that ingestion of many of these pesticides will cause significant health problems, such as cancer, nervous system disorders and birth defects.

If applied in the correct quantities for a particular soil, crop and climate, animal waste (manure) is a valuable source of nitrogen for crops. These wastes will also help condition (ie build up the organic content) the soil. However, if applied in excessive quantities, the ammonia nitrogen (NH_3) in the waste will dissolve in the percolating rainwater, forming principally ammonium ion (NH_4^+), which could migrate beyond the crop root zone, where some of it is converted to the nitrate nitrogen form (see Fig 1). Once in the nitrate ion form, it is not so readily absorbed to soil particles and can migrate down to the groundwater table.

The safe limit for nitrate in drinking water has been set at 10 mg/L, when expressed as nitrogen. This limit is based on the knowledge that concentrations in excess of this value could result in infantile methemoglobinemia, a condition where the oxygen carrying capacity of the blood is reduced and, in extreme cases, has been known to cause death.

In the United States, extensive surveys of groundwater quality have been carried out and having found extensive areas with elevated nitrate concentrations and pesticide residues, changes to regulations and farming practices are being instituted (Jones and Bostian, 1989 and Bouwer, 1990).

Groundwater in the Fraser Valley

Water bearing sediments (aquifers) are an important source of water in the rural areas of the Fraser Valley. The sediments that were deposited in the Lower Fraser Valley during the period following the last ice advance include many areally extensive and permeable zones, which have proven to be productive aquifers (Halstead 1986).

Today, there are in excess of 10,000 water wells in the region and the estimated total groundwater extraction in 1987 was 46 million cubic metres (Piteau Associates, 1990). This usage can be broken down into municipal (33.3%), domestic wells in rural areas (17.2%), industrial (3.5%), aquaculture (31.4%) and irrigation (9.9%). Municipalities using significant quantities of groundwater include the District of Chilliwack, Town of Hope, Corporation of the Township of Langley, and City of White Rock.

Since precipitation is the principal source of recharge to these aquifers, and as much of this water must first pass through agricultural soil zones, the nature and amount of residual chemicals present in these zones affect the quality of groundwater below. If the soil zone is contaminated at the time that the rain infiltrates (late fall and winter), and if the soil does not have sufficient capacity to absorb or allow time for natural degradations of nitrogen and pesticides, then aquifer contamination will result.

Nitrogen Contamination in the Valley

Groundwater quality information for the Lower Fraser Valley area is very limited, particularly for dissolved organics, such as pesticide residues. Nitrate concentrations exceeding 10 mg/L have been identified in extensive areas of the Abbotsford Aquifer (Kwong, 1986; see illustration in Fig 2) and the Brookswood Aquifer (Piteau Associates, 1983). These studies have determined that the principal source of the nitrogen is land spreading of animal wastes, followed by leaching from manure piles and septic tanks.

Joint studies carried out by the BC Ministries of

Health, Environment and Agriculture have examined the impacts of animal wastes produced from poultry, pork, mink, beef and dairy farming. They determined that wastes generated by dairy farms are generally spread over a wide area, and do not result in significant contamination. The same applies for beef production, unless the animals are concentrated in large feed lots. Most other farming operations have small land holdings and are set up to raise a large number of animals or birds in confined space, akin to factory production, and hence there is little room for disposal of the wastes on the same property.

At present, there are only a limited number of horticultural and vegetable farmers in the Lower Fraser Valley, whose management practices include scientifically based use of the available animal manures. Consequently, animal wastes are often treated as "a waste to be disposed of" rather than as a resource for crop production. Thus, in this situation, the waste disposal contractors have a strong incentive to over-apply the wastes on the nearest available land, at a time of year that is most convenient for the producer, rather than to apply it in proper manner at the environmentally correct time of the year.

Since March 1988, the BC Environment has been carrying out studies of groundwater at three sites (identified as A, B and C, on Fig 2). This work has involved installation of three nests of monitoring tubes (piezometers) set at depths of 3, 11, 17 and 23 metres below ground, and on-going monitoring of water quality and hydrodynamics of the aquifer. Water quality analyses have included major cations and anions, all forms of nitrogen, phosphorous and heavy metals. In addition, analyses of relative concentrations of the nitrogen isotope (^{15}N) vs the common ^{14}N isotope were conducted to assist with assessing the significance of sources of nitrogen found in the groundwater. Preliminary results (Kohut et al, 1989) have confirmed that the nitrate in the area is primarily derived from nitrogen in poultry manure that has been spread on the sandy soils overlying the aquifer. These wastes have been primarily applied to condition the soil in the area, rather than for its nutrient value.

These studies have been greatly enhanced by parallel studies being carried out by Environment Canada and authorities in Washington State, who are working on trans-boundary issues. They have determined that while the nitrate contamination is areally extensive, it is currently restricted to the shallower portions of the aquifer, on both sides of the Canada/USA border. Of the domestic wells surveyed in the Canadian portion of the survey area, 60% had nitrate concentrations in excess of 10 mg/L and 20% exceeded 20 mg/L.

The problem of nitrogen contamination has been known for a number of years, and the BC Government agencies are working with the industries involved to make them aware of the problems, to help them develop proper farming practices and to encourage self policing.

The existing regulations under the BC Waste Management Act provide for exemptions from discharges of certain "plant and animal wastes emanating from traditional farming operations which are managed and applied in a *reasonable* manner . . .". However, as this regulation lacked detail as to what was *reasonable*, the

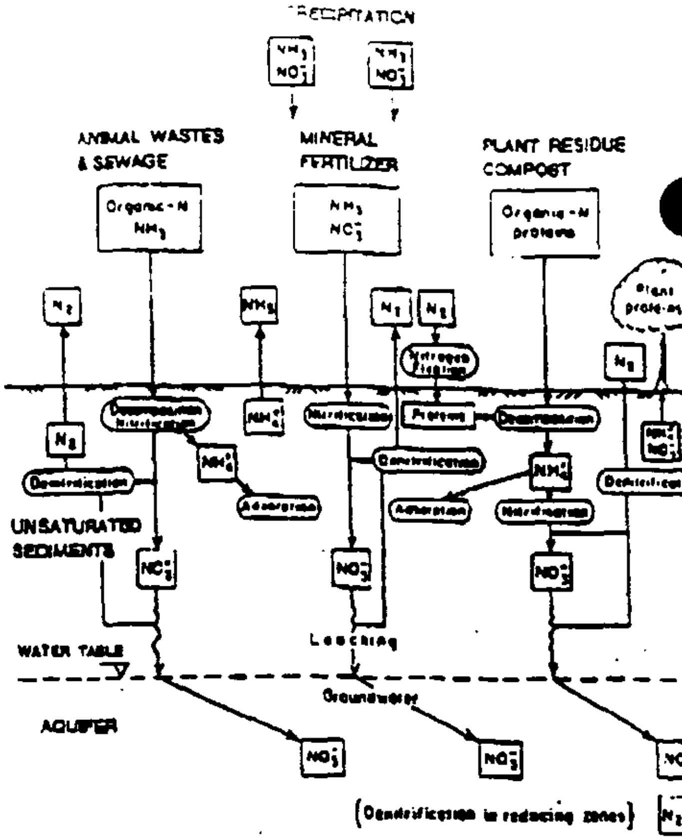


Figure 1. Nitrogen sources and pathways in the subsurface environment.

Agricultural Waste Control Regulation has recently been redrafted, in consultation with the industries involved (latest draft, June 1991). These revi provide a more precise definition of "agricul operation" and refers to a "Code". Under this regulation, "a person who carried out an agricultural operation in accordance with the Code is exempt from the requirement of holding a (waste discharge) permit or approval under the Act . . .". The Agricultural Code of Practice (the Code) sets out procedures to be followed for storage, land spreading and composting of the wastes and disposal of mortalities.

The code approach is in complete contrast to other regulations under the same Act, such as those dealing with industrial wastes and contaminated soils, where reliance is placed on the risk assessment approach. For example, in the draft code, it states that application of wastes should not be applied to the land if ". . . escape of agricultural wastes causes contamination of a water course or groundwater". However, as there is no specific requirement for monitoring of the receiving waters, it is not clear to the writer how compliance with the code, and hence the regulations, can be confirmed. In contrast, the Regional Managers of the Waste Management Branches have consistently required that solid waste (landfill) and sewage effluent discharge operations collect surface and groundwater monitoring data to prove that contamination is not occurring.

It is recognized that as agricultural waste disposal operations in the Valley are wide spread and disposal operations are intermittent, direct compli monitoring will be difficult. However, having worked on numerous groundwater projects in the Valley, the writer is convinced that it is essential that risk assess-

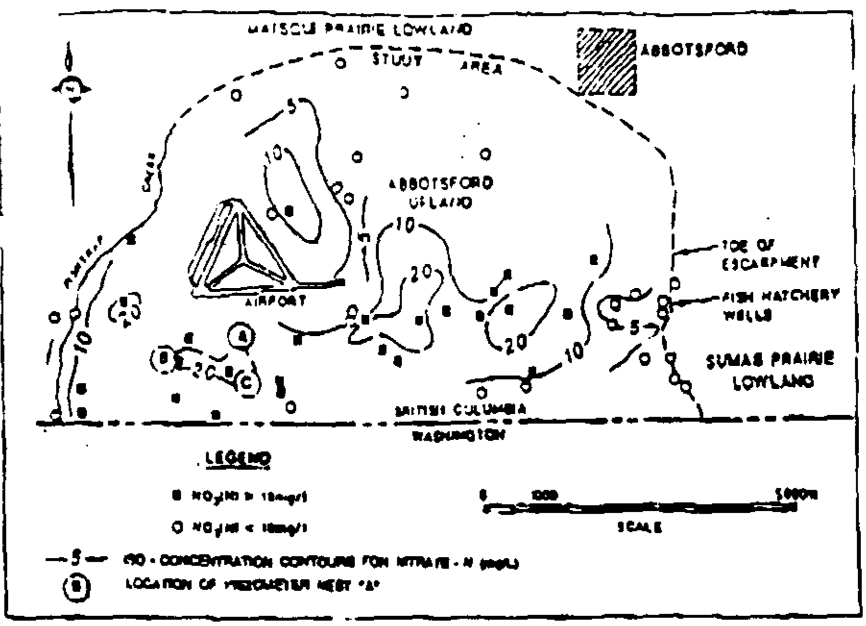


Figure 2. Distribution of nitrate-nitrogen in groundwater sampled from domestic wells in the Abbotsford aquifer (after Kwong, 1986).

ments be carried out to delineate the most vulnerable areas and that, as a minimum, a systematic regional monitoring program should be implemented. This could take the form of information gathering, prioritizing the risks, providing maps showing vulnerable areas, producing summary reports and information pamphlets, and designing a scientifically appropriate water quality monitoring plan for the region.

In the Groundwater Quality Brief (APEBC, 1985) a number of recommendations were outlined, including evaluating groundwater flow systems and providing publications and maps showing the extent of the aquifers, sources and nature of contaminants reaching the water table. Also recommended were the establishment of information data bases and provision of legislation to help with management of the groundwater resources of the Province.

Pesticides

As well as the above-mentioned nitrate studies, Environment Canada, the National Research Institute and Agriculture Canada have (since 1984) been carrying out evaluations of the distribution of a number of pesticides in the Abbotsford Aquifer. The current focus is on DCP (1,2 and 1.3 dichloropropanes), as these toxic compounds are commonly used in the area and have been found in unacceptably high concentrations (exceeding recommended US Environmental Protection Agency safe drinking limit) in the Abbotsford Aquifer.

Many uninformed operators apparently mix pesticide solutions in areas close to the well head, and allow spilled pesticide to seep back into the well, causing contamination of the aquifer. In some areas, pesticides are over applied or sprayed before a heavy rainfall event. As with the nitrate problem, there is a need to promote safe operating practices to delineate vulnerable areas and for selective monitoring of compliance.

CONCLUSION

1. The groundwater resource of the Fraser Valley is very valuable and every effort should be made to ensure that its availability and quality are preserved.

2. Poorly controlled application of animal wastes and pesticides onto agricultural land is causing a buildup of nitrate concentrations and pesticide residues in Lower Fraser Valley aquifers in both British Columbia and neighbouring Washington State. If not corrected soon, extensive areas will be without a safe drinking water source.

3. Promoting better farming practices is an essential first step, but more extensive evaluations of the extent of the problem and establishment of a systematic water quality monitoring plan are also needed. These would be easier to implement if the recommendations set out in the Association's briefs were implemented by the BC Government.

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Mr Dakin joined Piteau Associates in 1979 and is now head of the Groundwater Division and a company Vice-President. His area of specialization is in groundwater engineering and hydrogeology. He graduated from the University of Canterbury with a Bachelor of Engineering (Civil) in 1965 and received his Master of Science (Earth Science) from the University of Waterloo in 1975. During the past twenty one years, Mr Dakin has coordinated over 150 groundwater projects in Canada and other parts of the world. Mr Dakin is also a member of the Association's Environment Committee. O

WHATCOM COUNTY

LANNING DEPARTMENT
401 Grand Avenue
Bellingham, Washington 98225

Scan: 769-6756 *Fax: 676-7727*
206/676-6756 *206/398-1310*

PRESS RELEASE

RELEASED TO:	Bellingham Herald, Lynden Tribune and Westside Record Journal
DATE OF RELEASE:	May 25, 1990
ADDITIONAL INFORMATION:	Diane Harper, Senior Planner or Dan Taylor, Director
PHOTOGRAPHS:	Technicians in the field photographs are available by calling Sue Kale at 734-4732 or Stephen Cox at (206) 593-6510.

GROUNDWATER STUDY BEGINS

A groundwater study of central Whatcom County has begun according to County Executive Shirley Van Zanten. Over the next 2 1/2 years the area between the Nooksack River and Canada from Sumas Mountain west to Markworth Road will be studied by the United States Geological Survey (USGS) in cooperation with the cities of Lynden, Everson, Sumas, and Nooksack. The western boundary of the study meets the boundary of the Blaine groundwater study so that the entire Canadian border west of the mountains is included.

Executive Van Zanten said that "We very much appreciate the efforts of the cities of Lynden, Everson, and Sumas who initiated interest in a groundwater study. The County is pleased to have been able to obtain a State Centennial Clean Water Fund grant through the Department of Ecology and also to have the USGS provide federal matching funds for the project. As growth continues throughout the county, we will need to know much more about our sources of water than we have in the past. This study for the first time will allow us to plan future water supplies based upon solid information about our groundwater."

Within the study area a number of groundwater problems have been found, including nitrates, chlorides (or salt water), and recently organic pesticides such as EDB. About 15% of the total county population lives in this area, including about 7300 people within the four cities. One third of these currently use Nooksack River water provided by the City of Lynden, and the rest rely on groundwater. However, the City of Lynden has been looking for a source of water other than the Nooksack River for about 40 years.

Mayor Maas of Lynden said "Whenever I talk to people about the problems of growth, I emphasize that one of the major problems we have is water supply. The north Whatcom County groundwater study is being conducted at this time, and addresses this factor. In order to make the study as effective as possible, we encourage everyone who is contacted to cooperate fully with representatives of USGS."

The Mayors and the County Executive request that well owners cooperate with the study, which needs information on location, altitude, construction, use, and water level on over 600 wells in this area. USGS staff is currently contacting residents of the area for permission to measure their wells. About 90 of the wells will be revisited later in 1990 for further tests.

Chuck Swift, the Acting Chief of the Water Resources Division, Pacific Northwest District of the USGS, said that their approach will be to describe or map the extent of water bearing deposits, determine areas of groundwater recharge and discharge, and determine the direction of groundwater movement. He added that "the 200 square mile study area includes about 30 square miles in Canada where groundwater is believed to flow southward across the border into the United States." The USGS will interpret the data obtained this summer during 1991, and a final report reviewed by many groundwater professionals will be available in mid-1992.

The County and Cities will be reviewing this information with all concerned water users, and will have several local committees advising the USGS. The total study cost is about $570,000, with Lynden providing $60,000, Everson $15,000, the State Centennial Clean Water Fund $210,000, the County providing $37,000 of staff time, and USGS providing $240,000 in staff time through a federal matching program for state and local funds.

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APPENDIX E

INTER-AGENCY GROUNDWATER COMMITTEE File: 101-1-IAGC

Monday - February 3, 1992 - 9:30 a.m.
Bakerview Room Abbotsford Health Unit

AGENDA

A. Acceptance of Minutes of Meeting January 13, 1992

B. Approval of Agenda

C. Discussion with visitors

- Bayne Vance, Regional Pesticide Manager, MoELP
- Madeline Waring - Pesticides, MoAFF
- K. Ashley - Fisheries Branch, MoELP

D. Business Arising

1. Confirm Terms of Reference
   - Chris Pharo or Hugh Liebscher — Dr. Webb
2. Public Information Campaign
   - Latest Developments — Dr. Webb/ R. Bertrand
   - Community Environmental Health Public Policy Committee — Dr. Webb
   - Next Step
3.
4.

E. New Business

1. Activities the Committee should be monitoring
   - Groundwater Study
   - Septic Tank Effluent Study
2.
3.

F. Next Meeting

INTER AGENCY GROUNDWATER COMMITTEE

Minutes of a meeting held on February 3, 1992 at the Upper Fraser Valley Health Unit at 9:00 a.m.

<u>Present</u>: Chairman: Dr. M.L. Webb

Members:	Al Kohut	Guests:	Robert Adams
	Ron Bertrand		Madeline Waring
	Robin Busch		Ken Ashley
	Craig Maple		Don Larson
Regrets:	Chris Pharo		
	Larry Percival		

1. <u>ORDER OF BUSINESS</u>

Previous minutes approved.

Craig Maple of Whatcom County updated the committee on events happening south of the border.

1) two more lists of EDB and 1,2 DCP have been found in Bertrand Creek area. Two dogs have passed away, however, it is unclear if the deaths are due to drinking the water or not. Bodies have been sent to lab.

2) Craig is visiting his health offical, Dr. David Jennings, who is quite interested in the work of the committee.

3) another public meeting is scheduled with geology surveyors and the general public. This meeting will discuss aquifer contamination.

4) Steve Cox's report will be released on March 1, 1992. 15-20 different pesticides were sampled for in 10-15% of 600 wells.

Committees guests were updated on the history of the I.A.G.C.

Madeline Waring discussed procedure of obtaining approval of a pesticide: Approval of pesticides must go thorough Agricultural Canada, Environment Canada, Fisheries Department, and Health and Welfare Canada. Once advisors have looked at the data then a meeting is held if the approval is given and gives the regisitration number with guidelines of usage.

.../2

1) Specialists in the Ministry of Environment review produce guides and pesticide commonly involved and give most effective pesticide to use.

2) Health & Welfare monitors for pesticide residues on domestic and imported foods - (spot checks only) 5% of samples have detectable limit. Samples are taken as soon after harvesting as possible. It is felt that due to the cost of pesticides and spot checks, the farmers are motivated to use the recommended amounts.

3) Ag Canada involved in border crossing control. Nothing in states is allowed in Canada unless PCP # given by Canada is available.

Invitation to Ag Canada will be extended to join our next meeting. Else Rupner is contact. Madeline will get # for Dr. Webb.

Barry Morgan is also a contact with Health and Welfare regarding pesticides in food.

Pesticide problems can occur:

- at the well head when mixing pesticides
- when pesticides are applied through an irrigation system
- through arial spraying - concerned with winds causing drifts and that there could be plane crashes causing spills.
- the only requirement is that pilot must be certified for pesticide application and know hazards of various pesticides, (not especially trained for arial application.)

The company that flies airplanes must have license issued by Ministry - can have license invoked or impose conditions.

ie. 1) inform ministry 24 hours in advance
2) distances from schools
3) time restrictions

Home Study Package has been implemented:

- A two day course is recommended but not mandatory prior to a three hour exam

64 - 74% results gives a one year

75+ results gives a five year certificate

.../3

It was felt that the committee could help best by compiling a list of pesticides used in the area. Then the pesticides could be reviewed and information give.

For example:

1,2 DCP is a nematicide with a 1\2 life of 150-300 days in the soil; life is unknown in water.

1,3 DCP is also a nematicide - it is rapidly broken down

1.2 DCP has not been registered since 1985 but once the registration is cancelled the supply can be used up.

Use of 1.2 DCP was cancelled in 1990.

Fisheries expressed concern for rising levels of nitrates and possible pesticide. Exchange of data will take place.

2. NEW BUSINESS ARISING

Public Information Campaign

Public relations people in Victoria have decided that health will be in the lead.

Package has been expanded with a few changes. Victoria wants to make it a community project. The Union Board of Health is interested in working on this forum and will be hiring a process person to put together a forum for the public.

Environmental Health Local Policies to come from Union Board of Health.

Next Meeting:

February 24, 1992
Monday - at 9:30 am

RB/fps

INTER-AGENCY GROUNDWATER COMMITTEE

Monday, February 24, 1992, 9:30 a.m.
Bakerview Room Abbotsford Health Unit

AGENDA

A. Acceptance of Minutes of Meeting February 3, 1992

B. Approval of Agenda

C. Discussion with Visitors

- Pesticide Residues in Food - Bert Lukey, NH&W

D. Business Arising

1. Public Information Campaign
   - Latest Developments
   - Community Environmental Health Public Policy Committee

2.

3.

E. New Business

1. Response to Lipsey Statements

2. Mathias Report Recommendations *final copy due 2.25.92*

3. What Pesticides should we be Testing for in Water

4. Activities the Committee should be Monitoring
   - Groundwater Study *- LENS, MOE, Hughes Study*
   - Septic Tank Effluent Study *- may get funded yet*
   - *Code of Practice*
   -

5.

6.

F. Next Meeting

RECEIVED

MAR 10 1992

Whatcom Co. Planning Dept.

FILE NO. 153-1

INTER AGENCY GROUNDWATER COMMITTEE

Minutes of a meeting held on February 24, 1992 at the Upper Fraser Valley Health Unit at 9:00 a.m.

Present: Chairman: Dr. M.L. Webb

Members: Al Kohut
Ron Bertrand
Craig Maple
Robin Busch
Larry Percival

Guest: Bert Lukey

Regrets: Chris Pharo
Hugh Liebscher

A. **Minutes reviewed**, two changes to the previous minutes:

i) page 2 #1) should read:
"Specialist within the Ministry of Agri Food & Fisheries review production guidelines and assess which would be the most effective pesticide to use."

ii) page 2 - Point of information. The home study package is a separate issue from aerial spraying. Addition - The home study package is available to all farmers.

Minutes were accepted.

B. **Agenda was approved.**

C. Mr. Bert Lukey from Health and Welfare was introduced. **Discussion on pesticides in food** ensued.

Mr. Lukey stated 34 food products are sampled - mostly berries. Only 8 have been in excess of limits, however, some of those in excess were found to be illegal for use in Canada or for that product.

Therefore, even a low level is unacceptable, ie berry samples - captan, permethrin, vendozolin. Captan is the only one with potential hazard. Vendozolin is only allowed in the U.S.A. just because the company has not chosen to register their product in Canada does not mean it is unsafe, therefore, any detection is in excess even if it is well below the standards set forth in the states.

Mr. Lukey pointed out that the sampling is biased as the inspectors return to farms which have had trouble in the past.

It would appear that the excessive levels found are still very close to the acceptable limit.

If food is found above the limits, it would depend on the circumstances as to whether the product is removed from the market (usually not). Return inspections and additional samples would then be carried out.

Imported foods have fairly strict controls. Health and Welfare are advising people of potential risks and hazards.

Bert Lukey offered their assistance for some sampling if it was required. Mrs. Lukey will also forward the computer list analysis of pesticides in food to Dr. Webb.

D. **Business Arising**

Minister of Health is planning to come meet with the mayors in Upper Fraser Valley Health Unit and possibly the mayors of Lynden and Everett, Washington. From this meeting, a committee would be formed that would work on the public information campaign. A locally based communications person will be hired to make this campaign happen.

E. **New Business**

i) Response to Dr. Lipsey's Statements
Dr. Lipsey has made unfounded incorrect statements. A transcript is being compiled to review at which time all his misleading comments will be addressed.

ii) Dr. Mathias' Report Recommendation
A review of the report done by Dr. Rick Mathias was discussed to bring committee members up to date with this issue.

iii) What Pesticides Should we be Testing for in Water?

Madeline Waring, Craig Maple, Environment Canada, and Agriculture Canada will be approached to supply a list of pesticides which are of potential risk to the ground water or which have been found in the ground water. Dealers of pesticides should also be contacted in an attempt to determine volumes used.

iv) a) Water Quality Study for the Eastern Fraser Valley is in the process. A data base is being compiled by Gartner Lee. The final report is due before the end of the fiscal year.

b) Septic Effluent Study is presently on hold, however, noises from Ottawa are beginning to set the project in motion.

Other studies of interest regarding Nitrates and Pesticides

Lynden, Everett, Nooksack Study of Groundwater Quality, Environment, Agriculture Canada, and the National Hydrolocic Research Institute, Ministry of Environment Land and Parks

It was recommended that this committee monitor the status of the proposed Code of Practice in addition to the Waste Management Act.

Meeting adjourned at 11:55

Next meeting's date not determined yet.

RB/fps

INTER AGENCY GROUNDWATER COMMITTEE MEETING
MINUTES
May 12, 1992 at 2:00 p.m.
2881 Garden Street, Matsqui

Present: Dr. M.L. Webb, Chairman
Al Kohut, Member
Chris Pharo, Member
Larry Percival, Member (minutes)

Regrets: Robin Busch
Ron Bertrand

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1. **Business Arising**

- Transcript of Dr. Lipsey's allegations will be distributed to all committee members for comment.
- Minutes reviewed - last paragraph referring to the Code of Good Practice requires clarifying. Refer to Ron Bertrand.
- Minutes accepted.

2. **Approval of Agenda** - approved.

3. **Gartner-Lee Groundwater Report**

a) 1-2 and 1-3 DCP - Washington State has set standards.
- EPA has set a health advisory standard

Conclusion #4 in Gartner-Lee report is technically correct.

b) Recommendation 11 - "basic chemistry parameters" is usually the DW3 package which includes general ions.
- copy will be provided

c) Pg. 32 - "database should be updated annually - recommend this be updated on a continual basis.

d) Pg. 32 - Water Check Program - Ministry of Environment has no control over homeowner completing sampling location accurately ie. may list mailing address rather than sample location on requisition.

e) #2 remove word "appropriate" from first sentence.

f) G.W. Monitoring Proposal (confidential)
- costs have been reduced by 25% based on cost savings in the tendering process
- primary and secondary testing networks described
- Municipal mayors and engineers are invited to attend an information meeting scheduled for June 2, 1992 at 11:30 a.m. at Kings Crossing. The report will be presented and discussed along with the G.W. Monitoring Proposal.

Basically complete - AI monitors GW levels at quite a few sites

4. **Environment Canada Groundwater Report**
- has been circulated internally and should be ready for external review by May 15, 1992. Public release one month later.
- proposed green plan (Robin Busch proposal for sewage contamination transfer) was cancelled last year but the proposal has been resubmitted. May be reactivated in future.

5. **Environmental Health Community Action Proposal**
- approved in principle
- community driven proposal steered by the Union Board of Health
- prepare a comprehensive survey of environmental health of the community

- four steps
  a) create Environmental Health Steering Committee
  b) develop plan
  c) develop database
  d) develop task force function

- Environmental Health Community Advisory Committee to be created, then:
  - Local Action Committees to be created
  - Environmental Health Technical Advisory Committee to be created (farmers, government, etc.)

Motion Approved - I.A.G.C. will be Environmental Tech. Advisory Committee report to Community Advisory Committee.

- cost of program approximately $250,000.00
  - coordinator required

- time frame is probably 2 years

6. **Whatcom County Groundwater report**
- unknown status

7. **Dog Deaths - Whatcom County**
- unknown status

8. **Lists of pesticides and chemicals for groundwater testing**
- Barry Willoughby/Larry Percival working on

9. **Pesticide residues in food**
- Ron Bertrand may be able to provide more info

.../3

provincial govt. release prior to public

10. Velma Street Cluster

- investigation into concern of cancer cases in Velma Street residents
- Dr's Mathias/Archibald reviewed data
- public meeting was held to present results

11. S.C.I.D.S. (Fraser Illness Syndrome)

- looking at providing support for these individuals

Sweeney has questionable credibility
concern w/ people getting adequate treatment
[illegible] wanted to set up big clinic to treat people

Meeting Adjourned at 4:10 p.m.
Next Meeting - June 8, 1992 at 9:30 a.m. - Abbotsford Health Unit

moving away from Fraser Valley as the only geographical location (perhaps a wellness clinic) - tentatively at UBC or Vancouver general

LRP/jmn
92.05.20

Parameter	Lab Detection Limits	Canadian Drinking Water Quality Guidelines 1989 Health related	Aesthetic related	Price
community systems		mg/L	mg/L	
Physical Tests				
pH	0.1 pH units	-	6.5 - 8.5	
Specific Conductance	1 us/cm	-	-	
Colour	5 TCU	-	≤ 15	
Turbidity	0.1 NTU	1	≤ 5	
Solids, Total Dissolved	10 mg/L	-	≤ 500	
Hardness	0.2 mg/L	-		
Anions				
Alkalinity	0.5 mg/L	-	-	
Chloride	0.5 mg/L	-	≤ 250	
Fluoride	0.1 mg/L	1.5	-	
Nitrogen, NO2+NO3	0.02 mg/L	10.0	-	
Nitrogen, Nitrate (NO3-N)	0.02 mg/L	10.0	-	
Nitrogen, Nitrite (NO2-N)	0.005 mg/L	1.0	-	
Sulfate	1 mg/L	500	≤ 150	
Metals				
Aluminum	0.02 mg/L	-	-	
Antimony	0.015 mg/L	-	-	
Arsenic	0.04 mg/L	0.05	-	
Barium	0.001 mg/L	1	-	
Beryllium	0.001 mg/L	-	-	
Bismuth	0.02 mg/L	-	-	
Boron	0.008 mg/L	5	-	
Cadmium	0.002 mg/L	0.005	-	
Calcium	0.01 mg/L	-	-	
Chromium	0.002 mg/L	0.05	-	
Cobalt	0.003 mg/L	-	-	
Copper	0.001 mg/L	-	≤ 1.0	
Iron	0.003 mg/L	-	≤ 0.3	
Lead	0.001 mg/L	0.01	-	
Magnesium	0.02 mg/L	-	-	
Manganese	0.002 mg/L	-	≤ 0.05	
Molybdenum	0.004 mg/L	-	-	
Nickel	0.008 mg/L	-	-	
Phosphorus	0.4 mg/L	-	-	
Potassium	0.4 mg/L	-	-	
Selenium	0.03 mg/L	0.01	-	
Silicon	0.03 mg/L	-	-	
Sodium	0.01 mg/L	-	≤ 200	
Silver	0.01 mg/L	-	-	
Strontium	0.001 mg/L	-	-	
Sulfur	0.03 mg/L	-	-	
Tellerium	0.02 mg/L	-	-	
Thallium	0.003 mg/L	-	-	
Tin	0.015 mg/L	-	-	
Titanium	0.003 mg/L	-	-	
Vanadium	0.003 mg/L	-	-	
Zinc	0.002 mg/L	-	≤ 5.0	
Zirconium	0.003 mg/L	-	-	
Microbiology				
Coliform, Total	< 2.0 CFU	not detected (< 2.0)		
Package Price 1992				**$187.28**
Package Price Without Coliforms				**$161.80**

+ pesticides

Union Board of Health, - policies only associated w/ Health.
- members defined but can change

INTER AGENCY GROUNDWATER COMMITTEE MEETING
MINUTES
June 8, 1992 at 9:30 a.m.
Abbotsford Health Unit

Present: Dr. M.L. Webb, MHO (Chairman)
Al Kohut, BC Ministry of Environment
Larry Adamche, Environment Canada
Susan Blake, Whatcom County Health Dept.
Larry Percival, UFVHU (Chair and minutes)

Regrets: Robin Busch
Ron Bertrand

Guest: Dr. Sverre Vidal, UBC
Dr. Mike Brower, Environmental Engineer

The guest speakers gave an informative presentation on regional air pollution. The Lower Mainland is unique in that recharge air to the region is relatively clean from south westerly air flows and in that there is a lack of industry and industrial air pollutants. They are planning an ozone monitoring grant proposal, likely at Camp Luther on Hatzic Island, where children will wear individual monitors which will be compared to a stationery atmospheric ozone monitor. Further grant proposals include using expired breath and urine biomarkers to assess lung damage. Michael spoke on the possibility of researching particles less than 10 microns and acid aerosols in the region. Generally, the Air Quality Index will be based on the highest significant component and ozone will fall in the following ranges:

AQI	Ozone
0-25	50 ppb
25-30	80 ppb

Ozone has been shown to be detrimental to human health when in the 80-120 ppb range.

Old Business

4. Hugh Liebscher's report is now released internally. It is hoped the report will be released to our Ministries 30 days before public release. Larry Adamache will look into this.

6. Steve Cox's report will be in draft stage by June 30. A mid July release to a group of about 30 people is planned with full release around the end of July.

   Al Kohut will present the Gartner-Lee report to US interests. Hugh Liebscher will represent Environment Canada.

The Gartner-Lee report and the Fraser Valley Ground Water Monitoring Program were discussed. Ground water table levels are measured at 18 sites in the Fraser Valley, with seven of these in Abbotsford/Matsqui. Ground Water Legislation is planned for BC, however, there are 60,000 existing ground water sources in the province and these will have to be addressed.

7. There were too many variables to suggest ground water contamination contributed to the death of two dogs. No autopsy was done. The sarcoma diagnosis was from a biopsy. Sarcoma is common in dogs.

   The DW-3 attachment to the minutes was discussed.

New Business

1. The Environmental Cooperation Agreement between Washington and BC was discussed and distributed.

   Earl Anthony is the Director General of Environment Canada.

2. The Lipsey report will be distributed.

3. The Community Environmental Health Committee and the Risk Assessment Dept. were discussed.

   Negotiations are taking place to create a SCIDS diagnostic centre at UBC, which could serve the province.

4. S. Albinet released the Lipsey report the day after the Gartner-Lee report was released.

5. The role of the IAGC was discussed. Agreed the Committee should continue. The Environmental Health Committee proposal is attached. Dr. Webb will continue to chair the IAGC.

6. Green Plan proposal is being rewritten in down-sized form. Support in writing would help. Health Research Foundation may be able to provide supplemental funding.

Meeting adjourned at 12:10 p.m.
Next meeting at call of chair

LP/ro

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Mail Stop PV-11 • Olympia, Washington 98504-8711 • (206) 459-6000

September 16, 1992

Dr. Frank E. James
Health Officer
Whatcom County Health Department
P.O. Box 935
Bellingham, Washington 98227

Dear Dr. James:

As you may know, Governor Gardner and British Columbia Premier Mike Harcourt signed an Environmental Cooperation Agreement in May of this year. That Agreement established a B.C./Washington Environmental Initiative "to ensure coordinated action and information-sharing on environmental matters of mutual concern."

The first meeting of the Initiative Council will be held on October 1, 1992 in Seattle. A copy of the almost-final agenda is enclosed; as you will see, the agenda includes discussion of the Abbotsford/Sumas Aquifer. In light of the County's interest and involvement in this topic, we are pleased to invite you to attend the meeting as an observer. You are welcome to come for the whole day or just for that portion of particular interest to you.

Please feel free to call me if you have any questions about the meeting or the Environmental Initiative; I can be reached at 206-493-9111. We look forward to seeing you on October 1.

Sincerely,

Carol Jolly

Carol Jolly
Special Assistant to the Director

cc: Fred Olson, Director

I have tried to reach you to discuss your recent letter but have not been successful. Perhaps you can give me a call. CJ

DRAFT

ENVIRONMENTAL INITIATIVE COUNCIL MEETING

Thursday, October 1, 1992
8:30 – 4:30

EPA Region 10
1200 Sixth Avenue, Room 12A
Seattle, Washington

AGENDA:

8:30 – Introductory Comments — Fred Olson, WA Department of Ecology
Gerry Armstrong, BC Ministry of Environment, Lands & Parks
Earle Anthony, Environment Canada, Regional Director
Bob Burd, U.S. Environmental Protection Agency

ISSUES:

9:00 – Nooksack River Flood Control Management – Jim McCracken [B.C.]
Jerry Louthain [WA]

10:00 – Break

10:15 – Abbotsford/Sumas Aquifer Management – Terry Husseman [WA]
Jim McCracken [B.C.]

11:15 – Columbia River/Lake Roosevelt Protection – Rick Crozier [B.C.]
Carol Jolly [WA]

12:00 – Lunch

PRESENTATIONS:

1:15 – Puget Sound/Fraser Basin Status – Nancy McKay, PSWQA [WA]
B.C. Speaker to be determined

JOINT INITIATIVES:

2:15 – Air Quality Monitoring and Permitting – Jim McTaggart–Cowan [B.C.]
D.J. Patin [WA]

3:00 – Break

3:15 – State of the Environment Reporting – B.C. Speaker to be determined
Mike Reed [WA]

4:00 – Next Steps

4:30 – Adjourn

APPENDIX F

THE ABBOTSFORD-SUMAS AQUIFER INTERNATIONAL TASK FORCE INTERIM STATUS REPORT

Report by

ABBOTSFORD-SUMAS AQUIFER
INTERNATIONAL TASK FORCE

November 3, 1993

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FIGURES

APPENDICES

EXECUTIVE SUMMARY

As part of an over-arching effort to resolve transboundary hydrologic issues the Environmental Cooperation Council, in November 1992, created the Abbotsford-Sumas Aquifer International Task Force to coordinate groundwater protection efforts. The transboundary management of the groundwater resource is considered a high priority issue which requires immediate joint attention. The Council charged the Task Force to make recommendations on both water quality and water resource management issues on both sides of the border.

The Abbotsford-Sumas Aquifer is the largest aquifer in the Lower Fraser Valley in British Columbia and the Nooksack River Valley in Washington State. It is widely utilized as a source of water for industrial, irrigation, municipal and domestic uses as well as providing baseflows for surface water streams tributary to the Fraser, Nooksack and Sumas Rivers. These streams and rivers in turn support other uses such as fish and wildlife habitat, power generation, recreation and many other instream values. Geologically, the aquifer is a near surface deposit consisting of highly permeable sand and gravel and there is a high potential for groundwater contamination from surface activities. There does not appear to be any crisis in the current state of the aquifer which allows the Task Force to take a proactive role in identifying solutions to current and future issues, and recommend long term strategies to solve the more systematic problems facing the resource.

Roughly 9800 people in Whatcom County, and 94,000 people in British Columbia rely on well water from the Abbotsford-Sumas Aquifer to meet all or part of their drinking water requirements. Various Canadian agencies have documented a steady deterioration in water quality over the past forty years as nitrate concentrations have increased, and trace levels of pesticides have been recently detected in scattered wells on both sides of the border. In addition to nitrates and pesticides, an increasing number of volatile organic compounds (VOCs) are being detected in the Abbotsford-Sumas Aquifer. VOCs are most commonly associated with industrial uses - degreasers and solvents are some of the most common VOCs.

The Task Force membership includes federal, provincial/state, and local government agencies, as well as Aboriginal/Tribal and public health representatives. The meetings are structured to provide opportunities for the public to obtain information about the issues confronting the aquifer and to provide comment. Identification of five priority issue areas led to establishing five sub-committees whose reports form the main body of this report. The sub-committees were assigned primary tasks and had deliverables identified as follows:

1. Identification and definition of the Abbotsford-Sumas Aquifer; its size, shape, hydrologic and hydrogeologic boundaries, and catchment size.

   The surface boundary the aquifer is roughly bounded by Bertrand Creek to the west, the surficial geology near the Fraser/Nooksack topographic divide on the north, Sumas Mountain and the Sumas River on the east, the groundwater divide between Nooksack River and Sumas River in the southeast corner, and the Nooksack River to the south.

The boundary alignment is guided in most areas by river alignment and surficial geology [Armstrong, 1980a, 1980b(B.C.); and Easterbrook, 1976(U.S.)], and coincides primarily with the occurrence of permeable outwash deposits known in British Columbia and Washington State as Sumas Drift and Sumas Outwash, respectively.

2. A determination of what Land Use issues exist and how legislation involving groundwater can be applied to protect the resource.

   The groundwater quality in the Abbotsford-Sumas Aquifer has been affected by land use practices on the land surface. Although traditional farming practices are usually singled out as the largest contributor to groundwater contamination, other sources include septic systems, fuel storage tanks, airplane de-icing procedures, stormwater runoff, industrial activities, landfills, gravel extraction, asphalt manufacture, and surface and underground storage of chemicals. The nature and extent to which these various activities impact groundwater quality is not clearly understood. The presence of contaminants reinforces the message that the Abbotsford-Sumas Aquifer is vulnerable surface land use. It is important to realize that all facilities and operations conducted over the aquifer need to take steps to reduce the possibility of releasing contaminants into the environment that may migrate into out drinking water supply.

3. What are Public Health issues connected to contaminated groundwater. Are health concerns over increasing nitrate levels and trace amounts of pesticides and volatile organic compounds justified?

   Groundwater quality data has been collected on both sides of the border for many years through on-going regulatory monitoring programs and special studies. Parameters analyzed include nitrates, inorganics, bacteria and pesticides. Although information is incomplete, recent studies indicate that the aquifer is being impacted by human activities. Of particular concern from a public health standpoint are elevated nitrate levels. In addition, the detection of pesticides, volatile organic compounds, and metals in some of the monitored wells indicate that proactive steps need to be taken to prevent contaminant levels from rising and exceeding drinking water standards.

4. A list of Technical Data which exists for the aquifer. What agencies are involved, their data requirements and data sharing methods. A second component will be to identify data gaps and suggest possible remedies.

   Data information and management will be dey to assisting both policy matters and scientists to understand the aquifer and policy makers as they begin to work on a comprehensive strategy for managment of this transboundary resource. It is essential to undersand what information already exists and what does not and how to access the information.

5. What Public Education programs/projects need to be developed. Guidance to Canadian and US agencies on what the message should be and how to get it out.

A proactive program of public education and awareness for a continual exchange of information pertaining to the Abbotsford-Sumas Aquifer and the International Task Force is needed. The public education and awareness requires full involvement of stakeholders to maximize its efforts, and to promote best aquifer management practices.

The Task Force recognizes that the Abbotsford-Sumas Aquifer requires joint management via a proactive approach to identifying problems and recommending long term strategies for aquifer management. Changes in traditional farming practices, and other land use activates such as septic fields, industrial and municipal sources which contribute to the nitrate loading on the aquifer are needed. In addition, the detection of extremely low levels of pesticides in wells on both sides of the border, and the presence of non-agricultural chemicals from industrial activities indicate the vulnerability of the aquifer. Public health concerns stem from elevated nitrate levels, and the detection of other chemicals indicate a proactive approach to the prevention of further contamination is needed.

The public education and awareness requires full involvement of stakeholders to maximize its efforts, and to promote best aquifer management practices. A communication program aimed initially at the farming community regarding pesticide persistence, leachability, application practices that may increase the probability of leaching and sound pest control practices is needed. Industrial and municipal sources are the next set of stakeholders who need to be involved in the communication efforts.

Management and protection of the Abbotsford-Sumas Aquifer is a high priority issue if this source of high quality groundwater is to be maintained for future users. The Task Force is the obvious vehicle for ensuring transboundary cooperation, coordination and enhancement of this resource is continued.

1.0 BACKGROUND

On May 7, 1992, the Province of British Columbia and the State of Washington agreed to promote and coordinate efforts to protect, preserve and enhance our shared environment. The Environmental Cooperation Council (ECC) Agreement signed by Premier Harcourt and then Governor Gardner provided a politically endorsed structure for long term transboundary cooperation and coordination and information sharing. The Environmental Cooperation Agreement established the British Columbia/Washington Environmental Coordination Council...

> ...to promote and coordinate mutual efforts to ensure the protection, preservation and enhancement of our shared environmental for the benefit of current and future generations,
>
> AND
>
> ...to develop an action plan which shall form part of these effort, reflecting mutual priorities and to enter into specific arrangements necessary to address environmental problems.

As part of an over-arching effort to resolve other transboundary hydrologic issues such as flooding (Nooksack River International Task Force, 1991), the British Columbia/Washington State Environmental Cooperation Council (the Council) created the Abbotsford-Sumas Aquifer International Task Force (the Task Force) to coordinate groundwater protection efforts in this very susceptible aquifer in November 1992. The transboundary management of the groundwater resource in the Abbotsford-Sumas Aquifer required immediate joint attention due to the trend toward increased contamination. The Council charged the Task Force to make recommendations on both water quality and water resource management issues on both sides of the border. The Abbotsford/Sumas Aquifer is the largest aquifer in the Lower Fraser Valley in British Columbia and the Nooksack River Valley in Washington State. It is widely utilised as a source of water for industrial, irrigation, municipal and domestic uses. Geologically, the aquifer is a near-surface deposit consisting of highly permeable sand and gravel and there is a high potential for groundwater contamination from surface activities.

Water quality has been documented by various Canadian agencies as steadily deteriorating over the past forty years due to increases in nitrate concentrations. More recently trace levels of pesticides have been detected in scattered wells on both sides of the border.

There does not appear to be any crisis in the current state of the aquifer which allows the Task Force to identify and recommend long term strategies for the more systematic problems facing the resource. The Task Force decided to take a proactive role in identifying solutions to current and future aquifer management issues.

2.0 TASK FORCE ACTIVITIES

The International Task Force met in March, May, July and September of 1993. Current membership includes federal, provincial/state, and local government agencies, as well as Aboriginal/Tribal and public health representatives. The meetings are structured to provide opportunities for the public to obtain information about the issues confronting the Aquifer and to provide comment.

The Task Force established its Vision and Mission Statements and developed its Terms of Reference. The Terms of Reference include:

- Establish a managerial approach
- Develop and exchange information
- Develop aquifer management strategies
- Education and public involvement.

The complete text of the Mission and Vision Statements and the Terms of Reference can be found in Appendix One. Identification of five priority issue areas led to establishing five sub-committees whose reports form the main body of this report. The sub-committees were assigned the following primary tasks:

1. Define the Abbotsford-Sumas Aquifer - size, shape, hydrologic and hydrogeologic boundaries, catchment size.

2. Determine what Land Use issues exist and how legislation involving groundwater can be applied to protect the resource.

3. What are the Public Health issues - nitrate levels are continuing to rise, and trace amounts of pesticides have been detected in scattered wells.

4. Listing Technical Data which exists for the aquifer - what are agencies doing, their data requirements and ways to make the data available. A second component will be to identify data gaps and suggest possible remedies.

5. What Public Education programs/projects need to be developed - guidance to Canadian and US agencies on what the message should be, and how to get it out.

The Task Force identified the following deliverables for each of the sub-committees.

1. Expand on the draft reports on Public Health Concerns and the impacts of Land Use patterns

2. Outline a Media and Public Education strategy

3. Identify Database/Information Systems, information gaps and research needs

4. Identify existing regulatory framework for protecting the aquifer for current and future needs.

5. To outline a program for full and continuous public involvement by stakeholders of the Abbotsford-Sumas Aquifer.

3.0 INTRODUCTION

3.1 GENERAL AQUIFER DESCRIPTION

The surface boundary of the area known as the Abbotsford-Sumas Aquifer is shown by the map in Figure 1. The a real extent of the aquifer is approximately 100 square miles (260 km_2) and the area is close to evenly divided by the Canadian-U.S. border. The aquifer is roughly bounded by surficial geology near the Fraser/Nooksack topographic divide on the north, the Sumas River and Sumas Mountain on the east, the Nooksack River to the south, and Bertrand Creek to the west. The boundary alignment is guided in most areas by surficial geology [Armstrong, 1980a, 1980b (B.C.); and Easterbrook, 1976 (U.S.)], and coincides primarily with the occurrence of permeable outwash deposits known in Washington State as Sumas Outwash and in British Columbia as the recessional glaciofluvial deposits of Sumas Drift. For the purposes of this report, the extensive permeable surficial deposits on both sides of the border are regarded as Sumas Outwash.

On the Washington side, the Abbotsford-Sumas Aquifer area is located on a flat glacial outwash plain known as the Lynden Terrace (WSB No. 12, 1960). The aquifer area is located north of the City of Lynden and situated between Bertrand Creek on the west and the City of Sumas on the east.

4.0 AQUIFER BOUNDARY DEFINITION

4.1 INTRODUCTION

[illegible] Abbotsford-Sumas Aquifer is the largest unconfined aquifer in both the lower Fraser Valley in British Columbia and the Nooksack River Valley in Washington State. The [illegible] is an important source of water for municipal, industrial, domestic and agricultural [illegible] both sides of the border. The Abbotsford-Sumas Aquifer also serves as an important [illegible] of base flow for surface water streams tributary to the Fraser, Sumas and Nooksack [illegible] Canada and the United States. In July 1992, Environment Canada released a report [illegible] the results of groundwater studies conducted on the Abbotsford-Sumas Aquifer [illegible] and 1990 (Liebscher et. al., 1992). Elevated nitrate concentrations and [illegible]tions for pesticides in the aquifer prior to 1990 were documented. The Aquifer [illegible]committee of the Abbotsford-Sumas Aquifer Task Force was formed to define [illegible]d-Sumas Aquifer boundaries and describe the criteria for definition of the

4.2 LAND USE AND WELLS

Land use on the Abbotsford-Sumas Aquifer is mostly agricultural and consists primarily of dairy, poultry, swine, potato, berry and corn production. Urban development including light industrial activities are centered around the communities of Clearbrook and Abbotsford in British Columbia and Lynden and Sumas in Washington State. In Canada, half of all British Columbia farm income comes from the Fraser Valley. Abbotsford is the most productive raspberry growing area in Canada. On the Washington side of the aquifer, dairy and berry farming are the predominant land uses. Whatcom County is the most productive raspberry growing county, and one of the most productive dairy counties in the United States. On both sides of the border, groundwater is the primary source of water for agriculture and water supply over the aquifer area. The Fraser Valley Trout Hatchery is a significant user of groundwater and is situated in British Columbia north of the international border along the eastern edge of the aquifer.

Large parts of the Washington side of the aquifer area are served by public water systems such as Lynden Water Association, but there are numerous privately owned domestic wells. In British Columbia, the District of Abbotsford and the community of Clearbrook draws their water supply from the aquifer. Many shallow wells for both irrigation and domestic supply are completed in Sumas Outwash and range in depth from 20 to 35 feet (6 to 11 m). Typical shallow well construction utilizes 36 inch (90 cm) diameter cylindrical concrete tiles with perforations in the bottom 3 to 6 feet (1 to 2 m) of well tiles. The typical wellhead is finished at or slightly above grade or, less frequently, in a subsurface vault. Alternative well construction utilizes 6 or 8 inch (15 to 20 cm) diameter steel casing with a screen or perforations emplaced near the bottom of the well. Drilled wells in British Columbia range from 50 to 150 feet in depth (15 to 45m).

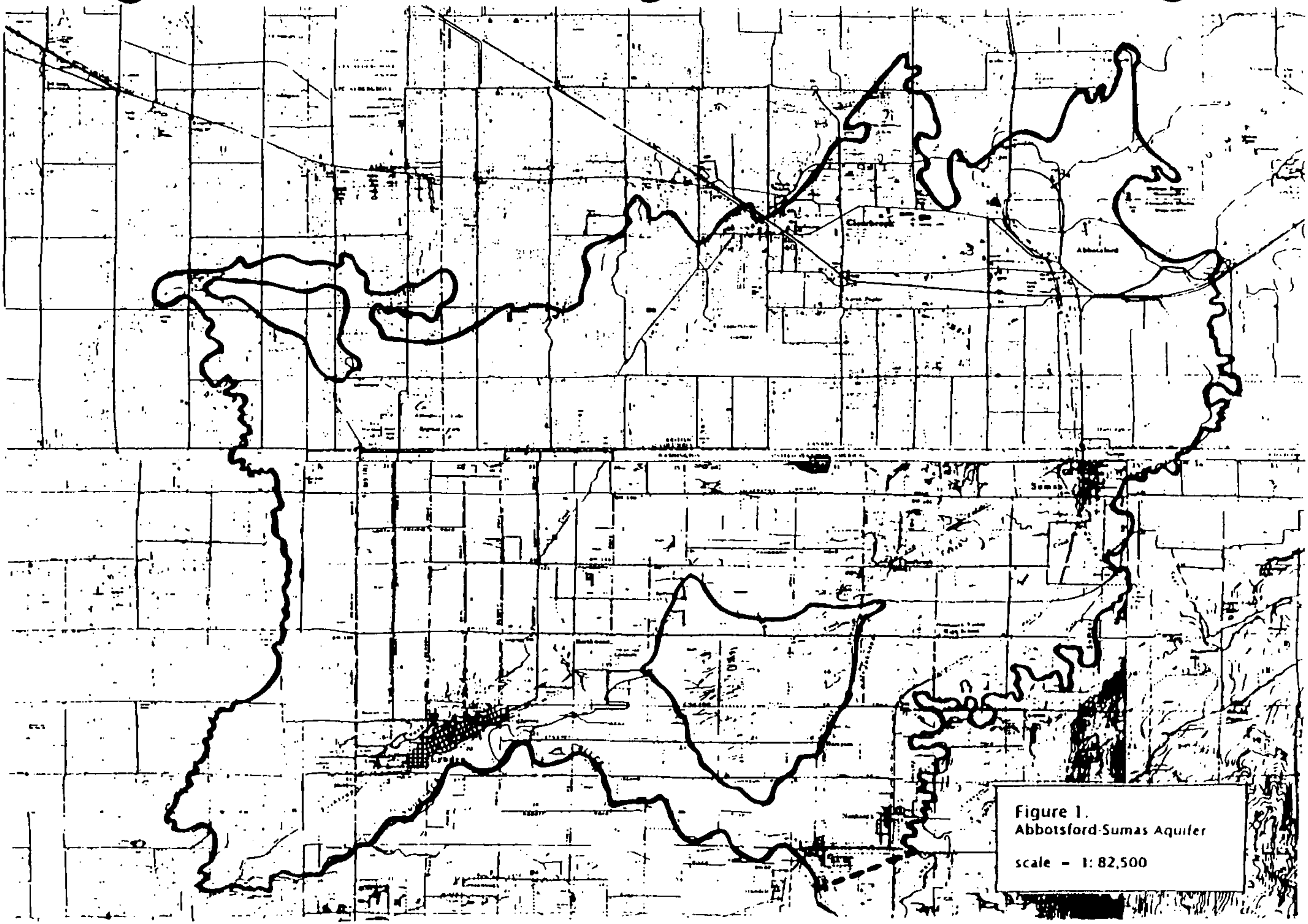

Figure 1.
Abbotsford-Sumas Aquifer

scale = 1: 82,500

4.3 GROUNDWATER QUALITY

Groundwater quality in the Abbotsford-Sumas Aquifer has been impacted by agricultural and other land uses, with numerous occurrences of elevated nitrate concentrations and pesticide detections [Erickson and Norton, 1990(U.S.); and Liebscher et. al., 1992(B.C.)]. Groundwater contamination problems involving nitrates and pesticides were recently documented in the Abbotsford area in British Columbia, Canada (Liebscher, et.al., 1992). The high vulnerability of the Abbotsford-Sumas Aquifer to contamination from the land surface, largely due to the high permeability of the aquifer materials, has been noted in several reports. Fertilizer application, animal husbandry, septic systems, and other liquid and solid waste storage and/or disposal are identified activities which can cause infiltration of contaminants and can locally increase the supply of chloride, pesticides and soluble nitrogen compounds in the groundwater.

Erickson (1991) concluded that groundwater monitoring results at a dairy lagoon near Lynden showed some leakage of nitrogen compounds following lagoon construction. The same study also indicated that groundwater contamination from nitrate was occurring due to land application of dairy manure. In British Columbia, Kwong (1986) concluded nitrate contamination was associated with septic and agricultural sources. Recent studies of groundwater quality in the Abbotsford-Sumas Aquifer indicate good quality for most water quality constituents; however, concentrations of nitrate, iron, and pesticides are of concern in some areas. Twenty-seven percent of wells sampled had nitrate concentrations greater than the Canadian and U.S. drinking water of 10 milligrams per liter. Twenty-three percent of wells sampled had iron concentrations greater than U.S. secondary drinking water standards of 0.3 milligrams per liter and fifteen percent of wells sampled had detectable pesticide concentrations.

In December 1990, the Department of Ecology adopted Water Quality Standards for Groundwaters of the State of Washington, Chapter 173-200 Washington Administrative Code. The standards apply a policy of antidegradation to all groundwaters of the state that occur in a saturated zone or stratum beneath the surface of land or below a surface water body (Ecology, 1990). Contaminant concentrations found in saturated soils where contaminants have been applied at agronomic rates for agricultural purposes, and where contaminants have been applied at approved rates and under approved methods of land treatment, are exempt from the standards if the contaminants will not cause pollution of any groundwaters below the root zone.

4.4 BOUNDARY DEFINITION CRITERIA

4.4.1 Geology

The Abbotsford-Sumas Aquifer is located on a flat glacial outwash plain extending from the Clearbrook-Abbotsford area south to Lynden where it is known as the Lynden Terrace (WSB No. 12, 1960). The Lynden Terrace is a flat glacial outwash plain that slopes gently south toward the Nooksack River floodplain. The surficial geology of the Lynden Terrace consists of sand and gravel, with some finer materials and local peat deposits. The area is geologically mapped as Sumas Outwash and Sumas Drift which was deposited during the Late Pleistocene Sumas Stade of the Fraser Glaciation (Easterbrook, 1971; Armstrong, 1980a, 1980b).

Sumas Outwash was formed by meltwater streams flowing southward from a glacial moraine just north of the Canadian Border. Halstead (1986) has mapped the stratigraphy of deposits comprising the Sumas Drift in British Columbia.

During the last phase of the most recent glaciation of the B.C./Puget Sound region, glacial ice stood just north of the Canadian Border near Abbotsford with a lobe extending southward across the border at Sumas. Meltwater streams flowing southward from the glacier built an outwash plain from the upland near Abbotsford to Lynden and from Everson westward nearly to Ferndale. The outwash plain consists of gravel near the glacier margin grading to sand southward to Lynden and Laurel. Kahle (1990) mapped an enlarged area of less permeable ice contact deposits in the eastern aquifer area near Sumas. Peat deposits, developed from plant material accumulated near streams and wetlands, filled many of the abandoned meltwater channels and depressions in the outwash (Easterbrook, 1971). The areal boundary of the Abbotsford-Sumas Aquifer coincides primarily with the surficial outcrop of the highly permeable Sumas Outwash deposits [Armstrong, 1980a, 1980b(B.C.); and Easterbrook, 1976(U.S.)]. Geology also guides the aquifer boundary in the three dimensional sense. The permeable outwash deposits accumulated in most places upon older deposits of less permeable glaciomarine silt and bedrock.

4.4.2 Hydrogeology

Except for limited groundwater under confined conditions below local ice contact deposits near Sumas, the Abbotsford-Sumas Aquifer is an unconfined water table aquifer.

Typical groundwater levels near the boundaries of the aquifer range from 0 to 15 feet (0 to 5m) below land surface and fluctuate seasonally over ranges of from 5 to 10 feet (2 to 3m). Deeper water levels up to 100 feet (30m) occur in the central portion of the aquifer. Hydrographs for selected wells in Whatcom County are compared in Figures 2 and 3. Irrigation well hydrographs in Figure 2 indicate that ranges in water-level fluctuations attenuate with distance downgradient. Similar patterns are evident in data for British Columbia, (Kohut, 1987).

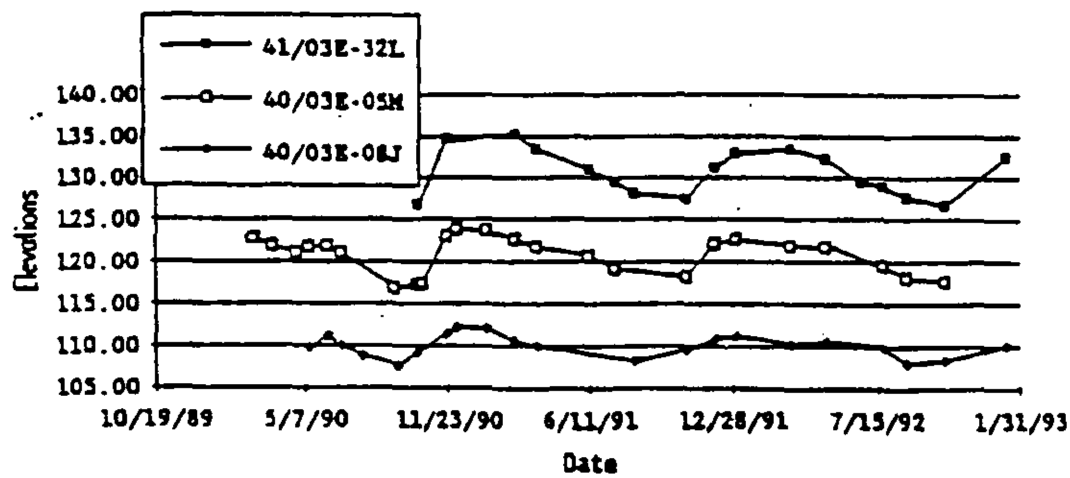

FIGURE 2. Hydrographs for irrigation wells near Lynden, Washington.

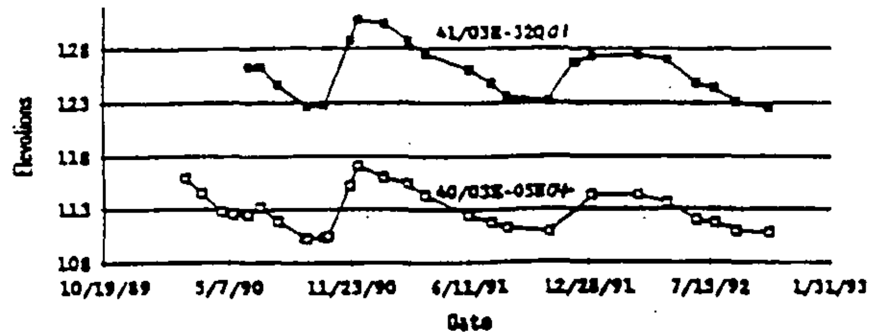

Figure 3. Hydrographs for domestic wells near Lynden, Washington.

The groundwater flow direction throughout the major portion of the aquifer is predominantly south and southeasterly. A generalized water-table contour map of the southern portion of the Abbotsford-Sumas Aquifer based on surveyed wellhead elevations and water-level measurements is shown in Figure 4, from Liebscher et. al. (1992). There are deviations in the predominant flow direction near the east and west aquifer boundaries where groundwater is proximate to surface streams. This is especially the case at the eastern aquifer boundary where groundwater discharges to Johnson Creek and the Sumas River which flow north to the Fraser River. Other minor variances from the predominantly southern flow direction are expected where groundwater approaches local drainage ditches and surface streams. A regional groundwater study on the Washington side conducted by Western Washington University also indicated general southerly directions of ground-water flow in two study areas near Lynden for both March and September of 1987 (Creahan and Kelsey, 1988).

Portions of the aquifer area extend into the Nooksack and Sumas River valleys where it is expected that the presence of permeable deposits and municipal groundwater withdrawals may cause direct hydrologic interrelationships with aquifer zones in the river valley alluvium. In British Columbia the aquifer extends from Bertrand Creek on the west to Sumas Prairie on the east encompassing the communities of Clearbrook and Abbotsford.

4.4.3 Topography

Topography is a criterion for the alignment of the Abbotsford-Sumas Aquifer boundary only in the northeast corner of the aquifer area where the permeable outwash deposits abut Sumas Mountain bedrock.

4.4.4 Drainage

Recharge to the Abbotsford-Sumas Aquifer is derived from precipitation that falls directly on the upland north of Lynden and in Canada. Average annual rainfall over the aquifer ranges from 40 to 60 inches (1000 to 1500 mm) based on precipitation measurements at Blaine and Abbotsford (Kohut et al, 1989).

The high rainfall and relatively shallow water table in the study area causes a significant portion of precipitation to run off via surface water drainage ditches. The network of drainage ditches on the Lynden Terrace generally follows the local orthogonal road pattern, and ultimately discharges to Bertrand and Fishtrap Creeks and the Nooksack River, or to Johnson Creek and the Sumas River. Several major stream networks drain the Abbotsford-Sumas Aquifer area and are eventually tributary to one of the river systems surrounding the aquifer area. One of these streams, Bertrand Creek, serves as the entire western boundary of the Abbotsford-Sumas Aquifer. From the confluence of Bertrand Creek and the Nooksack River, the aquifer boundary follows the Nooksack River east for six miles (10 km). At the southeast corner of the aquifer, a six mile (10 km) reach of the Sumas River serves as part of the aquifer boundary.

4.4.5 Other Factors

There are two places along the Abbotsford-Sumas Aquifer boundary where the line is established by the shortest distance between other boundary line segments with geologic or topographic rationale. The aquifer boundary is an arbitrary straight line for 1.5 miles (2.4 km) running southeast from the base of Sumas Mountain to the Sumas River about 1 mile (1.6 km) north of the border. This alignment strikes a direction which is expected to be normal to the direction of flow of groundwater in the Sumas River Valley.

Another straight line segment on the aquifer boundary is at the southeast portion of the aquifer area and runs for 3.5 miles (5.6 km) from the outwash/alluvium contact near Johnson Creek (Easterbrook, 1976) due east to the Sumas River. The boundary configuration in the western portion of the aquifer is intended to encompass a sufficient area of the Sumas River Valley alluvium to include the area of influence from pumping in the City of Sumas wells.

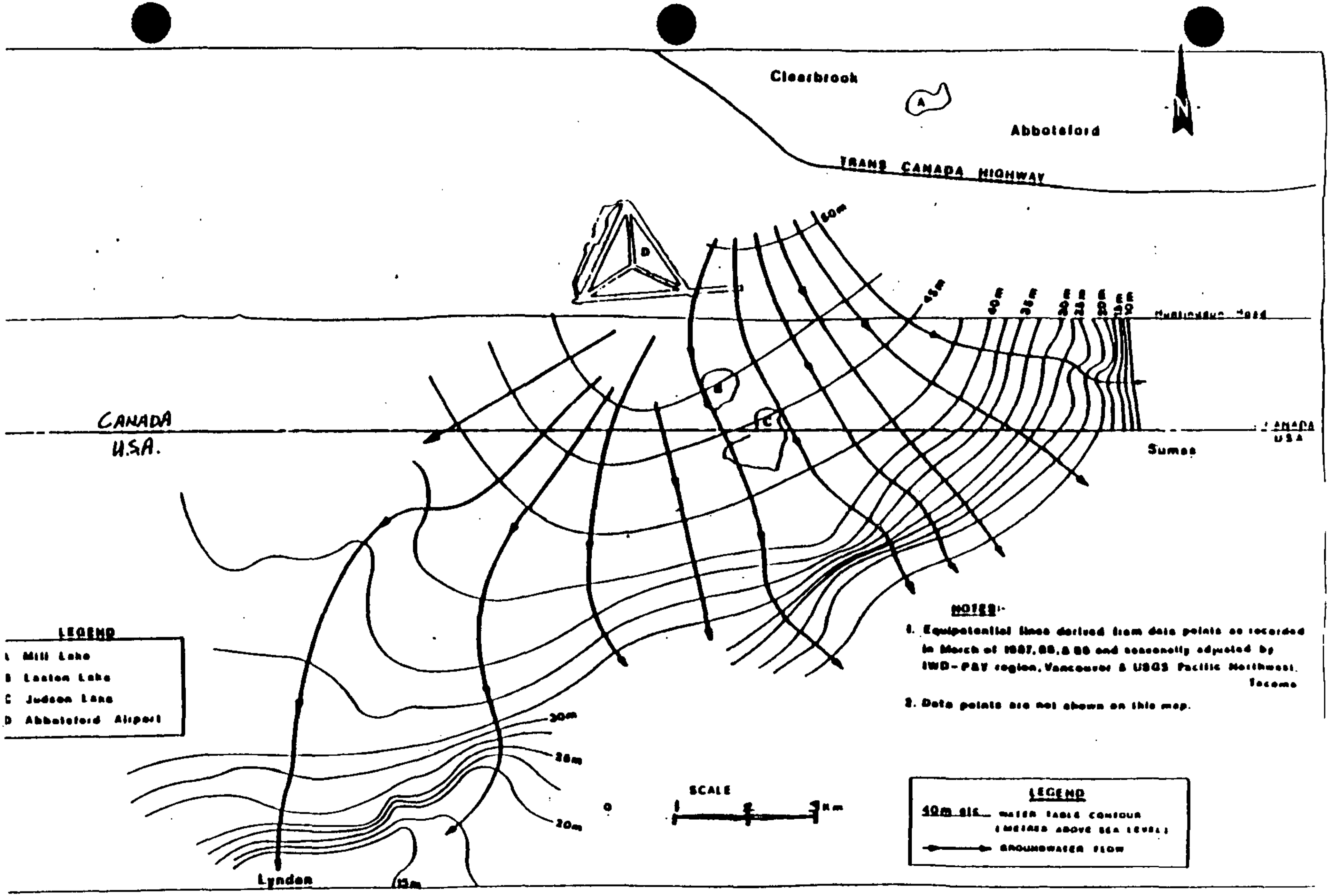

Figure 4. Groundwater Flow in the Abbotsford-Sumas Aquifer (from Liebscher et. al., 1992)

5.0 LAND USE

5.1 INTRODUCTION

The groundwater quality in the Abbotsford/Sumas Aquifer has been affected by land use practices on the land surface. Animal manure application to land, pesticides, septic fields, gravel extraction, etc. are known (or speculated) to have resulted in a range of organic and inorganic contaminants being found in the water. It is clear that some of these land use practices must change to improve the quality of water in the aquifer and to prevent further contamination. The following discussion identifies the priority issues and the actions required to protect the aquifer.

5.2 AGRICULTURAL SOURCES

It is important to recognize that agricultural operations are carried out on private lands by business men and women who are endeavoring to maximize their success in the market place. Land and resource stewardship and conservation policies and initiatives must take into account the potential affect on short-term profitability of individual farm enterprises. The challenge, then, is to find ways of meeting the joint goals of environmental protection and farm viability.

5.2.1 Nitrate from Field Storage of Animal Manures

Historically, one of the major sources of nitrate was thought to be the uncovered, over-winter storage of animal manures (mostly poultry manure) in fields. Although this practice is now prohibited in B.C. by the Code of Agricultural Practice for Waste Management (Code), it remains a concern. In Washington, most of the manure from dairy operations is stored in earthen lagoons. Improper construction and/or location of the lagoons can contribute to groundwater contamination.

It should be noted that manures do not contain nitrate. Virtually 100% of the inorganic nitrogen in manure is in the form of ammonium (NH_4^+) or ammonia (NH_3). The NH_4^+ form is subject to leaching by precipitation from the manure piles into the underlying soil. It is then held by soil colloids and is not readily leached further down the soil profile. Once soils warm in the spring, a natural soil process takes place - nitrification - which converts ammonium to nitrate. The nitrate is not held by soil colloids and any that remains in the soil and is not taken up by plants is subject to leaching over the winter months. The NH_3 is volatile and subject to loss to the atmosphere.

Objective: To eliminate over-winter field storage of uncovered manure.

Actions:

1. Awareness: make all producers over the aquifer aware of the issue and the acceptable types of ameliorative measures.

2. Financial Assistance: provide farmers with funds to assist with construction of acceptable storage facilities.

3. Monitoring: assess the degree to which farmers have made the necessary on-farm changes.

Regulations: British Columbia

1. Ensure all producers are in compliance with "Code of Agricultural Practice for Waste Management".

2. Ensure "peer review" process is effective.

3. Enact legislation and regulations that allow for protection of sensitive recharge and discharge areas.

Washington

1. Ecology should continue monitoring selected waste storage ponds on the aquifer to determine their potential groundwater contamination impact; and Ecology and SCS should complete the review of waste storage pond construction standards and recommend revisions if necessary.

5.2.2 Nitrate from Land Application of Manure

In the past, almost 100% of the manure produced in the area was recycled back to adjacent lands as a fertilizer for crop production. In B.C., raspberries is a crop that receives a substantial amount of poultry manure and is also a crop uniquely suited to the well drained soils over the aquifer. When the amount of nitrogen in manure is compared to crop requirement, it is clear that all of the manure can not be applied to land over the aquifer. There is simply more nitrogen being produced than is needed by the crops.

Dairy farming is the principle enterprise on the U.S. part of the aquifer. The high density of farms, estimated at 150 commercial dairies, generate a substantial volume of manure, most of which is collected and land applied for its fertilizer benefit. Issues of concern include nitrate leaching potential from late summer/fall applications, particularly on bare soil, and over application/improper accounting of nutrients available in the manure.

Objective: To apply manure according to crop needs and in a manner that maximizes efficiency of nitrogen use.

Actions:

1. Research: increase understanding of nitrogen behavior in manures and soils.

2. Technology Transfer: facilitate adoption of best manure and fertilizer management practices.

3. Inventory: determine the amount of manure being produced and compare to crop need.

4. Alternate Manure Uses: find practical alternatives to application of manure to land.

Regulations: British Columbia

1. Ensure all producers are in compliance with "Code of Agricultural Practice for Waste Management".

2. Ensure "peer review" process is effective.

3. Enact legislation and regulations that allow for protection of sensitive recharge and discharge areas.

Washington

1. Implement the dairy waste management program.

5.2.3 Pesticides

Pesticides have not been found in the aquifer at levels that are a health risk. However, the fact that some have been detected, even at extremely low levels, is of concern. Because of the pesticides being used or the application practices, some of the materials are not being completely broken down in the soil and are being leached to groundwater.

Pesticides were detected during limited studies on the southwest portion of the aquifer. Of the 27 wells tested, 12 showed at least one pesticide. Five different pesticides were detected. Seven detections were above the maximum level proposed by the U.S. EPA.

Objective: To use pesticides and application practices that will not result in materials being detected in groundwater.

Actions:

1. Monitoring: establish on-going programs to detect the presence of pesticides in the groundwater.

2. Pesticide Review: identify the pesticides that may have sufficient persistence and leachability to pose a concern.

3. On-farm Practices: identify the pest control practices that may increase the probability of leaching.

4. Research: find combinations of pesticides and practices that will not result in pesticide leaching.

5. Technology Transfer: communicate sound pest control practices to farmers.

Regulations: British Columbia

1. Ensure producers are using chemicals according to relevant legislation and regulations.

2. Enact legislation and regulations that allow for protection of sensitive recharge and discharge areas.

Washington

1. Ensure agricultural producers are using and storing chemicals according to relevant legislation and regulations.

2. Develop generic groundwater/pesticide plan with the view to developing site specific/chemical specific regulations.

5.2.4 Well Construction and Wellhead Management

There are two general issues associated with wells and groundwater quality. First, improperly constructed or maintained wells may serve as direct pathways for surface applied contaminants to rapidly move to deeper groundwaters. Second, known zones of contribution to high priority wells can function as prioritizing tools for focusing implementation activities. It is important that both well construction and wellhead management practices be carried out in a manner that minimizes the risk to the groundwater resource.

Objective: To construct and manage wells from a groundwater protection perspective

Actions:

1. Establish well construction standards to ensure properly constructed wells.

2. Ensure compliance with well construction standards through education and enforcement of well drillers.

3. Implement wellhead protection programs to target pollution prevention and risk reduction implementation efforts around priority wells.

Regulations: British Columbia

1. Legislation and regulations to: regulate water well drillers, certify well drillers, and establish standards for construction, maintenance, testing and abandonment of wells.

2. Legislation and regulations that allow for land use zoning for the purpose of wellhead protection.

Washington

1. RCW 18.104, as amended in 1993, required that well drillers be licensed and established continuing educational requirements. Well construction standards are defined, as well as well abandonment procedures. Placement of a unique well identification tag on all new wells is mandated. A fee structure is established to offset the cost of program administration. Delegation of well construction portion of program to local governments is possible.

2. State Drinking Water Regulations, Chapter 246.290 WAC, are in the process of being modified to require wellhead protection planning by all groundwater based public drinking water systems serving 25 or more persons, or more than 10 connections. Wellhead protection requirements include: delineating wellhead protection areas for each well or well field, inventorying within these areas for potential sources of groundwater contamination, notifying agencies and local governments of the results of the inventory, and developing contingency and spill response plans in the event of a contamination incident. In Washington, local governments have a variety of tools, such as developing comprehensive land use plans, adopting development regulations and ordinances to protect critical groundwater areas. In an effort to promote local protection efforts, the state included protection of water quality and the availability of water among its planning goals under the Growth Management Act, Chapter 36.70A.020 (10) RCW.

5.2.5 Septic Field Sources

On-site sewage disposal, particularly in areas overlying unconfined aquifers, has come under increased attention. If on-site systems are inappropriately installed or inadequately maintained, they may not adequately treat domestic sewage, potentially leading to nitrate and/or microbial contamination of groundwaters. In addition, on-site systems are not equipped to treat non-biological waste such as solvents, degreasers and other common household chemicals.

Keys to minimizing impacts of on-site septic systems to groundwater quality include: only siting systems in areas with appropriate soil characteristics; choosing an on-site system design which treats waste prior to releasing to soil; choosing an on-site system design compatible with both the soil absorption qualities and the expected loading; taking steps to ensure that non-biological wastes will not be discharged through the system; and controlling the density of on-site systems to a level that allows for mitigation through dispersal to occur.

Objectives: To provide on-site sewage disposal systems that do not adversely impact groundwater quality in receiving area.

Actions:

1. Identify how effective present sewage disposal system designs treat domestic sewage.

2. Identify alternative system designs that target reductions of specific contaminants.

3. Educate uses of on-site disposal systems as to the limitations of such systems.

4. Review and recommend appropriate changes to pertinent legislation.

Regulations: British Columbia

1. Regulations for minimum, as well as maximum, percolation rates.

2. Regulations that allows for provincial input into local development/zoning plans and decisions.

Washington

1. Chapter 246-272 WAC (rules passed initially in 1974, amended in 1980, 1983, 1989) addresses use, permit, and design requirements for conventional on-site sewage systems. Alternative and experimental systems are provided for, with use and design standards set forth in separate guidelines.

2. Alternative and experimental technologies are evaluated by and standards established by WA State Dept. of Health (DOH) through the Technical Review Committee (required by WAC). Alternative system guidelines exist for various systems: aerobic treatment devices, alternating and dosing systems, graveless drainfield systems, sand filter systems, mound systems, composting toilets, incineration toilets, vault and pit privies, holding tanks, and pressure distribution systems. Administrative guidelines exist for alternative and experimental systems, as well as application of Treatments Standards 1 and 2 (two performance standards applied to the repair or replacement of failing marine shoreline systems).

The Department of Health (DOH) is in the process of redrafting the rules, with scheduled public hearings and adoption before the State Board of Health in November and December of 1993. Significant changes and additions to the current rules in terms of vertical separation, use of alternative systems, maintenance and operation, and areas of special concern are expected.

Local health departments are the implementation agencies for state on-site rules. Jurisdictions is based on daily sewage flow for the system being permitted: local HD's, 1-3500 GPD; DOH, 3501-14, 500 GPD; and Ecology, > 14,500 GPD.

5.2.6 Industrial and Municipal Sources

There are various industrial and urban-related activities on land over the aquifer. These include: landfills, gravel extraction and asphalt manufacture, and surface and underground storage of chemicals. Groundwater monitoring studies have found traces of chemicals that are not related to agricultural activities.

Objective: To ensure that industrial and urban-related activities are conducted in a manner that minimizes the potential for groundwater contamination.

Actions:

1. Conduct an inventory of active and closed landfill sites and establish a monitoring program for closed sites.

2. Ensure fuel storage and handling associated with gravel extraction and asphalt manufacture is according to environmentally sound practices.

Regulations: **British Columbia**

1. Enact underground storage tank regulation which will require all tanks to be registered and of a specified quality.

Washington

1. The Underground Storage Tank Act, Chapter 90.76 RCW authorized the development of the "Underground Storage Tank (UST)" Regulations, Chapter 173-360 WAC and is administered by the Toxics Cleanup Program, UST/LUST Section. The purpose of the UST regulations is to address the serious threat posed to human health and the environment by leaking underground storage systems containing petroleum and other regulated substances (Chapter 173-360-100 WAC).

2. The National Pollutant Discharge Elimination System Permit Program, Chapter 173-220- WAC, establishes a state permit program, applicable to the discharge of pollutants and other wastes and materials to the surface waters of the state, operating under state law as part of the National Pollutant Discharge Elimination System (NPDES), created by Section 402 of the Federal Pollution Control Act (FWPCA). Permits issued under this chapter are designed to satisfy the requirements for discharge permits under both section 402(b) of the FWPCA and Chapter 90.48 RCW.

6.0 PUBLIC HEALTH IMPLICATIONS OF GROUNDWATER CONTAMINATION IN THE ABBOTSFORD/SUMAS AQUIFER

6.1 BACKGROUND

The Abbotsford-Sumas Aquifer is an essential source of water for drinking, agricultural and industrial uses in both the United States and Canada. It also provides the baseflow for many streams and rivers in the area. These streams and rivers in turn support other uses such as fish and wildlife habitat, power generation, recreation and many other instream values.

Of particular importance from a public health perspective is its value as a drinking water source. On the U.S. side of the border, the Abbotsford-Sumas aquifer is the primary source of drinking water for approximately 9,800 people. Of this number, about 3,500 obtain their water from one of the 21 public water systems in the area. These public systems are subject to on-going monitoring and public health regulations. The remaining 6,300 people are on "private" wells. The water utilized by residents using private wells is not routinely monitored from a water quality perspective.

In Washington State, the Department of Ecology is responsible for the legal allocation of surface and groundwater for beneficial uses. Beneficial uses include out-of-stream uses such as drinking water, agriculture, and industry, as well as instream uses such as fisheries, recreation, and water quality. For a variety of reasons, the legal availability of additional water for any of these uses is very limited in the Sumas aquifer area.

In Washington, drinking water wells which withdraw less than 5,000 gallons per day are exempted from the formal water right allocation process-the paperwork required to obtain legal use of the water. The consequences of this exemption are significant from a public health perspective because it provides a strong incentive to develop either drinking water systems that are very small (less than six homes per system) or individual wells to serve individual residences. Very small public systems (fewer than 15 homes) must comply with minimal on-going monitoring requirements. Wells serving individual homes have no on-going monitoring or other health related requirements

Use of the Abbotsford-Sumas Aquifer on the Canadian side, in total number of users, is significantly higher than the number of users on the American side. There are 18,000 residents using water from the Abbotsford water system (6 wells) and 4,000 from the Clearbrook water system (3 wells). In addition, there are an estimated 550 private wells serving 1250 residents and 500 persons using groundwater distributed by a mobile home park. The City of Matsqui has a wellfield it uses as its backup supply for 70,000+ people. When all these users are combined, a total of 94,000 Canadian residents are dependent upon well water from the Abbotsford-Sumas Aquifer to meet all or part of their drinking water requirements.

6.2 WATER QUALITY ISSUES

There are numerous potential sources of groundwater contamination within the Abbotsford-Sumas Aquifer. A partial listing includes septic systems, agricultural handling of manure, fertilizer use, fuel storage tanks, airplane de-icing procedures, stormwater runoff, industrial activities, and surface mining activities. The nature and extent to which these various activities impact groundwater quality is not clearly understood.

Groundwater quality data has been collected on both sides of the border for many years through on-going regulatory monitoring programs and special studies. Parameters analyzed include nitrates, inorganics, bacteria and pesticides. Although information is incomplete, recent studies indicate that the aquifer is being impacted by human activities. Of particular concern from a public health standpoint are elevated nitrate levels. In addition, the detection of pesticides, volatile organic compounds, and metals in some of the monitored wells indicate that proactive steps need to be taken to prevent contaminant levels from rising and exceeding drinking water standards.

Nitrate has been detected at levels exceeding drinking water standards. This is causing concern to public health officials on both sides of the border. Excluding the potential acute effects of elevated nitrate levels on sensitive individuals, the primary concern is the result of an increasing appreciation that the groundwater present in the Abbotsford-Sumas Aquifer is very vulnerable to man's activities, and that if steps are not taken now to reduce contamination of the aquifer, future drinking supplies may be at risk.

6.3 IMPLICATIONS OF CONTAMINATED DRINKING WATER

The consequences of contaminated water include not only direct public health impacts, but a number of other costs as well. This includes increased monitoring requirements and possible water treatment costs; costs of implementing contaminant source controls or developing alternative water supplies; health impacts on livestock; and less well defined/understood adverse impacts on other beneficial uses (such as salmonid fisheries). In addition, on the US side of the border, Washington State's Growth Management Act does not allow the issuance of building permits or subdivision approval unless safe, adequate supplies of water are available. Financial lending institutions are also increasingly reluctant to finance homes if water supplies do not meet drinking water quality standards. This is already a significant problem for some residents of Whatcom County.

6.4 PUBLIC HEALTH ISSUES RELATED TO GROUNDWATER QUALITY IN THE AQUIFER

Public health concerns related to groundwater include those associated with nitrates, pesticides, and volatile organic compounds. A discussion of each area follows.

6.4.1 Nitrates

6.4.1.1 Background

Nitrate data is available through studies on both sides of the border. A recent groundwater monitoring study in the Fraser Valley tested a total of 240 wells, of which 23 (10%) had nitrate levels exceeding the Maximum Acceptable Concentration (MAC) for nitrate of 10 mg/l (Gartner Lee, 1993). Sample values ranged from no detection to 83.3 mg/l. Of the total wells tested, 45 were from the Abbotsford Aquifer. The average nitrate value of these wells was 7.29 mg/l. Of those 45 wells, 29 (64%) had nitrate values greater than 3 mg/l and 14 (31%) had readings exceeding the MAC.

Data obtained from studies on the U.S. side also indicate that nitrate is a significant concern. Nitrate concentrations greater than 3 mg/l are often considered indications of anthropogenic impacts to water quality. Of 141 wells recently sampled for nitrate, 135 had nitrate concentrations exceeding 3 mg/l (Cox, 1993, *in preparation*). Almost half of the 135 wells (59), had nitrate concentrations exceeding the drinking water standard.

Nitrate concentrations can exhibit significant seasonal variation, particularly in areas where the water table is within 20 feet (6 m) of the land surface. Concentrations tended to be higher in the fall and early winter, and lower in the spring and summer.

6.4.1.2 Public Health Concerns Relative to Elevated Nitrate Levels

Both American and Canadian authorities have set the Maximum Contaminant Level for nitrate at 10 mg/l. This is based on a risk of health effects from acute exposure (i.e. there may be health effects occurring from short term exposure). Acute exposure to high levels of nitrates can cause methemoglobinemia.

Methemoglobinemia is a toxic response to nitrate exposure that inhibits transport of oxygen by the blood. When the capacity of the blood to carry oxygen is reduced, symptoms of oxygen starvation begin to occur. In extreme cases, individuals may die.

The majority of the population is not susceptible to this illness. Sensitive individuals are generally infants less than 6 months of age, but also can include individuals having reduced gastric acidity, with a hereditary lack of methemoglobin reductase, or with other blood disorders that reduce their oxygen carrying capacity. It is important to note that any adults which fall into this sensitive group should also take care to minimize intake of nitrates through non-water related sources as well[1].

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[1] Vegetables such as beets, celery, lettuce, radishes and spinach contribute about 85 to 90% of an typical adult's dietary intake of nitrate, with nitrate levels ranging from 17 to 24 mg/ 10 grams of food (60 to 75 mg/ ounce). Baked goods and cereals, beets, corn, spinach and turnip greens are major sources of nitrite (0.02 to 0.04 mg/ 10 grams of food | 0.06-0.12 mg/ ounce).

There have been no identified cases of methemoglobinemia to date in Whatcom County, and only one suspected case in British Columbia in the past 15 years. Some studies have suggested a possible link between nitrates and cancer and birth defects. These findings, however, have not been confirmed.

Perhaps the most important public health concern associated with elevated nitrates is related to their role as an indicator of overall water quality. Nitrates are easily detected and can indicate that the water source is vulnerable to contamination by surface activities and chemical releases (chemicals which are usually much more expensive to detect and treat). Depending on the source of the nitrate, the water may also contain bacteria and/or viruses (if the nitrates come from septic systems or concentrated animal feeding operations), agricultural chemicals (if the nitrate source is plant fertilizer), or solvents and other chemicals (if the nitrates are coming from industrial sites). Regardless, elevated nitrate levels are often indicative of groundwater susceptible to contamination.

6.4.2 Pesticides

6.4.2.1 Background

Agricultural pesticides have been detected in monitoring and drinking water wells on both sides of the border. In the great majority of the samples, the levels of pesticides detected were well below 50% of the applicable US Maximum Contaminant Level (MCL) or the Canadian Maximum Allowable Concentration (MAC)

A partial listing of pesticides detected in groundwater from the Abbotsford/Sumas Aquifer includes:

1,2-DCP	1,3-DCP
alachlor	atrazine
azinophos-methyl	carbofuran
chlordane	DDT
diazinon	dimethoate
dinoseb	endosulfan
EDB	oxamyl
simazine	

6.4.2.2 Public Health Concerns Relative to Elevated Pesticide Levels

The drinking water MCLs and MACs for most pesticides are based on long-term (chronic) exposure. Due to different <u>assumptions</u> the Canadian and U.S. drinking water standards and guidelines for various pesticides vary. Regardless, the levels of pesticides detected to date in the Abbotsford/Sumas aquifer are low levels relative to the drinking water standards/guidelines: they do **not** pose any imminent health threat. The presence of pesticides in drinking water supplies *does* indicate that steps need to be taken to reverse the trend and minimize the amount of pesticides entering the groundwater.

Because pesticides have been detected during drinking water monitoring, some public water systems on the side are facing significantly elevated costs associated with increased water quality monitoring and source protection requirements.

6.4.3 Volatile Organic Compounds and Synthetic Organic Compounds

In addition to nitrates and pesticides, some volatile organic compounds (VOCs) are being detected in the Abbotsford/Sumas Aquifer. VOCs can be associated with industrial uses–degreasers and solvents being some of the most common VOCs. Their presence indicates that the Abbotsford/Sumas Aquifer is vulnerable to contaminants released at or near the surface. It is important to realize that all facilities and operations conducted over the aquifer need to take steps to reduce the possibility of releasing contaminants into the environment that may migrate into aquifer.

7.0 DATA INFORMATION AND MANAGEMENT

7.1 INTRODUCTION

The development of successful management plans designed to protect the shared water resources of the Abbotsford-Sumas Aquifer will rely in large part on an accurate understanding of the aquifer system. Accurate hydrologic data is a prerequisite to this understanding of the groundwater resource. The goal of the Data Sub-committee is to assure that accurate hydrologic information is available for developing plans for the protection of the resource. The objectives include:

* Compilation and description of the types of hydrologic information related to the Abbotsford-Sumas Aquifer currently available;

* Identify data or informational gasps which significantly limit current understanding of the aquifer system and will affect development of effective management plans;

* And to facilitate the exchange of groundwater quality and other pertinent data between U.S. and Canadian agencies.

Large quantities of data related to the Abbotsford-Sumas Aquifer have all ready been collected. These data range from regional databases collected primarily by local or national governmental agencies to topical reports and site specific data available in consulting reports and university theses. Information is generally in the form of maps, completed reports, and paper or electronic data files.

This interim report represents the initial effort to compile existing available data. The compilation is divided into three segments; an index of existing hydrologic and geologic maps; an index of completed hydrologic and geologic reports; and a tabulation and description of existing databases and monitoring programs. Later versions of this report will include a brief description of major data gaps that impact current understanding of the Abbotsford-Sumas Aquifer. The compilation and identified data gaps will be updated as additional information becomes available. It should be noted that these data may have been collected and analyzed at different times, by different investigators, for different purposes and may have involved different sample collection and analytical techniques. Consequently, before the data can be directly compared or combined, it is recommended that an assessment of data compatibility be performed.

7.2 AQUIFER STUDIES INDEX

Numerous hydrologic and hydrogeologic studies have been conducted in all or parts of the Abbotsford-Sumas Aquifer area. Many of these studies and investigations involved collection of data on groundwater quality and/or groundwater quantity. The following is a list of Reference Studies whose study areas coincide with the numbered areas indicated on the Aquifer Studies Index map in Figure 5. Reference numbers for regional studies are listed in the upper left-hand corner of Figure 5.

1. Creahan, Kathy, and Harvey M. Kelsey. Hydrogeology and Groundwater Flow near Lynden, Washington. Prepared by Western Washington University for Dept. of Ecology, September 1988.

   Physical groundwater characteristics of the unconfined aquifer in sites A and B are described using water table maps based on well level measurements obtained in March and September, 1987.

   119 wells measured in Lynden area (site A)

   113 wells measured in Bertrand Creek area (site B)

2. Cox, Stephen, et. al., 1993. Hydrogeology, Hydrochemistry, and Sources of Nitrate in Lowland Glacial Aquifers of Whatcom County, Washington, and British Columbia, Canada, U. S. Geological Survey, Water Resources Investigations Report - in preparation.

3. Black and Veatch Architects - Engineers, 1986. Phase 1 Investigation of Ethylene Dibromide Sites, Whatcom County, Washington for State Department of Ecology Remedial Action Division, consulting report, 1986, 90 pp.

4. Erickson, Denis, 1991. Edaleen Dairy Lagoon Groundwater Quality Assessment, February 1990 to February 1991. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, 1991, 32 pp.

5. Erickson, Denis, 1992. Groundwater Quality Assessment, Whatcom County Dairy Lagoon #2, Lynden, Washington. Washington State Department of Ecology Report, Environmental Investigations and Laboratory Services Program, 1992, 26 pp.

6. Erickson, Denis and Dale Norton, 1990. Washington State Agricultural Chemicals 'Pilot Study - Final Report. Washington State Department of Ecology, Environmental

Investigations and Laboratory Services Program, November 1990, 76 pp.

7. Garland, Dave, and Denis Erickson, 1993. Groundwater Quality Survey near Edaleen Dairy, Whatcom County, Washington, January 1990 to April 1993. Department of Ecology, Water Quality Open-File Report - in preparation.

8. Kohut, A. P., 1987. Groundwater Supply Capability: Abbotsford Upland. British Columbia, Ministry of Environment and Parks, Water Management Branch. Victoria, B.C., 18 pp.

9. Kohut, A. P., Sather, S., Kwong, J. and Chwojka, F., 1989. Nitrate Contamination of the Abbotsford Aquifer, British Columbia. Groundwater Section, Water Management Branch, Ministry of the Environment, Victoria, B.C. Paper submitted to Symposium on Ground-Water Contamination, June 14-15, 1989, Saskatoon, Saskatchewan, 22 pp.

10. Liebscher, Hugh, Basil Hii, and Duane McNaughton. Nitrate and Pesticide Contamination of the Groundwater in the Abbotsford Aquifer, Southwestern British Columbia. Environment Canada, June 1992, 85 pp.

11. Turney, G. L. Quality of Groundwater in the Puget Sound Region, Washington, 1981. U. S. Geological Survey Water Resources Investigations Report 84-4258, 1986, 170 pp.

12. Washington Dept. of Conservation. Water Resources of the Nooksack River Basin. Water Supply Bulletin No. 12, Division of Water Resources, 1960, 187 pp.

7.3 BIBLIOGRAPHY OF OTHER RELATED DESCRIPTIVE REPORTS/STUDIES

The studies listed below in are primarily descriptive. These studies do not contain water quality data associated with specific study areas such as in the Reference list (7.2), but provide valuable background discussion and physical descriptions of the aquifer area.

1. Easterbrook, Don J., 1971. Geology and Geomorphology of Western Whatcom County. Western Washington University Department of Geology, 1971, 68 pp.

2. Hydrology Branch - Groundwater Section, 1993. Groundwater Resources of British Columbia. B. C. Environment, Water Management Division.

3. Ecology, Department of, Water well construction reports for wells constructed in the State of Washington. Paper files. For Abbotsford-Sumas Aquifer area (Whatcom County), contact Judith Fisher - Northwest Regional Office Central Files at Bellevue, phone (206) 649-7239.

4. Nooksack River International Task Force, 1991. Preliminary Repry Report on Nooksack River Trans-Boundary Flooding, December, 1991, 17 pp.

7.4 GEOLOGIC MAPS

These are a listing of the geological maps that cover the aquifer.

1. Armstrong, J. E., 1980a. Surficial Geology, Mission, British Columbia. Geological Survey of Canada, Map 1485 A.

2. Armstrong, J. E., 1980b. Surficial Geology, New Westminister, British Columbia. Geological Survey of Canada, Map 1484 A.

3. Easterbrook, D.J., 1976. Geologic Map of Western Whatcom County, scale 1:62,500, U. S. Geological Survey Miscellaneous Investigations Series, Map #I-854-B.

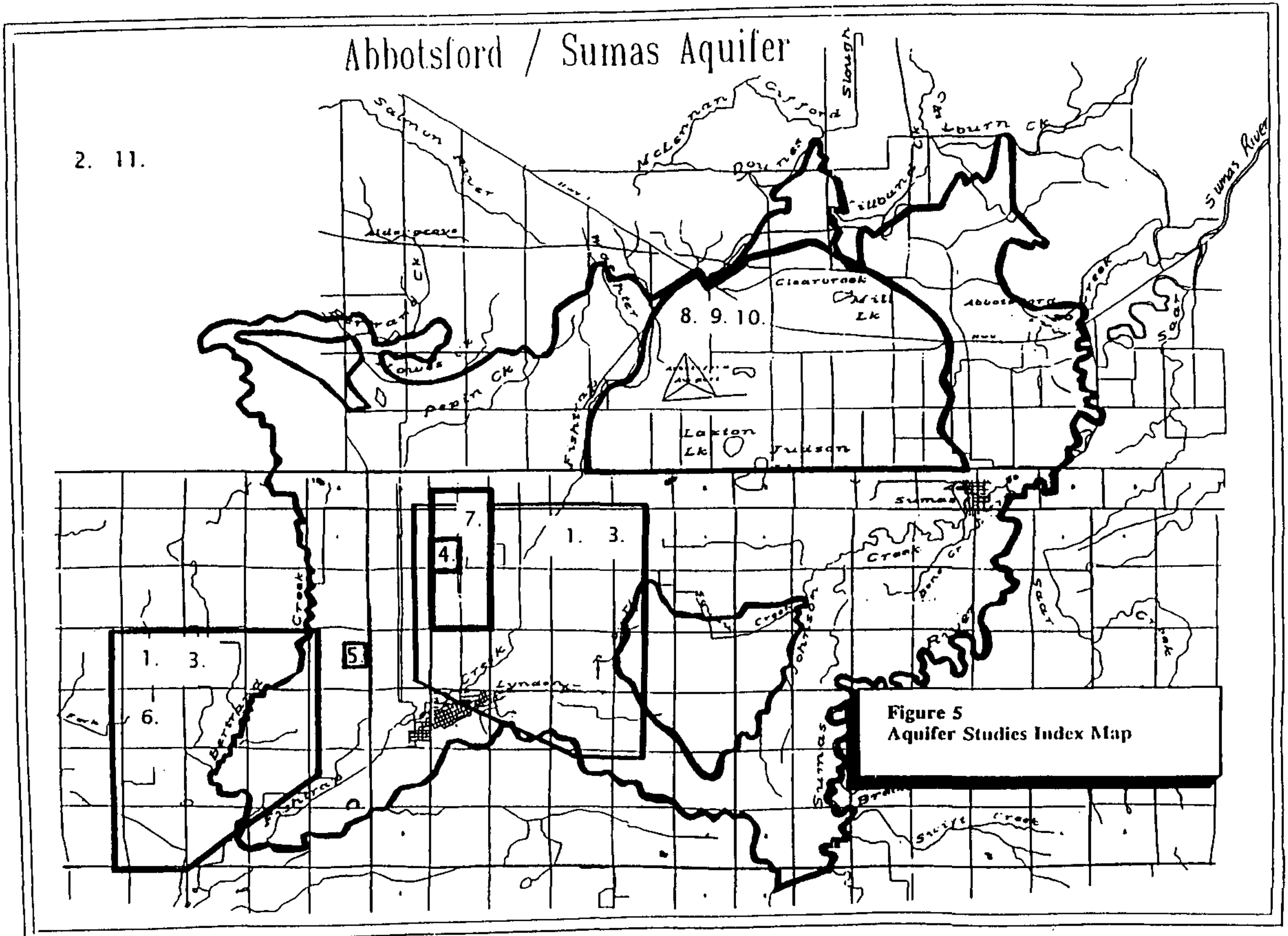

Figure 5
Aquifer Studies Index Map

7.5 ELECTRONIC DATABASES

In addition to the individual studies listed in the above Aquifer Studies Index list and map, considerable water resource and water quality data for the Abbotsford-Sumas Aquifer area is stored in electronic databases. Computer databases are typically edited and maintained by the public agency collecting the data. Data published in the paper reports listed above in the Aquifer Studies Index may or may not be part of an electronic database. The following is a list of agencies with electronic databases and the types of stored data.

7.5.1 B.C. Environment

1. Ambient Water Quality Monitoring Program: A listing of homeowners water quality results from wells monitored by BC Environment.

2. Observation Well Network Database: Water levels and chemistry from the Provincial Network.

3. SEAM Data Base: Water quality results from all BC Environment testing.

4. Computerised Groundwater Database System (CGDS): A database containing well records submitted by drilling contractors for all of BC. Roughly 16,000 records for the Abbotsford-Sumas Aquifer.

5. Water Quality Check Program

6. Several information type databases generated by individual studies and projects.

7.5.2 B.C. Ministry of Health

1. Fraser Valley Groundwater Monitoring Program: Water quality results for the entire Fraser Valley, including 45 wells in the aquifer. This data is also listed in SEAM.

2. Community water supply systems data: A listing of all community wells in the Fraser Valley, including well construction details.

3. Data on septic fields, although not strictly an organised database.

7.5.3 Environment Canada

1. Groundwater level monitoring database: Environment Canada data from observation wells on the Abbotsford-Sumas Aquifer.

2. Groundwater quality databases: Chemistry data from both observation and private wells.

3. Naquadat data base: Obsolete database, replaced by Envirodat, may contain historic data. Data base includes water quality data for surface and ground water sites. Limited descriptive information of water quality sites.

4. Envirodat database: Updated database to replace Naquadat database, includes water-quality date for surface and groundwater site, hydrologic flow data for surface water sites and limited descriptive information on data sites.

7.5.4 Agriculture Canada

1. Various databases to support research on projects and studies.

7.5.5 Washington State Department of Ecology

1. Water Rights Information System (WRIS): Water Rights for Ground and Surface Water allocation in the State of Washington includes annual and instantaneous water quantities granted, uses, place of use, and date of priority of right.

2. Water Rights Application Tracking System (WRATS): A database being developed by Ecology of all water right applications, permits, and certificates. It includes location of use, priority date, type of use, annual and instantaneous quantity, holders of application, permit, or certificate. This database will contain all information required for a water right application field inspection.

3. LaSpina, James and Robert Palmquist, 1991: Catalog of Contaminant Databases: A listing of databases of actual or potential contaminant sources. Washington Department of Ecology Groundwater Vulnerability Project. 55 pp.

4. Leaking Underground Storage Tanks (LUSTs): The Leaking Underground Storage Tank (LUST) database contains information relevant to formal and informal LUST cleanups regulated under the Model Toxics Control Act, Chapter 173-340 WAC as well as other general information regarding cleanup actions and site status: reporting requirements as specified in the regulation and dates met; owner & site information; tank information; cleanup status; whether free product is/has been present; cleanup reports received (date of report and whether interim or final); consultant contact and company; and general information in a "comments" section (NWRO tracks petroleum contaminated soil status, technologies used, and cleanup actions on an ongoing basis, but different regions use this area as each wishes). Computer file - contact person: Jeannette Barreca (206-438-3040); restrictions - no commercial/political use.

5. Underground Storage Tank (UST) Database: Database lists all regulated tanks in Washington State. Hotline number; 1-800-826-7716

6. Environmental Report Tracking Database (ERTS): Regional databases of incidents or complaints filed with each Ecology Regional office. Types of information include spills, water quality, air, and potential hazardous waste sites incidents.

7. Site Management Information System (SMIS): The Site Information tracks information about hazardous substance sites for the Toxics Cleanup Program. The information includes site name, location, owner(s) and or operator(s), confirmed or suspected hazardous substances, the affected media (soil, surface water, groundwater, etc.) waste management practices, standard industrial classification codes, and site status information.

   Sites come to be listed in this database after a release of a hazardous substance or a suspected release has occurred. It is a requirement of the Model Toxics Control Act, Chapter 70.105D RCW, to report these releases to Ecology.

   Some of the sites listed are undergoing formal cleanup actions with state oversight. Other sites are following an independent cleanup process. All site cleanup progress is tracked in this database system.

   A list called the Confirmed and Suspected Contaminated Sites List is published by the Toxics Cleanup Program on a quarterly basis which compiles much of the above information. Sites on this list are continuously updated.

7.5.6 Washington State Department of Health

Inventory and water quality information from Public Water Systems Inventory. Data include source type and location, population served, and treatment provided. Water quality data include coliform and chemical monitoring results.

7.5.7 U. S. Environmental Protection Agency

1. STORET - Water Quality Database

2. Groundwater Management Database - includes well information, site information, and sampling analysis data. Will eventually be linked with a GIS.

3. Agricultural Pesticides - Survey of pesticides used in selected areas having vulnerable groundwaters in WA State. Book - rev. Jul 87; EPA 910/9-87-169.

4. National Pollutant Discharge Elimination System (NPDES). Names of industries & municipalities, receiving water, type of industry, permit status, discharge monitoring reports. Mainframe database; in ADA Base (natural).

7.5.8 U. S. Geological Survey

Water Resource electronic databases maintained by the U. S. Geological Survey fall under the umbrella of the National Water Information System (NWIS). Development is currently underway to modernize NWIS and link it with a Geographic Information System (GIS). The first release of NWIS-II is anticipated for late 1993. Types of USGS databases are described on the following pages.

7.5.8.1 Groundwater Data Subject Area:

1. Ground-Water Descriptive Data Subject Group:

   Ground-water data are collected by the USGS and maintained in the NWIS database by a unique identifier based on latitude and longitude. In addition, a local number based on the Public Land Survey System is also used to identify the locations of ground-water data.

2. Ground-Water Quality Data Subject Group:

   Ground-water quality data are collected by the USGS and maintained in the NWIS database. Ground-water quality data are usually collected for a limited period of time for a specific study.

3. Ground-Water Quantity Data Subject Group:

   Parameters associated with ground-water quantity are maintained in the NWIS database. Examples include well yield, hydraulic conductivity, transmissivity, lithologic units, and aquifer designations. These parameters are considered interpretive, however, and can only be shared with the public if they have been published.

4. Ground-Water Use Data Subject Group:

   Ground-water use data are maintained in the NWIS database. Some of these data are collected by USGS personnel for a limited period of time for a specific study, while more continuous data are obtained from other sources such as the Washington State Department of Health and the Washington State University Irrigated Agriculture Research Station (Thomas W. Ley, at (509) 786-2226).

7.5.8.2 Well Data Subject Area:

1. Well Descriptive Data Subject Group:

   Well location data are collected by the USGS and maintained in the NWIS database by a unique identifier based on latitude and longitude, as well as a local name based on the Public Land Survey System.

2. Well Quality Data Subject Group:

   This subject group is identical to the ground-water quality subject group for the USGS purposes.

3. Well Quantity Data Subject Group:

Well quantity data are collected by the USGS and maintained in the NWIS database. These data are gathered for specific studies. The data sources consist of driller's reports submitted to the Washington State Department of Ecology and observations in the field by USGS personnel.

7.5.8.3 Well Use Data Subject Group:

1. Well Descriptive Data Subject Group

Well location data are collected by the USGS and maintained in the NWIS database by a unique identifier based on latitude and longitude, as well as a local name based on the Public Land Survey System.

2. Well Quality Data Subject Group

This subject group is identical to the ground-water quality subject group for USGS purposes.

3. Well Quantity Data Subject Group

Well quantity data are collected by the USGS and maintained in the NWIS database. These data are gathered for specific studies. The data sources consist of driller's reports submitted to the Washington State Department of Ecology and observations in the field by USGS personnel.

4. Well Use Data Subject Group

This subject group is identical to the ground-water use subject group for USGS purposes.

7.5.8.3 Spring Data Subject Area:

1. Spring Descriptive Data Subject Group:

Spring data are collected by the USGS and maintained in the NWIS database by a unique identifier based on latitude and longitude. In addition, a local number based on the Public Land Survey System is also used to identify spring locations.

2. Spring Quality Data Group:

Spring water-quality data are collected by the USGS and maintained in the NWIS database. Spring-quality data are usually only collected for a limited period of time for a specific study.

3. Spring Quantity Data Subject Group:

Spring quantity data are collected by the USGS and maintained in the NWIS database. Spring quantity data are usually only collected for a limited period of time for a specific study.

4. Spring Resource Data Subject Group:

The USGS does not collect or maintain spring resource data.

5. Spring Use Data Subject Group:

Spring water-use data are maintained in the NWIS database. Some of these data are collected by USGS personnel for a limited period of time for a specific study, while more continuous data are obtained from other sources such as the Washington State Department of Health.

7.5.8.4 Stream Data Subject Area:

1. Stream Descriptive Data Subject Group:

Stream data are collected by the USGS and maintained in the NWIS database by a unique identifier based on a USGS site numbering convention. The latitude and longitude are stored for each site also. The elevation and drainage area are usually available for each site.

2. Stream Quality Data Subject Group:

Stream water-quality data are collected by the USGS and maintained in the NWIS database. Stream water-quality data are collected on a continuous basis for many streams in Washington State and include chemical measurements as well as sediment load determinations. Certain streams may be monitored more intensely for limited periods of time for specific studies.

3. Stream Quantity Data Subject Group:

The USGS collects and maintains stream quantity data at many river throughout the state. The data consists of routine measurements of stage that are collected on a continuous basis. The USGS converts stage measurements to streamflow (discharge) measurements through the application of in-house rating curves. A number of streams may be monitored for a limited time only for a specific study.

4. Stream Resource Data Subject Group:

Stream resource information collected by the USGS is available as published reports.

5. Stream Use Data Subject Group:

Stream water-use data are maintained in the NWIS database. Some of these data are collected by USGS personnel for a limited period of time for a specific study, while more continuous data are obtained from other sources such as the Washington State Department of Health and the Washington State University Irrigated Agriculture Research Station (Thomas W. Ley, at (509) 786-2226). Irrigation water-use data are not identified by surface-water type.

7.5.8.4 Lake Data Subject Area

1. Lake Descriptive Data Subject Group:

Lake data are collected by the USGS and maintained in the NWIS database. Some lakes are monitored on a continuous basis, while others are studied for a short period of time.

2. Lake Quality Data Subject Group:

Water-quality information for lakes is collected by the USGS and maintained in the NWIS database. Water-quality data are collected for limited periods of time for specific studies only.

3. Lake Quantity Data Subject Group:

Water-quantity information for lakes is collected throughout the state. Some lakes are monitored on a continuous basis, while others are monitored for the duration of a specific study only. The collected data are maintained in the NWIS database.

4. Lake Resource Data Subject Group:

Lake resource information is available for selected lakes in published USGS reports only.

5. Lake Use Data Subject Group:

Lake water-use data are maintained in the NWIS database. Some of these data are collected by USGS personnel for a limited period of time for a specific study, while more continuous data are obtained from other sources such as the Washington State Department of Health and the Washington State University Irrigated Agriculture Research Station (Thomas W. Ley, at (509) 786-2226). Irrigation water-use data are not identified by surface-water type.

7.5.8.5 Geographic Locator Data Subject Area:

The latitude and longitude is used by the USGS for all data collection sites. Latitude and longitude are required entries in the NWIS database. Wells and springs are assigned a unique identification number based on the latitude and longitude system.

The Public Land Survey System is used by the USGS in addition to the latitude and longitude system to identify wells and springs. The local well and spring number assigned by the USGS is based on the Public Land Survey System.

The State Plane Coordinate System and the Universal Transverse Mercator System are used interchangeably for individual studies that use a Geographic Information System (GIS). For example, both systems are frequently used for ground-water and surface-water modeling studies.

8.0 EDUCATION AND PUBLIC AWARENESS

The Mandate of the Education and Public Awareness Subcommittee is to develop a proactive program to provide opportunities for a continual exchange of information about the Abbotsford-Sumas Aquifer and the activities of the International Task Force to meet the management needs for the aquifer and its stakeholders.

The purpose of the subcommittee is to outline a program for full and continuous involvement by stakeholders of the Abbotsford-Sumas Aquifer to maximize public awareness of the activities of the Task Force and issues of the aquifer, and to promote best aquifer management practices to all stakeholders utilizing existing agencies.

The scope of the subcommittee was defined by the Task Force to:

1. Develop a needs assessment to determine which areas need to be addressed through education.

2. Outline strategies for implementing public education and efforts.

3. Outline a media plan with strategies.

4. Promote implementation of these public education and involvement efforts.

An Organizational Planning Model including a communications plan was developed and presented to the Task Force at the July 21, 1993, meeting in Lynden, Washington. Details of the model are provided in Appendix 2. The model outlines the procedures of the subcommittee. An external review is being conducted to determine the current status of public awareness and education programs offered by other organizations including all levels of government, advocacy organizations, and industries in Canada and the United States.

Also, a review of the media will ensure maximum coverage is underway. Members of the Task Force were requested to conduct an internal review as directed by areas of consideration developed by the subcommittee. Long-range goals and directions were determined for an awareness phase and an intensive phase.

The management of the model was outlined separately as a communications plan. The plan consisted of:

1. Goal
2. Stakeholders
3. Objectives of the subcommittee for each stakeholder
4. Research of stakeholders including the knowledge required by each stakeholder (Needs Assessment)
5. Strategies
6. Evaluation Criteria
7. Schedule (to be developed)
8. Budget (to be developed)

Details of the communications plan are in Appendix 3.

9.0 CONCLUSIONS

The following conclusions are drawn from the Task Forces' meetings and the five sub-committee reports presented above. Since all the sub-committees dealt with the aquifer, and many issues are common to multiple sub-committees, the source of each conclusion is not identified:

1. The Abbotsford-Sumas Aquifer requires joint management as groundwater quality has been documented as decreasing over the past forty years. There does not appear to be any crisis in the current state of the aquifer, allowing the Task Force to adopt a proactive approach to identifying problems and recommending long term strategies for aquifer management.

2. The surface boundary of the area known as the Abbotsford-Sumas Aquifer is shown by the map in Figure 1. The areal extent of the Aquifer is roughly bounded by Bertrand Creek to the west, the surficial geology near the Fraser/Nooksack topographic divide on the north, Sumas Mountain and the Sumas River on the east, the groundwater divide between Nooksack River and Sumas River in the southeast Corner, and the Nooksack River to the south. The boundary alignment is guided in most areas by river alignment and surficial geology [Armstrong, 1980a, 1980b (B.C.); and Easterbrook, 1976 (U.S.)], and coincides primarily with the occurrence of permeable outwash deposits known in British Columbia and Washington State as Sumas Drift and Sumas Outwash, respectively.

3. The three dimensional boundary of the Abbotsford-Sumas Aquifer coincides with the lower horizon of Sumas Outwash deposits and any related aquifer zones below the surface aquifer boundary. Geologic units underlying the Sumas Outwash deposits are considered part of the Abbotsford-Sumas Aquifer where aquifer zones in those units are in direct hydraulic continuity with groundwater in the Sumas Outwash deposits.

4. Groundwater contamination is reflected in increasing nitrate concentrations, extremely low levels of pesticides being detected in wells on both sides of the border, and chemicals not related to agriculture contributed by industrial activities. Although traditional farming practices are usually cited as the main contributor, septic fields, industrial and municipal sources also add to the nitrate loading problem.

5. Roughly 9800 people in Whatcom County, and 94,000 people in British Columbia rely on well water from the Abbotsford-Sumas Aquifer to meet all or part of their drinking water requirements. Population growth has increased in both Whatcom County and B.C., thus increasing the demand on the aquifer.

6. Public health concerns stem from elevated nitrate level in the Abbotsford-Sumas Aquifer. In addition, the detection of other chemicals indicate proactive steps need to be taken to prevent contamination levels from rising.

7. A proactive program of public education and awareness for a continual exchange of information pertaining to the Abbotsford-Sumas Aquifer and the International Task Force is needed. Such a program will assist in preventing further impacts if the key sources contributing to the contamination are targeted.

10.0 RECOMMENDATIONS

In light of the Conclusions listed above, the Task Force submits the following Recommendations:

1. That the Task Force continue to operate in order to ensure that long term strategies for the management of this highly sensitive resource are developed jointly.

2. That legislation protecting groundwater is enacted in British Columbia as soon as possible to ensure driller licensing, well construction standards, wellhead protection programs and underground storage tank regulations.

3. That the Abbotsford-Sumas Aquifer Task Force, and ultimately the International Environmental Cooperation Council, accept the boundaries of the so called Abbotsford-Sumas Aquifer as defined in this subcommittee report.

4. That all parties acknowledging what is known here as the "Abbotsford-Sumas Aquifer" recognize that the boundary does not encompass the entire areal extent of the Sumas Outwash surficial geologic unit. Rather the aquifer boundary is an area of interest where the most permeable outwash deposits are found and where aquifer susceptibility to contamination is therefore highest.

5. That funds, technology and research initially be made available and directed towards to the farming community in order to reduce the negative impacts on groundwater quality by manure derived nitrates to improve pesticide use through communication of sound pest control practices, and to reduce the negative impacts on groundwater quality by septic field derived nitrates through the use of "state of the art" or new technology in the field of septic disposal.

6. That an inventory of active and closed landfill sites and other potential contamination sources is conducted, the establishment of a monitoring program for closed sites and ensuring fuel storage and handling associated with gravel extraction and asphalt manufacture is according to environmentally sound practices.

7. An assessment of the major sources of groundwater contamination within the Abbotsford-Sumas Aquifer is needed. In addition, a relative risk ranking and implementation prioritization ranking should be conducted to better target future control efforts.

8. Wellhead protection planning should be pursued for the larger community wells and wellfields.

9. All levels of government, on both sides of the border, should prioritize management actions for potential sources of gound-water contamination. On-going cross border exchange of information on monitoring and other data, as well as identified protential contaminant sources having a high likelihood to affect the shared groundwater resource, should continue.

10. That a comprehensive public education and awareness campaign be initiated by all agencies dealing with management of the aquifer. Such a campaign should be target at:

a. special interest groups whose activities have a major impact on groundwater quality;

b. general public whose everyday activities impact on groundwater quality;

c. school children;

d. organizations such as business associations, municipal councils and others.

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APPENDIX 1

ABBOTSFORD-SUMAS AQUIFER MANAGEMENT INTERNATIONAL TASK FORCE

MISSION STATEMENT

Recognizing the immediacy of the issues, the Mission of the Task Force is to coordinate efforts directed towards protecting the aquifer across the common border between Canada and the United States. These efforts will establish a managerial approach, develop aquifer management strategies and identify mechanisms to educate and involve the public in protecting the Aquifer's water quality and water resource values.

July 21, 1993

ABBOTSFORD-SUMAS AQUIFER MANAGEMENT INTERNATIONAL TASK FORCE

VISION STATEMENT

The Abbotsford/Sumas Aquifer is viewed as a shared resource and is being cooperatively managed and protected, insuring water resources of high quality and in sufficient quantity to provide for the future and current needs of the citizens and the environments of British Columbia and Washington State.

July 21, 1993

ABBOTSFORD/SUMAS AQUIFER INTERNATIONAL TASK FORCE

Role and Purpose of the Task Force
TERMS OF REFERENCE

DISCUSSION

In May of 1992, the Province of British Columbia and the State of Washington agreed to promote and coordinate efforts to protect, preserve and enhance our shared environment. This commitment to working cooperatively on environmental issues was recently reconfirmed by Premier Harcourt and Governor Lowry. They agreed that the existing Environmental Cooperation Agreement signed in 1992 ensures a process for information sharing and coordinated action on environmental matters of mutual concern.

The Environmental Cooperation Agreement established the British Columbia/Washington Environmental Coordination Council...

> ...to promote and coordinate mutual efforts to ensure the protection, preservation and enhancement of our shared environment for the benefit of current and future generations,
>
> AND
>
> ...to develop an action plan which shall form part of these efforts, reflecting mutual priorities and to enter into specific arrangements necessary to address environmental problems.

MANDATE/PURPOSE

The BC/WA Environmental Coordination Council met in October of 1992 to confirm an overall preliminary action plan and establish priorities. The Council concluded as one of the issues that:

> Management of the ground water in the Sumas-Abbotsford area is considered to be a HIGH PRIORITY ISSUE and requires immediate joint attention.

The Council moved to arrange a Task Force to address this issue of special significance. In doing so the Council noted that "the aquifers are of particular concern as a result of domestic use on both sides of the border. Improved coordination of the activities of all parties to address both groundwater quantity and quality will encourage more effective resolution."

MEMBERSHIP

It is recognized that a diversity of interests must be involved in the process to effectively address the environmental issues. The Task Force process should allow for government agencies, tribes and constituent groups to participate in the discussion, development of information and recommendations. Membership will be defined (but not limited to) the following:

WASHINGTON

State & Federal Agencies
U.S. Environmental Protection Agency
U.S. Soil Conservation Service
U.S. Geologic Survey
WA Department of Ecology
WA Department of Health
WA Department of Agriculture

Local Government Agencies
City of Sumas (BLENS)
Whatcom County Health Department

Tribal Governments
Nooksack Indian Nation
Lummi Indian Nation

Non-Governmental
WSU Cooperative Extension Service

BRITISH COLUMBIA

Provincial & Federal Agencies
Environment Canada
Agriculture Canada
Health & Welfare Canada
BC Ministry of Environment
BC Ministry of Health
BC Ministry of Agriculture

Municipal Agencies
District of Abbotsford
District of Matsqui
Central Fraser Valley Regional District

Aboriginal
Sto:lo Nation

Non-Governmental
Project Enviro-Health

TASKS/ACTIVITIES

Establishment of the Task Force facilitates a process to coordinate our efforts to address environmental problems. The role of the Task Force can be described as including (but not limited to) the following activities:

Establish a Managerial Approach

This includes establishing standing for interested parties coordinating the activities of and communication between government agencies, tribes and other groups, and promoting government-to-government relationships to accomplish the objectives identified by the Task Force. The Task Force may establish subcommittees or work groups to provide a focus on specialized studies or technical information needs.

Develop and Exchange Information

Develop a means for determining information needs, developing and sharing data, including recommending standard methodology for studies to be conducted. This will insure a complete and reliable foundation of information to base recommendations on.

Develop Aquifer Management Strategies

The Task Force will take a proactive role in identifying solutions to current aquifer water quantity and water quality problems and suggest ways to avert future problems. The coordination and application of available management tools and programs is the preferred approach. The Task Force will establish clear goals and objectives, set the order of priority and recommend appropriately designed action plans.

Education and Public Involvement

The Task Force process is one of self-education and ideally should allow for local citizens to be informed of aquifer issues and made aware of the Task Force activities, and opportunities to participate in the discussion. They are the ones who have livelihoods dependent on a safe and reliable supply of water. The Task Force will develop as a part of the program a proactive citizen involvement and education component.

The role of the Task Force should not be assumed to have the authority to direct implementation efforts. Authority resides with the Council to endorse the activities and recommendations of the Task Force and participating governments maintain their discretion to implement actions recommended by the Task Force.

An annual report will be made to the British Columbia/Washington Environmental Coordination Council. The report will describe the aquifer environmental problems and issues, outline recommended actions and strategies, and summarize activities and accomplishments of the Task Force.

May 12, 1993

ABBOTSFORD-SUMAS AQUIFER INTERNATIONAL TASK FORCE

1. DEFINING AQUIFER BOUNDARIES SUBCOMMITTEE

Scope:
1. Geographic boundaries
2. Policy Implication of boundaries
3. Procedural issues
4. Hydrogeologic of boundaries

Chair: Al Kohut , B.C. Environment
Members: Martha Sabol, U.S. Environmental Protection Agency
Dave Garland, WA. ST. Dept. of Ecology
Stephen Cox, U.S. Geological Survey

Product: Identification of Additional Boundaries

2. DATA/INFORMATION MANAGEMENT SUBCOMMITTEE

Scope:
1. Identification of available Databases/Information management Systems: Who has them (location)?;
2. Types of data available;
3. Identification of Data/Information gaps, What research is needed? How to fill in gaps, How to fund additional studies? How to fund additional data base needs?
4. Access to data across the border;
5. How to display key data/information?

Chair: Stephen Cox, U.S. Geological Survey
Members: Dave Moon, AG Canada - BC Land Resource Unit
Dave Garland, WA.ST. Dept of Ecology
Steve Hirschey, WA.ST. Dept of Ecology
Ginny Stern, WA.ST. Dept. of Health
Lee Ringham, BC Environment

Products: Draft work plan outline.
List of databases.
Needs Assessment.
Proposal.

3. PUBLIC HEALTH SUBCOMMITTEE (Issues Impacting Public Health)

Scope: Working Paper that:

1) Discusses the nitrate/pesticide contamination across border; why we think there is a problem from a public health perspective.

2) Water Quality standards across border (implications);

3) Identification of data gaps (e.g. understanding chronic effects)

4) Recommends actions that can be taken to improve the Aquifer's water quality

Chair: Sue Blake, Whatcom County Health
Members: Dr. Webb, Upper Fraser Valley Health Unit
David Jennings, WA. St. Dept. of Health
Barry Willoughby, Ministry of Health

Product: Working paper

4. LAND USE/LAWS and REGULATIONS SUBCOMMITTEE

Scope:

1. Identify the impacts to the aquifer
2. Identify the laws and regulations in BC/WA
3. Identify the associations and committees in BC/WA who are dealing with Aquifer issues
4. Identify the management tools and control strategies available to various jurisdictions.
5. Identify the sociological aspects of the land users.

Co-Chairs: Ron Bertrand, Ministry of Agriculture, Fisheries and Food
Ann Wick, WA. ST. Dept. of Agriculture
Members: John Gillies, U.S. Soil Conservation Service
Al Kohut, B.C. Environment
Janet Thompson, WA.St. Dept of Ecology
Peter Andzans, District of Matsqui
Herman Almojera, Nooksack Tribe
Doug Dobyns, Nooksack Tribe
David Jennings, WA. St. Dept. of Health
Bill Koberstein, Upper Fraser Valley Health Unit

Products: Draft list of Committees and Laws and Regulations.
Draft working paper on the impacts to the aquifer.

5. EDUCATION/PUBLIC INVOLVEMENT SUBCOMMITTEE:

Scope:

1. Needs Assessment - What areas need to be addressed through education?
2. Outline strategies for implementing public education/efforts?
3. Outline media plan/strategy.
4. Promote the implementation public education/involvement efforts.

Chair: Bradley Whittaker
Members: Craig MacConnell
Don Bowins
Robert Mitchell
Peter Andzans

Product: Draft Needs Assessment.

APPENDIX 2

AN ORGANIZATIONAL PLANNING MODEL

A. SITUATIONAL REVIEW

Mandate

The Education and Public Awareness Subcommittee will develop a proactive program to provide opportunities for a continual exchange of information about the aquifer and the activities of the Task Force to meet the needs of the aquifer and its stakeholder.

External Review

The Subcommittee will review other organizations' programs on public awareness, education, remedial methods and practical alternatives which allow better management of the aquifer. This review is being conducted at this time and will include programs provided by all levels of government, advocacy organizations and industries in Canada and the United States.

A review of the media and contacts will be conducted to ensure maximum coverage and to reach the greatest number of people as possible.

A list of stakeholder and our objectives for them will be developed. Stakeholders will be researched to determine their position or role with respect to the aquifer, their leaders, and their goals.

Internal Review

The Subcommittee will review its requirements with regard to Task Force members, other Task Force subcommittees, and the Task Force itself. Several areas have been identified to date and the subcommittee requires clarification on:

1. Media

a) In responding to inquiries from the media:

Question	Recommendation
• Who are the primary contacts (Canada & U.S.)	• Co-chairs, delegate to task force organizers in each jurisdiction
• who decides what should be said	• each Subcommittee writes press release for approval from task force chair and distributed by designated Education and Public Awareness Subcommittee member
• who should be in constant contact with media (Canada & U.S.)	• designated Education and Public Awareness Subcommittee in each jurisdiction

b) Task Force meetings

• who determines the presence and the role or capacity of the media at Task Force meetings	• U.S. law - open to public, Canada - to be considered
• who creates news releases and has final input or approval on these releases	• Task Force organizers or Education and Public Awareness Subcommittee requiring final approval from co-chairs

c) Clarification of protocol

• who is responsible for news releases from subcommittees	• Subcommittee chair submit to co-chair of Task Force and distribution by Education and Public Awareness Subcommittee

2. Task Force

a) Subcommittee structure

• what process or system will be used for communication between subcommittees	• Subcommittee chair distributes minutes or reports to other subcommittees
• who is responsible for approval of information to be released from subcommittees	• co-chairs of Task Force

Question	Recommendation
• are subcommittees responsible for providing information to the education and public awareness subcommittee for use in educational and promotional packages	• yes
• who will determine what information is important and the target of that information	• each subcommittee identifies: - information requiring development, - target audience of information - delivery agency for development of information
b) Implementation of communications plan	
• what resources will be made available to carry out the communications plan and how will these resources be funded • who will create the required educational and promotional materials	• If the mandate of the Task Force is to develop communication plans and utilize existing agencies, then the Task Force will work with these existing agencies to implement and fund the communications plan and the educational and promotional materials.

B. STRATEGIC PLANNING

Mission/Purpose

The Education and Public Awareness Committee will outline a program for full and continuous involvement by stakeholder of the Abbotsford-Sumas Aquifer to maximize public awareness of the activities of the Task Force and the issue of the Aquifer, and to promote best aquifer management practices to all stakeholder utilizing existing agencies.

Goals and Directions

a) To identify stakeholder and their relationship to the Abbotsford-Sumas Aquifer.

b) To make stakeholder aware of the Task Force and its general activities.

c) To cooperate with other subcommittees in identifying agencies which will develop and deliver information and programs:

- to determine the impact of each stakeholder's activities on the aquifer.
- to address each stakeholder's concerns through continual two-way communications.
- to involve each stakeholder in developing the best methods of educating their constituents on the aquifer and on best practice management.
- to establish a priority list of stakeholder in order to target those who currently have or may have the most impact on the aquifer.
- to develop the best and most effective methods of communication specific to each stakeholder.
- to identify agencies which will develop and deliver information and programs.

APPENDIX 3
COMMUNICATION FRAMEWORK

1. GOAL

To make stakeholders aware of the condition and vulnerability of the aquifer and of methods of prevention of contamination.

2. STAKEHOLDERS	3. OBJECTIVES
General public Home owners Renter Neighborhoods	To use products and methods which will protect the aquifer. These products/methods should be convenient, economical, and efficient for continual use.
Agriculture Industry: Farmers: dairy poultry berry hog	To utilize best waste management practices as outlined by the Ministry of Agriculture. To employ the best agricultural methods to prevent contamination of the aquifer.
Food Processing	To minimize the amount and use of manure, fertilizers, and chemical pesticides and insecticides.
Advocacy Groups:	
Sustainable development groups	To support and promote methods which prevent contamination of the aquifer.
Provincial and regional associations	To research alternate products which cause less contamination.
Manufacturers and suppliers of agricultural products:	To sell best products causing least contamination.

2. STAKEHOLDERS	3. OBJECTIVES
Petroleum Industry Transportation Industry	To employ best methods of production of chemicals/products which will prevent contamination of the aquifer.
Businesses: Dry cleaners Plastics manufacturers Gravel Mining Retailers Solid waste management Printers	To use the best "aquifer-friendly" products and methods. To use the best method of disposal; recycle, reduce, reuse.
Construction Industry: Painters Construction Drywallers	To use the best method of disposal of waste material. To use construction materials which cause least contamination during and after construction.
Developers	To develop land to minimize current and future impact on groundwater.
Abbotsford Airport	To use methods which minimize impacts on groundwater: e.g. petroleum spills, "anti-freeze" for planes.
Governments:	
Municipalities Regional Districts	To promote developments which minimize impact on groundwater. To promote proper disposal of solid waste.
Provincial Government Federal Government	To support an education program to protect the aquifer from contamination.

2. STAKEHOLDERS	3. OBJECTIVES
Schools	To use best methods for solid waste disposal including the 3 Rs.
	To use best methods for disposal of liquid wastes.
	To promote methods for students to utilize at home for prevention of contamination.
Media	To provide correct and recent information regarding groundwater issues to the public.
	To provide information to the public about attitudes, approaches and preventative measures for the maintenance and improvement of the quality of groundwater.

4. RESEARCH STAKEHOLDERS - KNOWLEDGE REQUIRED BY STAKEHOLDERS

I. Aquifer

A. Aquifer location

1. locally
2. internationally

B. Water quality

1. Nitrates

a. potential sources
- in water
- in diet

b. health implications

2. Pesticides

   a. potential sources
   b. health implications

3. Volatile Organic Compounds

   a. potential sources
   b. health implications

4. Other

   a. potential sources
   b. health implications

C. Water Quantity

1. Surface water
2. Groundwater
3. Inter-relationship

   a. hydraulic continuity

4. Beneficial uses

   a. usage
   b. allocation strategies

II. Task Force

A. Mission
B. Participants
C. Activities
D. Proposals

III. Protection / Conservation

A. BMPs to protect from contamination
B. Conservation practices
C. Sources of assistance

1. Education
2. Technical
3. Financial

IV. Regulations

V. Data

A. Existing data
B. Data gaps
C. Planned studies

VI. Other

A. Position on issue
B. Opinion leaders
C. Message
D. Priority List of Stakeholders

1. Contaminant Contributors

a. Major - targeted first
b. Minor

5. STRATEGIES

A. Preparation of multimedia presentations:

1. Video, slide show and pamphlets/brochures of the land use activities and their possible consequences on the groundwater quality.

2. Video, slide show and publications of alternate approaches, uses, and activities to minimize groundwater contamination.

3. Series of articles for local newspapers on the condition of the groundwater and alternative methods of activities to limit contamination.

4. A regular series on prevention of contamination advertisements/stories for local newspapers and radio.

5. Large billboards "advertising" the recharge area and encourage prevention of contamination.

6. Information pamphlets specific to special interest groups (those responsible for contamination) regarding improvement in methods of operation to prevent contamination.

7. Models, static and dynamic, illustrating the physical properties of the aquifer to promote a better understanding of the "operation" of the aquifer.

8. Education packages for certain grades in the school system.

B. **Target groups for presentations**

1. Special interest groups whose activities have a major impact on the quality of groundwater.

2. General public whose everyday activities impact on groundwater quality.

3. School children from primary to college.

4. Organizations (associations, groups, clubs).

C. **Methods and arenas for presentations**

1. General public:

    - organized activities, e.g. meetings, trade shows, exhibitions, conferences
    - unorganized activities, e.g. malls, displays

2. Specific organizations:

    - general meetings, special workshops, on-site

3. Schools:

    - in-class lessons and assignments by teachers and ITF personnel

4. Media:

    - prepared articles, talk shows, instructional videos

5. In office:

    - individual and group presentations, discussions and inquiries
    - telephone contacts and inquiries

6. EVALUATION CRITERIA

Each activity performed by the ITF should be evaluated and monitored to determine that the most effective methods continue to be used and the least effective be discontinued or improved. Evaluation also assists in continual updating with most recent information and programs, and follow-up of impact on the targeted groups.

A. Indicators

1. Number of organizations and people who receive:
   - presentations, workshops, pamphlets, brochures
2. Number of classes and students who receive instruction in preventative methods.
3. Number of instructional packages given out to organizations.
4. Amount of air time on television and radio.
5. Number of inquiries via telephone and in person.
6. Number of articles and "advertised" stories printed in newspapers, magazines, trade and conference materials.

7. SCHEDULE

8. BUDGET