A Department of Ecology Report

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Nooksack Watershed Surficial Aquifer Characterization

Summary

Nooksack Watershed Surficial aquifers (the uppermost saturated zone, typically an unconfined water-table condition, and of mappable extent) are identified and characterized using existing hydrogeolgic, soils, and well information. Data are compiled, stored, and analyzed using the ARC/INFO Geographic Information System. A surficial aquifer map delineates the lateral boundaries of all identified surficial aquifers in the watershed. The principal surficial aquifer in the watershed is designated the Sumas-Blaine Aquifer. Additional maps characterize the Sumas-Blaine Aquifer thickness, depth-to-water, and water-table contours. All data files, including detailed soil property information, are documented and available for use.

Recommendations

- Compile existing groundwater quality data for the watershed and place in Ecology's Environmental Investigations and Laboratory Services (EILS) database.

- Conduct a groundwater quality assessment of the Sumas-Blaine Surficial Aquifer for nitrate, ammonia, and total nitrogen. Focus on the area west of the U.S. Geological Survey (USGS) study area.

- Use the information compiled for this project to calibrate a groundwater flow model for the Sumas-Blaine Surficial Aquifer. The model will be used to estimate the groundwater/surface water interaction and, when combined with the groundwater quality data, would be used to estimate potential contaminant loading to the Nooksack River. For realistic results, refined spatial distributions of hydraulic conductivity and lithology will be needed.

by John Tooley and Denis Erickson
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Introduction

Purpose

The purpose of this project is to compile existing hydrogeologic data and characterize surficial aquifers in the Nooksack Watershed. A surficial aquifer is defined as the uppermost saturated zone, typically an unconfined water-table condition, of mappable extent. Characterization consists of delineation of lateral boundaries and spatial definition of lithology, thickness, water-table elevations, and flow direction. Data are stored, analyzed, and displayed using the ARC/INFO Geographic Information System (GIS). Support and data files compiled for this report are available for use by others including the Groundwater Vulnerability Assessment Project. This report describes methods and results, and also provides data set documentation in Appendix A.

Site Description

The Nooksack River Watershed is located at the northern end of Puget Sound. The study area coincides with Water Resources Inventory Area #1 which includes nearly all of Whatcom County and a small piece of northern Skagit County (Figure 1). The study area is bounded by the Strait of Georgia to the west, Canada to the north, the Cascade Range to the east and the Skagit River Basin to the south.

General Geology and Hydrogeology

The geologic framework controls the occurrence and movement of groundwater, and the geology in the Nooksack Watershed is quite diverse. The Whatcom Basin, the west portion of the watershed, is characterized by glacial and alluvial sediments up to 600 feet thick overlying sedimentary bedrock. The Eastern Upland (central, east and south portions watershed) consists of sedimentary, metamorphic and igneous bedrock (Shumway, 1960). Generally, the bedrock transmits water poorly and is not considered significant for this project.

The hydrogeology of the Whatcom Basin is characterized by a vertical distribution of sand and gravel water-bearing zones, sandwiched between silty and clayey units of low permeability. This study focuses on the uppermost water-bearing units exposed at the ground surface. Surficial aquifers are a major source of water in the region and are recharged by infiltrated precipitation and irrigation. They readily interact with surface water and serve as an important source of summer streamflows for the Sumas and Nooksack Rivers and tributaries.

Data Quality Objectives and Procedures

The data quality objectives are to maintain accuracy and precision of the source data, document the accuracy, and minimize errors introduced by data entry and spatial analysis. These were achieved by carefully controlling spatial tolerances (GIS software settings which control the precision of spatial data) when editing and analyzing spatial data.

The spatial distribution of lithologic thickness, depth-to-water, and water-table elevation were defined using only wells that have been field verified and identified as being completed in the aquifer unit being evaluated.

Verification plots were prepared and compared with source maps. All label errors and dangling arcs were removed from the polygon layers.

Methods

Information Sources

There were three primary sources of information used in the course of this project. These included: 1) published and unpublished hydrogeologic investigations, 2) hydrogeologic and soils maps (including digital GIS versions), and 3) well construction information. Published reports and unpublished investigations are listed in the bibliography. Other data sources are listed below.

The lateral extent of surficial aquifers was delineated using the following sources:

- Digitized Surficial Aquifer Map (Larson, 1994, unpublished)

- Digitized Natural Resource Conservation Service (formerly Soil Conservation Service) soil maps provided by Whatcom County Planning Department.

- Washington Department of Natural Resources digitized soil maps in the Skagit County portion of the project area.

- Geologic map for Whatcom County from Easterbrook (1976)

- Digitized geologic map provided by Whatcom County (Digital version of Easterbrook)

Land surface elevation and surface water elevation were determined from the following sources:

- Washington Department of Natural Resources 1:24,000 Digital Elevation GRID

- Washington Department of Fish and Wildlife 1:100,000 Washington Rivers Information System stream center lines.

Well construction information was obtained from the USGS Groundwater Site Inventory System. Site description, water level, and lithology information was obtained for all wells within the project area. Only those wells identified by the USGS as being completed within the *Sumas Drift of Frasier Glaciation* were used for depth-to-water and water-table contour analyses.

Additional well construction and lithology data were obtained from the Blaine Groundwater Management Area Study (Golder, 1990 and 1992), Bellingham Frozen Foods facility well logs, and USGS well logs on file in Tacoma, Washington.

Data Management Procedures

Fortunately digital data were available for the project area and generally only needed to be reformatted, converted to a standard map coordinate system, and/or converted to ARC/INFO data layers. Since these data were automated by others, we could not control the data-entry procedures.

In general the assignment of a polygon attribute code was used to designate the presence of the surficial aquifer. Some minor editing of the spatial data was required to adjust aquifer boundaries in a few areas. This editing followed the data entry guidelines developed by USGS for 1:100,000 Digital Line Graph data (USGS, 1989). The guidelines specify that the resolution of the digitizer be 0.001 inch with an absolute accuracy of 0.003 to 0.005 inch. Digitizer registration error was maintained at less than the .003 Root Mean Square as recommended by ARC/INFO software developers (ESRI, 1991). The following ARCEDIT tolerances were used:

- grain and weed tolerance = 40 feet
- node-snap tolerance = 40 feet
- arc-snap tolerance = 40 feet
- intersect arcs = ON
- duplicate arcs = OFF

Well data were managed using Microsoft Access database software with data fields modeled after the USGS Groundwater Site Inventory database. Digital well data maintained by the USGS were downloaded from the USGS Washington District Office computer in Tacoma, Washington. These data were imported into the Access database and water-level data summarized prior to being exported to ARC/INFO.

Aquifer Characterization

The lateral boundaries of the surficial aquifer units were determined using an iterative process of delineation based mapped hydrogeology, mapped soil units, and lithology obtained from well logs. A rough delineation of the surficial aquifer was first based on hydrogeologic units (floodplain alluvium, river terraces, beach deposits, glacio-fluvial terraces, and outwash terraces) shown on the geologic map developed for western Whatcom County (Easterbrook, 1973).

Soil mapping units and soil properties available from the Natural Resource Conservation Service, Whatcom and Skagit County soil surveys, were then used to provide a more detailed delineation of the aquifer units. Those soils which formed on the hydrogeologic units mentioned above were included within the surficial aquifer lateral boundary. Pockets of till and glaciomarine drift identified by the soil properties were then excluded from the aquifer units.

The final step was to examine lithology from well logs and further refine the lateral boundary. Wells located within and outside the lateral boundary were examined to verify the location of the boundary. The lateral boundary was then adjusted based on the presence of shallow confining layers shown in the well logs which had not been indicated by either geologic or soil mapping.

Because of limited data availability, aquifer thickness, depth-to-water, and water-table contours were mapped for only the Sumas-Blaine Aquifer.

Thickness was determined by plotting the depth to the top and bottom of the Sumas-Blaine unit and completed well depth on a 1:60,000 scale base map. For those wells designated by Cox and Kahle as completed in the Sumas but without lithology specified, the total well depth was assumed to reflect a minimum unit thickness. From these points isopach lines were drawn to fit the data. These were then digitized into an ARC/INFO line and polygon layer.

Depth-to-water contours were developed based on information from those wells completed in the Sumas-Blaine Aquifer. For each well a depth-to-water was assigned based on either the mean value of periodically measured depth-to-water, if periodic measurements were available, otherwise the depth-to-water at construction was used. The wells and depth-to-water were plotted on a 1:60,000 scale base map, and depth-to-water contours were drawn to fit the data. These were then digitized into an ARC/INFO line and polygon layer.

Water-table contours were prepared using water levels from those wells identified as being completed in the Blaine-Sumas Aquifer and stream elevations at points where streams crossed land surface elevation contours. An ARC/INFO triangular irregular network surface model was fit to the well and surface water elevations. Next a surface smoothing algorithm was applied and the final water-table contours calculated.

Results and Conclusions

The surficial aquifers mapped during this project were grouped into the following aquifer units:

- Sumas-Blaine Aquifer
- Upper Valley Aquifers
- Discontinuous Surficial Aquifers

The lateral boundaries of these surficial aquifers are shown in Plate 1. The following sections describe each of these aquifers in detail.

Sumas-Blaine Aquifer

We have designated the principal surficial aquifer in the Nooksack Watershed as the Sumas-Blaine Aquifer. The Sumas-Blaine Aquifer continuously underlies the flat glacial outwash plain between the towns of Sumas, Blaine, Ferndale and the Nooksack River floodplain. It occupies an area of about 150 square miles. The aquifer consists predominately of sand and gravel glacial outwash deposits and alluvial gravel, sand, silt and clay deposits of the Nooksack and Sumas Rivers. The thickness of the deposits is shown in Figure 2 and ranges from over 75 feet thick near Sumas to less than 25 feet near Blaine. The depth-to-water table is shown in Figure 3. The water-table is shallow, typically less than 10 feet. Exceptions occur near Sumas where depth-to-water exceeds 50 feet and near the eastern margin of the aquifer where depths exceed 25 feet.

A water-table contour map for the Sumas-Blaine Aquifer is shown in Figure 4. Water-table contours represent the elevation of the water-table surface and can be used to estimate groundwater flow direction. Groundwater flows at approximate right angles to the contours from high to low water-table surface elevations. In general, groundwater flows toward the Nooksack and Sumas Rivers which act as regional drains. The contours imply that, in addition to infiltrated precipitation, the aquifer is hydraulically connected to water-bearing zones beneath the upland areas near Sumas and east of Blaine.

Hydraulic conductivity, the ease that water moves through an aquifer, is one of the most important parameters that affects the rate that groundwater moves, the quantity of water that moves through an aquifer, and the degree that an aquifer interacts with surface water. Hydraulic conductivity of glacial and alluvial deposits are highly variable, commonly ranging over numerous orders of magnitude (Davis and DeWeist, 1966; Freeze and Cherry, 1979).

Regionally, hydraulic conductivity and transmissivity of the Sumas-Blaine Surficial Aquifer is expected to decrease to the west and south as the grain size of the outwash deposits become finer and the deposits thin. Cox and Kahle (in progress) used specific capacity data from 164 wells to estimate the hydraulic conductivity and transmissivity (hydraulic conductivity times aquifer thickness)of the Sumas outwash deposits. They reported hydraulic conductivity ranged from 7 to 7,800 feet per day. Further analysis of these data by Culhane (1993) showed the transmissivity results were log-normally distributed with a geometric mean of about 12,000 to 13,000 gallons per day/foot (gpd/ft). Culhane also reported that 95% of transmissivity values fell within the range of 720 to 220,000 gpd/ft.

Upper Valley Aquifers

Upper valley aquifers, associated with the three forks of the Nooksack River (north, middle, and south forks), are significant surficial aquifers in the watershed. The upper valley aquifers consist of interlayered mixtures of gravel, sand, silt and clay and occupy the river valley bottoms. They are limited in extent by surrounding bedrock with low hydraulic conductivity. In many cases the upper valley aquifers are hydraulically connected to glacio-fluvial terrace deposits and outwash terrace deposits along valley walls. The hydraulic relationship of the terrace deposits is significant because the valley aquifers may receive a large portion of their recharge through these deposits. The North Fork Valley Aquifer appears to be hydraulically connected to a broad outwash terrace beneath the Columbia Valley.

There were insufficient wells with verified well locations in the databases to define aquifer properties (thickness, depth-to-water, and water-table contours) of the upper valley aquifers. Well data are insufficient to define the relationship of the alluvial and terrace deposits.

Discontinuous Surficial Aquifers

Numerous Discontinuous Surficial Aquifers were identified in the watershed. They consist of a variety of geologic deposits including beach (modern and remnant), glacio-fluvial terrace deposits, modern alluvial and floodplain deposits, isolated outwash terraces, and marine terrace deposits.

The hydrologic properties of these aquifers are expected to vary as widely as the geologic processes by which they were formed. Although potentially locally significant, they are usually thin and not a major source of water. The lateral boundaries are based solely on parent associations of soils, as there is little well information able to confirm lateral boundaries and define hydrologic properties.

Soils Properties

Soil properties constitute an important component in the assessment of aquifer susceptibility to contamination. Examples of some critical properties include soil permeability; soil texture, particle size distribution and clay content; depth-to-water; organic content; cation exchange capacity; and pH.

As an example of the utility of soil property data, Figure 5 shows the occurrence of moderate to high permeability soils (equal to or greater than 2 inches/hour) relative to the surficial aquifers and depth-to-water contours. Areas where highly permeable soils occur over shallow groundwater likely correspond to areas susceptible to contamination from surface activities. These areas are readily apparent on the map. In addition we have juxtaposed on Figure 5 the locations of commercial dairies ranked by size. The information from this map could be used to establish permitting or site inspection priorities based on the potential for groundwater contamination. Again, this is only an example of the utility of combining the soil property data with the surficial aquifer information and is not intended to imply that dairies are the only potential sources of contamination in the area.

Appendix B contains a full list of soil properties available for each of the 6,062 soil polygons within the project area. Listed below is a shortened list of the soil properties considered important for groundwater susceptibility analysis.

- Surface Soil Texture
- Soil Permeability Rate expressed as inches/hour
- Water-table Depth measured to seasonally high water-table
- Hydrologic Group
- Soil Drainage Class code describing natural drainage condition of soil (e.g., well, excessive, poorly)
- Minimum Organic Content expressed as percent by weight
- Soil pH
- Cation Exchange Capacity
- Soil Texture Class - Code for USDA texture (e.g., Loam [L] Sandy Loam [SL])
- Clay Content expressed as percent material < 2mm (%)
- Unified Soil Classification
- Depth of upper boundary of the cemented pan (inches)
- Cemented Pan Thickness

Spatial and Tabular Data

Several spatial and tabular data sets were compiled during this project. These will be made available to staff working on the Groundwater Vulnerability Assessment Project, regional water quality hydrogeologists, and any other interested staff. The major data sets are listed in the table below.

GIS Data Layer	Description	Number of Spatial Features Present in the Data Layer
nook-aq	Aquifer layer, based on SCS soils data with aquifer attributes assigned.	6072 polygons, 5 regions
nookwell	Wells from USGS Groundwater Site Inventory, Blaine Groundwater Management Area Study, Facility files, and USGS well logs.	2,111 points
nook-dtw	Sumas-Blaine Surficial Aquifer depth-to-water contours and polygons based on wells identified as being completed within the Sumas-Blaine Surficial Aquifer	87 arcs, 27 polygons
nook-iso	Sumas-Blaine Surficial Aquifer lithologic thickness contours and polygons based on wells identified as being completed within the Sumas-Blaine Surficial Aquifer	36 arcs, 28 polygons
nook-ws	Sumas-Blaine Surficial Aquifer water-table surface contours based on water levels in wells identified as being completed within the Sumas-Blaine Surficial Aquifer and stream elevations	102 arcs
Tabular Data	**Description**	**Columns/Records**
comp	Soil component data - describes soil properties which apply to the whole soil mapping unit	52 Columns 10,801 Records (Statewide)
layer	Soil layer data which describes soil properties for a particular layer of the soil mapping unit	56 Columns 35,625 Records (Statewide)
interp	Soil interpretation rating describing suitability and limitations of the soils	8 Columns 279,049 Records (Statewide)

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Acknowledgements

This project depended entirely on existing information. During times of government budget cuts, it is especially important to acknowledge agency data sources without which this project would have not been possible. Notable contributors of data are listed as follows:

- Steve Cox and Sue Kahle, U.S. Geological Survey, Water Resource Division, Tacoma, Washington.
- Terry Aho, Natural Resource Conservation Service, Spokane, Washington.
- John Hergesheimer, City of Blaine Public Works, Blaine, Washington.

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Appendix A - GIS Data Layer Documentation

COVERAGE: nook-aq

SERVER: shuksan

LOCATION: /net/shuksan/eils1/projects/fy96/gw/nook/final/nook-aq
DESCRIPTION: Surficial Aquifer of the Nooksack Watershed, developed from SCS soil survey, hydrogeology, and well information. Contains ARC/INFO region (named AQUIFER subclass) which delineates the surficial aquifers, those areas without surficial aquifers, and the un-characterized areas.

LAYER TYPE: POLY, REGION (AQUIFER subclass)

ANNOTATED: NO

MAP PROJECTION: WA State Plane South Zone (5626)

MAP UNITS: feet

MAP EXTENT: Water Resource Inventory Area 1

INPUT SCALE: 1:12000

INPUT FORMAT: digitized from soils maps, attributes edited in Arc/Edit
DATA SOURCE: SCS Soils with aquifer attribute assignment.

COMPLETION: 2-96
LAST UPDATED: 2-96

RELATED TABLES: comp - soil component attributes from SCS Map Unit Interpretation database

layer - soil layer attributes from SCS Map Unit Interpretation database

Item Format for INFO File NOOK-AQ.PAT

ITEM NAME	DESCRIPTION	DEFINITION
AREA	Area in coverage units	4,12,F,3
PERIMETER	Polygon perimeter in coverage units	4,12,F,3
NOOK-AQ#	Program assigned spatial feature identifier	4,5,B,0
NOOK-AQ-ID	User controlled spatial feature identifier	4,5,B,0
LITH.AQ.CD	Code describing geomorphic setting	2,2,I,0
	1 = alluvial 2 = outwash 3 = glaciofluvial terraces 4 = marine terraces 99 = not characterized	
AQUIFER-CD	Surficial Aquifer Unit Code	1,1,I,0
	0 = Surficial Aquifer not present 1 = Sumas - Blaine Surficial Aquifer present 2 = Discontinuous Surficial Aquifer present 3 = Valley Aquifers 9 = Not characterized	
SRC-CD	Data Source Code	3,3,I,0
	1 = WRIA boundary 2 = Wa. DNR Soil Survey 173 = SCS Soil survey for Whatcom County	
MUID	SCS Map Unit Interpretation Record statewide uniq	8,8,C,0

COVERAGE: nook-dtw

SERVER: shuksan

LOCATION: /net/shuksan/eils1/projects/fy96/gw/nook/final/nook-dtw

DESCRIPTION: Sumas - Blaine Surficial Aquifer depth to water contours based on well information

LAYER TYPE: NET

ANNOTATED: NO

MAP PROJECTION: WA State Plane South Zone (5626)

MAP UNITS: feet

MAP EXTENT: Sumas - Blaine Surficial Aquifer (Central Whatcom County)
INPUT SCALE: 1:60,000

INPUT FORMAT: Digitized from ARC/INFO Produced Base Map

DATA SOURCE: Professional interpretation of well water levels

COMPLETION: 2-96

LAST UPDATED: 2-96

RELATED TABLES: none

CLASSIFIED DATA: NO

NOTES: Usage: used to produce maps for report, and for characterizing depth to water

CONTACT: John Tooley (360) 407-6418
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Item Format for INFO File NOOK-DTW.AAT

ITEM NAME	DESCRIPTION	DEFINITION
FNODE#	From node number	4,5,B,0
TNODE#	To node number	4,5,B,0
LPOLY#	Polygon number to left of arc	4,5,B,0
RPOLY#	Polygon number to right of arc	4,5,B,0
LENGTH	Arc length in coverage units	8,18,F,5
NOOK-DTW#	Program assigned spatial feature identifier	4,5,B,0
NOOK-DTW-ID	User controlled spatial feature identifier	4,5,B,0
WAT-DP-QT	Depth to water contour	4,12,F,3

Item Format for INFO File NOOK-DTW.PAT

ITEM NAME	DESCRIPTION	DEFINITION
AREA	Area in coverage units	8,18,F,5
PERIMETER	Polygon perimeter in coverage units	8,18,F,5
NOOK-DTW#	Program assigned spatial feature identifier	4,5,B,0
NOOK-DTW-ID	User controlled spatial feature identifier	4,5,B,0
TH-CON-QT	Lower limit of depth to water for the polygon	4,12,F,0

COVERAGE:	nook-ws
SERVER:	shuksan
LOCATION:	/net/shuksan/eils1/projects/fy96/gw/nook/final/nook-ws
DESCRIPTION:	Water Table Contours based on selected wells and surface water elevations.
LAYER TYPE:	LINE
ANNOTATED:	NO
MAP PROJECTION:	WA State Plane South Zone (5626)
MAP UNITS:	feet
MAP EXTENT:	Sumas - Blaine Surficial Aquifer (Central Whatcom County, Washington)
INPUT SCALE:	1:100000
INPUT FORMAT:	Generated from surface analysis of Triangular Irregular Network
DATA SOURCE:	Hydrography from 1:100000 streams intersected with 7.5' DEM and wells from USGS GWSI and Water Quality Management Areas
COMPLETION:	2-96
LAST UPDATED:	2-96
RELATED TABLES:	no
CLASSIFIED DATA:	NO
NOTES:	Usage: Shows general water table elevations (indicator of flow direction)
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Item Format for INFO File NOOK-WS.AAT

ITEM NAME	DESCRIPTION	DEFINITION
FNODE#	From node number	4,5,B,0
TNODE#	To node number	4,5,B,0
LPOLY#	Polygon number to left of arc	4,5,B,0
RPOLY#	Polygon number to right of arc	4,5,B,0
LENGTH	Arc length in coverage units	4,12,F,3
NOOK-WS#	Program assigned spatial feature identifier	4,5,B,0
NOOK-WS-ID	User controlled spatial feature identifier	4,5,B,0
CONTOUR	Elevation of water table contour	4,12,F,3

COVERAGE: nook-iso

SERVER: shuksan

LOCATION: /net/shuksan/eils1/projects/fy96/gw/nook/final/nook-iso
DESCRIPTION: Sumas - Blaine Surficial Aquifer thickness based on well information

LAYER TYPE: NET

ANNOTATED: NO

MAP PROJECTION: WA State Plane South Zone (5626)

MAP UNITS: feet

MAP EXTENT: Sumas - Blaine Surficial Aquifer (Central Whatcom County, Wa.)

INPUT SCALE: 1:60000

INPUT FORMAT: Digitized from Arc/Info Produced Base Map
DATA SOURCE: Professional interpretation based on well logs

COMPLETION: 2-96

LAST UPDATED: 2-96

RELATED TABLES: none

CLASSIFIED DATA: NO

NOTES: Usage: used to produce maps for reports.

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Item Format for INFO File NOOK-ISO.AAT

ITEM NAME	DESCRIPTION	DEFINITION
FNODE#	From node number	4,5,B,0
TNODE#	To node number	4,5,B,0
LPOLY#	Polygon number to left of arc	4,5,B,0
RPOLY#	Polygon number to right of arc	4,5,B,0
LENGTH	Arc length in coverage units	8,18,F,5
NOOK-ISO#	Program assigned spatial feature identifier	4,5,B,0
NOOK-ISO-ID	User controlled spatial feature identifier	4,5,B,0
THK-QT	Isopach of aquifer thickness	4,12,F,0

Item Format for INFO File NOOK-ISO.PAT

ITEM NAME	DESCRIPTION	DEFINITION
AREA	Area in coverage units	8,18,F,5
PERIMETER	Polygon perimeter in coverage units	8,18,F,5
NOOK-ISO#	Program assigned spatial feature identifier	4,5,B,0
NOOK-ISO-ID	User controlled spatial feature identifier	4,5,B,0
THK-CON-QT	Lower limit of thickness for the isopach interval	4,12,F,0

COVERAGE: usgs

SERVER: shuksan

LOCATION: /net/shuksan/eils1/projects/fy96/gw/nook/final/nookwell

DESCRIPTION: Whatcom County Wells from USGS GWDATA system
Lithology, water level summaries from GWDATA
Intersected with Surficial Aquifer to encode Surficial
Aquifer Units

LAYER TYPE: POINT

ANNOTATED: NO

MAP PROJECTION: WA State Plane South Zone (5626)

MAP UNITS: feet

MAP EXTENT:

INPUT SCALE: variable

INPUT FORMAT: generated from reported latitude and longitude

DATA SOURCE: USGS Groundwater Database

COMPLETION: 11-15-95

LAST UPDATED:

RELATED TABLES:

CLASSIFIED DATA: NO

NOTES:

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Item Format for INFO File USGS.XAT

ITEM NAME	DESCRIPTION	DEFINITION
AREA	Not used	4,12,F,3
PERIMETER	Not used	4,12,F,3
WELLS#	Program assigned spatial feature identifier	4,5,B,0
WELLS-ID	User controlled spatial feature identifier	4,5,B,0
SITE_NR	USGS Site ID (unique station identifier)	15,15,C,0
F_MEAS_DT	Beginning date for water level measurements	8,10,D,0
L_MEAS_DT	Ending date for water level measurements	8,10,D,0
MIN_LVL_QT	Minimum measured depth to water (below land surf	8,25,F,5
MAX_LVL_QT	Maximum measured depth to water (below land surf	8,25,F,5
MEANLVL_QT	Average measured depth to water (below land surf	8,25,F,5
CNT_LVL_QT	Number of water level measurements	8,25,F,5
H-DEPTH_QT	Depth of hole (c27)	8,25,F,5
W-DEPTH_QT	Depth of well (c28)	8,25,F,5
T-INT-QT	Depth to top of interval (c91)	8,25,F,5
B-INT-QT	Depth to bottom of interval (c92)	8,25,F,5
AQUIFER_CD	USGS Aquifer code (c93)	8,8,C,0

112EVRS - Everson Interstade of Frasier Glaciation
112PLSC - Pliestocene Series
112SUMS - Sumas Drift of Frasier Glaciation
112VSHN - Vashon Drift of Frasier Glaciation
124CCKN - Chuckanut Formation

LITH_CD	USGS Lithology code (c96)	4,4,C,0

SILT - sils
DRFT - drift
SGVC - sand, gravel, clay
SDGL - sand, gravel
GLCL - glacial (undifferentiated)
SAND - sand
SNDS - sandstone

CONT_CD	USGS Contributing unit code (c304)	1,1,C,0

P - Principal contributing aquifer (only one per site)
S - Secondary contributing aquifer
N - Contributes no water
U - Unknown contribution

DESC_DS	Description of interval material (c97)	123,123,C,0
PROJ_NR	USGS Project identifier number	12,12,C,0
ACY-CD	Ecology assigned agency code	4,4,C,0

USGS - US Geological Survey
ECY - Washington Dept of Ecology

LOCAL_NR	Local well number (c12)	24,24,C,0
LAT_DS	Latitude (c9)	8,19,F,5
LONG_DS	Longitude (c10)	8,19,F,5
LL_CD	Lat-long accuracy code (c11)	1,1,C,0

S - The measurement is accurate to + 1 second.
F - The measurement is accurate to + 5 seconds.
T - The measurement is accurate to + 10 seconds.
M - The measurement is accurate to + 1 minute.

ALT_QT	Altitude of land surface reported from GWDATA (	8,19,F,5
REC_CD	Data reliability classification (c3) C=field che	1,1,C,0

C - Data have been field checked by the reporting agency.
L - Location not accurate.
M - Minimal data.
U - Data have not been field checked by the reporting

agency, but the reporting agency considers the data reliable.

TYPE_CD	Type of site (c2)	1,1,C,0

C - Collector or Ranney type well.
D - Drain dug to intercept the water table or potentiometric surface to either lower the ground-water level or serve as a water supply.
E - Excavation.
H - Sinkhole.
I - Interconnected wells, also called connector or drainage wells; that is, a well interconnected via an underground lateral.
M - Multiple wells. Use only for well field consisting of a group of wells that are pumped through a single header and for which little or no data about the individual wells are available.
O - Outcrop.
P - Pond dug to intercept the water table or potentiometric surface and serve as a water supply.
S - Spring (used only on spring schedule).
T - Tunnel, shaft, or mine from which ground water is obtained.
W - Well, for single wells other than wells of the collector or Ranney type.
X - Test hole, not completed as a well.

CONT_DT	Well construction date (c21)	8,8,D,0
USE_CD	Primary use of site (c23)	1,1,C,0

A - Anode	P - Oil or gas well
C - Standby emergency supply	R - Recharge
D - Drain	S - Repressurize
E - Geothermal	T - Test
G - Seismic	U - Unused
H - Heat reservoir	W - Withdrawal of water
M - Mine	X - Waste disposal
O - Observation	Z - Destroyed

WUSE_CD	Use of water (c24)	1,1,C,0

A - Air conditioning	I - Irrigation	R - Recreation
B - Bottling	J - Industrial (cooling)	S - Stock
C - Commercial	K - Mining	T - Institutional
D - Dewater	M - Medicinal	U - Unused
E - Power	N - Industrial	Y - Desalination
F - Fire	P - Public supply	Z - Other (explain in remarks)
H - Domestic	Q - Aquaculture	

WLVL_DT	Water level date (c31)	8,8,D,0
WLVL_QT	Depth to water at construction (c030)	8,19,F,5
LVL_MTH_CD	Method of measuring water level (c34)	1,1,C,0

A - Airline measurement
B - Analog or graphic recorder
C - Calibrated airline measurement
E - Estimated
G - Pressure-gage measurement
H - Calibrated pressure-gage measurement
L - Interpreted from geophysical logs
M - Manometer measurement
N - Nonrecording gage
R - Reported, method not known
S - Steel-tape measurement
T - Electric-tape measurement
V - Calibrated electric-tape measurement

Z - Other

STAT_CD Site status at water measurement (c37) 1,1,C,0

D - The site was dry (no water level is recorded).
E - The site was flowing recently.
F - The site was flowing, but the head could not be measured (no water level is recorded).
G - A nearby site that taps the same aquifer was flowing.
H - A nearby site that taps the same aquifer had been flowing recently.
I - Injector site (recharge water being injected into the aquifer).
J - Injector site monitor (a nearby site that taps the same aquifer is injecting recharge water).
N - The measurements at this site were discontinued.
O - An obstruction was encountered in the well above the water surface (no water level is recorded).
P - The site was being pumped.
R - The site had been pumped recently.
S - A nearby site that taps the same aquifer was being pumped.
T - A nearby site that taps the same aquifer had been pumped recently.
V - A foreign substance was present on the surface of the water.
W - The well was destroyed.
X - The water level was affected by stage in nearby surface-water site.
Z - Other conditions that would affect the measured water level (explain in remarks).

If no site status is indicated, the inventoried water-level measurement represents a static level.

SRC_CD Source of water level data (c33) 1,1,C,0

A - Reported by another government agency. Do not use "A" if the reporting agency is the owner of the well--use "O".
D - From driller's log or report.
G - Private geologist-consultant or university associate.
L - Depth interpreted from geophysical logs by personnel of source agency.
M - Memory (owner, operator, driller).
O - Reported by the owner of the well.
R - Reported by person other than the owner, driller, or another government agency.
S - Measured by personnel of reporting agency.
Z - Other source (explain in remarks).

STALVL_QT Static water level (c154) 8,19,F,5
HOR_K_QT Horizontal hydraulic conductivity (c108) 8,19,F,5
POR_QT porosity (c306) 8,19,F,5
LITH.AQ.CD Surficial Aquifer Code, , ,3=g 2,2,I,0

1 - alluvial
2 - outwash terrace
3 - Glacio-fluvial terrace
4 - Marine terrace

LITH_DP_QT Calculated Depth to bottom of lithology unit 8,24,F,2
WS_ELEV_QT Calculated water surface elevation (MSL) 8,24,F,2
ALT_DIF_QT Calculated difference between reported altitude 8,12,F,0
DEM_QT Calculated land surface elevation based on inter 4,12,F,3
SURFACE-CD Assigned code used in surface calculations 2,2,I,0

Appendix B - List of Soil Properties Contained in Soils Database

Table	Column	Data Type	Width	Description
comp	stssaid	Text	5	State Survey Area ID
comp	muid	Text	8	Map Unit Identification
comp	musym	Text	5	Map Unit Symbol
comp	compname	Text	35	Component Name
comp	seqnum	Number (Long)	4	Sequence Number
comp	s5id	Text	6	Soil Interpretations Record Number
comp	comppct	Number (Long)	4	Component Percent
comp	slopel	Number (Long)	4	Soil Slope - Minimum value for range of slope of a soil component within the mapunit
comp	slopeh	Number (Long)	4	Soil Slope - Maximum value for range of slope of a soil component within the mapunit
comp	surftex	Text	255	Surface Soil Texture
comp	otherph	Text	40	Class Dermining Phase Criteria - For selecting interpretation record
comp	compkind	Text	1	Kind of Component
comp	compacre	Number (Long)	4	Component Acres - The acreage of the component of a soil map unit
comp	clascode	Text	20	Taxonomic Classification Code
comp	anflood	Text	5	Annual Flood Frequency - descriptive term used to describe frequency of flooding
comp	anflodur	Text	3	Flood Duration Class - duration of annual flooding
comp	anflobeg	Text	3	Annual Flooding Month Begin
comp	anfloend	Text	3	Annual Flooding Month End
comp	gsflood	Text	5	Growing Season Flooding Frequency
comp	gsflodur	Text	11	Growing Season Flood Duration
comp	gsflobeg	Text	3	Growing Season Flood Begin Month
comp	gsfloend	Text	3	Growing Season Flood End Month
comp	wtdepl	Number (Long)	4	Water Table Depth - minimum value for the range in depth to the seasonally high water table
comp	wtdeph	Number (Long)	4	Water Table Depth - maximum value for the range in depth to the seasonally high water table
comp	wtkind	Text	5	Water Table Kind - type: apparent, perched, artesian
comp	wtbeg	Text	3	Water Table Begins - month in which seasonal water occurs as depth specified in normal year
comp	wtend	Text	3	Water Table Ends - month in which seasonal water subsides below the depth specified in normal year
comp	pnddepl	Number (Double)	8	Minimum Ponding Depth - minimum value for range in depth of surface water ponding on the soil
comp	pnddeph	Number (Double)	8	Maximum Ponding Depth - maximum value for range in depth of surface water ponding on the soil
comp	pnddur	Text	11	Ponding Duration - duration of surface water ponding
comp	pndbeg	Text	3	Ponding Begins - Month in which soil surface ponding begins in a normal year
comp	pndend	Text	3	Ponding Ends - Month in which soil surface ponding ends in a normal year
comp	rockdepl	Number (Long)	4	Minimum Depth to Bedrock the minimum value for the range in depth to bedrock (inches)
comp	rockdeph	Number (Long)	4	Maximum Depth to Bedrock the maximum value for the range in depth to bedrock (inches)
comp	rockhard	Text	5	Bedrock Hardness - degree of hardness of underlying rock
comp	pandepl	Text	255	Minimum Depth to Cemented Pan - minimum depth to upper boundary of cemented pan (inches)
comp	pandeph	Text	255	Maximum Depth to Cemented Pan - maximum depth to upper boundary of cemented pan (inches)
comp	panhard	Text	5	Cemented Pan Thickness
comp	subinitl	Number (Integer)	2	Minimum Initial Subsidence - min value for the range of initial subsidence when drained (inches)
comp	subinith	Number (Integer)	2	Maximum Initial Subsidence - max value for the range of initial subsidence when drained (inches)
comp	subtotl	Number (Integer)	2	Minimum Total Subsidence - min value for the range of total subsidence when drained (inches)
comp	subtoth	Number (Integer)	2	Maximum Total Subsidence - max value for the range of total subsidence when drained (inches)
comp	hydgrp	Text	3	Hydrologic Group
comp	frostact	Text	8	Potential Frost Action
comp	drainage	Text	5	Soil Drainage Class code describing natural drainage condition of soil ex: well, excessive, poorly, etc
comp	hydric	Text	1	Hydric Soil Rating - flag identifying hydric soils
comp	corcon	Text	8	Corrosion - Concrete - rating of susceptibility of concrete to corrosion in contact with soil
comp	corsteel	Text	8	Corrosion - Uncoated Steel - rating of susceptibility of steel to corrosion in contact with soil
comp	clnirr	Text	1	Nonirrigated Capability Class - rating of non-irrigated agricultural use
comp	clirr	Text	1	Irrigated Capability Class - rating of irrigated agricultural use
comp	sclnirr	Text	2	Nonirrigated Capability Subclass - rating of non-irrigated agricultural use
comp	sclirr	Text	2	Irrigated Capability Subclass - rating of irrigated agricultural use
layer	stssaid	Text	5	State Survey Area ID
layer	muid	Text	8	Map Unit Identification
layer	seqnum	Number (Integer)	2	Sequency Number
layer	s5id	Text	6	Soil Interpretations Record Number

layer	layernum	Number (Integer)	2	Layer Number - sequency identifying layers in the soil profile
layer	layerid	Number (Integer)	2	Layer Identification Number
layer	laydepl	Number (Integer)	2	Upper Layer Depth - Depth to the upper boundary of the soil layer or horizon (inches)
layer	laydeph	Number (Integer)	2	Lower Layer Depth - Depth to the lower boundary of the soil layer or horizon (inches)
layer	texture	Text	26	Soil Texture Class - Code for USDA texture ex: Loam (L) Sandy Loam (SL)
layer	kfact	Number (Single)	4	Soil Erodibility Factor includes rock fragments
layer	kffact	Number (Single)	4	Soil Erodibility Factor rock Fragment Free - factor used by Universal Soil Loss Equation
layer	tfact	Number (Integer)	2	T - Factor - Soil loss tolerance factor, maximum rate of soil erosion which will permit high crop production
layer	weg	Text	2	Wind Erodibility Group
layer	inch10l	Number (Integer)	2	Minimum Weight Percent >10 inches - Min value in range of rock fragments > 10 in. in size (%)
layer	inch10h	Number (Integer)	2	Maximum Weight Percent >10 inches - Max value in range of rock fragments > 10 in. in size (%)
layer	inch3l	Number (Integer)	2	Minimum Weight Percent 3-10 inches - Min value in range of rock fragments 3 - 10 in. in size (%)
layer	inch3h	Number (Integer)	2	Maximum Weight Percent 3-10 inches - Max value in range of rock fragments 3 - 10 in. in size (%)
layer	no4l	Number (Integer)	2	Minimum Weight Percent Passing Sieve #4 - Min in range passing #4 sieve (%)
layer	no4h	Number (Integer)	2	Maximum Weight Percent Passing Sieve #4 - Max in range passing #4 sieve (%)
layer	no10l	Number (Integer)	2	Minimum Weight Percent Passing Sieve #10 - Min in range passing #10 sieve (%)
layer	no10h	Number (Integer)	2	Maximum Weight Percent Passing Sieve #10 - Max in range passing #10 sieve (%)
layer	no40l	Number (Integer)	2	Minimum Weight Percent Passing Sieve #40 - Min in range passing #40 sieve (%)
layer	no40h	Number (Integer)	2	Maximum Weight Percent Passing Sieve #40 - Max in range passing #40 sieve (%)
layer	no200l	Number (Integer)	2	Minimum Weight Percent Passing Sieve #200 - Min in range passing #200 sieve (%)
layer	no200h	Number (Integer)	2	Maximum Weight Percent Passing Sieve #200 - Max in range passing #200 sieve (%)
layer	clayl	Number (Integer)	2	Minimum Clay - Minimum clay content expressed as percent material < 2mm (%)
layer	clayh	Number (Integer)	2	Maximum Clay - Maximum clay content expressed as percent material < 2mm (%)
layer	lll	Number (Integer)	2	Minimum Liquid Limit - Minimum value for liquid limit expressed as percent moisture by weight (%)
layer	llh	Number (Integer)	2	Maximum Liquid Limit - Maximum value for liquid limit expressed as percent moisture by weight (%)
layer	pil	Number (Integer)	2	Minimum Plasticity Index - Min value in range expressed as percent moisture by weight. (%)
layer	pih	Number (Integer)	2	Maximum Plasticity Index - Max value in range expressed as percent moisture by weight. (%)
layer	unified	Text	20	Unified Soil Classification
layer	aashto	Text	25	American Assoc. of State Highway and Transportation Officials Group (AASHTO) Classification
layer	aashind	Text	3	AASHTO group index (modification of AASHTO Classification)
layer	awcl	Number (Single)	4	Minimum Available Water Capacity - Min value in range expressed as inches/inch
layer	awch	Number (Single)	4	Maximum Available Water Capacity - Max value in range expressed as inches/inch
layer	bdl	Number (Single)	4	Minimum Bulk Density - Minimum value in range expressed as grams / cubic centimeter
layer	bdh	Number (Single)	4	Maximum Bulk Density - Maximum value in range expressed as grams / cubic centimeter
layer	oml	Number (Single)	4	Minimum Organic Matter - Min value in range expressed as percent by weight
layer	omh	Number (Single)	4	Maximum Organic Matter - Max value in range expressed as percent by weight
layer	phl	Number (Single)	4	Minimum Soil Reaction pH - Min in range expressed as pH units
layer	phh	Number (Single)	4	Maximum Soil Reaction pH - Max in range expressed as pH units
layer	salinl	Number (Integer)	2	Minimum Salinity - Min in range of salinity expressed as conductivity mmhos/cm
layer	salinh	Number (Integer)	2	Maximum Salinity - Max in range of salinity expressed as conductivity mmhos/cm
layer	sarl	Number (Single)	4	Minimum Sodium Absorption Ratio - Min in range of Sodium Absorption Ratio
layer	sarh	Number (Single)	4	Maximum Sodium Absorption Ratio - Max in range of Sodium Absorption Ratio
layer	cecl	Number (Single)	4	Minimum Cation Exchange Capacity in range
layer	cech	Number (Single)	4	Maximum Cation Exchange Capacity in range
layer	caco3l	Number (Integer)	2	Minimum Calcium Carbonate in range
layer	caco3h	Number (Integer)	2	Maximum Calcium Carbonate in range
layer	gypsuml	Number (Integer)	2	Minimum Sulfates Reported as Gypsum In The Range For The Layer
layer	gypsumh	Number (Integer)	2	Maximum Sulfates Reported as Gypsum In The Range For The Layer
layer	perml	Number (Single)	4	Minimum Permeability Rate in the Range For the Layer Expressed As Inches/Hour
layer	permh	Number (Single)	4	Maximum Permeability Rate in the Range For the Layer Expressed As Inches/Hour
layer	shrinksw	Text	9	Shrink-Well Potential
layer	wei	Number (Integer)	2	Wind Erodibility Index Assigned To Layer
interp	grpcode	Text	2	State Survey Area ID
interp	rating	Text	2	Sequence Number
interp	restct1	Text	2	Interpretative Group Code - ex: septic, excavations
interp	restct2	Text	2	Soil Interpretation Rating - specifies suitability for a particular use
interp	restct3	Text	2	Rating Limitation Restriction #1
interp	seqnum	Number (Long)	4	Rating Limitation Restriction #2
interp	stssaid	Text	5	Rating Limitation Restriction #3

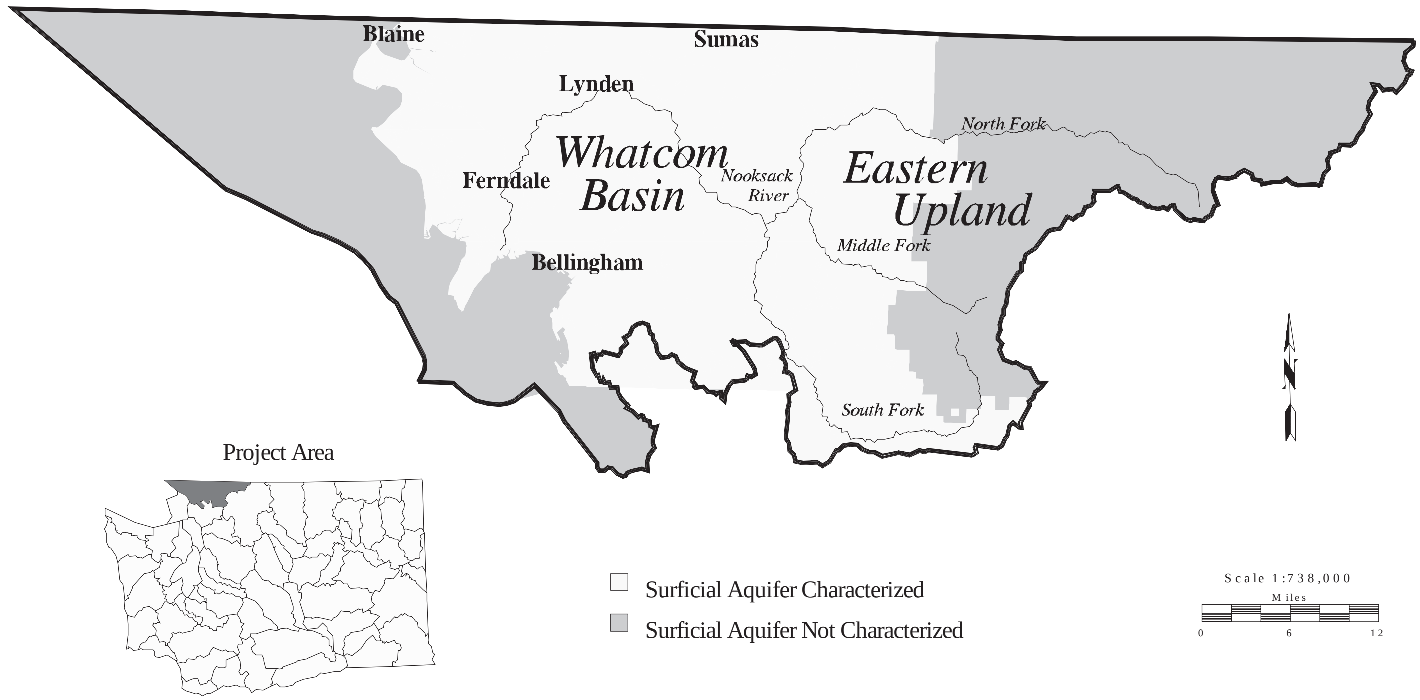

Figure 1 Nooksack Watershed Surficial Aquifer Characterization Area.

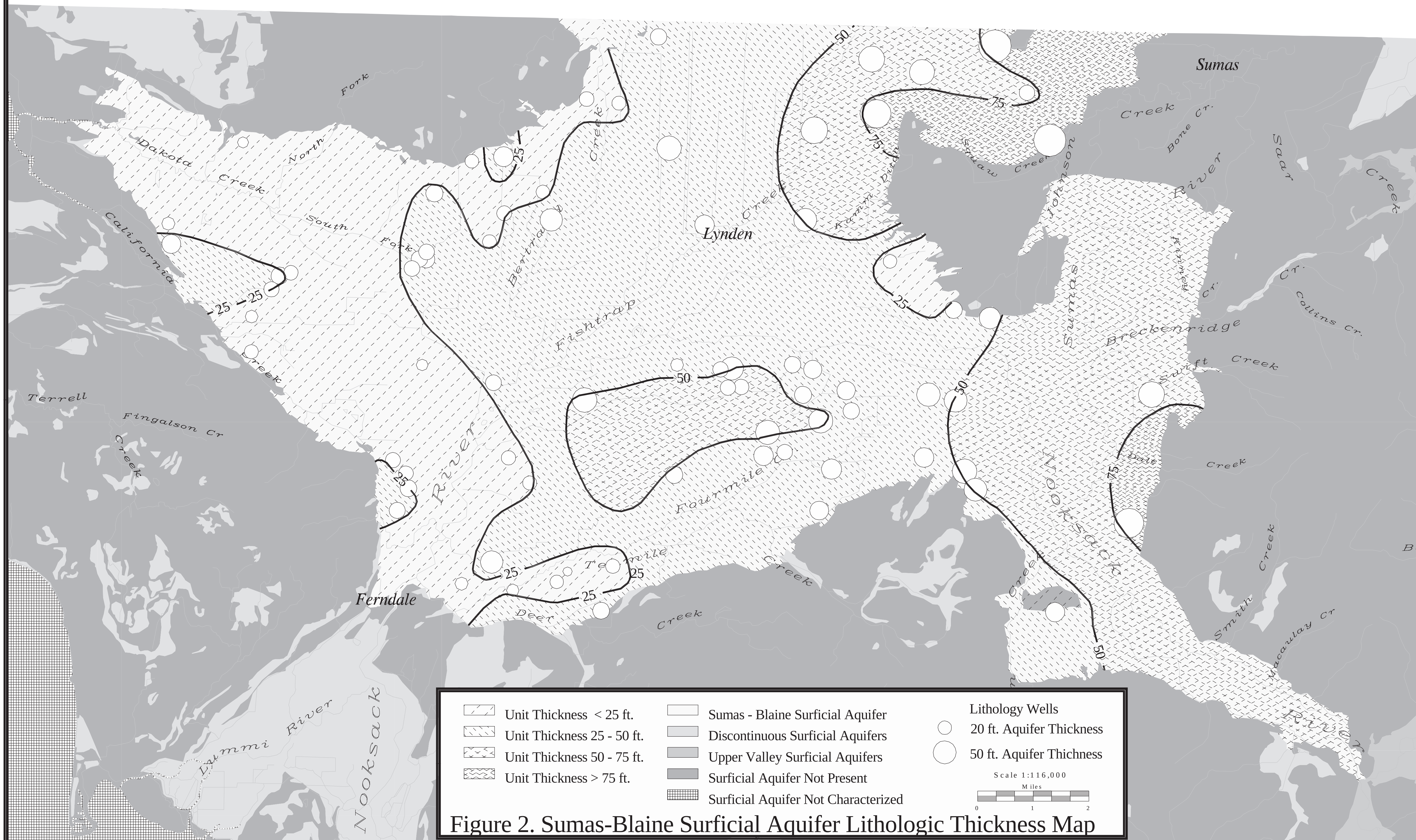

Figure 2. Sumas-Blaine Surficial Aquifer Lithologic Thickness Map

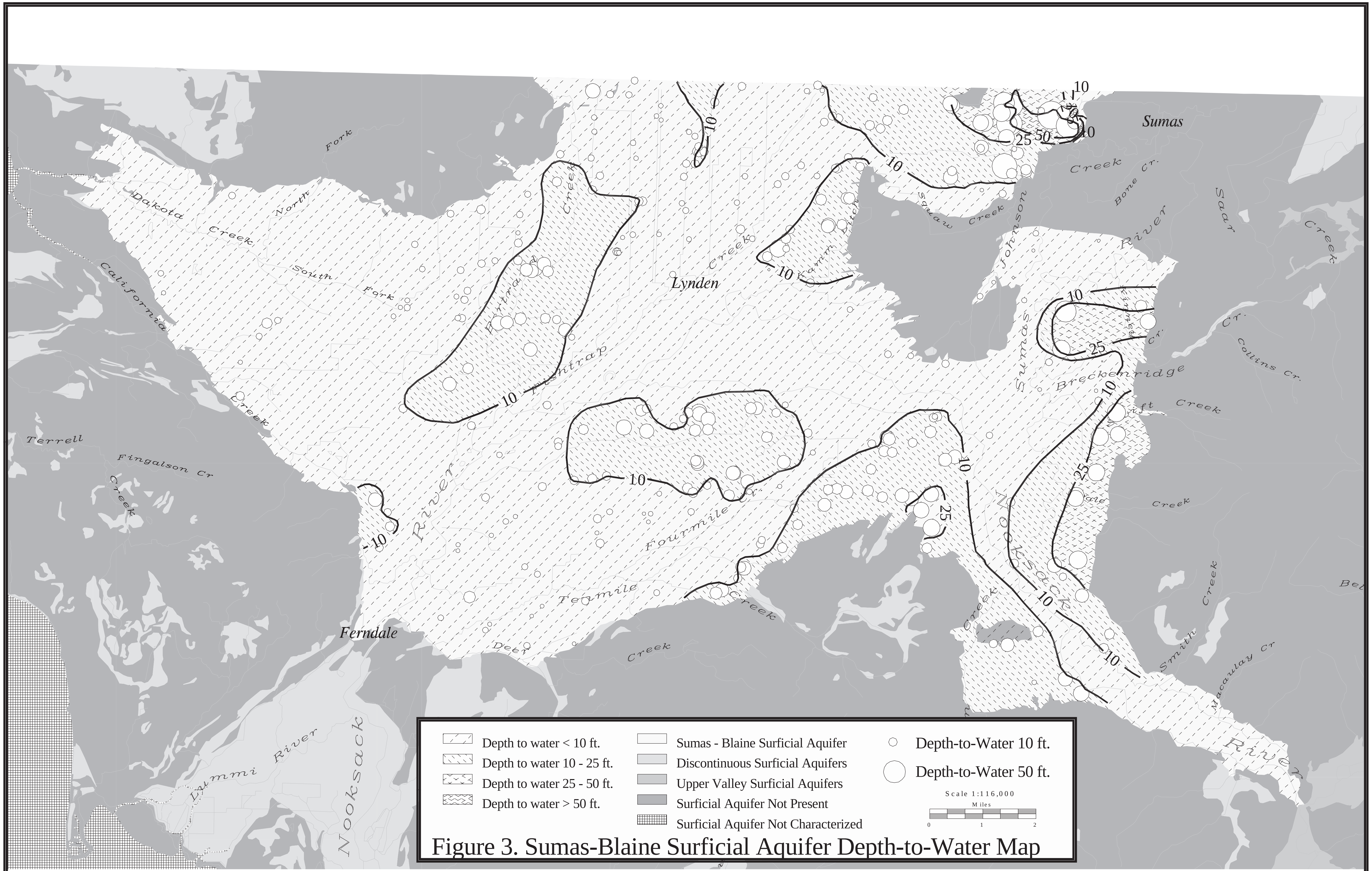

Figure 3. Sumas-Blaine Surficial Aquifer Depth-to-Water Map

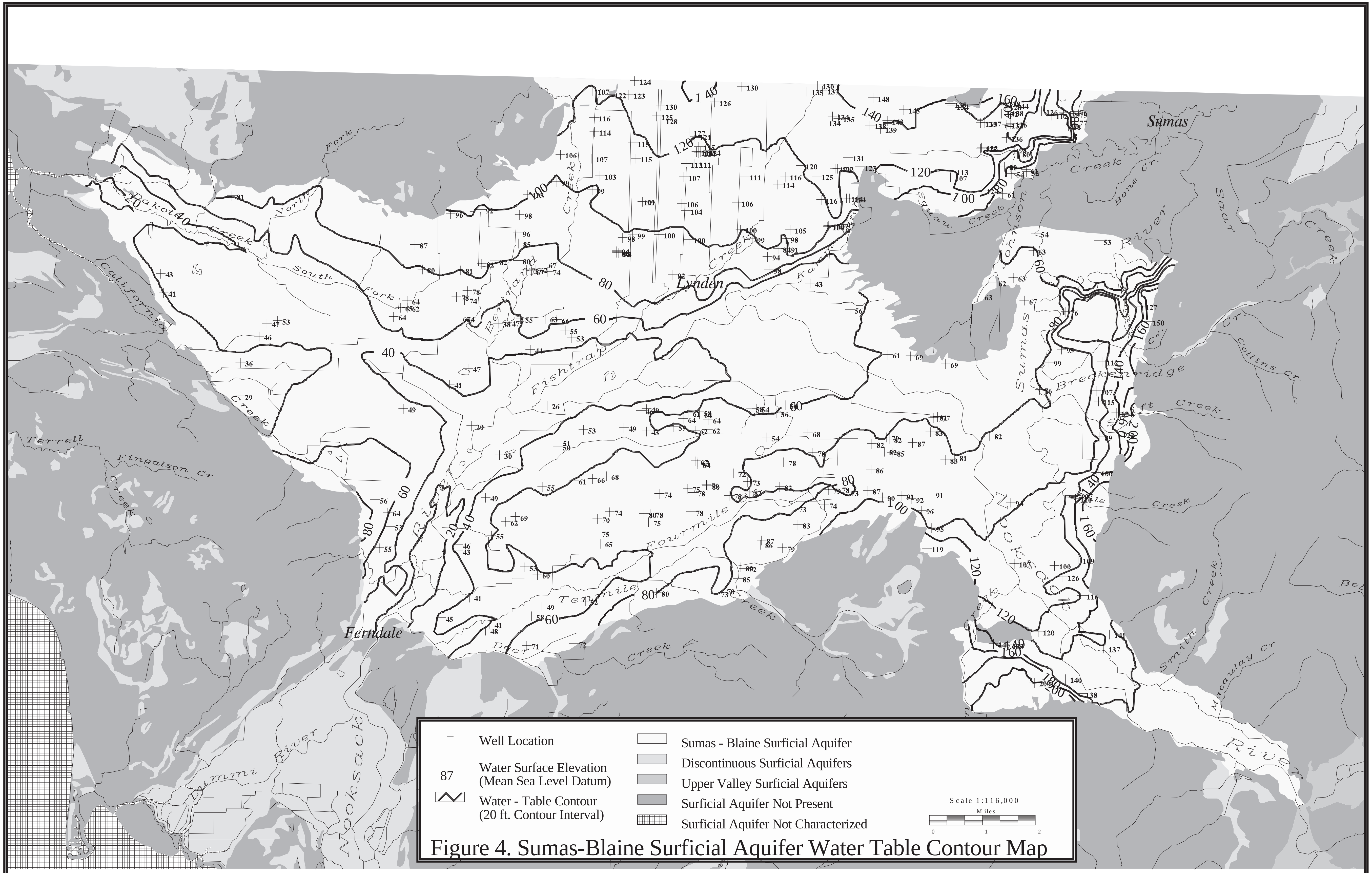

Figure 4. Sumas-Blaine Surficial Aquifer Water Table Contour Map

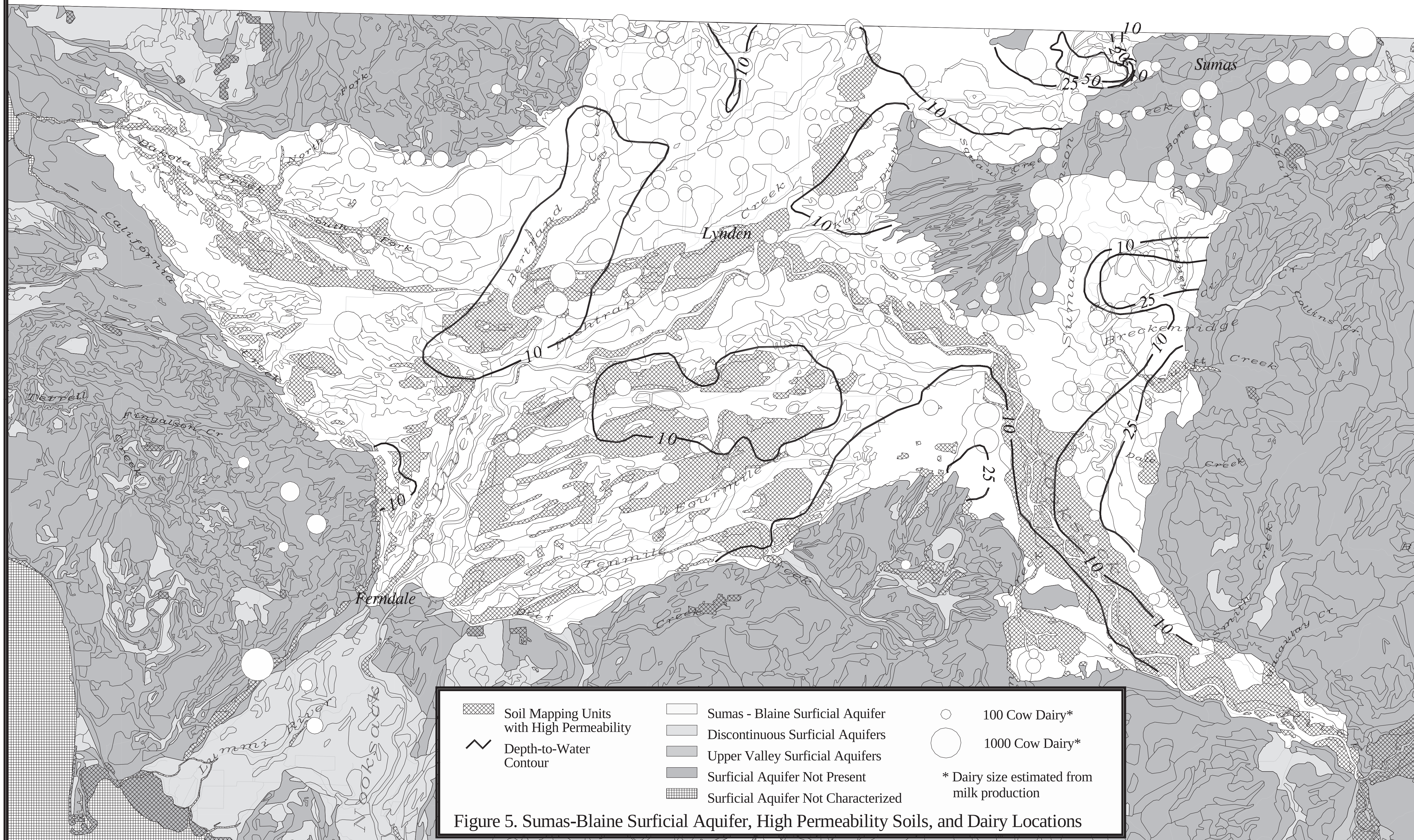

Figure 5. Sumas-Blaine Surficial Aquifer, High Permeability Soils, and Dairy Locations

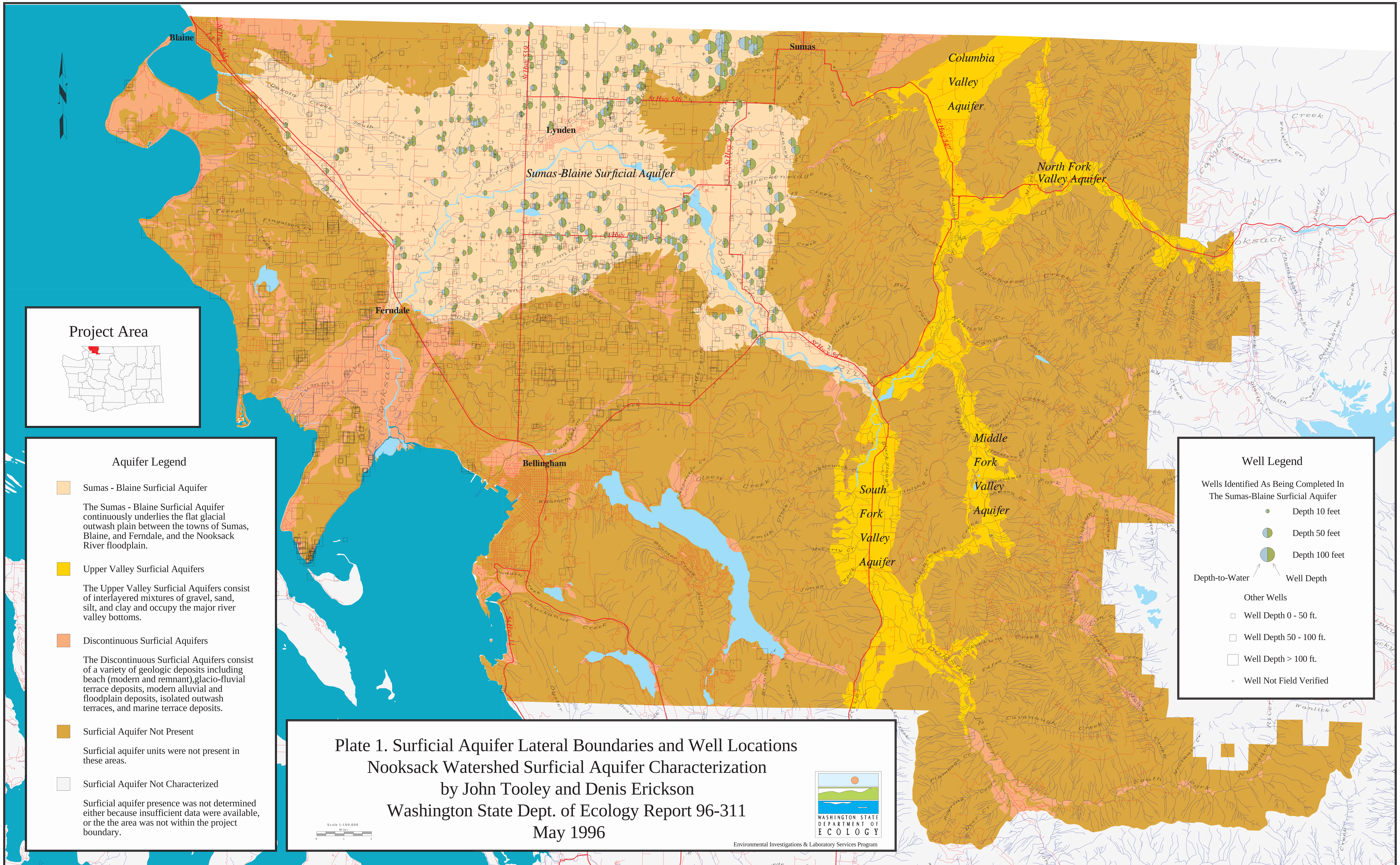

Plate 1. Surficial Aquifer Lateral Boundaries and Well Locations
Nooksack Watershed Surficial Aquifer Characterization
by John Tooley and Denis Erickson
Washington State Dept. of Ecology Report 96-311
May 1996