Appendix H

Groundwater Resource Assessment, 1991

17938

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GROUNDWATER RESOURCE ASSESSMENT
COORDINATED WATER SYSTEMS PLAN
SKAGIT COUNTY, WASHINGTON

AUGUST 10, 1991

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Groundwater Resource Assessment
Coordinated Water System Plan
Skagit County, Washington

Prepared for:
Economic and Engineering Services

Prepared by:
Pacific Groundwater Group

August 10, 1991

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1.0 INTRODUCTION

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This report presents the results of our assessment of the groundwater resources of Skagit County for use in the Comprehensive Water Supply Plan (CWSP). The purpose of the assessment was to provide an overview of the groundwater resources of the county with respect to regional water supply development.

The project area consisted of almost all of Skagit County (Exhibit 1-1). The mountainous areas east of Marblemount were not considered as little groundwater development is expected in this area. The smaller and less developed islands of the county were also not considered. Regional development is not considered viable in these areas.

The specific goals of this study were to:

o Estimate amounts of groundwater potentially available in the county,

o Identify preferred locations for additional development,

o Assess existing water quality and its potential effects on development, and

o Quantify the cost and general number of wells needed for the additional development.

This goal was met through an evaluation of existing data on the geology, hydrology, climate and water use in the county.

The amount of water needed for a regional water supply depends in part on the amounts generally available in the area. For the purposes of this project, well yields of at least 500 gpm (gallons per minute) and well-field yields of at least 1 to 2 mgd (million gallons per day) were considered necessary for a regional water supply in the main parts of the county. Supplies of this magnitude are not available on the islands (such as Guemes or Fidalgo) and smaller yields may be considered for an island-wide supply. In the case of Fidalgo, supplies can be (and are) readily brought in from outside areas and smaller well field yields need not be considered. On Guemes, smaller well-field yields may be considered, as a pipe line from the mainland is less practical.

The report is divided into eight chapters. Chapter 1 is this introduction. Chapter 2 is a summary of major findings and conclusions. Chapter 3 presents the geology and major aquifers of the county. Chapter 4 discusses potential well yields in various areas. Chapter 5 reviews existing information on water quality. Chapter 6 presents aquifer recharge and water budget analyses. Chapter 7 discusses development of additional groundwater. The report is concluded with Chapter 8, a list of references. Pertinent Exhibits are included at the end of each chapter.

This report was prepared under subcontract to Economic and Engineering Services, inc. (EES) for use in their engineering evaluation for Skagit County's Comprehensive Water Supply Plan. It was authorized by Mr. Robert Wubbena through subcontract work order 4-121, signed November 27, 1990.

This report has been prepared for the exclusive use of Skagit County and their consultant EES, for specific application to the referenced project, according to hydrogeological practices generally accepted at the time. No other warranty, expressed or implied, is made.

2.0 SUMMARY OF FINDINGS AND CONCLUSIONS

- Approximately 100 mgd (million gallons per day) of additional groundwater may be available in Skagit County, based on a mass balance analysis and an estimated capture ratio of 20 percent of total groundwater flow. An estimated 20 to 25 mgd may be feasible from a well field completed in the Marblemount area.

- Development of this 100 mgd would require approximately 70 to 100 wells and an expenditure of about $7 million. This cost does not include transmission lines, pumping stations and any costs outside of those required to install and develop the wells themselves.

- Regional supply aquifers are located beneath the Skagit Valley in alluvial deposits of gravel and sand lying within 200 feet of ground surface.

- The aquifers capable of regional supply are located near the Skagit River. Water pumped from these aquifers eventually reduces flow in the Skagit River. Full development of 100 mgd could reduce the flow of the Skagit by 1 percent (compared to average flow) to 3 percent (compared to low flows occurring 1 percent of the time).

- Reduction of Skagit flow does not appear to be a regulatory issue at this time as in-stream protection flows have not been established. Future requirements on Skagit flow could affect groundwater development in the basin.

- Well yields of 500 gpm to 800+ gpm appear locally feasible from properly designed and completed wells within the most productive aquifers in the valley. The highest yields (800+ gpm) appear to be found in the Marblemount vicinity. Slightly lower yields (500 gpm) are available from many other areas throughout the Skagit Valley.

- Deep aquifers (greater than 500 feet below ground surface) have not been identified in the valley or delta area. Most aquifers lie within 200 feet of surface. In the delta area, they appear to be underlain by several hundred feet of clay.

- Areas outside of the valley are generally much less productive. An exception is the Lake McMurray area where potential well yields in excess of 500 gpm are reported. Other glaciated areas have potential well yields of 100 gpm or less. Bedrock upland areas generally have well yields in the range of a few gallons per minute.

- Water quality in the regional supply aquifer areas is generally good. Excess concentrations of iron and manganese are relatively common in the Skagit Delta area. Excessive levels of iron and manganese are also reported in valley aquifers between Mt. Vernon and Concrete.

- Saline water has been reported in several locations in western Skagit County. The source of the salinity is typically salt water intrusion induced by pumping. Relic sea water left from the time of aquifer deposition may account for some of the salinity.

- Potential aquifer contamination from human sources are generally confined to the more populated western part of the county. A few abandoned landfills should be considered if a regional groundwater supply is developed in the eastern part of the county.

3.0 GEOLOGY AND AQUIFERS

3.1 Background and Overview

This chapter reviews and characterizes the geology and aquifers of the county. The purpose of the geologic characterization is to set the stage of the definition of aquifers and groundwater flow. The geology of an area is first described in order to define the positions and properties of the aquifers (water bearing zones through which groundwater flows) and the aquitards (low-permeability zone that restrict groundwater flow).

Aquifers are defined to show where groundwater is available and provide information that is required for assessment of potential well yields, aquifer yields, groundwater flow paths, recharge-discharge relationships and contamination assessment. Understanding the position and extent of the various aquifers in the county is needed to assess the existing groundwater situation and to plan for development of additional groundwater.

Aquifer definition plays a major role in assessing potential well yield. An aquifer comprising a thick and extensive gravel deposit allows a higher well yield than an aquifer that is thin, bounded (cut-off on one or more sides by low permeability material), or consisting of fractures in bedrock. An aquifer bounded near a well produces less water over the long term compared to a well completed in an areally extensive aquifer of otherwise similar nature.

3.2 Methods and Assumptions

The geology of the County was assessed based on a review of key geologic reports and construction of geologic cross sections through various portions of the county.

The key geologic reports included:

- Water in the Skagit Basin (Drost and Lombard, 1978),
- Preliminary Report on the Ground-Water Resources of Southwestern Skagit County (Sceva, 1950),
- Water Resources of the Swinomish Indian Reservation, (Drost, 1979),
- Bedrock Geology of the Port Townsend 30- by 60- Minute Quadrangle (Whetton, et al, 1988), and
- Surficial Geologic Map of the Port Townsend 30- by 60- Minute Quadrangle (Pessl et al, 1989).

These reports are the main references on the geology of the county. They represent the best overview of the geology at this time. No one map or report covers the geology of the entire county in detail. The Geologic Map of Washington, Northwest Portion (planned for release in 1995) will provide an overview, when completed.

Additional reports on San Juan and Island County were also reviewed and used in the interpretation of county geology. Many of the surficial deposits in Island County are similar to those of the glaciated portions of Skagit County while many of the bedrock units in the islands of Skagit County are similar to those in San Juan County.

After compiling the geologic reports, over 2000 well logs contained in the files of the Department of Ecology were reviewed. About 250 representative logs were obtained for our files. Logs were selected that indicated both hydrologic and geologic information. Were available, at least one representative log per square mile was obtained.

Geologic cross sections were then prepared for six transects of the county. These sections show the subsurface geology along the cross section line. Geologic units were interpreted from the drillers descriptions of the subsurface materials, based on geologic unit names in the various reports discussed above.

Because the sections lines cross almost the entire county from north to south, some are 20 miles or more long. Since wells are typically less than 200 feet in depth, presenting the subsurface conditions along the entire section in this report was not possible without excessive vertical exaggeration. The excessive exaggeration does not meaningfully demonstrate subsurface geology. Portions of the sections are presented, instead, to eliminate this problem. Each of these presented sections indicates the subsurface conditions over a smaller, representative area. The entire sections were used in our analysis, however.

3.3 Geologic Assessment Results

Most of the county's high-yield aquifers are associated with the Skagit River. They typically consist of coarse deposits of sand and gravel within the upper 200 feet of the alluvium that defines the Skagit Valley. Much of the area beneath the valley floor contains buried channels of sand and gravel from the meandering Skagit (Exhibits 3-2, 3-3, 3-4 and 3-7). The areas with the coarsest deposits appear to lie in the Marblemount area where the high energy environment of the river deposited gravels and coarse sand. The valley areas between Marblemount and Mt. Vernon (Exhibits 3-4 and 3-7) are also underlain by coarse deposits of sand and gravel. Aquifers in these areas are also highly productive.

The sand and gravel aquifers in the county are generally discontinuous. A sequence of deposits representative of one geologic unit is defined as an aquifer zone if a large number of higher-permeability deposits are contained within it. The Skagit River valley alluvium exemplifies an aquifer zone.

The eastern portions of the Skagit Delta are also underlain by sand and gravel aquifers (Exhibit 3-3). These aquifers were deposited as the Skagit emptied into a saltwater bay between what is now Mt. Vernon and Fidalgo Island. Sand and gravel was deposited where the river flowed into the "sea[1]." These deposits formed high-yield aquifers. Fine sand, silt and clay were deposited away from the delta front in the western portion of today's Skagit Delta (the lowland areas east of the Swinomish upland, Fidalgo Island, Bayview Ridge, etc.) These deposits formed aquitards or local low-yield aquifers.

No wells are known to penetrate the entire sequence of the alluvium in the delta area. Consequently, the extent, thickness, and potential for deep, high-yield aquifers is not well known. One well in the Mt. Vernon area was drilled to a depth of 500 feet penetrating 154 feet of clay beneath the sand and gravel aquifer zone. It is not known what lies at greater depths.

Sand and gravel aquifers are also found in some parts of the glaciated lowland areas (Exhibits 3-5 and 3-6) in the western part of the county (generally under 400 to 500 feet elevation) and along terraces associated with the Skagit River valley (Exhibit 3-7). Streams and rivers associated with advancing and retreating glaciers deposited sand and gravel that form aquifers within these areas.

Generally, the deposits are less extensive and/or finer-grained that the aquifers associated with the Skagit. One known exception lies south of Lake McMurray where gravel aquifers were identified in several well logs. Other non-bedrock areas are underlain by occasional deposits of sand. These were identified in the southwest part of the county near I-5, Guemes Island (Exhibit 3-1), the Swinomish Upland, the area directly east of Mt. Vernon, and the lower elevation areas near Alger and the Skagit Speedway.

Much of the upland portion of the county comprises bedrock with little or no cover by glacial or non-glacial deposits. Wells in these areas produce small quantities of water (generally not enough for more than one household) from fractures in bedrock. Since these are insufficient for regional water supply use, bedrock aquifers are not discussed further in this report.

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[1] In this report the term "sea" is used for all the salt water bodies lying along the western part of the county. "Sea" includes: bays, sounds, inlets, passes, channels, etc.

4.0 Potential Well Yield

4.1 Background and Overview

This chapter reviews potential well yield from various aquifer zones in the county. Potential well yield is defined as the short term yield that is likely available from a properly designed and constructed well, finished in the best aquifer (when more than one aquifer lie at depth) from some location within the area. This yield may not be possible with the existing wells installed in the area. They may be too small, finished in a different aquifer, or improperly designed or finished for high yield.

The purpose of the potential well yield analysis was to define the probable yield for a "good" well within a given area. This yield would be used for planning development of regional groundwater supplies. Not all wells finished in a region of defined potential well yield will have the indicated yield. Some will be less and some more. The listed potential yield is the short-term pumping rate that is likely from some wells within the area.

4.2 Methods and Assumptions

The potential yields for some 200 wells were evaluated based on information in the USGS database compiled for their Skagit River Basin project, and well logs collected from the Department of Ecology for the geologic analysis (discussed above). Only wells with all of the parameters needed for the analysis were considered. The parameters needed include:

- General well location (latitude-longitude coordinates, state plane coordinates, or well number that indicates location to the nearest 1/4-1/4 section),
- Pumping rate during a well test,
- Drawdown in water level caused by pumping at the given rate over an indicated time period,
- Static water level during a non-pumping period, and
- Aquifer or well screen depth.

The potential well yield was calculated using the specific capacity method. The equation used was:

$$Qp = 2/3*SC*AD$$

where:

Qp = estimated potential yield over a pumping period of a few weeks continuous pumping (gpm)

SC = specific capacity of the well (pumping rate divided by drawdown in feet) (gpm/ft)

AD = Available drawdown (the distance between the static water level and the well screen or open section of the well (ft)

The 2/3 factor accounts for decreasing specific capacity that results from:

- pumping longer than the short-term test (from which the calculation data were derived), and
- variations in water level that occur over time.

Some wells may be capable of actual short-term yields (on the order of a day or so of continuous pumping) that are larger than the calculated values as the 2/3 represents a "safety factor" to help account for hydraulic boundaries in the aquifer that cannot be assessed from the limited pumping data.

Four sets of potential yields analyses were made. The first was based entirely on wells in the USGS database. Several hundred wells are in the database but only 99 wells had all the information required to calculate potential well yield. It is not known how wells were selected for inclusion in the database.

The second set of analyses was based on wells used in the construction of the five, mainland, north-south cross section lines (discussed above). A total of 41 wells were used in these sections but only 34 had all the data required for the analysis.

A similar set of analyses was conducted for Guemes Island. Data for this analysis was obtained from the files of Dave Garland (1991) for his unpublished report on water quality on the island. A total of 42 wells were assembled in the file, 38 of which had the required data for a potential yield analysis.

The final set of analyses was conducted for areas identified through the geologic assessment as containing sand and gravel aquifers. Well logs in our files for these areas with sufficient data were used in the assessment.

Actual well yield was also considered, when listed on Ecology Water Rights printout. Wells with instantaneous water rights of greater than 300 gpm or more were assumed to have short-term potential yields of 500 gpm or more. Experience has shown that many wells have installed capacities that are less than their maximum. Smaller installed capacities often reflect the owners water use needs, rather than the aquifers maximum potential.

4.3 Well Yield Assessment Results

Exhibit 1-1 shows estimated potential yields throughout the county. The map shows anticipated yields from "good" wells within the area, finished in the highest yield aquifer below the site, over the short term. All areas are likely to contain anomalous wells that produce substantially different yields. These are not representative of yields that may be used in planning for regional water supply.

The highest yields are generally associated with the Skagit River Valley alluvial areas. Yields of 500 or more gpm are possible throughout much of the valley, with yields of more than 800 gpm possible near the Marblemount area. High yields are also possible in the eastern part of the Skagit Delta area. These yields are also in the 500 gpm or more range.

A small high-yield area was also identified near Lake McMurray. Potential well yields of 500 gpm or more are possible in this area from sand and gravel probably associated with glacial outwash deposits.

Other areas in the county have estimated potential yields of 100 gpm or less. These areas are shown in Exhibit 1-1. Since 100 gpm is not considered practical for a regional water supply, they are not considered further in this report.

The median and mean potential well yields for the USGS, cross section and Guemes Island analyses are listed in Appendix Tables AT-1 and AT-2. The tables indicate a median yield of about 40 gpm for the mainland, non-bedrock portions of the county. The mean yield is substantially higher, about 200 gpm. The higher value is the result of very high-yield wells used in the analyses that shifts the mean toward a higher value. Bedrock wells are not listed but typically have yields on the order of 1 to 2 gpm.

Guemes Island potential yields are also included in Appendix Table AT-2. The median and mean values are considerably less than those of the non-bedrock mainland areas. A median of around 7 gpm and a mean of around 40 gpm were calculated. The much lower values are the result of the finer grained aquifers in the glacial-interglacial deposits compared to the coarser sand and gravel of the Skagit Alluvium.

5.0 GROUNDWATER QUALITY

5.1 Background and Overview

This chapter reviews groundwater quality in various parts of the county. Groundwater quality was assessed to identify the likely water quality from locations that may be considered for regional water supply. Areas were identified where groundwater quality was known to meet drinking water standards. Areas with wells known not to produce water meeting the standards were also identified.

Three major categories of water quality problems were considered in our analysis:

- Saline water,

- Natural water contaminants as such as iron and manganese, and
- Industrial contamination.

Saline water is often results from pumping an aquifer that lies near a body of sea water. Such saltwater intrusion is common along many parts of coastal Washington, including parts of Skagit County. Saltwater water intrusion can occur because an individual well (or a group of a few wells) are pumping at rates that are too high. Saltwater intrusion can often be reduced in this situation by: reducing consumption and therefore the pumping rate at the well, replacing the well with another at an inland location, or using several wells pumping at lower rates to replace one well pumping at a higher rate.

Saltwater intrusion can also result because an entire area or region is over-pumped in relationship to natural groundwater recharge. Moving wells inland or reducing the pumping rate at one well by replacing it with several is unlikely to reduce the intrusion problem. The only solution is an overall reduction of pumping from the entire area.

Saline water can also occur in areas without significant well pumping. It may occur in aquifers containing relic sea water originating from the time of deposition. Natural groundwater flow in the area is too slow to purge the saline water with recharged fresh water or the nature. In this situation, there is no practical solution to the saline water problem. A different source or expensive treatment would be needed.

In either type of saline water problem area, new, high capacity wells are likely to be affected. Such areas are excluded from consideration as targets for a regional groundwater supply.

Iron and manganese are common "contaminants of concern" for groundwater in the county. Iron and manganese are generally considered "natural" contaminants as they occur in groundwater as a result of weathering of soil or rock. They are often present in many parts of western Washington in concentrations exceeding secondary drinking water standards.

Iron and manganese concentrations above the secondary standards are not considered health threats. The problem is usually one of aesthetics as they can give water an unpleasant taste and smell, or stain fixtures and plumping. A water supply without these contaminants exceeding the secondary standards is desirable, but not always mandatory. Water users either put up with the aesthetic problems or pay for treatment.

Areas with many reports of excessive iron and/or manganese are not recommended for development of a regional water supply. New wells in such an area have a high probability of excess levels, too. Since areas are available in the county that meet all the water standards (including secondary), areas with excess iron or manganese are excluded from consideration for regional supply.

Industrial contamination has recently become a major groundwater quality concern. Contamination can result from spills, leaks, or dumps of industrial waste, chemicals or fuels. It can also result from application of agricultural chemicals that are now considered dangerous or hazardous, especially if application rates were high or the chemical does not readily decompose. Older solid waste landfills can also be sources of industrial contamination. Older landfills were not designed or constructed to keep contaminants out of the groundwater system. Many are not monitored to assess their impacts on nearby groundwater.

Regional water supplies can be developed in areas with industrial contamination, if the wells are located far enough away or in a non-downgradient position. Locating regional supply wells in areas without industrial contamination, is preferred, however.

5.2 Methods and Assumptions

Wells with historical occurrences of excess levels of iron, manganese and salinity (indicated by chloride concentrations) were identified based on published records and Department of Health water system records supplied by EES (1991).

Published sources included those listed in Chapter 3 and the following:

- Reconnaissance of Sea-Water Intrusion along Coastal Washington, 1966-68 (Walters, 1971), and
- Seawater Intrusion into Coastal Aquifers in Washington, (Dion and Sumioka, 1978).

Additional information on saline water was obtained from well logs from the Department of Ecology (1991), discussion with well drillers Dean Hayes (1991) and Ken Fowler (1991), and data contained in the files of the Department of Ecology (Garland, 1991).

Information on potential industrial contamination was obtained from the Skagit County Health Department (Haycox, 1991) and Ecology listings of remediation sites in the county.

Criteria were established to designate water quality problem areas. Any report of iron or manganese exceeding the secondary standards of 0.30 mg/l (iron) or 0.05 (manganese) was taken as an indication that future problems in the area were possible. Chloride concentrations of 100 mg/l were taken as an indication that saltwater intrusion (or relic sea water) was present in the area and that future development in the area may have similar problems.

Industrial contamination was considered as a potential problem. The presence of an abandoned landfill, a gas station with a leaking tank, an industrial site such as a refinery or waste transfer/processor, or an agricultural area with known problems such as EDB were all noted, even if actual groundwater contamination had not been reported. For our regional groundwater analysis, we have assumed that these potential problem areas should be avoided, especially when other areas capable of regional supply yields without these problems, are available.

Areas with iron, manganese, chloride or industrial contamination were listed. Problem or potential problem areas were identified to the nearest 1/4-1/4 section based on the well number (for existing wells) and map location (for potential industrial sites).

5.3 Water Quality Assessment Results

Review of the data (Tables 5-1, 5-2 and 5-3) indicates that the area east of Concrete has the preferred water quality conditions for a regional water supply. The areas between Concrete and Sedro Woolley may also be acceptable. This area has fewer reported and potential water quality problems that areas further to the west.

A regional groundwater supply source developed in the area east of Concrete would be less likely to have excess iron or manganese that a source further down the valley or in the delta. Areas with wells reporting excess levels of iron and or manganese are listed in Table 5-1. The table lists the general location based on nearby geographic features. The table indicates that most iron and manganese problem areas lie in the Skagit delta. Some can also be found in glacial deposits in the western part of the county and on Guemes Islands. Areas up-valley east of Concrete do not report excess iron or manganese. Some portions of some aquifers within this area are likely to have excess levels as these contaminants are very common throughout the northwest. The data indicate that these problems are less common in this area, however.

A regional groundwater supply source developed in the area east of Mt. Vernon would be less likely to have saltwater intrusion than other areas closer to the delta front. Most areas more than a few miles inland, away from the river are also acceptable. Areas with wells reporting saline water are listed in Table 5-2. The table also lists the general location based on nearby geographic features. As would be expected, most saltwater intrusion problems occur near the sea, either on islands or near the coast in the delta. Guemes Island indicates many wells reporting saltwater intrusion, but this may be more of the availability of data from the unpublished Ecology study (Garland, 1991). Other islands (Fidalgo and Samish) also indicate some intrusion. Non-island intrusion areas are generally confined to the delta area. Some of these occur several miles inland. The salinity at these locations could be relic from the time of deltaic deposition or it could be the result of a wedge of saline water moving up the bottom of the Skagit River during high tides. Wells tapping aquifers connected to the river may be drawing this water into local aquifers.

Table 5-3 indicates areas with potential for industrial contamination in the groundwater. These potential sources are generally located near population centers. Most lie west of Range 5E as do most of the people in the county. A few abandoned landfills can be found further inland. Since these inland landfills are near small, non-industrial centers, they are unlikely to have taken a significant volume of hazardous materials. These small landfills are probably not a major concern for development of a regional groundwater supply. Based on these assumptions, the preferred location to minimize potential industrial contamination is inland, east of Concrete away from the few potential problem areas.

6.0 AQUIFER RECHARGE AND WATER BUDGET

6.1 Background and Overview

The water budget is a first-cut estimate of the major components of the hydrologic cycle. This estimate indicates the approximate volumes of water that are flowing in and out of the county's hydrologic system through precipitation, evapotranspiration, runoff, groundwater recharge, human consumption, and natural discharge.

The water budget serves as the basis for initial planning of ground water use. It provides a general understanding of the components of recharge, groundwater use and natural discharge. This general understanding helps in the management of groundwater resources by indicating the relative magnitude (importance) of each component of the flow system. It cannot be used by itself as a tool for accurate long-term management of groundwater resources. The variability of the natural earth system is too great to allow for precise knowledge of the individual components of the budget to the degree required for management of the resource by water budget analysis alone.

Estimates of the social, ecological and economic costs of diversion of natural discharge to human use is not part of a water budget. A comprehensive, site-specific assessment of an area is needed to detail the social, ecological and economic value of water discharging naturally and water diverted for human use. It is usually relatively easy to place a value and cost for water pumped by a well. The value of natural discharge is significantly more difficult to quantify. For example, natural discharge may be maintaining a stream or a wetland or the proper salinity balance in an estuary. Changes in natural discharge to these environments may affect plant and animal life, scenic beauty, fisheries and more. Assessment of the value of these situations is far beyond a hydrogeological evaluation. Society must make these decisions aided by input from many disciplines.

6.2 Methods and Assumptions

The water budget is based on the mass-balance principal: water going into the system is equal to the water flowing out of the system plus or minus the change in storage of the water within the system. This situation is true at all points of the system at all times based on the principle of the conservation of mass. In the natural system, groundwater storage changes seasonally and with dry/wet year cycles. Pumping of groundwater also changes the amount of storage in the system. In our analysis we have assumed that long-term (multi-year) changes in the system are zero. The water budget represents an "average" year.

With the assumption that change in storage is zero (equilibrium conditions) the mass balance equation becomes:

Recharge = Discharge

where: Recharge = Precipitation - Evapotranspiration - Runoff

and: Discharge = Consumption + Natural Discharge

From these equations the amount of recharge and discharge within the county were estimated by assessing:

- precipitation (A significant water input),
- evapotranspiration (a relatively large component),
- runoff (a relatively large component),
- groundwater recharge (relatively small compared to precipitation),
- consumption via wells and springs (relatively small compared to total recharge), and
- unaccounted natural discharge (a major component).

Each of the methods and assumptions used in the analysis of each of these components is discussed below.

The range in possible values of each of the hydrologic components in the mass balance analysis is high, often greater than the value of some of the other components. For example, estimated evapotranspiration for an area cannot be accurately measured and is typically estimated. The estimate has an uncertainty of two to three inches per year. The actual value of evapotranspiration is likely to lie somewhere within this range of uncertainty. Average annual precipitation is estimated based on interpolation between widely scattered points, using best meteorological judgement. Different methods of assessing average annual precipitation produce different results producing a calculated average that may vary by several inches from the "true" average precipitation for the area. The uncertainty in both precipitation and evapotranspiration require that the analysis be done using a range of values. Together the combined ranges in precipitation and evapotranspiration may be larger than the total amount of recharge to the groundwater system.

A conservative analysis of recharge would require using the higher end of the evapotranspiration range, the higher end of the run off range, and the lower end of the precipitation range. This approach would be misleading and often indicate that groundwater is not recharged, a situation contradicted by water level data that show flow within the system and on-going recharge. We have used a more "middle of the road" approach and used values closer to the center of the range of estimated values.

The water budget is typically based upon average conditions. Long-term averages for the various components of the hydrologic system are used in the analysis. Our assessment follows this convention.

6.2.1 Precipitation

Precipitation was estimated from an isohyetal (equal depth of rainfall) maps prepared by the National Weather Service (1957). The county was divided into townships (six miles by six miles) and the rainfall representing that township was estimated based on the isohyets bounding and crossing the area. (Guemes Island lies in four townships. Only one representative rainfall for the island was estimated.) This method assumes that the rainfall varies linearly over each of the areas being assessed. This assumption is not always true but likely introduces only a small error (estimated at 1 to 2 in or less for each of the areas). This error is relatively small compared to overall rainfall rate.

6.2.2 Runoff

Runoff was estimated for each of the townships by one of three methods. Runoff was estimated for most of the county using runoff coefficients based on conversations with NOAA (1991) flood forecasters. These values were based on their "best professional judgement" from working with actual data and computer forecast models. They varied from runoff equal to 80% of precipitation during the wetter months to 10% during the driest times of the year.

Normally runoff would be estimated by comparing rainfall and river hydrographs. The volume associated with a rapid rise in river flow would be compared with the volume of rainfall recorded for the same period. In a similar manner, summer flows during no rain periods would be assessed to determine the groundwater contribution to the river (base flow). This component would be subtracted during rainy periods and contributions from rainfall (runoff) would be calculated.

This approach was not possible as the series of dams on the Skagit and the numerous glaciers in the North Cascades introduce flow that cannot be readily separated from the available records. A major component of river flow in the summer comes from water released behind the dams. Natural flow in the fall and spring is typically reduced by storage behind the dams. Glaciers in the summer melt contributing flow that is unrelated to rainfall induced runoff or groundwater. Because of these complications, the best professional judgement estimate of runoff was used.

Runoff in the drier bedrock areas of Fidalgo Island was estimated based on data from San Juan County. Runoff was quantified in Boyce, 1983. Similar rock types, slopes and climate allow the use of the San Juan runoff coefficients on Fidalgo Island. The coefficients were generally in the 30% range.

Runoff from the glaciated portions of western Skagit County was estimated based on studies on Whidbey Island (PGG, 1988; Sapik et al, 1988). Runoff was generally in the range of only 10% of precipitation.

6.2.3 Evapotranspiration

Evapotranspiration (water evaporated by soil and transpired by plants) was estimated using the Blaney-Criddle method (USSCS, 1970) for each of the townships. This method uses crop, latitude and temperature to calculate potential evapotranspiration. A simple water balance within the soil based on rainfall and potential evapotranspiration was then used to relate potential to actual evapotranspiration. In this balance, actual evapotranspiration equals potential as long as rainfall is sufficient to keep the soil moist enough to provide plants with enough water. When the soil is drier, the actual rate decreases below the potential rate.

In our analysis we have computerized the soil mass balance procedure to calculate the actual evapotranspiration rate on a weekly basis. In this analysis monthly data (rainfall and temperature) are distributed evenly over four "weeks" of the month.

When precipitation was equal to or greater than potential evapotranspiration:

$$AET = PET$$

When precipitation was less than potential evapotranspiration:

$$AET = PET \quad (\text{when } SM/SMC >= 0.75)$$

or

$$AET = PET * 1.333 * (SM/SMC) \quad (\text{when } SM/SMC < 0.75)$$

Where:

AET = Actual evapotranspiration (in/yr)

PET = Potential evapotranspiration (in/yr), calculated by the Blaney-Criddle method

SM = Soil moisture content from the previous week (in)

SMC = Soil moisture holding capacity (in)

This linear function of the ratio of actual water content to soil moisture holding capacity is one of at least five methods used to relate actual to potential evapotranspiration reported in Dunne and Leopold (1978).

Precipitation and soil moisture holding capacity vary considerably. In our analysis we have calculated a series of evapotranspiration rates for the various precipitation rates indicated for each area and an estimated average soil moisture holding capacity of 6 inches. Total soil moisture holding capacity is equal to soil moisture holding capacity per foot of soil times total depth of soil, generally about 3 feet.

The choice of values for representative "crop factors" proved problematical. Most of Skagit County is vegetated by coniferous trees. The published crop factors for the method include many irrigated crops, but not coniferous trees. Possible values were proposed by several workers in the field. These values were based on analyses conducted in eastern Washington. They did not appear reasonable. The reported values were more likely for actual evapotranspiration and not potential. Comparison with the literature indicated that crop factors for grass were greater than the proposed conifer crop factor. In order to use a conservative approach (i.e. tending toward underestimating recharge) we have used the grass crop factor in our analysis.

6.2.4 Groundwater Recharge

Groundwater recharge was calculated using the precipitation, evapotranspiration and runoff values calculated using the methods discussed above. Recharge was calculated using the mass balance equation listed above. This equation calculates a rate (in/yr). The rate was converted to a volume per year by multiplying the rate by the recharge area where the rate is valid. Recharge area was estimated based on the physiography of each township. Upland areas were assumed to be recharge areas. Lowland areas near streams, rivers or sea were assumed to be discharge areas. The approximate area for each was estimated.

Recharge in the hard rock areas was assessed using two methods. The first is the Blaney-Criddle method described above. The second is a "permeability limited" method where it was assumed that bedrock underlying the evapotranspiration zone cannot accept all the surplus water generated in the high precipitation areas. Assuming a hydraulic conductivity of 10^{-6} cm/sec[2] and a vertical gradient approaching 1.0, the maximum possible recharge rate in these areas is limited to about 1 foot per year. Additional surplus would be discharged as delayed runoff from soil.

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[2] The bulk hydraulic conductivity of bedrock forming the mountainous regions of the county has not been measured. Modelling studies of mountainous terrains by Forster (1991) indicate that bulk hydraulic conductivities of mountainous regions often range from 10^{-8} cm/sec to 10^{-6} cm/sec. We have use the upper bound of this range as many studies have shown the upper 100 to 300 feet contains the majority of permeable fractures and is the hydraulically active.

This method provides a better approximation to the actual recharge rates in the county, than does the standard Blaney-Criddle method. The higher recharge rates in the wetter parts of the study area generated by the unmodified Blaney-Criddle method would require hydraulic conductivity values higher than those typically observed or reported in the literature. The "permeability limited" method takes into account the hydraulic effects of bedrock lying beneath the soil zone experiencing evapotranspiration.

6.2.5 Consumption

Consumption was based on water rights. A listing of all groundwater rights for the county was reviewed and the total rights for each township totaled. Water rights as the sole basis for water use may underestimate existing use, as those with rights pending or those who have never applied are not considered. These uncounted users may be off set, however. Our experience in other counties indicates that many water rights are not fully used. The differences between non-used rights and unaccounted for users without rights may be self-canceling.

Water rights for the erstwhile proposed Skagit Nuclear power plant were excluded from the analysis. Their rights represented the majority rights within the sections where they had been appropriated. Since it is unlikely that this plant will be built, these rights will probably never be used.

6.2.6 Natural Discharge

Natural Discharge is the portion of total discharge that is not used by wells and springs. In Skagit County, most groundwater discharges to the Skagit River. Only a small portion either discharges to areas out of the county or to the sea.

The usual method for quantifying natural discharge is by difference. Groundwater consumption (wells and springs) is quantified and subtracted from the total amount of discharge (which under equilibrium conditions is equal to recharge). The difference is equal to natural discharge.

6.2.7 Additional Yield

Only a portion of the undeveloped natural discharge can be developed as additional yield. The percentage that can be used is a function of many factors including economics, social impact, environmental concern and more. The percentage of total discharge that can be developed depends on how much society is willing to pay on an economic, social and environmental basis.

Several studies have assumed a percentage of total discharge ("capture ratio") as an estimate of the total water that may be available with acceptable impacts. These capture ratios have range from 20% to 50%. We have used a 20% capture ratio in our estimate of additional groundwater available. This number is taken from Drost (1979). Twenty percent is considered a conservative portion. It is the lowest value known to be used in a number of northwest resource studies. The actual percentage of groundwater discharge that can be "successfully" developed will depend on a number of factors beyond the scope of this project.

6.3 Water Budget Results and Aquifer Recharge

The results of the recharge portion of the water balance analysis are presented in Table 6-1. This table summarizes the rates and volumes of best estimates of recharge to each township during typical conditions. "Permeability Limited" values indicate rates where the underlying bedrock limits recharge. These values are more likely representative than those calculated by the unmodified Blaney-Criddle method, as discussed in section 6.2.5.

The total recharge to aquifers in the county is on the order of 600,000 acre-feet per year (530 mgd), using the modified method. This amount represents the recharge to all the aquifers in the county. The specific amounts to each zone cannot be accurately estimated from the existing data.

The total water balance is listed in Table 6-2. This table lists recharge, water use, difference between the two ("natural discharge") and an estimate of additional groundwater development that would be possible based on a 20% capture ratio. On a county-wide basis, an additional 100,000 acre-feet per year (about 100 mgd) may be available. Additional yield is discussed further below.

7.0 REGIONAL GROUNDWATER SUPPLY DEVELOPMENT

7.1 Background, Overview and Method

A regional water supply must be capable of producing water of sufficient quantity and quality such that development is cost effective. The quantity and quality needed are relative to other sources of water that are available in the general area. In order to assess the potential for regional water supply development from groundwater, several criteria were established for this study. These are discussed below.

A regional supply aquifer is one capable of producing at least 500 gpm from a single well, and preferably 1000 gpm or more. The aquifer should be capable of supplying a well field (two or more wells) of 2.0 mgd (1400 gpm) or more without long-term depletion of the aquifer (water level declines). It should not be located in an area closed to groundwater development or in a basin where surface water minimum flows inhibit groundwater pumping during part or all of the year.

Water quality should meet the state standards for all primary and secondary contaminants. Treatment for secondary or other parameters may be considered, if cost effective. Rejection of a regional supply aquifer capable of the desired yields but requiring treatment is an economic decision.

The previous chapters assessed the parameters affecting regional water supply from groundwater. These included: aquifer locations (Chapter 3), potential well yield (Chapter 4), water quality (Chapter 5) and aquifer yield (Chapter 6). The information in these chapters was combined to identify areas capable of meeting regional water supply needs. These areas have:

- high well yields,
- adequate recharge to sustain aquifer yield, and
- water meeting state drinking water standards.

In addition, other factors affecting groundwater development were assessed including:

- general potential water quality impacts associated with existing and future land use,
- the relationship of the Skagit River to groundwater development, and
- costs associated with development of additional groundwater supplies.

This chapter discusses the points listed above.

7.2 Additional Groundwater Development

The existing data indicate additional groundwater supplies can best be developed in the alluvial deposits in the Skagit River Valley. High-yield aquifers are present beneath the valley at many locations (Exhibit 1-1). High-yield wells appear feasible at most locations from the vicinity near Marblemount to the Skagit Delta west of Mt. Vernon. The available data indicate water quality is better and well yields possibly higher in the area just east of Marblemount. Other areas between Marblemount and Concrete also appear to have good water quality but slightly lower well yields. The valley areas further downstream near Sedro Woolley and Mt. Vernon also appear to have the potential for relatively high well yields but water quality may not be as good with more wells reporting excessive concentrations of iron, manganese, and in some areas near the coast, saline water.

A few areas outside the Skagit Valley indicate relatively large well yields such as near Lake McMurray. The limited extent of the aquifer in these areas make major development of a regional source less feasible, however. Other areas show moderate well yields, such as north of the Skagit River Valley. A large number of wells could be installed to produce a regional supply. The costs would likely be prohibitive, making other supply areas more desirable.

7.2.1 Regional Supply Well Yields

Yields from properly constructed wells, finished in the more productive aquifer(s) in the Skagit Valley area, are likely to be in the 500 gpm to 800+ gpm range. Deposits of gravel and sand lying within 200 feet of ground surface allow these high individual well yields. The highest well yields appear feasible in the Marblemount area where the high energy environment of the Skagit and Cascade Rivers allowed the deposition of the coarser grained materials. Localized high yields are also feasible further downstream where aquifers also comprise gravel and sand deposits. Areas of silts and fine sands are also present, however, making consistent very high yields (800+ gpm) less likely.

Upland areas surrounding the valley do not have regional water supply capability because well yields are generally low. These areas contain bedrock aquifers and only very localized and limited sand and gravel deposits. The bedrock areas typically have well yields of under 10 gpm and often much less. The sand and gravel areas may have yields that are higher, sometimes greater than 100 gpm. These yields are still below those needed for an economic regional water supply. They could be used for local supply, however.

7.2.2 Regional Supply Aquifer Yields

The water budget analysis indicates 100 mgd of additional groundwater may be available for development within the county. This estimate is a "first cut" planning value. It is based on as assumed capture ratio of 20 percent. More (or less) than 20 percent of total recharge may be potentially available, depending on the economic, environmental and social costs that society is willing to pay. We have used this rate to be conservative and consistent with previous studies in the county.

Much, but not all, of this water flows to the aquifers lying beneath the Skagit River Valley floor. Data were not available to measure groundwater flow direction through the construction of water level contour maps. Our experience shows, however, that the generally low permeability of the uplands, the very large topographic relief and low elevation of the Skagit River, all indicate that groundwater flow will generally follow the topography of the county. Since the river is the local topographic low point, it defines the regional groundwater discharge point for most of the county. Only areas on the extreme west (the western portions of the Skagit Delta; Fidalgo, Guemes and other Island; and the Chuckanut areas), and some areas near the southern and northern boundaries of the county have groundwater that does not discharge to the Skagit River. As such, most of the 100 mgd surplus in the county is available from aquifers in the Skagit Valley.

Development of the 100 mgd would require a series of wells along the Skagit River Valley. Full development would likely require 70 to 100 wells from Mt. Vernon to beyond Marblemount. Such a series of wells would be needed to intercept groundwater before it discharged to the river. Some areas would require more wells than others, as yield from individual aquifers will vary, locally.

The yield from individual aquifers lying in the Skagit Valley alluvial deposits has not been calculated. Aquifer yields depends on several factors, one of which is the hydraulic relationship of the river to the valley aquifers. This relationship may be the most important factor and is discussed in a following section.

A series of wells or well fields is recommended for the high yield (800 gpm) area near Marblemount. The total volume of additional yield available from this area (indicated in Exhibit 1-1) cannot be accurately estimated. Only a portion of the 100 mgd available in the county is available from this area. Assuming that groundwater discharges to the river at a rate proportional to river bank length, perhaps 1/5 to 1/4 of the 100 mgd may be developable from the high-yield area. Thus, a yield from this area of about 20 to 25 mgd may be feasible.

An additional percentage of the 100 mgd could also be obtained from the moderate yield (500 gpm) area between the 800 gpm area and Mt. Vernon. Using the same relationship of discharge proportional to river bank length an estimated 70+ mgd may be feasible. Not all of this water may be desirable. Water quality may be an issue in these areas, as discussed below.

Because aquifers in this area are known to connect to the Skagit River (Hart Crowser, 1981), the total yield from wells completed in this area may be considerably higher than that possible without connection to the river. If groundwater withdrawals from aquifers connected to the Skagit is acceptable (discussed in section 7.2.3), a larger percentage of the

100 mgd may be feasible. On-site testing and regulatory interaction will be needed to quantify actual yield.

7.2.3 Regional Water Supply Quality

The existing data indicate that water quality in the valley aquifers east of Concrete generally meets state standards, both primary and secondary. A regional water supply developed in this area is also expected to meet the standards. Local concentrations of iron and manganese above the standards are possible, however. The aquifer materials contain minerals that weather to produce iron and manganese. Elevated levels are not expected to dominate. A regional supply system could likely mix the water from areas with elevated levels (should they exists) with water from other areas to lower the concentrations to below the criteria.

Valley aquifers down-valley from Concrete are more likely to exceed state secondary standards for iron and manganese. Several water systems and wells in this area have reported elevated levels. Since a regional system would likely mix water, excess iron or manganese concentrations may be controlled through mixing of sources.

Iron and manganese levels above the standards are more common in the delta area, west of Mt. Vernon. Many wells and water systems have reported iron above the secondary standard. A regional supply developed in this area would likely require treatment or mixing. A selective use of supply areas without excess levels of iron or manganese may be possible if a test well program can identify such areas. High-capacity wells in this area, especially those located further to the west could induce saltwater intrusion. A regional water supply well field is not recommended in this area for this reason.

The existing data indicate that industrial water quality problems would not be likely in a regional groundwater supply established up valley, say east of Concrete. A few abandoned landfills are known in the area (Table 5-3). Since these lie away from major urban and industrial areas, contaminants reaching the groundwater system are less likely to be significant. Supply wells should not be located in an area directly downgradient and close proximity to these old landfills. Water quality testing and a site-specific hydrogeological assessment should be undertaken before a well field is established.

7.2.3 Factors Affecting Additional Groundwater Development

Several factors may affect development of a regional groundwater supply system from a Skagit Valley aquifer. The main factor is the relationship between the aquifer(s) and the river.

The Skagit River is the discharge point for most groundwater in the county. Almost all groundwater eventually discharges to the river (except for a small amount that discharges to the sea or to Snohomish or Whatcom County). Development of groundwater in the Skagit Valley removes groundwater before it reaches the river. In some cases, a high capacity well will also cause a reversal in flow gradients and draw water from the river.

In either situation, development of groundwater from Skagit Valley aquifers reduces the flow of the river. Over the long term (after pumping has removed water from storage and an equilibrium situation is established), the reduction in flow to the river may approximately equal the volume of water pumped.

Comparison of Skagit River flows and the estimated additional available groundwater shows that the reduction in flow is relatively very small. The mean flow of the Skagit is 16,870 cfs (Drost and Lombard, 1978). This flow is more than 100 times the 100 mgd (approximately 155 cfs) potentially available. The river exceeds 5,250 cfs more than 99 percent of the time. Complete development of 100 mgd is still less than 3 percent of this low-flow rate. These river flow rates indicate that on a volumetric basis, development of groundwater to the full 100 mgd capacity is not significant to river flow.

Full development of groundwater may be significant on a legal basis in the future, however. Currently, Ecology indicates the Skagit has no in-stream protection flow rates (S. West, 1991). Development of groundwater does not legally require consideration of impacts on the river flow. Most river basins in western Washington have in-stream protection requirements. These rivers have mandated minimum flows throughout part of the year. Many of these basins are closed to further development of groundwater because of the impacts of pumping on river flow. If similar restrictions are placed on the Skagit, groundwater development could be affected. The full 100 mgd of additional groundwater estimated in this study may not be available.

Changes in land use can affect groundwater development. Impacts can occur as changes in water quantity available and quality. Most of the area supplying groundwater to the regional supply aquifer(s) is rural to totally undeveloped. It is unlikely that future development will affect the quantity of water recharged to these aquifers. Development will be too minor in comparison to the total area.

Changes in land use near the supply area could possibly affect water quality. If areas upgradient from supply wells were over-sprayed with hazardous agricultural chemicals, converted to industrial use with poor "housekeeping" or allowed to be used for dumping of industrial waste, water quality could be affected. Development of a regional water supply should be accompanied by a wellhead protection program to monitor and minimize such potential problems.

7.3 Regional Supply Well Development Costs

Full development of the 100 mgd source estimated in this study could cost about $7 million. These costs are based on an estimated 70 to 100 wells needed to supply the water. The estimated cost for these wells ranges from about $71,000 to $83,000, as shown in Table 7-1. These costs include drilling, testing, production pump installation, engineering and construction of a small well house. They are based on a compilation of estimates provided by several well drilling firms. The estimated average well depth is 150 feet. Diameters would likely range from 12 to 16 inch, based on anticipated peak yields of 600 to 1000 gpm.

The costs for transmission lines, plumbing, and other appurtenances are not included. Estimation of these costs is beyond the scope of a hydrogeologic evaluation. They would likely be more than the costs of well installation and development discussed above, as the source lies many 10's of miles from the population center of the county.

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Tables

Table 5–1 – Summary of Wells With Known Iron or Manganese Groundwater Problems in Skagit County

Township/ Range		Excess Iron (Fe > 0.30 mg/l)	Excess Manganese (Mn > 0.05 mg/l)	Location(s)/Source Aquifer(s)
33	3	9H1	–	S. Delta, near Rexville: Alluvial
	4	–	33D1	SW County, Near I–5: Glacial
	5	–	–	
	6	–	–	
	7	–	–	
	8	–	–	
	9	–	–	
	10	–	–	
34	1	–	–	
	2	2N1,15C1,15R1,26F1,34R6,35G1,35G3,35G4,35L1	–	Swinomish Upland: Glacial/Interglacial
	3	4L1,12N1,12Q1,13F1,25H1,25H2	–	S.Delta, W and NW of Mt. Vernon: Alluvial
	4	5D1,5D2,6H1,7P2,7P14,8C1,8C2,17D1,19N1,18R1,19B2,19L1,30J1,30P1,32C1,32B1,32P1	–	Mt. Vernon area: Alluvial
	5	19K1	–	Walker Valley: Glacial
	6	–	–	
	7	–	–	
	8	–	–	
	9	–	–	
	10	–	–	
	1	–	–	
	2	–	–	
	3	–	–	
	4	13R1,13R2,22C1,22L1,25C1,25J1,25K1,28L1,28P3,32P1,33B1	–	Sedro Wolley–Burlington area: Alluvial
	5	8D2,19D1,30K2,30K3,30L1	–	Sedro Wolley: Glacial and Alluvial
	6	–	–	
	7	–	–	
	8	–	–	
	9	–	–	
	10	–	–	
36	2	–	–	
	3	–	–	
	4	–	–	
	5	–	–	
	6	–	–	
	7	–	–	
	8	–	–	
	9	–	–	
	10	–	–	
Guemes Is.				
35	1	12P	–	S. Guemes: Glacial/Interglacial
	2	–	–	
36	1	36K	–	N. Guemes: Glacial/Interglacial
	2	–	–	

Table 5-2 – Summary of Wells With Known Indication of Saline Water Intrusion in Skagit County

Township/ Range		Saline Intrusion (Cl > 100 mg/l)	Location(s) / Source Aquifer(s)
33	3	8A1	S. Delta, near N. Fork: Alluvial
	4	–	
	5	–	
	6	–	
	7	–	
	8	–	
	9	–	
	10	–	
34	1	–	
	2	34R6,34R7	SW Swinomish upland, on coast: Glacial/Interglacial
	3	35P	Inland S. Delta, w of Skagit City: Alluvial
	4	25F	Inland S. Delta, near Mt. Vernon: Alluvial
	5	–	
	6	–	
	7	–	
	8	–	
	9	–	
	10	–	
35	1	27Q1	Fidalgo, Burrows Bay, on coast: Bedrock
	2	1A1	S of Samish Island, on coast: Alluvial
	3	11R1	SW of Bow, on Edison Slough: Alluvial
	4	–	
	5	–	
	6	–	
	7	–	
	8	–	
	9	–	
	10	–	
36	2	26R2	Samish Island,on coast: Glacial
	3	26N	N of Bow (1 mi): Glacial
	4	–	
	5	–	
	6	–	
	7	–	
	8	–	
	9	–	
	10	–	
Guemes Is.			
35	1	11L,13D	SW Guemes, on coast: Glacial/Interglacial
	2	8K	SE Guemes, on coast: Bedrock
36	1	25N,26A,26A,26H,26K,35G,36C,36C,36G,36K,36L	N Guemes, mostly on coast, some inland: Glacial/Interglacial
	2	–	

Table 5–3 – Summary of Areas With Known or Potential Industrial Contamination

Township/ Range		Sections with Possible or Known Industrial Contamination	Source(s) or Possible Source(s)
33	3	–	
	4	16,28	Abandoned Landfills
	5	–	
	6	–	
	7	–	
	8	–	
	9	–	
	10	33	Abandoned Landfill
34	1	–	
	2	2,10,1116,26,34	Abandoned Landfills, Industrial Waste Recycling
	3	–	
	4	18,19,28	Abandoned Landfills, Leaking Tank
	5	–	
	6	–	
	7	–	
	8	–	
	9	–	
	10	5	Abandoned Landfills
35	1	13,14,24,26	Leaking Tank, Abandoned Landfills
	2	21,28,29,33	Oil Refineries, Industrial Waste Recycling
	3	–	
	4	8,24	Septic Disposal Lagoon, Solvent Spills, Leaking Tank
	5	–	
	6	8,27	Abandoned Landfills
	7	8,17	Agricultural chemicals, Abandoned Landfill
	8	–	
	9	28	Abandoned Landfill
	10	–	
36	2	–	
	3	–	
	4	–	
	5	–	
	6	–	
	7	–	
	8	14	PCB Spill
	9	–	
	10	–	
Guemes Is.		–	
35	1	–	
	2	–	
36	1	–	
	2	–	

Table 6-1 – Summary of Estimated Recharge in Skagit County

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Tnshp /Rng	Loc Data Ctr*	Est Rech Area mi2	Rate** B-C Method in/yr	Rate** Limited Perm*** in/yr	Volume B-C Method mgd	Volume B-C Method ac-ft/yr	Volume Limited Perm mgd	Volume Limited Perm ac-ft/yr	Comments
33 3	A	1	9.9	9.9	0.5	530	0.5	530	One sq.mi. NOT Skagit Valley delta. GW discharge area.
4	SW	35	12.0	12.0	20	22000	20	22000	Fifty percent bedrock upland.
5	SW	35	9.6	9.6	16	18000	16	18000	Sixty five percent bedrock upland.
6	SW	34	13.2	12.0	21	24000	19	22000	Eighty percent bedrock upland.
7	C	35	15.8	12.0	26	30000	20	22000	All bedrock upland
8	C	35	15.8	12.0	26	30000	20	22000	All bedrock upland
9	D	35	16.7	12.0	28	31000	20	22000	All bedrock upland
10	D	24	14.8	12.0	17	19000	14	15000	Thirty five percent Sauk River valley floor, rest bedrock.
34 2	A	17	5.3	5.3	4.3	4800	4.3	4800	Likely recharge 17 sq.mi. of Swinomish Upland, only.
3	A	2	9.2	9.2	0.9	980	0.9	980	Ninety five percent Skagit delta. GW discharge area.
4	SW	24	15.4	12.0	18	20000	14	15000	Till capped recharge area. One third Skagit delta.
5	SW	35	12.7	12.0	21	24000	20	22000	Seventy percent bedrock upland.
6	SW	34	16.7	12.0	27	30000	19	22000	All bedrock upland
7	C	35	17.6	12.0	29	33000	20	22000	All bedrock upland
8	C	35	22.4	12.0	37	42000	20	22000	All bedrock upland
9	D	32	11.7	11.7	18	20000	18	20000	Ten percent Sauk/Skagit River valley floor.
10	D	34	14.8	12.0	24	27000	19	22000	Five percent Sauk River valley floor, rest bedrock.
35 3	A	13	11.4	11.4	7.0	7900	7.0	7900	Sixty percent Skagit Valley delta. GW discharge area.
4	SW	13	15.0	12.0	9.3	10000	7.4	8300	Sixty percent Skagit Valley delta. GW discharge area.
5	SW	22	10.2	10.2	11	12000	11	12000	Forty percent Skagit Valley floor. GW discharge area.
6	SW	31	15.7	12.0	23	26000	18	20000	Fifteen percent Skagit Valley floor. GW discharge area.
7	C	31	10.7	10.7	16	18000	16	18000	Fifteen percent Skagit Valley floor. GW discharge area.
8	C	31	11.3	11.3	17	19000	17	19000	Fifteen percent Skagit Valley floor. GW discharge area.
9	C	32	14.3	12.0	22	24000	18	20000	Ten percent Skagit Valley floor. GW discharge area.
10	C	29	14.3	12.0	20	22000	17	19000	Twenty percent Skagit Valley floor. GW discharge area.
36 3	SW	32	8.1	8.1	12	14000	12	14000	Thirty percent bedrock upland, Ten percent Skagit Delta
4	SW	32	11.9	11.9	18	20000	18	20000	Forty percent bedrock upland, Ten percent flood plains.
5	SW	35	10.2	10.2	17	19000	17	19000	Fifty percent bedrock upland.
6	SW	35	14.9	12.0	25	28000	20	22000	Ninety five percent bedrock upland.
7	C	35	15.8	12.0	26	30000	20	22000	Ninety five percent bedrock upland.
8	C	31	17.0	12.0	25	28000	18	20000	Eighty percent bedrock upland.
9	C	35	27.6	12.0	46	52000	20	22000	Ninety five percent bedrock upland.
10	C	35	21.0	12.0	35	39000	20	22000	Ninety five percent bedrock upland.
Guemes	A	5.75	7.2	7.2	2.0	2200	2.0	2200	Non-bedrock recharge area about 5.5 to 6 sq.mi.
Fidalgo	A	23.5	2.5	2.5	2.8	3100	2.8	3100	Estimated recharge area 22 to 25 sq.mi. Mostly bedrock
TOTALS					670	750000	530	590000	

*Note: A=Anacortes, C=Concrete, D=Darington, SW= Sedro Wolley

**Note: All estimates to 2 significant figures, only.

***Note: Vertical permeability of till and fractured bedrock estimated at 10-6 cm/sec.

BK0094PG4309

Table 6–2 – Water Balance for Skagit County

Township/ Range		Perm. Limited Recharge* ac–ft/yr	GW use by Water Rights** ac–ft/yr	Change in Storage (Average) ac–ft/yr	Inflow– Outflow+ Change in Storage ac–ft/yr	Estimated Additional Yield***		Comments
						ac–ft/yr	mgd	
33	3	530	735	0	−210			Almost all GW discharge area.
	4	22000	1388	0	21000	4100	3.7	About 50 percent bedrock (permeability–limited) recharge area.
	5	18000	5314	0	13000	2500	2.3	About 65 percent bedrock (permeability–limited) recharge area.
	6	22000	None	0	22000	4400	3.9	About 80 percent bedrock (permeability–limited) recharge area.
	7	22000	None	0	22000	4400	3.9	Almost all bedrock (permeability–limited) recharge area.
	8	22000	None	0	22000	4400	3.9	Almost all bedrock (permeability–limited) recharge area.
	9	22000	None	0	22000	4400	3.9	Almost all bedrock (permeability–limited) recharge area.
	10	15000	None	0	15000	3000	2.7	About 35 percent GW discharge area, the rest bedrock recharge area.
34	2	4800	877	0	3900	780	0.7	About 50 percent GW recharge area, about 50 percent recharge area.
	3	980	27016	0	−26000			Almost all GW discharge area.
	4	15000	9100	0	5900	1200	1.1	About 35 percent GW discharge area, the rest glacial sediment recharge area.
	5	22000	3	0	22000	4400	3.9	About 70 percent bedrock (permeability–limited) recharge area.
	6	22000	None	0	22000	4400	3.9	Almost all bedrock (permeability–limited) recharge area.
	7	22000	None	0	22000	4400	3.9	Almost all bedrock (permeability–limited) recharge area.
	8	22000	None	0	22000	4400	3.9	Almost all bedrock (permeability–limited) recharge area.
	9	20000	None	0	20000	4000	3.6	About 10 percent GW discharge area.
	10	22000	None	0	22000	4400	3.9	About 5 percent GW discharge area, the rest bedrock recharge area.
35	3	7900	5686	0	2200	440	0.4	About 60 percent GW recharge area, about 40 percent recharge area.
	4	8300	6639	0	1700	330	0.3	About 60 percent GW recharge area, about 40 percent recharge area.
	5	12000	5300	0	6700	1300	1.2	About 40 percent GW recharge area, about 60 percent recharge area.
	6	20000	1295	0	19000	3700	3.3	About 15 percent GW recharge area, about 85 percent recharge area.
	7	18000	513	0	17000	3500	3.1	About 15 percent GW recharge area, about 85 percent recharge area.
	8	19000	None	0	19000	3800	3.4	About 15 percent GW recharge area, about 85 percent recharge area.
	9	20000	None	0	20000	4000	3.6	About 10 percent GW recharge area, about 90 percent recharge area.
	10	19000	None	0	19000	3800	3.4	About 20 percent GW recharge area, about 80 percent recharge area.
36	3	14000	162	0	14000	2800	2.5	About 10 percent GW recharge area, about 30 percent bedrock recharge area.
	4	20000	426	0	20000	3900	3.5	About 10 percent GW recharge area. Possible GW inflow from Whatcom County.
	5	19000	38	0	19000	3800	3.4	About 50 percent bedrock recharge area. Possible GW inflow from Whatcom County.
	6	22000	None	0	22000	4400	3.9	Almost all bedrock (permeability–limited) recharge area.
	7	22000	336	0	22000	4300	3.9	Almost all bedrock (permeability–limited) recharge area.
	8	20000	1773	0	18000	3600	3.3	About 80 percent bedrock (permeability–limited) recharge area.
	9	22000	127	0	22000	4400	3.9	Almost all bedrock (permeability–limited) recharge area.
	10	22000	4	0	22000	4400	3.9	Almost all bedrock (permeability–limited) recharge area.
Guemes Is.		2200	142	0	2100	410	0.4	Mostly glacial sediment recharge area.
Fidalgo Is.		3100	238	0	2900	570	0.5	Mostly bedrock recharge area.
TOTALS		588000	67112	0	518000	104000	92	

*Note: Rounded to 2 significant figures.

**Note: Based on WDOE water rights minus Skagit Nuclear Power Plant allotments.

***Note: Based on a 20% capture ratio used in Drost, 1979 (USGS OFR 79–12). Negative values not shown where in discharge area (Yield not limited by local recharge).

Table 7-1 – Production Well Cost Estimates

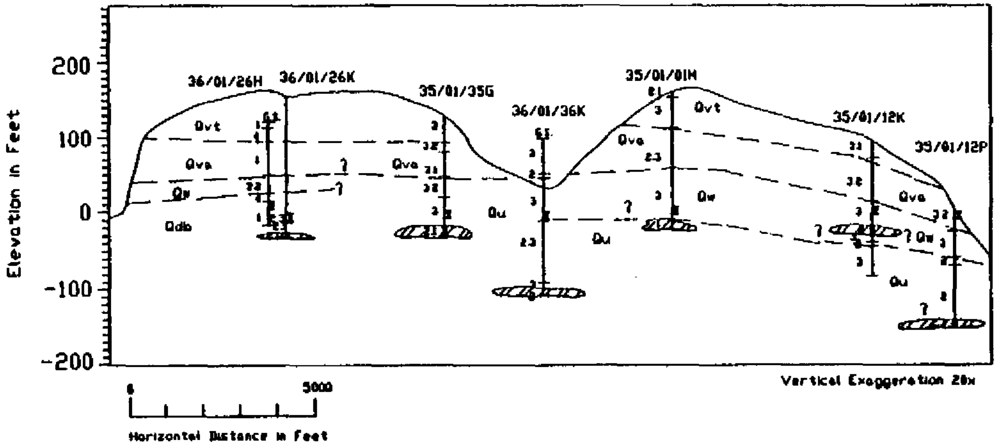
16-IN WELL (1000 gpm)

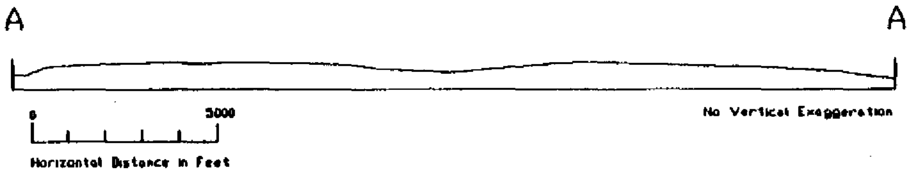
Item Description	Quantity	Unit Price	Total Price
Mob./Demob.	1	$2,500	$2,500
Surface Seal	1	$1,800	$1,800
16-Inch Drilling	150	$50	$7,500
16-inch Drive Shoe	1	$900	$900
16-inch Casing	150	$24	$3,600
Screen Assembly	1	$6,000	$6,000
Authorized Hourly	100	$90	$9,000
Test Pump Rental, Installation, Rem	1	$1,500	$1,500
Pump Test Hourly	28	$75	$2,100
Extra Materials	1	$500	$500
Production Pump (1000 gpm)	1	$9,000	$9,000
Pump controls, plumping etc	1	$8,000	$8,000
Pump Building	1	$15,000	$15,000
Engineering			$10,000
Subtotal			$77,400
WSST (@7.6%)			$5,882
TOTAL			$83,282

12-IN WELL (600 gpm)

Item Description	Quantity	Unit Price	Total Price
Mob./Demob.	1	$2,000	$2,000
Surface Seal	1	$1,500	$1,500
12-Inch Drilling	150	$45	$6,750
12-inch Drive Shoe	1	$400	$400
12-inch Casing	150	$20	$3,000
Screen Assembly	1	$4,000	$4,000
Authorized Hourly	100	$90	$9,000
Test Pump Rental, Installation, Rem	1	$1,000	$1,000
Pump Test Hourly	8	$75	$600
Extra Materials	1	$500	$500
Pump (600 gpm)	1	$6,000	$6,000
Pump controls, plumping etc	1	$7,000	$7,000
Pump Building	1	$15,000	$15,000
Engineering			$10,000
Subtotal			$66,750
WSST (@7.6%)			$5,073
TOTAL			$71,823

Exhibits





Legend

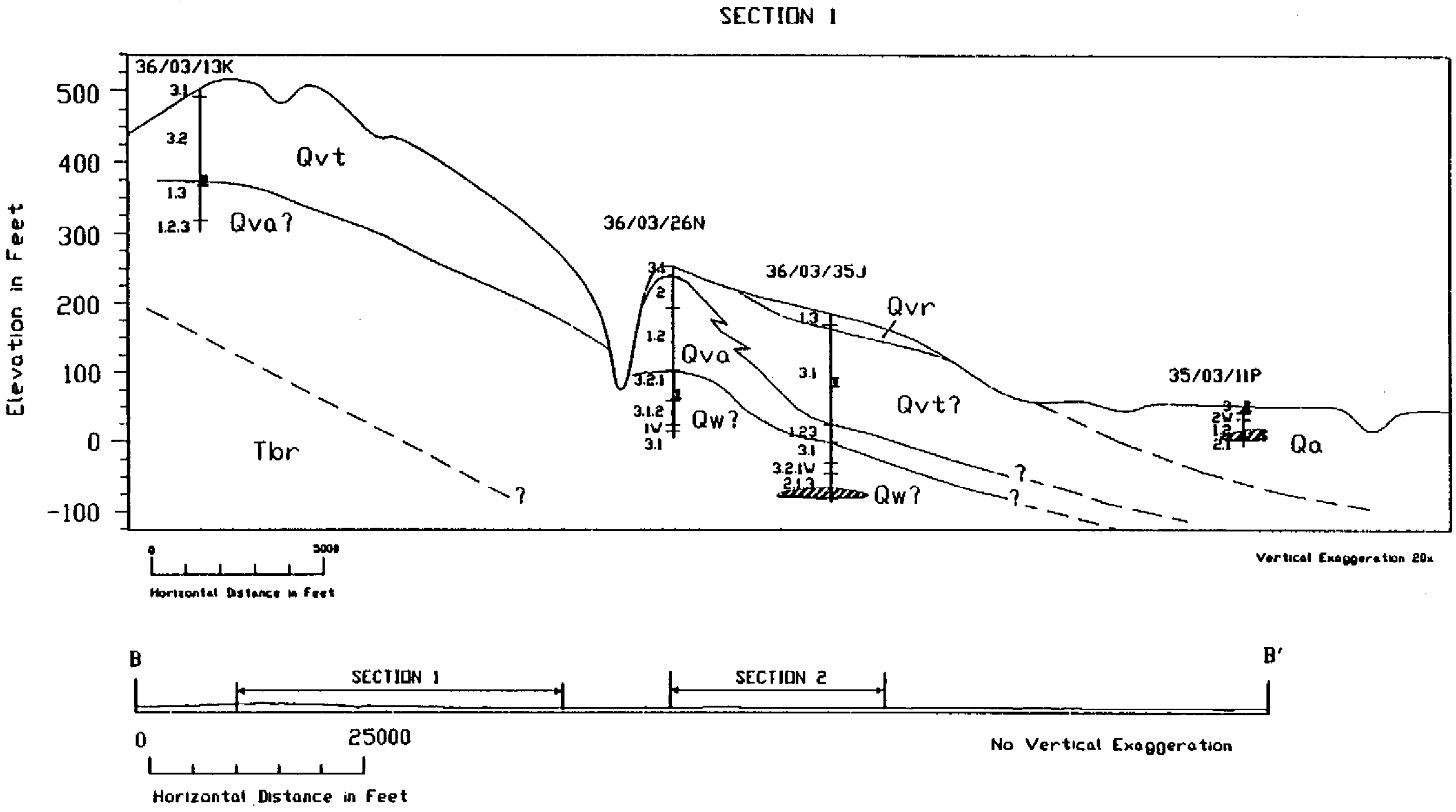
Qvt – Vashon Till
Qva – Vashon Advance Outwash
Qw – Whidbey Formation
Qdb – Double Bluff   Qu – Undifferentiated Glacial
▨ – Aquifer

1 – Gravel
2 – Sand
3 – Silt/Clay
4 – Till
R – Rock
W – Wood

EXHIBIT 3-1
GEOLOGIC CROSSECTION
Crossection A-A'

Skagit CWSP JU9007

Pacific
Groundwater
Group



Legend

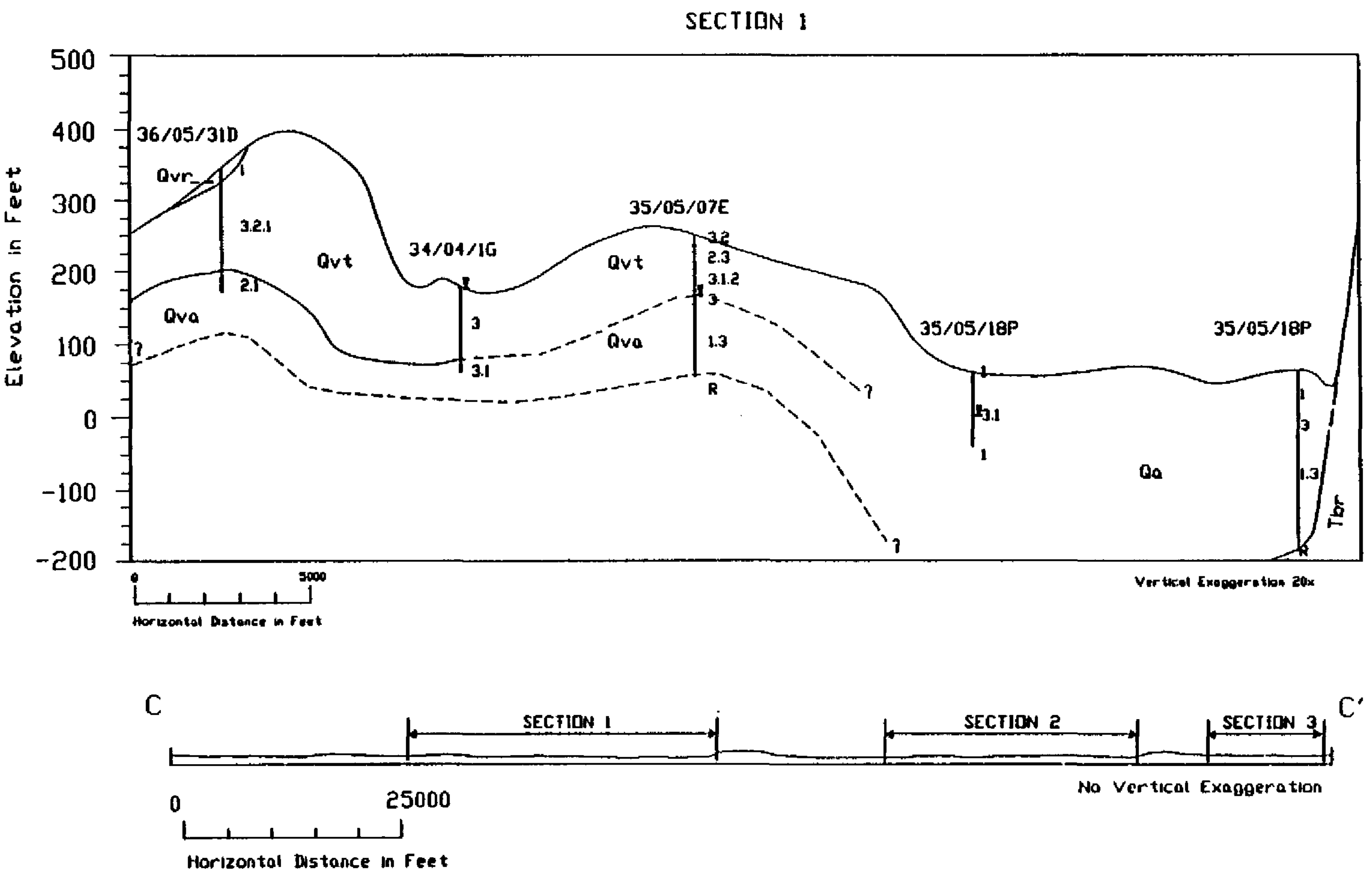
Qa – Alluvium
Qvr – Vashon Ressional Outwash ┐
Qvt – Vashon Till │ Qu – Undifferentiated
Qva – Vashon Advance Outwash ┘
Qw? – Whidbey Formation?
Tbr – Tertiary Bedrock
▨ – Aquifer

1 – Gravel
2 – Sand
3 – Silt/Clay
4 – Till
R – Rock
W – Wood

EXHIBIT 3-2
GEOLOGIC CROSSECTION
Crossection B-B' Section 1

Skagit CWSP JU9007

Pacific Groundwater Group



Legend

Qa – Alluvium
Qvr – Vashon Ressional Outwash ⎤
Qvt – Vashon Till ⎥ Qu – Undifferentiated
Qva – Vashon Advance Outwash ⎦
Qw? – Whidbey Formation?
Tbr – Tertiary Bedrock
▨ – Aquifer

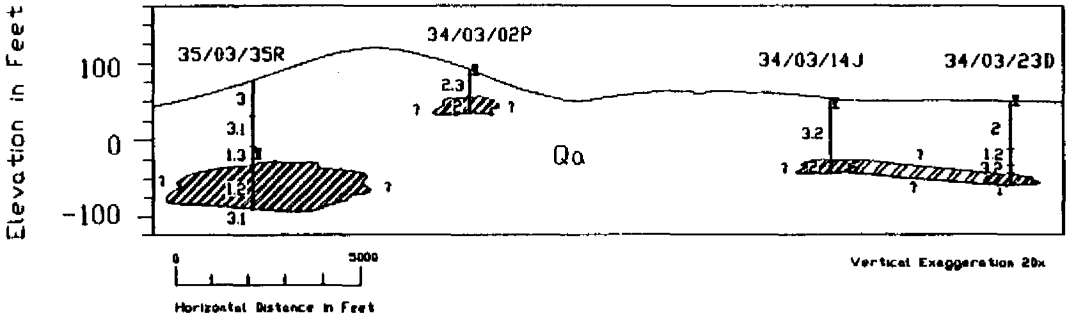
1 – Gravel
2 – Sand
3 – Silt/Clay
4 – Till
R – Rock
W – Wood

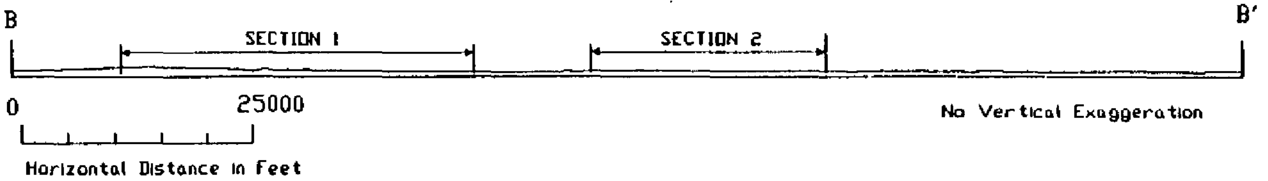
EXHIBIT 3-4
GEOLOGIC CROSSECTION
Crossection C-C' Section 1

Skagit CWSP JU9007

Pacific Groundwater Group

SECTION 2





Legend

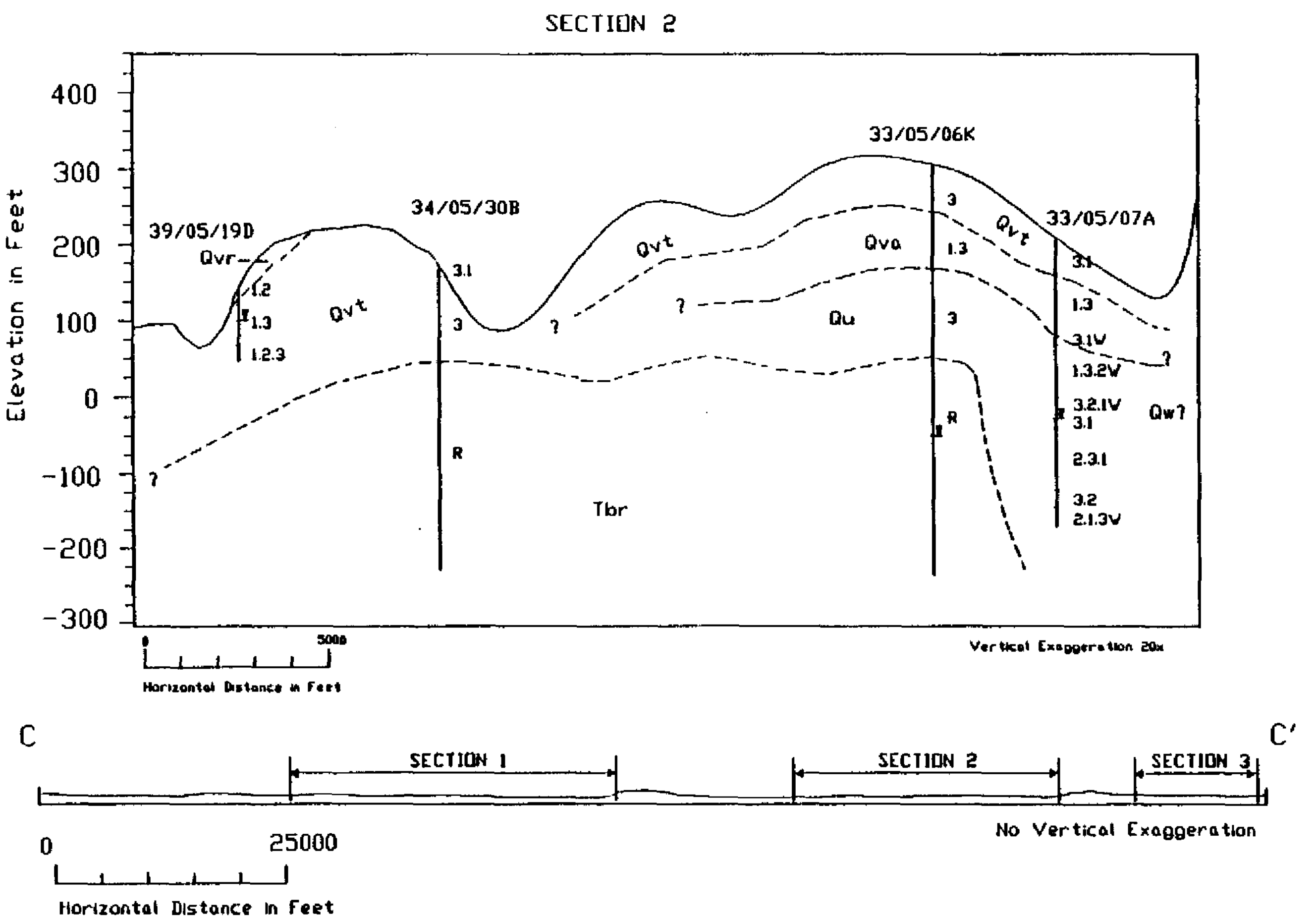
Qa – Alluvium
Qvr – Vashon Ressional Outwash
Qvt – Vashon Till
Qva – Vashon Advance Outwash
Qu – Undifferentiated
Qw? – Whidbey Formation?
Tbr – Tertiary Bedrock
▨ – Aquifer

1 – Gravel
2 – Sand
3 – Silt/Clay
4 – Till
R – Rock
W – Wood

EXHIBIT 3-3
GEOLOGIC CROSSECTION
Crossection B-B' Section 2

Skagit CWSP JU9007

Pacific Groundwater Group



Legend

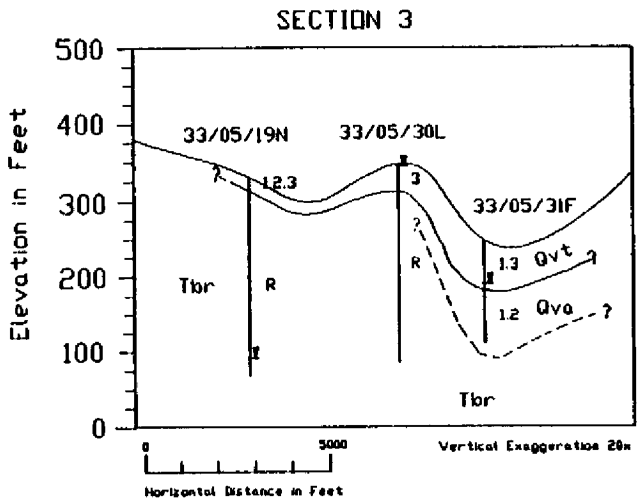
Qa - Alluvium
Qvr - Vashon Ressional Outwash
Qvt - Vashon Till
Qva - Vashon Advance Outwash
Qu - Undifferentiated
Qw? - Whidbey Formation?
Tbr - Tertiary Bedrock
▨ - Aquifer

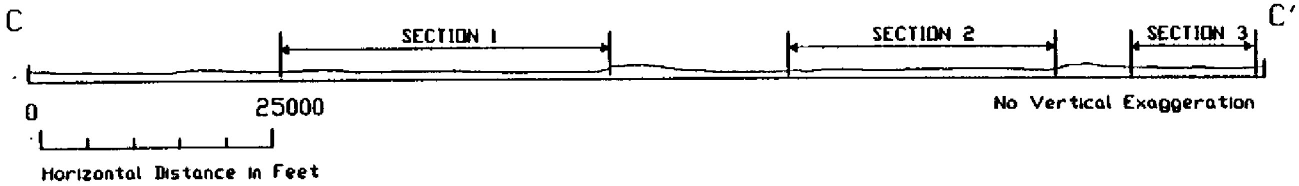
1 - Gravel
2 - Sand
3 - Silt/Clay
4 - Till
R - Rock
W - Wood

EXHIBIT 3-5
GEOLOGIC CROSSECTION
Crossection C-C' Section 2

Skagit CWSP JU9007

Pacific Groundwater Group





Legend

Qa – Alluvium
Qvr – Vashon Ressional Outwash
Qvt – Vashon Till
Qva – Vashon Advance Outwash
Qu – Undifferentiated
Qw? – Whidbey Formation?
Tbr – Tertiary Bedrock
▨ – Aquifer

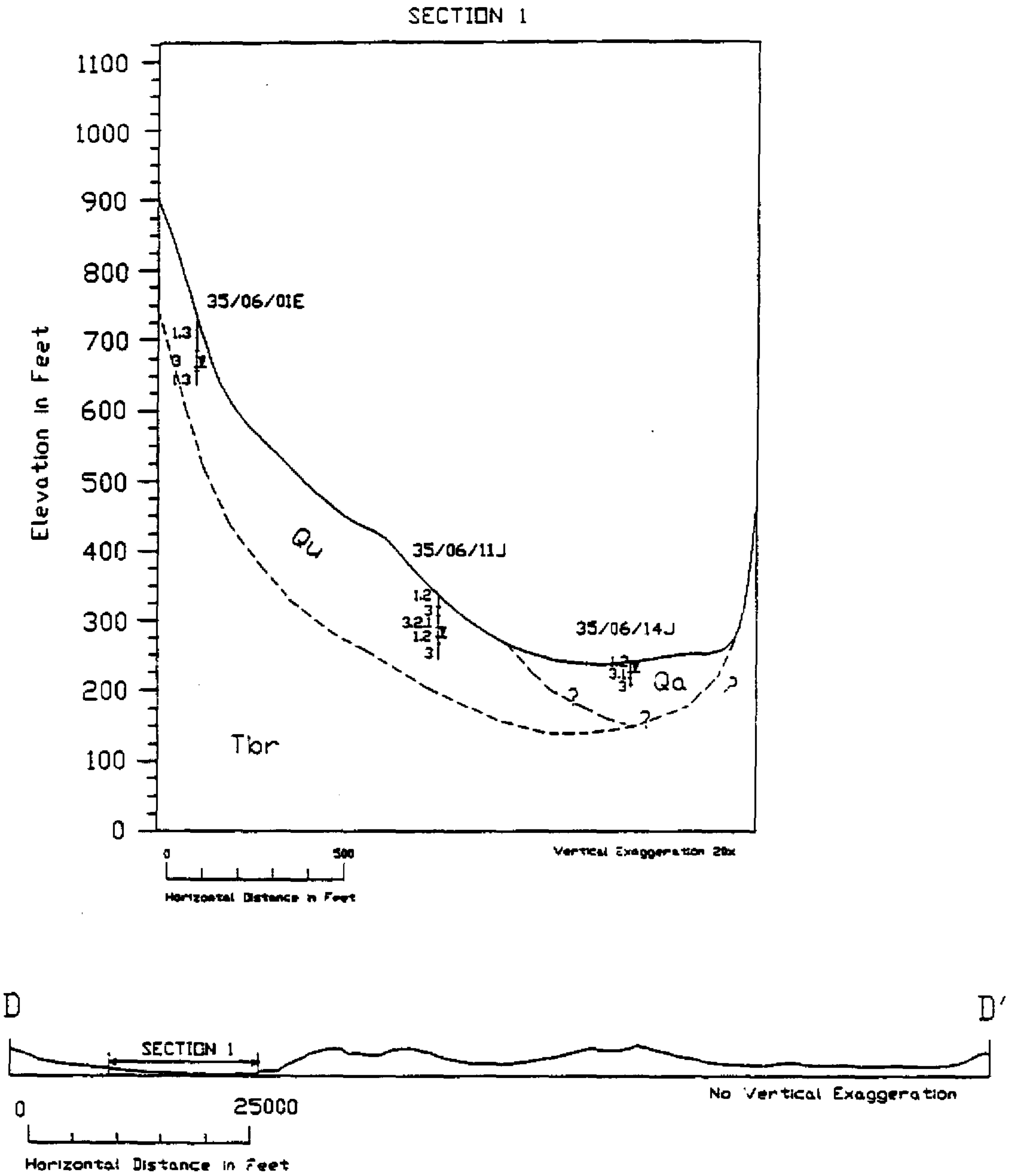
1 – Gravel
2 – Sand
3 – Silt/Clay
4 – Till
R – Rock
W – Wood

EXHIBIT 3-6
GEOLOGIC CROSSECTION
Crossection C-C' Section 3

Skagit CWSP JU9007

Pacific Groundwater Group

17938 17938



Legend

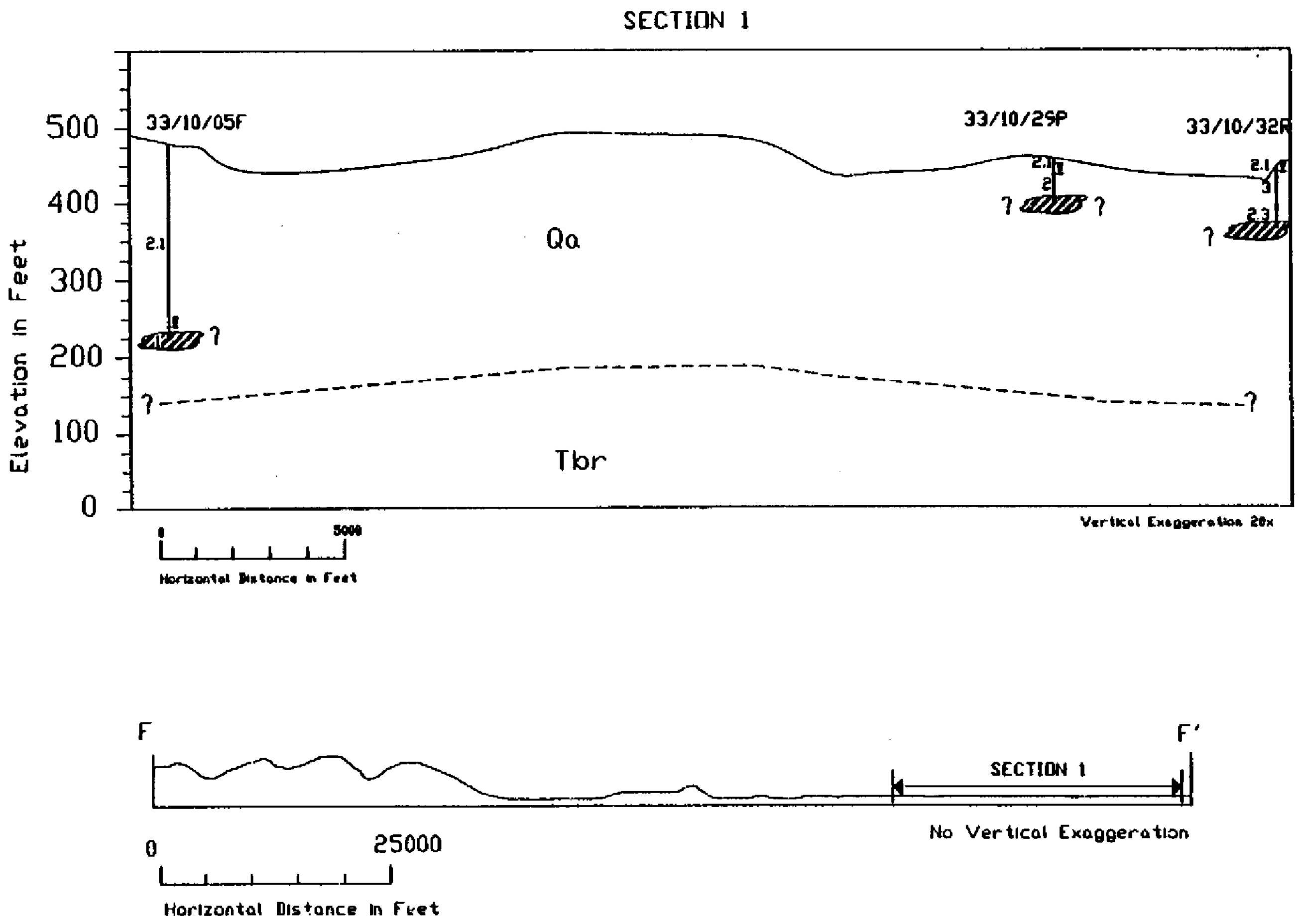
Qa - Alluvium
Qvr - Vashon Ressional Outwash
Qvt - Vashon Till
Qva - Vashon Advance Outwash
(Qvr, Qvt, Qva) Qu - Undifferentiated
Qw? - Whidbey Formation?
Tbr - Tertiary Bedrock
▨ - Aquifer

1 - Gravel
2 - Sand
3 - Silt/Clay
4 - Till
R - Rock
W - Wood

EXHIBIT 3-7
GEOLOGIC CROSSECTION
Crossection D-D' Section 1

Skagit CWSP JU9007

Pacific Groundwater Group



Legend

Qa – Alluvium
Qvr – Vashon Ressional Outwash
Qvt – Vashon Till
Qva – Vashon Advance Outwash
(Qvr, Qvt, Qva) Qu – Undifferentiated
Qw? – Whidbey Formation?
Tbr – Tertiary Bedrock
▨ – Aquifer

1 – Gravel
2 – Sand
3 – Silt/Clay
4 – Till
R – Rock
W – Wood

EXHIBIT 3-8
GEOLOGIC CROSSECTION
Crossection F-F' Section 1

Skagit CWSP JU9007

Pacific Groundwater Group

Appendix

Table AT-1 – Summary of Well Yield Data Available in USGS Database

17938

Well Number	Latitude	Longitude	Surface Altitude ft msl	Owner	Boring Depth ft	Well Depth ft	Well Diam in	SWL Depth ft	Pump Rate gpm	Specific Capacity gpm/ft	Aquifer Elevation ft msl	Est. Maximum Short-Term Well Yield gpm
35N/04E-05E	483313	1221954	72.00	WEIDBAMP JOHN	49.0	37.0	6	4	200	119.8	35	2600
35N/03E-11P	483200	1222331	16.00	YOUNGQUIST 1 JOHN	53.0	47.0	8	3	490	78.4	-31	2300
35N/04E-07B	483238	1222025	42.00	SAMISH RVR PK 1	35.0	35.0	10	5	500	55.6	7	1100
34N/03E-20R01	482502	1222643	5.00	HART		27.0	36	8	100	50.0	-22	630
35N/03E-24E01	483036	1222229	20.00	BURLINGTON		74.0	8	9	167	41.8	-54	1800
35N/03E-11P	483201	1222328	15.00	YOUNGQUIST 2 JOHN	46.0	43.0	8	5	400	32.0	-28	820
35N/03E-11R03	483203	1222212	25.00	ROUTON HOWARD	72.0	72.0	8	8	250	27.8	-47	1200
35N/04E-05G01	483316	1221912	70.00	STATE DEPT OF		44.0		14	450	22.5	26	450
35N/04E-05D	483322	1221955	70.00	DEPT FISH	44.0	44.0	12	14	450	22.5	26	450
35N/03E-22Q01	483001	1222425		COOPER ROBERT L	42.0	42.0	8	5	200	22.2	-42	560
34N/02E-03K01	482735	1223212	144.00	SKAGIT-PUD	200.0	200.0	8	132	142	20.3	-56	920
35N/08E-15E	483130	1214548	195.00	EDWARDS EDWARD	61.0	60.5	6	16	15	18.1	135	530
35N/05E-21J02	483019	1220945		MULDER JAN	42.0	42.0	8	30	60	17.1	-42	140
34N/02E-03L01	482740	1223214	90.00	LARSON J	128.0	108.0		74	3	12.5	-18	290
35N/05E-30M01	482927	1221316	45.00	SKAGIT PUD	50.0	50.0	12	9	250	12.5	-5	340
34N/02E-15L01	482602	1223236	240.00	JOHNSON CHARLES	201.0	200.0	6	184	12	12.0	40	130
36N/04E-05D01	483840	1221950	420.00	RHONE		97.0	6	75	12	12.0	323	180
34N/02E-15R01	482545	1223148	234.00	SWIN-TRIBE	230.0	143.0	6	113	53	10.1	91	200
35N/04E-29E01	472939	1221952	20.00	DYKSTRA DOUWE	39.0	38.0	8	7	100	10.0	-18	210
35N/07E-10A	483238	1215242	288.00	GRAHAM JACK	127.0	127.0	6	95	60	10.0	161	220
34N/02E-26C01	482448	1223113	273.00	DAN GASPER	46.0	46.0	6	33	10	10.0	227	90
34N/02E-26F01	482432	1223115	281.00	EDWARDS REGGIE	43.0	40.2	6	25	10	10.0	241	100
34N/02E-23P01	482457	1223118	262.00	MCCLOUD VERN	46.0	46.0	6	39	10	10.0	216	49
35N/11E-16D02	483129	1222327	365.00	DNR,CASCADE ISL M2	70.0	60.0	6	20	30	9.6	305	250
35N/11E-16D01	483134	1222332	360.00	DNR,CASCADE ISL M1	70.0	70.0	6	23	30	9.1	290	280
35N/04E-18A01	483135	1222012	35.00	SKAGIT CO		27.0	6	6	18	9.0	8	130
34N/02E-03G01	482755	1223157	15.03	SKAGIT-PUD	19.0	18.5	8	1	75	8.9	-3	110
36N/04E-27A01	483504	1221619	239.00	PROSSER		28.0	6	10	15	7.5	211	90
35N/04E-10C01	483233	1221654	800.00	ANDERSON		24.0	6	6	25	6.3	776	75
34N/02E-26F02	482428	1223115	265.00	SCOLERI CARMAN	161.0	161.0	6	135	10	5.0	104	87
36N/03E-24J01	483542	1222127	300.00	MCTAGART		173.0	6	151	10	5.0	127	73
34N/02E-25C01	482445	1223011	125.00	CHARLES NORVAL	30.0	30.0	6	14	10	5.0	95	53
36N/04E-33K01	483355	1221739	100.00	RUTHFORD		26.0	6	10	15	5.0	74	53
34N/02E-35E01	482333	1223143	206.00	BAILEY GEORGE		108.0		88	15	4.8	98	64
35N/03E-12D01	483207	1222238	70.00	KING		170.0	6	135	18	4.5	-100	110
34N/02E-02N01	482727	1223132	86.00	SWIN-TRIBE	100.0	89.8	6	69	18	4.5	-4	62
33N/02E-03A04	482257	1223152	45.00	DAMEN DAISY	33.0	28.0	6	5	16	3.2	17	49
34N/03E-23D01	482534	1222347	15.00	DRALLE EARL	107.0	107.0	8	11	200	3.1	-92	200
35N/05E-27E01	482958	1220921	50.00	WINTER BOB	50.0	50.0	6	31	30	3.0	0	38
34N/02E-23F01	482527	1223114	245.00	CAYOU ROGER	135.0	135.0	6	108	9	3.0	110	54
36N/04E-20N	483518	1221942	180.00	MORRISON ROBERT	84.0	84.0	6	34	15	3.0	96	100
34N/02E-34H01	482340	1223207	35.00	WAGNER PAUL F		53.0			50	2.8	-18	99
36N/04E-20F01	483548	1221922	260.00	WEST		15.0	6	8	8	2.7	245	13
36N/04E-26C01	483503	1221532	215.00	MEITZLER		59.0	6	43	10	2.5	156	27
36N/04E-32N01	483335	1221947	85.00	MCINNES		82.0	6	40	12	2.4	3	67
35N/08E-09F01	483218	1214649	190.00	THEODORATUS GEOR(	53.0	53.0	8	15	40	2.1	137	53
34N/02E-23L02	482502	1223115	250.00	MCLEOD HECTOR	49.0	49.0	6	37	25	2.1	201	17
34N/02E-23L01	482505	1223112	254.00	IRVINE ALBERT	100.0	93.0	6	68	10	2.0	161	33
33N/04E-25K01	481903	1221352	250.00	CHENEY		88.0	6	-1	40	1.9	162	110
34N/02E-34R09	482314	1223156	50.00	JORGENSON	80.0	80.0	6	49	15	1.7	-30	35
36N/01E-26H01	483448	1223809	100.00	CHARLES STUART	134.0	134.0	6	116	15	1.5	-34	18
34N/02E-27D10	482447	1223300	29.00		78.0	75.0			15	1.5	-46	75
34N/02E-34R01	482307	1223153	32.00	EVERITT G L	35.0	35.0	6	2	14	1.4	-3	31
34N/04E-22Q01	482502	1221627		HALD MORRIS C		262.0		185	20	1.3	-262	68
33N/04E-05K	482236	1221918	10.00	MCCAULEY ROBERT	120.0	108.0		8	50	1.3	-98	83
33N/02E-02D02	482254	1223148	90.00	SILVERMAN BARBARA	99.0	99.0	6	79	8	1.1	-9	15
35N/03E-11R01	483002	1222242	18.00	ROUTON L H	197.0	197.0	4	12	20	1.1	-179	140
34N/02E-22E01	482519	1223304	98.00	CHARLES RAY	109.0	107.0	6	83	7	1.0	-9	16
34N/02E-27K04	482411	1223230	44.00	SNEE-OOSH	54.5	54.0	6	21	10	0.8	-10	18
34N/02E-22N02	482458	1223305	36.00	ERICKSON DR.	64.0	64.0	6	12	20	0.8	-28	28
34N/02E-27K01	482410	1223229	48.00	SNEE-OOSH	89.0	89.0	6	6	14	0.7	-41	39
34N/02E-35L01	482320	1223116	235.00	SWORD JAMES	289.0	130.0	6	109	4	0.7	105	10
36N/04E-08N01	483701	1221951	305.00	SCIDMORE		44.0	6	9	10	0.7	261	16
34N/02E-15C01	482630	1223238	193.00	CAMPBELL LARRY	165.0	150.0	6	109	20	0.6	43	17
34N/02E-27D01	482440	1223301	21.00	WAGNER PAUL F		108.0		4	30	0.6	-87	42
34N/02E-27D11	482439	1223259	26.00	BEDINGFELD DAVID	141.0	141.0	[illegible]	7	30	0.5	-115	45
34N/02E-27K03	482409	1223229	46.00	SNEE-OOSH		48.0	[illegible]	45	46	0.5	-2	11
34N/02E-22N01	482457	1223304	34.00	MISNER ROBERT	52.0	52.0	4	9	7	0.5	-18	13

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Table AT-1 – Summary of Well Yield Data Available in USGS Database (Cont'd)

Well Number	Latitude	Longitude	Surface Altitude ft msl	Owner	Boring Depth ft	Well Depth ft	Well Diam in	SWL Depth ft	Pump Rate gpm	Specific Capacity gpm/ft	Aquifer Elevation ft msl	Est. Maximum Short-Term Well Yield gpm
35N/03E-32N01	482822	1222733	30.00	JENSEN ELMER	77.0	76.0	6	37	12	0.4	-46	11
34N/02E-21J09	482509	1223310	25.00	SKOMERZA GLENN	93.0	93.0	6	17	24	0.4	-68	22
34N/02E-35R01	482310	1223039	80.00	SHLTER-BAY	91.0	91.0	6	46	7	0.4	-11	12
34N/02E-34R10	482302	1223150	65.00	SNELSON GREG	130.0	125.0	6	60	15	0.4	-60	16
34N/02E-22N05	482453	1223301	34.00	ASHLAND SIGNE	47.0	47.0		9	7	0.3	-13	8
34N/02E-27D03	482438	1223300	25.00	HOVRUD OLA		112.0	4	12	10	0.3	-87	19
34N/02E-22N03	482458	1223303	32.00	HULBERT PAT	42.0	42.0	6	8	7	0.3	-10	6
34N/02E-27R02	482358	1223209	113.00	CLIFTON ROBERT	88.0	85.0	6	33	9	0.3	28	9
34N/03E-06A01	482816	1222757	3.00	TIEMERSMA		108.0	6	5	17	0.3	-105	18
34N/02E-22E03	482522	1223503	120.00	SMITH HENRY	133.0	132.0	6	107	5	0.3	-12	4
35N/01E-14B01	483144	1223839	25.00	YOUNG RODGER	81.0	81.0	6	20	10	0.3	-56	10
34N/02E-22N06	482455	1223302	40.00	HULBERT MRS. ROBT.	78.0	77.0	6	20	8	0.2	-37	9
34N/02E-21H10	482524	1223319	45.00	EVANS KEN	76.0	76.0	6	34	7	0.2	-31	6
33N/05E-08L01	482138	1221145	250.00	CARLSON		130.0	6	60	10	0.2	120	9
33N/02E-03H02	482238	1223151	38.00	CRIBB BEN H	92.0	92.0	6	25	8	0.2	-54	8
34N/02E-34B01	482354	1223223	13.00	DAN MORRIS		112.0	6	-3	6	0.2	-99	15
35N/03E-15D02	483148	1222512	10.00	JENSEN		103.0		11	15	0.2	-93	10
34N/02E-27R03	482358	1223211	111.00	CLIFTON ROBERT	72.0	72.0	6	39	4	0.2	39	4
34N/02E-27L02	482421	1223241	50.00	WAGNER PAUL	113.0	112.0	6	12	15	0.2	-62	11
34N/02E-35H04	482338	1223039	170.00	EFEIR MAUDE	110.0	110.0	6	64	4	0.1	60	4
34N/02E-27R01	482355	1223207	100.00	LOMBARD F L	73.0	73.0	6	21	5	0.1	27	5
34N/02E-27Q02	482400	1223221	46.00	SHOREWOOD		117.0		-0	12	0.1	-71	9
34N/02E-34A04	482348	1223210	37.00	NELLES JOE	95.0	95.0	6	30	6	0.1	-58	5
34N/02E-34A01	482346	1223211	36.00	THORP LOUIS	92.0	89.0	6	30	5	0.1	-53	4
34N/02E-27F02	482423	1223246	42.00	REEF-POINT	103.0	98.0	6	18	7	0.1	-56	5
34N/02E-27L01	482420	1223305	40.00	REEF PT.	99.0	99.0	6	6	7	0.1	-59	6
34N/02E-27D06	482438	1223252	68.00	HUGHES L H	183.0	177.0	6	31	9	0.1	-109	9
34N/02E-34R02	482304	1223152	43.00	SMITH C. P	95.0	95.0	6	38	3	0.1	-52	2
34N/02E-34A02	482345	1223210	38.00	ANDERSON LEROY	99.0	99.0	6	30	3	0.04	-61	2
34N/02E-34A05	482348	1223205	50.00	LAMMERS ARBERTA	160.0	128.0	6	38	3	0.04	-78	2
33N/02E-03H01	482239	1223151	41.00	BALICH MAX	113.0	113.0	6	28	2	0.04	-72	2

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Table AT-2 – Summary of Selected Well Yield Information

Wells Used in Mainland Cross Sections (Ecology Files)

PGG Well No.	Well No.	SWL Depth ft	Aquifer Depth ft	Pump Test Type	Pumping Rate gpm	Drawdown FT	Test Time hrs	Est. Maximum Short-Term Well Yield gpm
1	36N/03E-13K	139	198	B	10	0.5	1	800
2	36N/03E-26N	181	216	P	20	3	NA	200
3	36N/03E-35J	123	242	P	50	100	6	40
4	35N/03E-11P	4	31	P	490	6	1	1000
5	35N/03E-35R	138	174	B	25	7	1	90
6	34N/03E-02P	7	41	P	250	25	4	200
7	34N/03E-14J	11	77	A	100	20	NA	200
8	34N/03E-35P	5	67	P	150	15	1	400
9	34N/03E-23D	11	97	B	200	65	NA	200
10	33N/03E-10J	NA	17	NA	NA	NA	NA	–
11	36N/05E-19B	105	137	A	15	132	1	2
12	36N/05E-31D	77	162	P	68	22	6	200
13	36N/05E-18D	32	58	B	25	2	3	200
14	36N/05E-07L	140	178	A	80	175	1	10
15	35N/05E-30J	NA	18	NA	NA	NA	NA	–
16	35N/05E-18P	61	100	B	60	61	NA	30
17	35N/05E-06J	NA	135	P	10	140	1	–
18	35N/05E-07E	80	198	A	20	193	1	8
19	34N/04E-01G	1	111	B	6	99	NA	4
20	34N/05E-30B	NA	400	NA	NA	NA	NA	–
21	34N/05E-19D	39	93	A	4	90	1	2
22	33N/05E-06K	360	437	B	10	80	NA	6
23	33N/05E-07A	235	377	A	50	NA	NA	–
24	33N/05E-19N	242	260	B	0.3	15	1	0
25	33N/05E-31F	60	135	P	350	7	24	3000
26	33N/05E-30L	0	300	NA	NA	NA	NA	–
27	33N/06E-35A	12	38	A	60	35	1	30
28	33N/06E-26M	18	134	B	3	112	NA	2
29	33N/06E-22P	10	60	B	4	33	4	4
30	35N/06E-14J	15	48	B	24	3	6	200
31	35N/06E-11S	60	69	B	10	1	3	60
32	35N/06E-01E	73	100	A	40	95	NA	8
33	35N/08E-24A	26	52	A	75	46	1	30
34	35N/08E-15D	40	70	P	15	1	4	300
35	36N/08E-35L	63	92	A	15	20	NA	10
36	35N/10E-30G	80	287	A	10	280	1	5
37	34N/10E-18F	14	36	A	20	7	NA	40
38	34N/10E-19P	14	40	A	15	6	NA	40
39	34N/10E-29E	19	37	B	20	10	NA	20
40	33N/10E-32R	7	75	P	30	33	2	40
41	33N/10E-29P	21	55	P	38	0	12	–
42	33N/10E-05F	240	251	B	6	10	NA	4

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Wells in Guemes Data Base (Garland File)

PGG Well No.	Well No.	SWL Depth ft	Aquifer Depth ft	Pump Test Type	Pumping Rate gpm	Drawdown FT	Test Time hrs	Est. Maximum Short-Term Well Yield gpm
43	35N/01E-02F	57	79	B	15	0	1	–
44	35N/01E-01A	135	151	P	12	0	6	–
45	35N/01E-01K	108	200	A	5	90	NA	3
46	35N/01E-01M	160	185	A	12	12	NA	20
47	35N/01E-01R	90	223	B	12	66	1	20
48	35N/01E-02G	88	130	A	30	20	NA	40
49	35N/01E-11A	65	107	B	45	10	NA	100
50	35N/01E-11H	168	190	B	3	43	NA	1
51	35N/01E-12N	90	140	A	7	30	NA	8
52	35N/01E-11N	42	55	A	15	8	NA	20
53	35N/01E-11Q	68	101	B	20	20	4	20
54	35N/01E-11	20	76	B	10	40	4	9
55	35N/01E-12H	120	220	B	4	80	2	3
56	35N/01E-12N	38	75	A	20	1	NA	500
57	35N/01E-12K	28	30	B	10	2	2	7

Table AT-2 – Summary of Selected Well Yield Information (Cont'd)

PGG Well No.	Well No.	SWL Depth ft	Aquifer Depth ft	Pump Test Type	Pumping Rate gpm	Drawdown FT	Test Time hrs	Est. Maximum Short-Term Well Yield gpm
58	35N/01E-12K	100	117	B	3	15	NA	2
59	35N/01E-12	23	159	B	45	45	NA	90
60	35N/01E-12	70	255	B	6	170	NA	4
61	35N/02E-08K	46	76	A	4	32	NA	3
62	35N/02E-08S	0	189	B	4	NA	1	-
63	35N/02E-06N	160	20	B	1	NA	NA	-
64	35N/02E-06G	60	150	B	7	85	NA	5
65	35N/02E-07A	71	108	B	30	40	NA	20
66	35N/02E-08H	47	115	B	15	60	NA	10
67	36N/01E-25N	68	72	B	10	2	4	10
68	36N/01E-26H	116	129	B	15	10	2	10
69	36N/01W-26	163	184	B	20	1	1	300
70	36N/01E-26P	20	26	P	5	0.5	4	40
71	36N/01W-35E	133	150	A	20	15	NA	20
72	36N/01E-35G	147	158	B	8	10	NA	6
73	36N/01E-36K	108	200	B	5	90	NA	3
74	36N/01E-26R	149	156	B	10	0.5	1	90
75	35N/01E-12N	80	99	B	2	15	2	2
76	35N/01E-12H	67	121	B	32	57	NA	20
77	35N/01E-12F	90	115	B	5	24	NA	3
78	35N/02E-07C	57	99	B	6	35	NA	5
79	36N/01E-36P	26	41	B	15	11	NA	10
80	36N/01E-36P	7	44	B	8	35	1	6
81	36N/01E-36C	59	66	P	15	1	3	70
82	36N/01E-36C	29	37	B	10	4	NA	10
83	36N/01E-26R	167	189	B	10	4	2	40
84	36N/01E-26K	101	152	B	20	24	NA	30

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MEDIAN YIELD (GUEMES) GPM 6.5

Saltwater in Guemes Island wells prompts study proposal

(4) 2075

By TIM CHRISTIE
Staff Writer

MOUNT VERNON — Skagit County officials and Guemes Island residents know saltwater is getting into wells on the island's fringes. What they don't know is why it's happening or what can be done about it.

To find out, the U.S. Geological Survey has proposed a $202,000 comprehensive ground water study for the island. Survey officials have pledged $101,000, and the state Department of Ecology has offered $50,500 through the state's Centennial Clean Water Fund.

Now a committee of island residents is asking the Skagit County Commissioners to provide the remaining $50,500 as a match for the state money.

Commissioners Bill Vaux and Robby Robinson took no action Monday after meeting with county Health Department officials and island residents, but promised to have an answer by the Feb. 22 deadline for applying for the state funds.

"We're saying, where are we going to get $50,000?" Commission Chairman Vaux said after the meeting.

The Department of Ecology has identified at least six pockets of saltwater intrusion along the south, west and northwest coasts of the island. The problem is probably worse during the summer months when the island population increases, water consumption rises and little rain falls, said John Thayer, the county's environmental health director.

A layer or lens of fresh water floats on top of saltwater, Thayer said. When the fresh water lens is drawn down too rapidly, saltwater gets into wells.

Thayer guessed more than 125 homes are affected by saltwater intrusion in wells.

Saltwater doesn't run out of the home's taps, but there is an excess concentration of chlorides in the drinking water, Thayer said. Chloride is an element of salt, which dissolves in water.

"I have not heard anybody complain that the chloride level is so great that the taste is obnoxious," Thayer said. "They are not in danger from a public health standpoint."

Information from the USGS study is needed to make informed decisions about land-use planning and ground-water quality protection, say members of the Guemes Island Water Resource Committee. The committee represents the two main community organizations — the Guemes Island Property Owners Association and the Guemes Island Environmental Trust.

"The alarm bells are going off, saying you're pumping too much water," said Joseph Miller, a committee member.

That could mean residents are either pumping water in the wrong places or that the island has reached its population limit, beyond which there aren't sufficient supplies

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Guemes well study proposed

Continued from Page A3

of water, he said.

"The main question we hope to answer is whether we have a resource problem or a distribution problem," Miller said. "If there is a sufficient resource, it becomes a distribution problem."

County Finance Director Mike Woodmansee said today the commissioners have not yet talked to him about finding an extra $50,500 in the county budget. He said he'll find out from them how urgent the need is and whether it can wait until the next budget year.

"We have a budget process that should be followed. If the project has so much merit that it overrides our normal standards, then we do what we can do," he said.

"If something is going to have a significant effect on property values or people then we usually step up and make whatever budget changes we have to make."

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