EASTERN JEFFERSON COUNTY

GROUNDWATER CHARACTERIZATION STUDY

May 1994

Prepared By

ECONOMIC AND ENGINEERING SERVICES, INC.

In Association With

PACIFIC GROUNDWATER GROUP

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May 19, 1994

File #: 42780

Mr. Jim Parker
Public Utility District No. 1 of Jefferson County
24 Colwell Street
PO Box 929
Port Hadlock, WA 98339

Subject: Eastern Jefferson County Groundwater Characterization Study

Dear Mr. Parker:

Economic and Engineering Services, Inc. (EES) is pleased to submit the Eastern Jefferson County Groundwater Characterization Study (Study). This Study was undertaken by EES, in conjunction with Pacific Groundwater Group (PGG), to begin the process of evaluating the groundwater supply in Jefferson County (County) by utilizing existing data. During this process, existing geology, water resource and quality data, and land use information has been analyzed. Further data has been developed in a digital format to begin a process of long-term groundwater database development.

A specific benefit of this project has been the development of Geographic Information System (GIS) mapping products. These digital products are consistent with other work developed by the County, and complement the County's efforts. Specifically, funds from this project were used in conjunction with County funding to develop a land use map for Eastern Jefferson County utilizing Assessor's parcel data. The result is a powerful, analytical tool which can be utilized in the future to examine land use in relation to other data layers. In this report, a first analysis is presented as geology, recharge, and land use layers were used to prepare a groundwater vulnerability map. A much more site specific and detailed analysis can occur in the future now that this data exists in GIS format.

As the report indicates, there is adequate water to meet projected future demands. However, this supply may not be where it is most needed, and may be expensive to find and develop. Specific development of future regional supply will require detailed analysis using this work as a base. Additionally, future supply will require Wellhead Protection and considerations for potential contamination which may affect siting.

From a regulatory standpoint, future groundwater sources will require more testing, analysis, and some increase in treatment to meet federal and State requirements. Wellhead protection programs will be required for all groundwater sources within the next two years (based on current information). This indicates a higher cost of development and operation of groundwater systems. The work summarized in this report should help minimize development costs by providing the basis for analysis for future supply alternatives.

We look forward to assisting the PUD, the County, and other water purveyors in developing a water supply plan to meet the future needs of the citizens of Jefferson County.

Sincerely,

Marc A. Horton
Project Manager

MAH:aa:w

Enclosure

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SECTION I

Section I
Introduction

1. Background

In 1983, the Jefferson County Commissioners declared Jefferson County (County) a Critical Water Service Area. Under State law, the declaration of a Critical Water Service Area begins the process of development of a Coordinated Water System Plan (CWSP) to establish service areas, service protocols and criteria, and to help the purveyors better coordinate service. From a supply standpoint, the CWSP process provides an assessment of existing water supply, future demands, and identification of future sources.

The CWSP was completed in 1986. It called attention to the limits of supply to the region. Particular attention was given to the existing surface supply for Port Townsend (the Big and Little Quilcene Rivers). Groundwater was seen as a secondary supply, but not necessarily a supply for regional distribution. For the regional supply, the CWSP recommended development of surface water from the eastern slope of the Olympic Mountains (Dosewallips River Area). This led to consideration of an existing water right application by Port Townsend, and subsequently, to a request for "reservation" of surface supply from the Dosewallips River to meet the area's future water needs. The Department of Ecology (Ecology) did not respond to the draft petition, but rather deferred any decision to further study.

Growth has continued in the County, exceeding previous projections. Water supply has continued to be met primarily by the Quilcene River system serving urban growth near Port Townsend. However, significant growth has also occurred outside of Port Townsend's service area. These needs have been met by development of groundwater resources.

Groundwater supply has, to-date, been adequate. However, the increase in demand resource and increased population density have brought attention to reports of water level declines, salt water intrusion, and high iron and manganese content at various locations in the County. Almost all of the 153 public water systems in the County rely on groundwater. Although much of the population is currently served by the Port Townsend surface water supply, the future economic development of the County will depend heavily on groundwater development.

Limits of the Quilcene River supply, along with the unlikely future for a Dosewallips River supply, and an increasing dependence on the groundwater resource, all fostered the initiation of this Eastern Jefferson County Groundwater Characterization Study (Study).

2. Study Purpose

Purveyors such as the Jefferson County Public Utility District (PUD), which rely on groundwater, are concerned about the levels and location of future supply. The PUD is expanding its services in the County, either by expansion of its service area on the perimeter of Port Townsend's service area or by the acquisition or management of "Satellite" water systems in outlying areas. The PUD Commissioners authorized this Study to begin answering key questions surrounding the extent and nature of the groundwater resource.

This Study was designed as a preliminary characterization of the groundwater resources of Eastern Jefferson County. As such, it has made use of existing information and has addressed the following objectives:

- Characterization of area aquifers,
- Analysis of vulnerability of aquifers,
- Creation of an initial groundwater database, and
- Identification of strategies for groundwater protection.

This Study is intended to complement and assist in the critical regional planning which is underway in Eastern Jefferson County through the "Chelan Process" and County comprehensive planning. The "Chelan Process" is examining water supply from the Quilcene/Dungeness systems; and, the comprehensive planning is now underway in Jefferson County under the provisions of the Growth Management Act (GMA).

Economic and Engineering Services, Inc. (EES) and Pacific Groundwater Group (PGG) were authorized under a contract with the PUD to complete this Study. The efforts of this Study have been partially funded by a grant from Ecology under the Centennial Clean Water Fund.

SECTION II

Section II
Summary Of Conclusions And Recommendations

The following major conclusions and recommendations are presented in the main body of this report. They are brought forward here to highlight their importance. The main body of the report should be consulted for specific detail and supporting data.

1. Additional groundwater development appears feasible in Eastern Jefferson County. Water budget analyses based on estimates of recharge, runoff, groundwater consumption, and the assumption that 20 percent of total recharge can be developed without unacceptable consequences, indicate 20 to 25 million gallons per day (mgd) in addition to current withdrawal may be feasible.

2. Potential well yields in Eastern Jefferson County are generally low (less than 200 gallons per minute - (gpm)). About 6 percent of the wells surveyed in the Eastern Jefferson County Groundwater Characterization Study (Study) had potential yields of greater than 500 gpm, and about 12 percent had potential yields of 200 to 500 gpm. The mean potential yield was 40 gpm while the median yield was 20 gpm. These statistics are based on an analysis of 254 wells manually selected from a well log data source of about 2,000 wells. This information was not field verified. Yields are based on information presented on the well logs.

3. A geologic map and eight cross sections constructed from geologic reports, maps, and well logs, show a series of glacial and interglacial deposits overlying bedrock of marine basalt and marine sediments. The glacial and interglacial materials represent repeated deposition and erosion of sediments over the past 1 million plus years. The coarser sand and gravel of these deposits form the major aquifers (water bearing units) in Jefferson County (County). Bedrock areas produce generally low potential well yields as water tends to flow only through limited fractures in the rock. The geologic cross sections were tested on well log information that was not field verified.

4. The geologic and well yield assessments indicate no extensive areas of moderate or high yield aquifers. Instead, moderate and high yield areas appear to be localized in zones where deposits of permeable materials are locally extensive. This distribution of well yields indicate that areas for preferred future development cannot be identified based on the resolution of this Study. Instead, small area-specific feasibility studies are recommended before well exploration and development programs are undertaken.

5. An assessment of aquifer susceptibility (to contamination) and aquifer vulnerability (the combination of susceptibility and potential for contamination sources) indicates that most of the County lies in low to moderate susceptibility and low vulnerability

areas. This assessment indicates the conditions for the uppermost aquifer. Deeper aquifers are often less susceptible and less vulnerable. The assessment indicates the County has low probability of significant aquifer contamination.

6. Existing water quality data are scarce. The few data that are available indicate limited water quality problems in public water systems with iron, manganese, and chloride contamination.

   Numerous studies have documented high chloride levels in groundwater from private wells in Jefferson County (see Section 7). These wells were noted for the following characteristics and should provide guidance for future production well siting.

   - ❑ Locations less than 500 feet from the coastline.
   - ❑ Bottom hole depths and intake elevations below sea level.
   - ❑ Location in areas with previous intrusion history.
   - ❑ Production from unconfined versus confined aquifers.
   - ❑ Locations in areas where well densities and aquifer withdrawal rates are high.

7. Several data gaps were identified during the course of this Study. These include: lack of positive location data for well logs (and the difficulty of their use in non-electronic format), the lack of usable water level data, the lack of water quality data, and lack of deep hydrogeologic data. Much additional information on the characteristics of groundwater in the County could be generated if these data gaps were rectified.

8. Additional work is recommended as a continuation of this characterization process. Continued development of a computerized data base for well logs, measurements of water levels and consumption, collection of water quality data and development of a computerized data base for water quality data, and the collection of deep hydrogeologic information from unexplored areas is recommended.

9. A Wellhead Protection Program will be required within the next few years. As such, Wellhead Protection is the strategy of choice for water quality protection. The Department of Health has recently published guidelines for such programs and regulations are expected to follow. All purveyors dependent on groundwater as a source should plan now for undertaking protection programs for their source(s). This groundwater characterization report will be useful as individual sources are analyzed under this program.

SECTION III

Section III
Aquifer Ranking Criteria

1. Method and Overview

Criteria for ranking aquifers were developed during the beginning of the project. The purpose for developing these criteria was to guide the hydrogeologic characterization in defining what is, and what is not, desirable for development of regional groundwater supplies. Nine criteria were identified as affecting the desirability of a groundwater source with regard to groundwater availability and management/operational issues. These criteria are as follows:

Groundwater Availability:

- ❑ Well yield (an important factor in determining development feasibility and cost)
- ❑ Water quality (an important factor controlling development and operational costs)
- ❑ Aquifer yield (a factor controlling overall feasibility of development)
- ❑ Instream basin closures (possibly prohibiting any new development)

Management/Operational Issues:

- ❑ The potential for saltwater intrusion (indicated by the distance to marine waters, among other things)
- ❑ Depth to water (a factor affecting development and pumping costs)
- ❑ Geographic location (a factor affecting distribution costs)
- ❑ Aquifer vulnerability (a factor affecting potential contamination)
- ❑ Existing water use in the area (a factor affecting water rights and related issues)

These criteria were identified through conversations with the Jefferson County Public Utility District (PUD), experience in other areas, and review of the hydrogeology of the area.

A matrix was then conceived for two categories of groundwater development: regional supply and local supply. A regional supply is one that is capable of producing groundwater in quantities and quality for transmission to distant areas of use. It represents the highest yield wells in the region. The high yields make development and transmission of groundwater economically feasible. A local supply aquifer is one where transmission of groundwater is economically feasible. A local supply aquifer is one capable of supplying water for local consumption but at rates less than those of the regional supply aquifer. The lower yield is usually sufficient to supply local development, but too small to be considered for delivery to areas further away.

After each of the nine criteria were identified, quantified values for each factor were developed for each of three categories (high, medium and low desirability) for each type of aquifer (regional or local). For example, a highly desirable regional supply aquifer in Jefferson County (County) should have yields of greater than 500 gpm, require no treatment to meet all drinking water standards, be situated away from closed basins and areas of likely saltwater intrusion, close to population centers or existing distribution lines, and be protected from potential contamination. A local supply aquifer may meet many of these criteria but be capable of producing less water.

The nine criteria were then placed in a matrix with the desirability ranking, the values for each, and how they apply to regional and local supply aquifers. Each of the criteria is considered in the sections that follow. Each factor was evaluated and quantified to help guide future groundwater explorations in the County.

2. Results

The aquifer ranking matrix is presented in Table III-1. The preferred aquifers targeted for additional regional or local development would have all criteria falling in the high desirability ranges as shown in the matrix. If a high desirability rating for all criteria cannot be met, then the next preferred option would be to have as many of the criteria fall in the high desirability ranges as possible. Aquifers with criteria falling in the low category were not considered as options for additional development. The application of the matrix (using values for the criteria developed during the Eastern Jefferson Groundwater Characterization Study and discussed in the following sections) is presented in Section X.

Table III-1
Aquifer Ranking Matrix

May 19, 1994

Regional-Supply Aquifer

AVAILABILITY

Desirability	Expected Well Yield (gpm)	Expected Water Quality in Area	Aquifer Yield	Instream Basin Closure
High	>500	Meets all MCL's	High	None
Medium	200 to 500	Meets all PMCL's Excess Fe or Mn Cl <100 mg/l	Medium	Part of Year
Low	<200	Meets all PMCL's Cl >100 mg/l	Low	Total (FATAL FLAW)

MANAGEMENT/OPERATIONAL CONCERNS

Distance to Marine Water	Depth to SWL (ft)	Geographic Location	Aquifer Vulnerability Near Site	Existing Water Use In Area
> 1 mile	<100	Near Population Center	Low	Low
0.5 to 1 mile	100 to 300	Away from Population Center, but near Water Mains	Medium	Medium
<0.5 mile	>300	Away from Population and Water Mains	High	High

Local-Supply Aquifer

AVAILABILITY

Desirability	Expected Well Yield (gpm)	Expected Water Quality in Area	Aquifer Yield	Instream Basin Closure
High	>200	Meets all MCL's	High	None
Medium	50 to 200	Meets all PMCL's Excess Fe or Mn Cl <100 mg/l	Medium	Part of Year
Low	<50	Meets all PMCL's Cl >100 mg/l	Low	Total (FATAL FLAW)

MANAGEMENT/OPERATIONAL CONCERNS

Distance to Marine Water	Depth to SWL (ft)	Geographic Location	Infiltration Potential Near Site	Existing Water Use In Area
> 0.5 mil	<100	Near Local Population Center	Low	Low
0.2 to 0.5 mile	100 to 300	Away from Local Population Center but Near Water Mains	Medium	Medium
<0.2 mile	>300	Away from Local Population & Water Mains	High	High

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SECTION IV

Section IV
Geology And Distribution Of Aquifers

1. Method and Overview

The first step in assessing the groundwater resources in an area is to evaluate the surficial and subsurface geology. Understanding the geology sets the framework for describing where groundwater is present, how it flows, how much can be developed, and what areas are most conducive to development. The geology must be understood first before the hydrology can be quantified.

The method used to present geologic and hydrogeologic data for this Eastern Jefferson County Groundwater Study (Study) was to compile and use currently available maps, cross sections, reports, well logs, and theses. This information was obtained from the following references: Purdy and Becker, 1992; Garrigues, 1992; Yount and Gower, 1991; Pessl et al 1989; Grimstad and Carson, 1981; Hanson, 1977; Gayer, 1977; Gayer, 1976; Carson, 1976; Birdseye, 1976; and Washington State Department of Ecology, 1991. Synopses of these references are given in the annotated bibliography of this report.

A geologic map of Eastern Jefferson County was compiled from sub-regional maps contained in the references listed above. In addition, five new hydrogeologic cross sections were constructed based on the stratigraphy interpreted from 37 geologic logs selected from the well database.

These cross sections were based on well drillers logs selected from about 2,000 available for Eastern Jefferson County. Because of budget limitations and level of effort appropriate to that budget, only selected well logs were used in the generation of the cross sections.

The following method was used to select the well logs for the analysis:

> A copy of all the Eastern Jefferson County well logs were obtained from the Jefferson County Public Utility District (PUD). Each log was quickly reviewed with the intent to select one log per section (1 square mile). A log was selected based on its completeness, level of detail, and depth. A log was considered complete if it had location information (to the nearest 1/4 1/4 section), water level information, pump test information (including type of test, drawdown at the end of the test, and pumping rate during the test), complete geologic log describing subsurface materials, and well screen/opening information. Where more than one complete log was available per section, the log was selected that indicated the largest potential

yield. Occasionally more than one log per section was selected, even if incomplete, when important information pertinent to that area was not included in the first log selected. In all, a total of 260 well logs were used in the selected log analysis.

Of the 260 well logs, 37 were then plotted along the topographic profile of the five section lines. The actual position of the well was estimated to the nearest 1/4 - 1/4 section. Since each well location was not field verified, the position of the well could be off by 660 feet, and the elevation of the well by 100 feet or more in steep-sloped areas. The subsurface geology was then interpreted based on: correlation with the surficial geology as indicated on the geologic map, comparison of the driller's descriptions with descriptions of the geologic units in the various reports and maps, site visits to selected cliff exposures in the Jefferson County (County), and experience with these geologic units in other parts of the north Puget lowland, especially Island County (which has many of the same geologic units as Jefferson County). Geologic contacts were then inferred between the wells and the geology in between well logs was interpreted. Because glacial and interglacial geology can vary over short distances, it is likely that some of the interpreted geology between the well logs differs from the actual conditions. However, the cross sections serve as a "best interpretation" of the available data used in the analysis.

The sections drawn as part of this project are supplemented with the three cross sections of Grimstad and Carson (1981). Their sections do not show the detail of new sections used here, as they describe all deposits older than Vashon (the most recent glaciation) simply as pre-Vashon undifferentiated.

2. Results

The geologic map of Eastern Jefferson County is shown on Exhibit IV-1. Hydrogeologic cross sections are shown on Exhibits IV-2 through IV-5. These exhibits show the surficial and subsurface geology of the project area.

2.1 Description of Units

The stratigraphic nomenclature used for the geologic map (Exhibit IV-1) is based on detailed geologic map units in Eastern Jefferson County. The current published map units of Grimstad and Carson (1981) include only the general categories of:

- Quaternary Alluvium,
- Quaternary Vashon Deposits,
- Quaternary Undifferentiated pre-Vashon Deposits, and
- Tertiary Bedrock.

However, additional units were designated within the categories above based on the geologic map (Exhibit IV-1) and other reports. The relationship between the geologic map units and those used in the hydrogeologic cross sections, is provided in the geologic key of Exhibit IV-1. Table IV-1 summarizes the major hydrogeologic units and their hydraulic significance.

A description of the geologic units used for the cross sections, and their hydraulic significance, is provided below.

Quaternary Alluvial Deposits - Quaternary Alluvial Deposits (Qal) consist of a variety of unconsolidated sediments that range from low-permeability, organic-rich clay and silt in wetland areas to high-permeability sand and gravel in alluvial fans areas. Floodplain deposits along streams of varying permeability consist of silt, sand, gravel. Delta and beach deposits of moderate to high permeability sand and gravel occur along coastal areas.

Floodplain and alluvial-fan deposits may yield moderate to large quantities of water to shallow wells. Development of groundwater from alluvial aquifers in hydraulic continuity with streams would be conditioned on instream flow criteria. Delta and beach deposits may also yield moderate to large quantities of water to shallow wells. Wells completed near sea level in delta or beach deposits would require proper management to prevent salt-water intrusion.

Quaternary Vashon Recessional Lacustrine - The Recessional Lacustrine Deposits (Qvrl) consist of locally laminated clay, silt, and sand. These sediments were deposited in lakes that formed adjacent to ice dams during recession of the Vashon glacier. Permeability of these deposits is low to moderate, and locally they may retard the downward movement of water from land surface to underlying aquifer zones.

Quaternary Vashon Recessional - The Vashon Recessional (Qvr) deposits consist of sorted and stratified, outwash sand and gravel. These sediments were deposited in and along meltwater channels during recession of the Vashon glacier. The Qvr deposits are locally capable of storing and transmitting large quantities of water where the thickness of saturated Qvr sediments is moderate to large.

Quaternary Vashon Till - The Vashon Till (Qvt) consists of unsorted and unstratified clay, silt, sand, gravel, cobbles, and boulders. Color of the till varies from gray to tan. The till is commonly referred to as "hardpan" or "cemented gravel" in boring logs because of its typically compact character. The compactness of the till resulted from the overburden pressure of the moving Vashon glacier. Permeability of the till is low, and where the till is laterally continuous it would retard the downward movement of water from land surface to underlying aquifer zones. Only localized aquifers of very low yield, suitable only for marginal domestic use from a shallow dug well, are present at some locations within the till.

Quaternary Vashon Advance - The Vashon Advance (Qva) deposits consist of outwash sand and gravel deposited in and along meltwater channels during the advance of the Vashon glacier. The Qva deposits are locally capable of storing and transmitting large quantities of water. The Qva unit is one of the principal water-bearing zones in the County, where it is saturated. The Qva aquifer is moderately well protected from land-use activity where the overlying confining unit is compact and laterally continuous.

Quaternary Vashon Lacustrine - The Vashon Lacustrine deposits (Qvl) consist of clay, silt, and fine sand. These sediments were deposited in lakes that formed during the early period of the Vashon glacier advance. Permeability of these deposits is low, and locally they may retard the vertical movement of water between aquifer zones.

Quaternary Possession Till - The Possession Till (Qpt) consists of unsorted, unstratified, well-consolidated sand, silt, and clay with clasts of boulders, cobbles, and gravel. Color of the till varies from tan-gray to red-brown. Permeability of the till is low, and where the till is laterally continuous it would retard the vertical movement of water between aquifer zones.

Quaternary Possession Stratified Drift - For this Study, Possession Stratified Drift (Qp) is identified as a gravelly sand deposit that occurs stratigraphically below the Possession Till. Its water transmitting and storage capacity may be substantial in areas where the Qp unit is relatively thick and laterally continuous.

Quaternary Whidbey Formation - The Whidbey Formation (Qw) consists of sand, silt, and clay with local peat beds. These sediments are well sorted and stratified, and range in color from light tan to dark gray. Local coarse-grained sections are cross bedded. The depositional environment for Qw was floodplain lakes, wetlands, and aggrading stream channels that existed during a relatively warm interglacial period. In general, Qw is a low permeability unit, however, the coarse-grained zones yield small to moderate quantities of water to domestic wells.

Quaternary Double Bluff Stratified Drift - For this Study, Double Bluff Stratified Drift (Qdb) is identified as a gravel, sand, and silty sand that occurs stratigraphically below the Whidbey Formation. These sediments were deposited as glacial outwash material during a period of glacial advance or recession. Locally, the Qdb aquifer is moderately permeable and may yield moderate to large quantities of water to wells.

Quaternary Double Bluff Till - The Double Bluff Till (Qdbt) consists of compact cobbles and gravel in a matrix of sand, silt, and clay. Its color is locally red-brown. This till is mapped on the sections below the Whidbey Formation. Permeability of the till is low, and where the till is laterally continuous it would retard the vertical movement of water between aquifer zones.

Quaternary Undifferentiated Deposits - For the cross sections A-A', C-C', and F-F' (Exhibits IV-2 through IV-4) the Undifferentiated Deposits (Qu) represent all glacial and interglacial sediments older than Vashon deposits (Grimstad and Carson, 1981). For the sections B-B', D-D', E-E', G-G', and H-H' (Exhibits IV-2 through IV-5) the Undifferentiated Deposits (Qu) represent all glacial and interglacial sediments that could not be interpreted as one of the hydrogeologic units described above. Permeability of Qu deposits may range from low for compact till to high for sand and gravel.

Tertiary Bedrock - Tertiary Bedrock (Tb) includes the Eocene-age volcanics interbedded and overlain with Eocene and Oligocene sandstone, siltstone, and shale. This unit generally yields very low quantities of water to wells, except where wells intersect joints and fractures that are interconnected and relatively continuous.

2.2. Geologic Map

The geologic map of Eastern Jefferson County is presented in Exhibit IV-1. The most widespread geologic unit exposed at land surface in the map area is the Vashon Till. Outcrops of till occur at a range of elevations, and therefore, it "mantles" both the underlying Quaternary deposits and Tertiary bedrock. Tertiary bedrock, and thin glacial deposits overlying bedrock are exposed throughout much of the west-central part of the map area, and the area north and south of Port Ludlow.

Geologic units older (stratigraphically lower) than the Vashon Till are exposed in valley walls that have been eroded from recent fluvial processes. Vashon recessional deposits locally occur in lowlands, valleys, and as small areas surrounded by till. Recent alluvial deposits occur in valleys, in wetland areas, and along beaches.

2.3 Hydrogeologic Cross Sections

The alignment of the hydrogeologic cross sections and location of wells used for constructing the sections are shown Exhibit IV-1. The eight cross sections are presented on Exhibits IV-2 through IV-5. Except for the south-north orientated cross section H-H', all other cross sections are orientated from west-east. The cross sections generally illustrate a layered sequence of Quaternary deposits overlying Tertiary bedrock.

In the context of groundwater resources in Eastern Jefferson County, the occurrence of moderate to large thicknesses of Quaternary deposits that contain substantial permeable aquifers would have the greatest potential for groundwater development. Areas that have these characteristics include the Miller and Quimper Peninsulas northward from section line B-B'; the eastern part of the central map area that occurs between section lines C-C', H-H', and F-F'; and the Toandos Peninsula.

Areas where groundwater resources may be limited, include the western part of the central map area as shown in sections C-C' through F-F', and the area southwest of Port Ludlow. These areas contain bedrock overlain by insignificant or small amounts of Quaternary deposits that are limited in areal extent. The exception to this might be river valleys that contain moderate amounts of Qva, Qvr or permeable Qal sediments. Examples would include Chimacum and West valleys (sections C-C' and D-D') and Leland Creek Valley (sections E-E')

In addition, an aquifer near sea level and coastlines would be more susceptible to saltwater intrusion than aquifers substantially above sea level and far from coastlines. Areas that would be susceptible to saltwater intrusion include Marrowstone and Indian Islands (sections A-A' and B-B'), and the Brinnon area (section G-G'). These areas contain permeable aquifers located both at sea level and near coastlines.

The general pattern of well completions for wells shown in the cross sections indicate that many of the these wells are screened, perforated, or open to water-bearing zones in any of the following:

- ❑ The Qva aquifer where it occurs above +100 feet msl,
- ❑ The Qva and Qdb aquifers where these units occur between +100 feet msl to -100 feet msl, or
- ❑ Aquifer zones within the Qu unit where they occur between +100 feet msl to -100 feet msl.

2.4 Significance in Jefferson County

The hydrogeologic cross sections show several geologic units that contain the major aquifers in the County. At the scale of cross sections shown in Exhibits IV-2 through IV-5, these aquifers are shown to be continuous for distances of one to five miles. However, the sedimentary texture and hydraulic properties of the Qva, Qdb, and Qu aquifers can vary considerably over distances of less than one mile, and nearby wells completed in the same aquifer often yield substantially different quantities of water. Based on the well yield analysis (in the following section), major, widespread occurrences of high yield portions of these aquifers does not appear in the project area. The hydrogeologic analysis indicates no specific areas to target for high yield aquifers, only the general guidelines on which hydrogeologic units generally act as aquifers, listed above in part C.

Table IV-1

Major Geologic Units and Their Hydraulic Significance

Geologic Unit	Map/Section Symbols	General Texture	Hydraulic Significance
Alluvium	Qal, Hx, Hb, Hf, Ha, and Hs	Typically sand and gravels Fill units can vary from clay to rip-rap	Generally high permeability Can allow rapid infiltration
Vashon Recessional Deposits	Qvr, Vro, Vrd, Vrl, and Vi	Typically coarse sand and gravels. Lake deposits of sand, silt and clay.	Generally high permeability can allow rapid infiltration. High-yield aquifer if significant saturation
Vashon Till	Qvt, Vat, and Vlt	A heterogeneous mixture of clay, silt, sand, gravels and occasional cobbles	Low permeability Slow infiltration Generally not an aquifer
Vashon Advance Outwash	Qva and Vao	Typically sand with local gravels	Moderately-high permeability Can allow rapid infiltration, if at surface Moderate-to-high-yield aquifer if significant saturation
Possession Till	Qpt, Pp, and Ps	A heterogeneous mixture of clay, silt, sand, gravels, and occasional cobbles	Low permeability Slow infiltration, if at surface Generally not an aquifer
Whidbey Formation	Qw and Pw	Layered deposits of clay, peat, silt, and sand	Layers of low and moderate permeability Slow infiltration Sand layers form low-to-moderate yield aqui
Double Bluff Till	Qdb and Pd	A heterogeneous mixture of clay, silt, sand, gravels and occasional cobbles	Low permeability Slow infiltration, if at surface Generally not an aquifer
Pre-Vashon Stratified Drift	Included in Qu, pQv, and Py	Sand and gravel	Moderately-high permeability Moderate-to-high-yield aquifer where extensi
Undifferentiated Deposits	Qu	Varies	Varies: aquifers were coarse, aquitards where fine-grained
Bedrock	Tc, Tb, Tg, Ts, and Ti	Consolidated rock: generally marine sediments and oceanic basalts	Slow infiltration and poor aquifers Almost all flow through fractures

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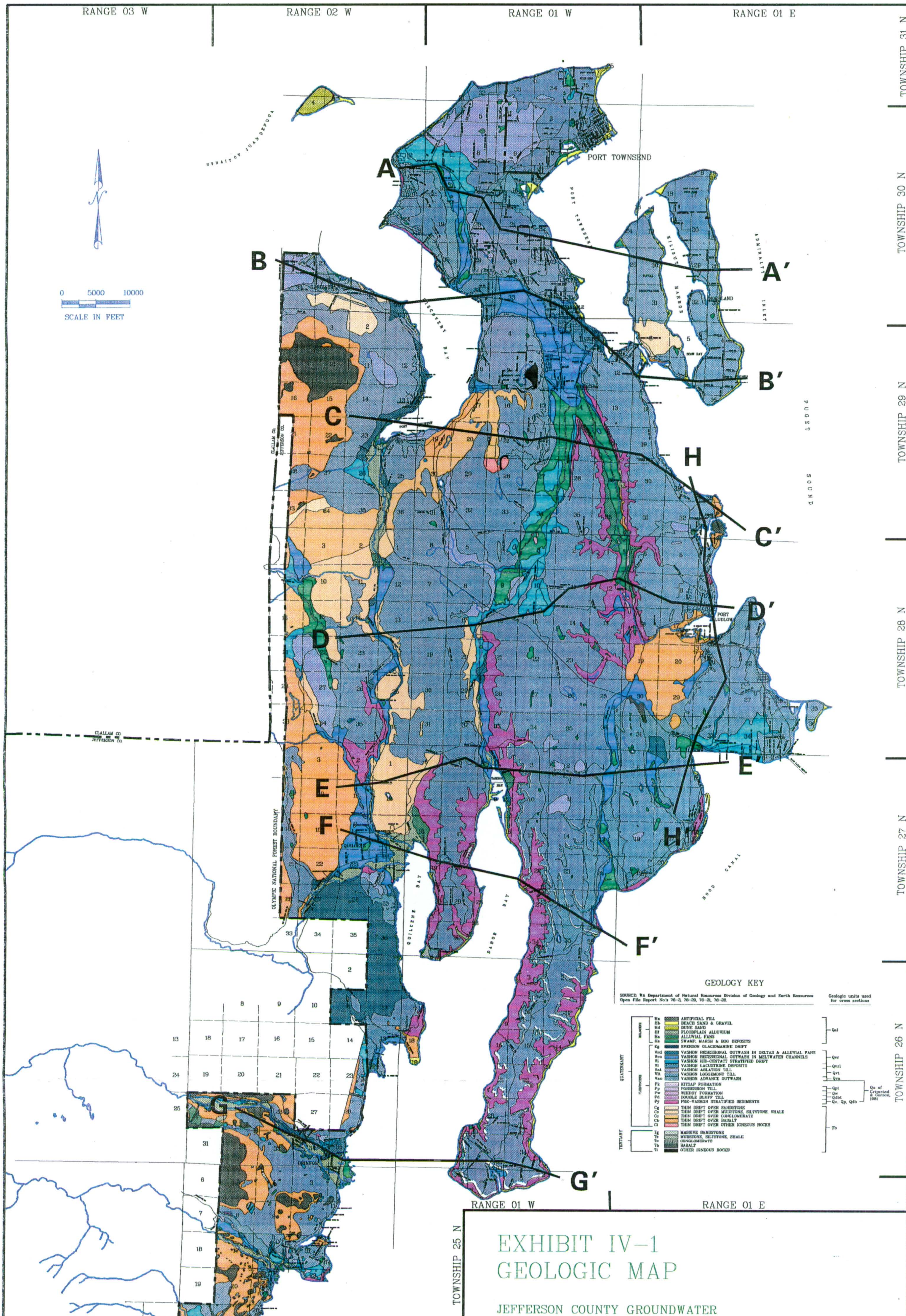
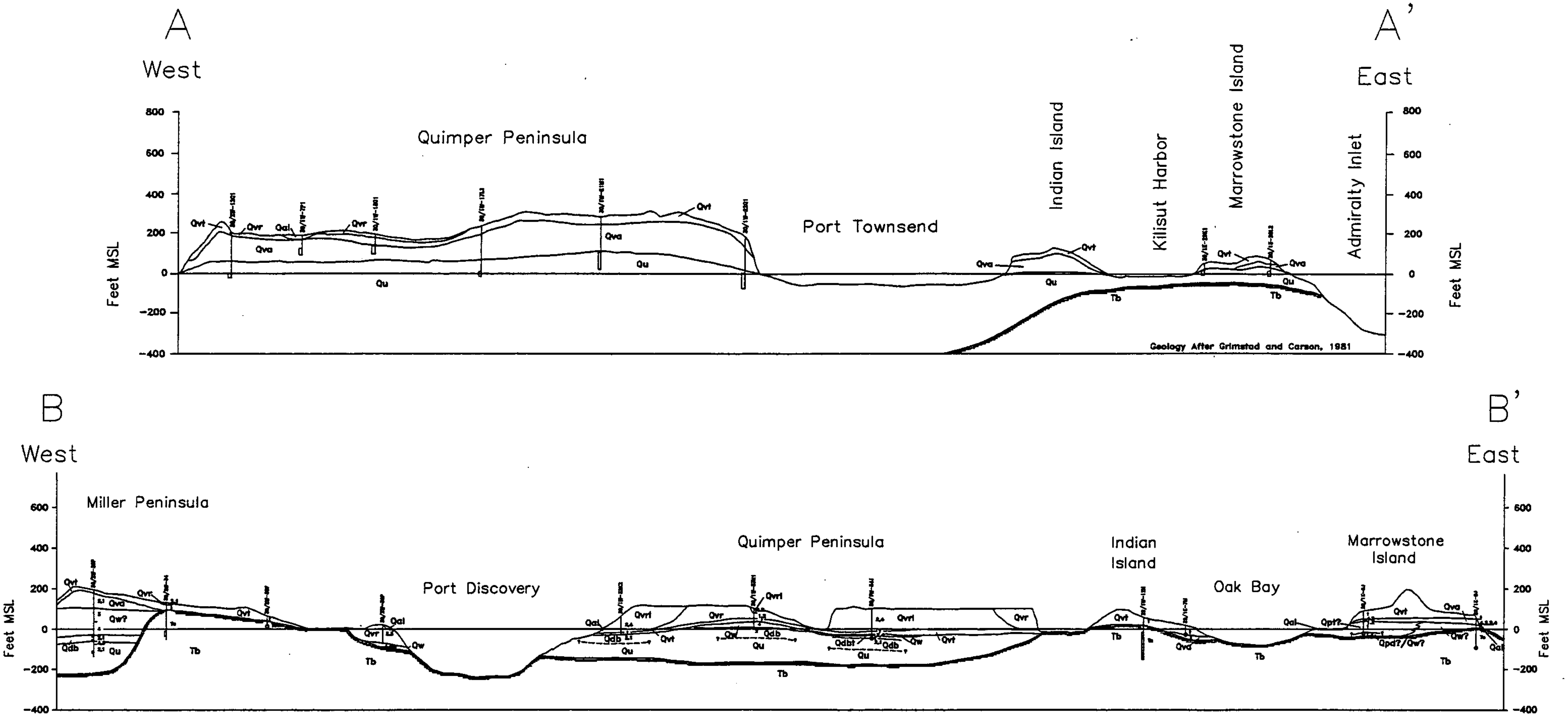


EXHIBIT IV-1
GEOLOGIC MAP

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.

Pacific Groundwater Group



FOOTNOTE:

LOCATIONS AND ELEVATIONS USED TO CREATE CROSS SECTIONS WERE OBTAINED FROM DRILLER'S WELL LOGS AND WERE NOT FIELD VERIFIED.

Symbol	Description
Qal	Quaternary Alluvial Deposits
Qvrl	Quaternary Vashon Recessional Lacustrine
Qvr	Quaternary Vashon Recessional
Qvt	Quaternary Vashon Till
Qva	Quaternay Vashon Advance
Qvl	Quaternary Vashon Lacustrine
Qp	Quaternary Possession Stratified Drift
Qpt	Quaternary Possession Till
Qw	Quaternary Widbey Formation
Qdb	Quaternary Double Bluff Stratified Drift
Qdbt	Quaternary Double Bluff Till
Qu	Quaternary Undifferentiated Deposits
Tb	Tertiary Bedrock (Sandstone, Shale, or Basalt)

30/2W-28P WELL NUMBER

Code	Material
1	GRAVEL
2	SAND
3	SILT
4	CLAY
t	TILL
om	ORGANIC MATTER
3,4	SILT and CLAY (read "," as "and")
1,2	Sandy GRAVEL (read "." as adjective)
Ts,Tv	Sandstone, Shale, or Volcanic Bedrock
0	Screen, Open Section, or Open Bottom

Geologic Contact, dashed where Inferred

Bedrock

VERTICAL SCALE IN FEET

0 500 1,000

0 5,000 10,000

HORIZONTAL SCALE IN FEET

EXHIBIT IV-2
HYDROGEOLOGIC SECTIONS
A – A' AND B – B'

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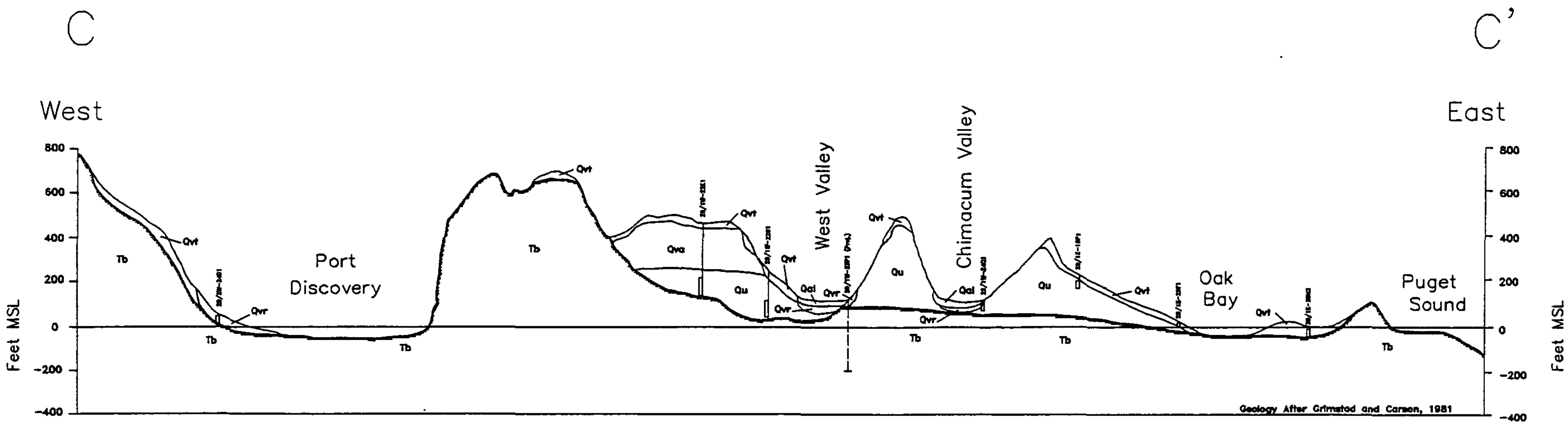

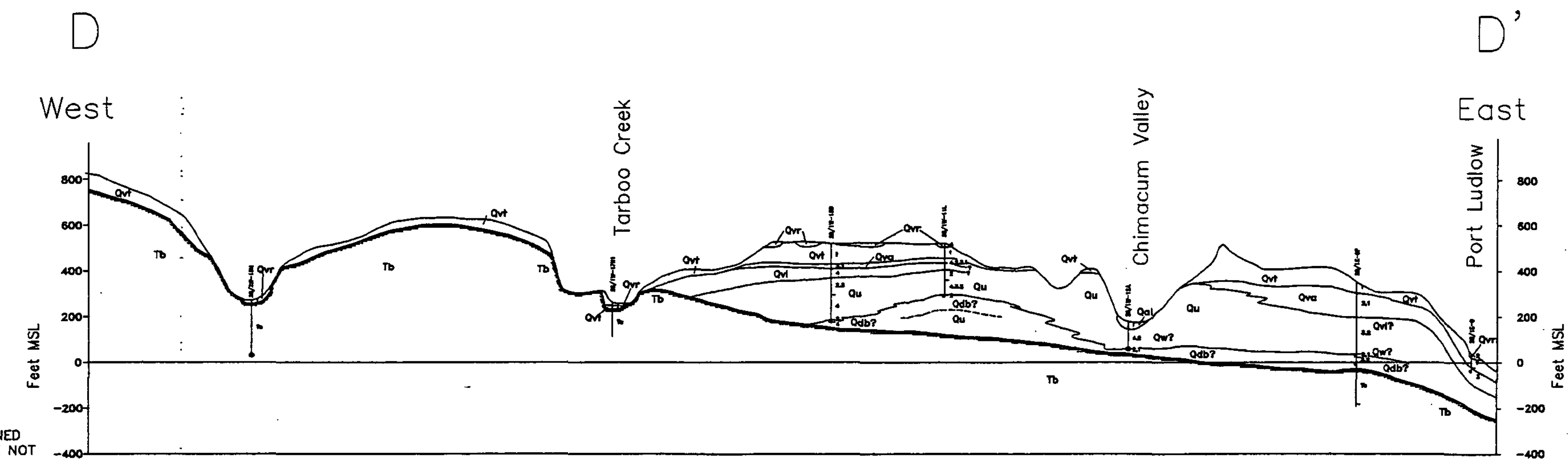

FOOTNOTE:

LOCATIONS AND ELEVATIONS USED TO CREATE CROSS SECTIONS WERE OBTAINED FROM DRILLER'S WELL LOGS AND WERE NOT FIELD VERIFIED.

Symbol	Description
Qal	Quaternary Alluvial Deposits
Qvrl	Quaternary Vashon Recessional Lacustrine
Qvr	Quaternary Vashon Recessional
Qvt	Quaternary Vashon Till
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Qvl	Quaternary Vashon Lacustrine
Qp	Quaternary Possession Stratified Drift
Qpt	Quaternary Possession Till
Qw	Quaternary Widbey Formation
Qdb	Quaternary Double Bluff Stratified Drift
Qdbt	Quaternary Double Bluff Till
Qu	Quaternary Undifferentiated Deposits
Tb	Tertiary Bedrock (Sandstone, Shale, or Basalt)

30/2W-28P WELL NUMBER

1	GRAVEL
2	SAND
3	SILT
4	CLAY
t	TILL
om	ORGANIC MATTER
3,4	SILT and CLAY (read "," as "and")
1,2	Sandy GRAVEL (read "." as adjective)
Ts,Tv	Sandstone, Shale, or Volcanic Bedrock
0	Screen, Open Section, or Open Bottom

Geologic Contact, dashed where Inferred

Bedrock

VERTICAL SCALE IN FEET

0 500 1,000

0 5,000 10,000

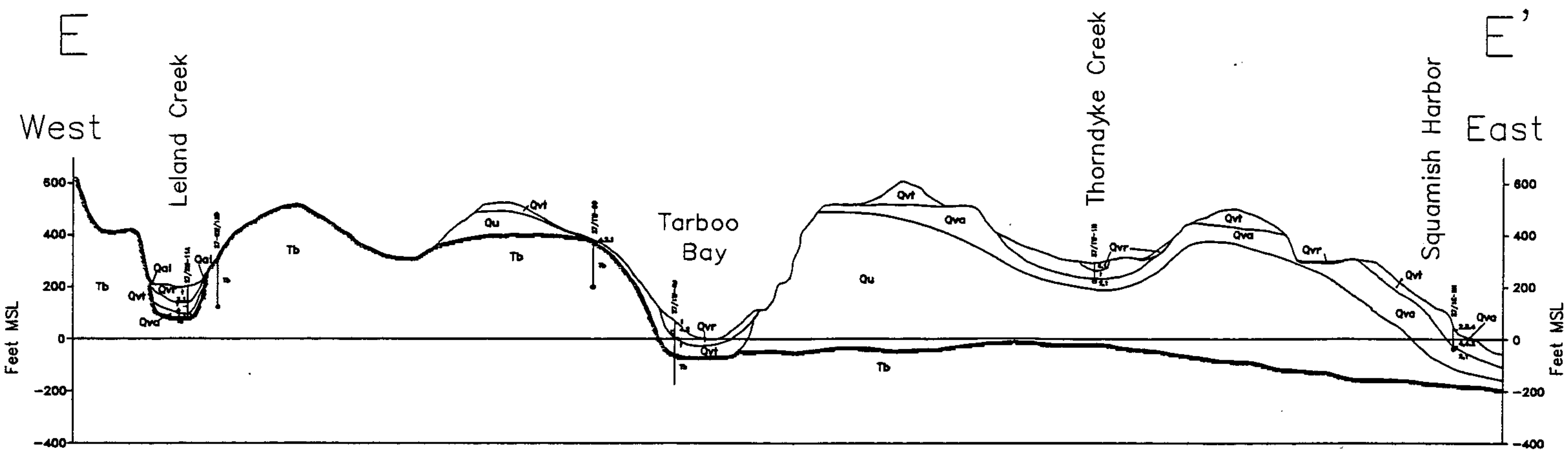
HORIZONTAL SCALE IN FEET

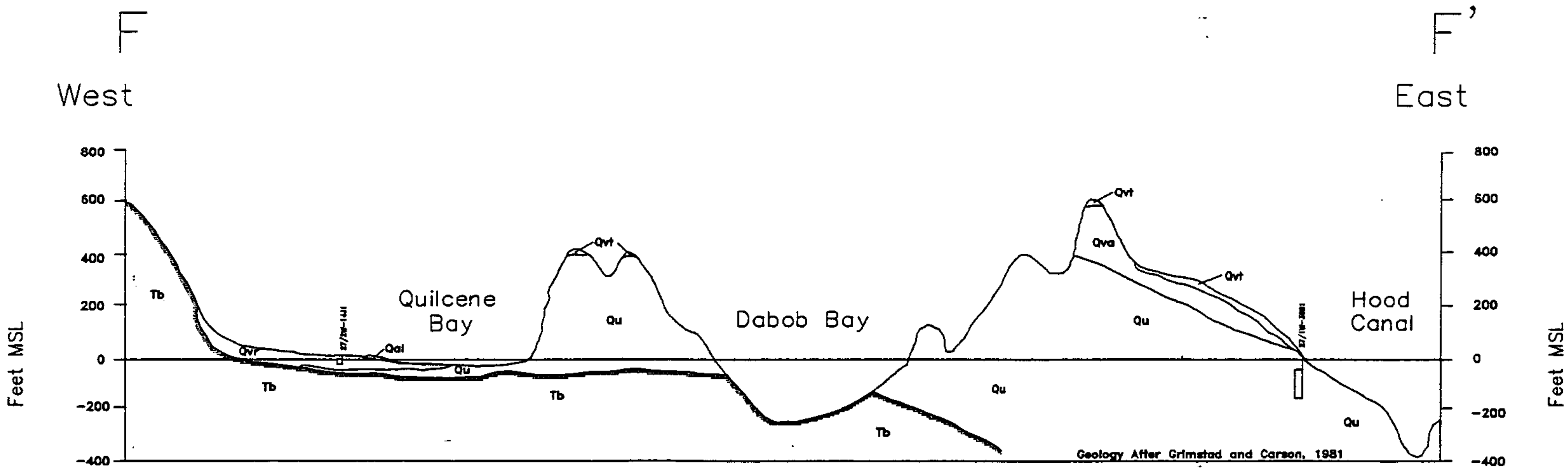
EXHIBIT IV-3
HYDROGEOLOGIC SECTIONS
C – C' AND D – D'

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.

Pacific Groundwater Group





FOOTNOTE:
LOCATIONS AND ELEVATIONS USED TO CREATE CROSS SECTIONS WERE OBTAINED FROM DRILLER'S WELL LOGS AND WERE NOT FIELD VERIFIED.

Symbol	Description
Qal	Quaternary Alluvial Deposits
Qvrl	Quaternary Vashon Recessional Lacustrine
Qvr	Quaternary Vashon Recessional
Qvt	Quaternary Vashon Till
Qva	Quaternay Vashon Advance
Qvl	Quaternary Vashon Lacustrine
Qp	Quaternary Possession Stratified Drift
Qpt	Quaternary Possession Till
Qw	Quaternary Widbey Formation
Qdb	Quaternary Double Bluff Stratified Drift
Qdbt	Quaternary Double Bluff Till
Qu	Quaternary Undifferentiated Deposits
Tb	Tertiary Bedrock (Sandstone, Shale, or Basalt)

Symbol	Description
30/2W-28P	WELL NUMBER
1	GRAVEL
2	SAND
3	SILT
4	CLAY
t	TILL
om	ORGANIC MATTER
3,4	SILT and CLAY (read "," as "and")
1,2	Sandy GRAVEL (read "," as adjective)
Ts,Tv	Sandstone, Shale, or Volcanic Bedrock
0	Screen, Open Section, or Open Bottom

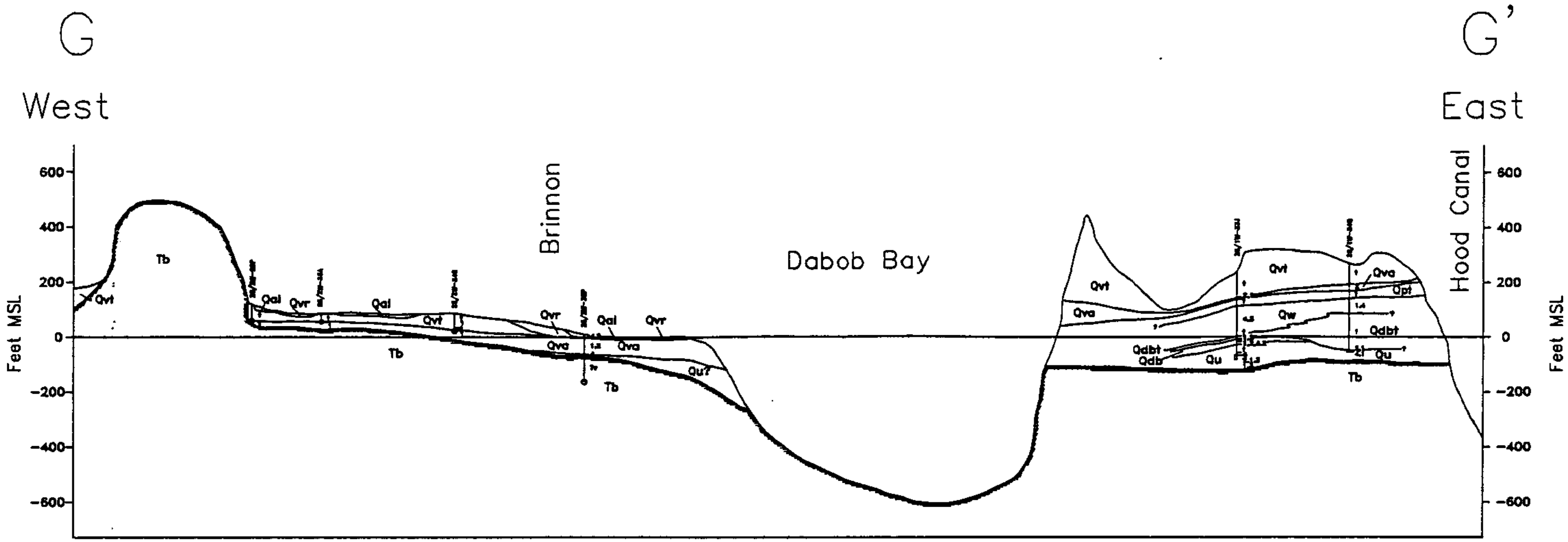
Geologic Contact, dashed where inferred
Bedrock

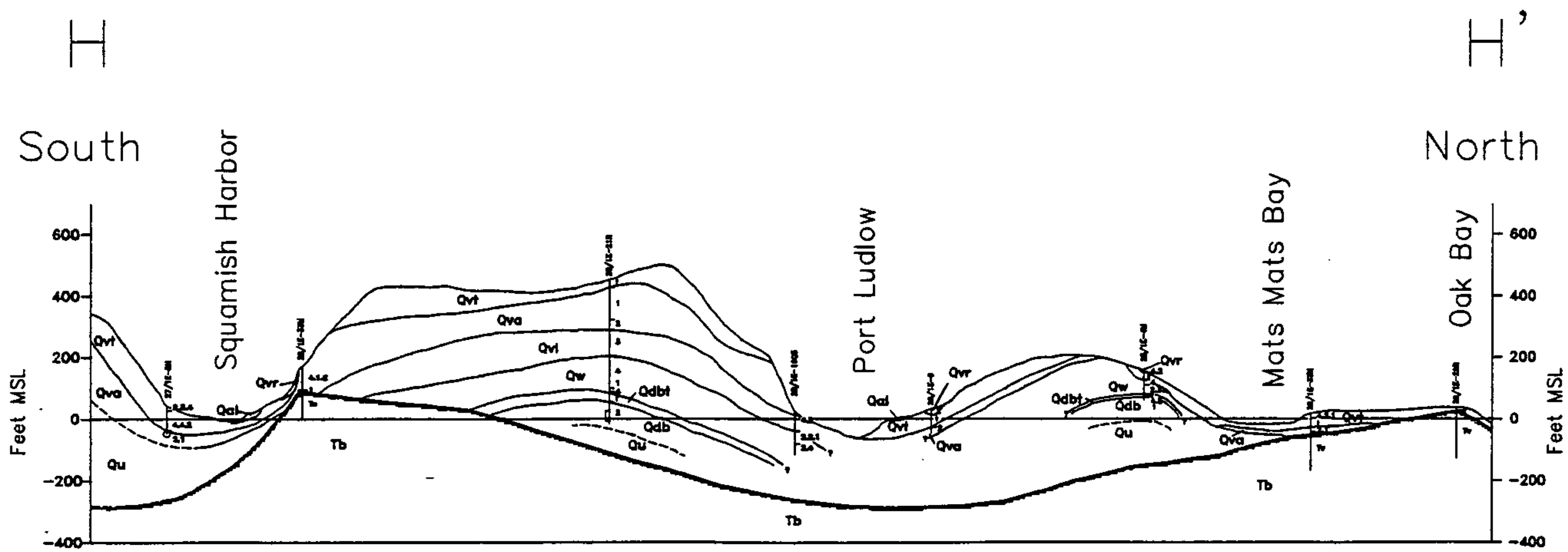
VERTICAL SCALE IN FEET
0 500 1,000
0 5,000 10,000
HORIZONTAL SCALE IN FEET

EXHIBIT IV-4
HYDROGEOLOGIC SECTIONS
E – E' AND F – F'

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.
Pacific Groundwater Group





FOOTNOTE:
LOCATIONS AND ELEVATIONS USED TO CREATE CROSS SECTIONS WERE OBTAINED FROM DRILLER'S WELL LOGS AND WERE NOT FIELD VERIFIED.

Symbol	Description
Qal	Quaternary Alluvial Deposits
Qvrl	Quaternary Vashon Recessional Lacustrine
Qvr	Quaternary Vashon Recessional
Qvt	Quaternary Vashon Till
Qva	Quaternary Vashon Advance
Qvl	Quaternary Vashon Lacustrine
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Qpt	Quaternary Possession Till
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Qdb	Quaternary Double Bluff Stratified Drift
Qdbt	Quaternary Double Bluff Till
Qu	Quaternary Undifferentiated Deposits
Tb	Tertiary Bedrock (Sandstone, Shale, or Basalt)

Symbol	Description
30/2W-28P	WELL NUMBER
1	GRAVEL
2	SAND
3	SILT
4	CLAY
t	TILL
om	ORGANIC MATTER
3,4	SILT and CLAY (read "," as "and")
1,2	Sandy GRAVEL (read "." as adjective)
Ts,Tv	Sandstone, Shale, or Volcanic Bedrock
0	Screen, Open Section, or Open Bottom

Geologic Contact, dashed where inferred

Bedrock

VERTICAL SCALE IN FEET

0 500 1,000

0 5,000 10,000

HORIZONTAL SCALE IN FEET

EXHIBIT IV-5
HYDROGEOLOGIC SECTIONS
G – G' AND H – H'

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.

Pacific Groundwater Group

SECTION V

Section V
Aquifer Characteristics And Potential Well Yield

1. Background and Overview

This section reviews potential well yield from various aquifer zones in Jefferson County (County). Potential well yield is defined as the short-term yield that is likely available from a properly designed and constructed well completed in the best aquifer (when more than one aquifer lies at depth). This potential yield may not be possible with the existing wells already installed in the area. The existing wells may be too small, completed in a different aquifer, or improperly designed 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.

Originally, the well yield analysis was performed to identify regions that had similar yields. Areas with similar yields would be identified and located on a map. These areas would then be labeled as having an identifiable yield potential.

The result of the analysis (discussed below) did not indicate regions of identifiable yield ranges. Instead, yield ranges of aquifer material types were generated. Although of less value than geographically identified yields, yield range as a function of aquifer material type is of value for planning purposes.

2. Methods and Assumptions

The potential yields for some 254 wells were evaluated based on information contained on selected well logs for the County. These are the same logs used in the geological analysis discussed above. The logs are on file with the Department of Ecology (WDOE, 1991). Only wells with all of the parameters needed for the analysis were considered. The parameters needed include:

- General well location (well number that indicates location to the nearest 1/4-1/4 section),
- Pumping rate during a well test,
- Drawdown of water level caused by pumping at the given rate over an indicated 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:

$Q_p = K*C_s*D_a$

where:

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

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

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

K= A constant that accounts for decreasing specific capacity over time

In the case of porous media aquifers (sand, gravel, or a mixture of the two) a K value of 0.5 was used. This value generally accounts for:

- Pumping periods longer than the short-term test (from which the calculation data were derived).
- Hydraulic boundaries not affecting pumping rates during the short-term test.
- Variations in water level that occur over time.

In the case of bedrock aquifers in which water generally flows through fractures, a constant of 0.1 was used. This smaller constant generally accounts for the effects listed above, plus:

- The reduction in fracture permeability that typically occurs as water levels decrease, pressures reduce, and fracture aperture becomes smaller.
- Free surface discharge of fractures lying above the pumped water level in the well. (Drawdown below the level of the fracture does not significantly increase yield of that fracture.)

Potential well yields were then plotted by location (to the nearest 40 acres, as identified by well number) and tabulated according to aquifer and aquifer material type. Simple statistical analyses were conducted on yield-as-a-function-of-aquifer-type data. These analyses included median yields, mean yields (based on the middle 80 percent of the wells with the smallest and largest 10 percent not used in the average, as the extremes tended to bias the results), lowest yield, and highest yield. These values were then compiled by aquifer and aquifer material type. Statistical analyses were also conducted on all the wells together without regard to aquifer or aquifer material type.

3. Results

3.1 Well Yield Geographic Distribution

Exhibit V-1 shows the results of the well yield analysis. Potential well yields are plotted in three categories: high (yields greater than 500 gpm), medium (yields between 200 and 500), and low (yields less than 200 gpm). The figure shows that low yield wells dominate in Jefferson County. Most wells have potential yields of much less than 200 gpm. These wells are not generally suitable for a regional water supply.

Only 15 high yield wells (of the 254 wells used in the analysis) had potential yields of 500 gpm or more. These wells amount to only 6 percent of the wells used in the analysis. No general distribution pattern of the high yield wells is apparent from the figure. No areas are identified as having generally high yield wells. Yields above 500 gpm appear to be localized only, resulting from aquifer zones of higher permeability or thickness. These localized zones are not extensive. Based on a selection of one well per section for the analysis and the lack of continuity between high yield well sites, areas of high yield appear to be less than one mile in any one direction.

Some extensive areas of high yield may be present in the County, but were not observed at the scale and detail of this analysis. A more complete analysis using a larger percentage of the available well log data may indicate some high yield areas. Based on the existing understanding of the geological units beneath Eastern Jefferson County, it is unlikely to have extensive areas of undetected high yield areas. If present, they would need to lie in deeper, unexplored areas of the north or southeast parts of the study area, where bedrock lies at great depth or beneath areas with sparse data such as the central or south eastern part of the study area. Future analyses should be conducted to verify these conclusions.

Medium yield wells are only slightly more numerous, with 27 of the 254 wells indicating theoretical potential yields of 200 to 500 gpm, or about 11 percent. They too, show a scattered distribution with no extensive areas indicating medium yield. As with the high yield wells, a detailed analysis using a greater percentage of the available well logs may possibly show some extensive areas of medium yield. With the existing analysis, areas with dimensions of greater than one mile with medium yields were not indicated.

3.2 Well Yields by Aquifer and Aquifer Material Type

Table V-1 shows the distribution of well yields by aquifer type. Because this groundwater characterization focuses on regional water supply, aquifer distribution was only assessed for high and medium yield wells. The analysis shows that high yield aquifers generally consist of glacial units, usually outwash, although the type of aquifer could not be identified for 6 of the 15 wells. Glacial outwash is typically more permeable and extensive than interglacial deposits laid down by low energy streams and lakes. Outwash deposits are also more permeable than glacial tills which consist of compacted mixtures of sand, gravel, and cobbles in a matrix of sand, silt and clay.

Medium yields are more widely distributed by aquifer type. All aquifer types had at least one medium yield well in the analysis, including bedrock (one of the 27 in the analysis). Localized deposits have sufficient permeability, thickness and available drawdown to produce medium yields at some locations.

The table also shows yield by age differentiation. The table indicates that high yield wells are distributed generally between the younger deposits (Vashon) and older (pre-Vashon). Medium yield wells appear to be more prevalent among older (pre-Vashon) deposits. Pre-Vashon deposits tend to lie deeper and are more likely to have larger available drawdown. The same type of material nearer the surface would likely have a small available drawdown and a corresponding potential yield. The tendency for more medium yield wells to lie in pre-Vashon than Vashon, or more recent deposits, may be related to the larger available drawdown typically associated with greater depth.

None of the high yield wells were finished in bedrock. Bedrock units are not generally high producing as the majority of flow passes through small or partially filled fractures in the rock. Bedrock aquifer have relatively low permeability and are best suited for domestic supplies. The one medium yield well finished in bedrock is likely to anomalous. It is likely finished in a zone with greater than normal fracturing. The greater number or size of the fractures allows for a greater yield.

Table V-2 shows well yield statistics by aquifer material type. The table shows that well yields in the County are typically low, with mean potential yields of 40 gpm and median yields of 20 gpm. Yields in the unconsolidated aquifers (sands and gravels) are higher with means of 43 to 69 gpm and medians of 20 to 30 gpm.

Table V-1 appears to indicate that mixtures of sand and gravel produce more than gravel alone, a situation contrary to that expected. This apparent anomaly is likely the result of the limited sample size that has led to an average available drawdown for the sand and gravel wells that is larger than that for the gravel-only wells. The average well depth for the sand and gravel aquifer wells is greater than that for the gravel only wells, generating an apparently larger available drawdown. It is likely that had more wells been used in the analysis, the average depths, depths to water, and available drawdowns would have been similar for the two aquifer material types. Yields would probably be larger for the gravel aquifers as their permeability would be the controlling factor.

3.3 Significance of Regional Water Supply in Jefferson County

The well yield analysis indicate that no area or areas appear likely to have extensive high yield aquifers suitable for regional water supply. Areas for high yield wells for regional water supplies are localized and can occur in many locations. Detailed site-specific analysis of the local hydrogeology is needed to specify locations for new high yield wells. Test drilling after the site specific study is also likely to be necessary to find, characterize, and verify a regional high yield well site.

Any non-bedrock type of aquifer can be targeted for a regional high yield well supply. The type of aquifer material to be targeted can include all glacial outwash deposits. Some areas with interglacial sands and gravels may be capable of high yields, but should not be targeted, as typically their yields are less than the outwash deposits.

A similar situation applies to medium yield wells. The aquifers capable of medium yields are also unlikely to be aerially extensive. They too, can occur in many locations and will likely require a site-specific review of the existing data for prediction of their locations.

Bedrock areas are likely to produce only small well yields. These areas appear suitable for domestic or small water system yields, only. They should not be targeted for regional water supply.

Table V-1
Summary of Potential Well Yield
by Aquifer Completion

Aquifer	Potential Yield (number of wells)*		
	High(1)	Medium(2)	Low(3)
Qal/Qvr		1	
Qvr	2	2	
Qvr/Qva	2		
Qva	3	1	
Qva/Qu		5	
Qw/Qdb	1	3	
Qdb	1		
Qu/Qdb		2	
Qu	3	9	
Tb		1	
Not Determined (4)	3	3	212(5)
Total	15	27	212

Summary as Vashon, Pre-Vashon, or Other:

Unit	High	Medium	Low
Post-Vashon		1	
Vashon	7	3	
Pre-Vashon	5	14	
Vashon or Pre-Vashon		5	
Bedrock		1	
Not Determined (4)	3	3	212(5)

(1) Potential well yield of > 500 gpm
(2) Potential well yield of 200 - 500 gpm
(3) Potential well yield of < 200 gpm
(4) Topography in well vicinity too steep to classify well by aquifer
(5) No attempt made to classify low yield wells by aquifer

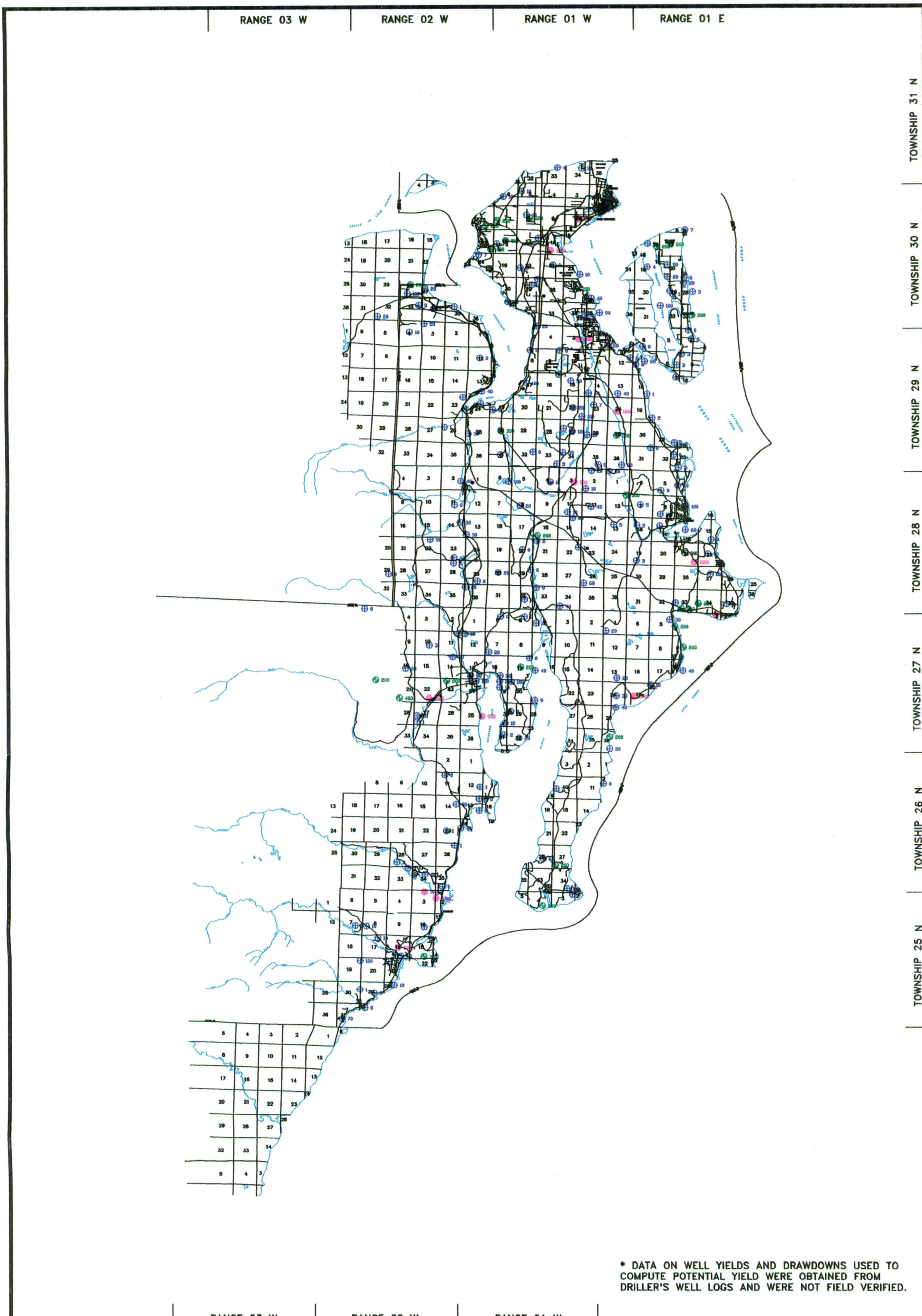
* Data on well yields and drawdowns used to compute potential yield were obtained from driller's well logs and were not field verified.

42780:tab5-1.xls

Table V-2
Summary of Aquifer Statistics for Selected Wells

Aquifer Type and Statistic	Potential Yield (gpm)*	Well Depth (ft)	Depth to Water (ft)
Basalt (15 wells)			
Median	0	151	20
Mean (middle 80%)	1.5	148.5	34.1
Low-High	0/300	22/440	0/200
Shale (37 wells)			
Median	5	127	35.5
Mean (middle 80%)	8.2	130.2	44.1
Low-High	0/100	23/443	0/150
Unsorted Rock (6 wells)			
Median	1	237	76
Mean (middle 80%)	1	228.5	74.75
Low/High	0/1	140/400	10/131
Sand (70 wells)			
Median	20	140.5	97.5
Mean (middle 80%)	47.9	151.8	108.7
Low/High	1/1000	20/432	2/362
Sand and Gravel (83 wells)			
Median	30	85	38
Mean (middle 80%)	69	113.4	61.5
Low/High	1/1000	19/503	0/440
Gravel (47 wells)			
Median	20	66	38
Mean (middle 80%)	43.1	84.6	51.7
Low/High	0/1000	15/337	1/240
Total Wells = 258			
Median: all aquifer types	20	108	50.5
Mean: all aquifer types (middle 80%)	40	126	68

42780:tab5-2.xls



* DATA ON WELL YIELDS AND DRAWDOWNS USED TO COMPUTE POTENTIAL YIELD WERE OBTAINED FROM DRILLER'S WELL LOGS AND WERE NOT FIELD VERIFIED.

N

HORIZONTAL SCALE IN FEET

0 | 20,000 | 40,000

Potential Yields

- Low Yield Wells (< 200 GPM)
- Medium Yield Wells (200–500 GPM)
- High Yield Wells (> 500 GPM)

EXHIBIT V–1

POTENTIAL WELL YIELDS

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.

Pacific Groundwater Group

SECTION VI

Section VI
Aquifer Recharge

1. Overview

Most, if not all, of the groundwater beneath the project area originated as precipitation falling on, and infiltrating through the ground surface. The process of replenishing groundwater is known as aquifer recharge. Recharge occurs where groundwater flow gradients have a downward component. Downward gradients typically occur beneath most of the project area. In theses areas (known as recharge areas) a portion of the groundwater flows downward to replenish the groundwater flowing from the system to wells, streams, and coastal waters. Only near the coast and in the deeper valleys where the rivers and streams are maintained by groundwater flow do groundwater gradients reverse, and groundwater flows upward in what is known as a groundwater discharge zone. Recharge occurs over almost all the of project area.

In a recharge area, most rain that falls is either evapotranspirated back to the atmosphere by plants, or runs off to streams or other surface water bodies. The relatively small amount left over flows downward until it encounters a water table. At this point the infiltrated precipitation becomes groundwater recharge.

2. Method

The recharge rates were estimated for Jefferson County (County) using the mass balance approach of Thornthwaite and Mather (1957). In this method, precipitation, run off, and evapotranspiration are quantified, and the surplus is calculated using the following formula:

$$Re = P - Ro - Et - dS$$

Where:
Re = Recharge (in/yr)
P = Precipitation (in/yr)
Ro = Run off (in/yr)
Et = Evapotranspiration(in/yr)
dS = Change in Storage (Assumed to be 0 over the long term, i.e., many years)

In this analysis, average recharge was quantified on a sectional basis (1 square mile). Average annual rates for precipitation, run off, and evapotranspiration were derived and recharge was calculated. The calculations were performed on a one-fourth-of-a-month basis (approximately one week) using synthesized average weekly[1] values for precipitation, runoff and evapotranspiration. Using a series of weekly calculations for each square mile of the County project area helps to decrease the potential for error. The analyses were performed using a spreadsheet for each of the 411 sections analyzed. The results were compiled into tables and a map.

Precipitation, evapotranspiration, and runoff values are not available for each square mile of the County. In most cases, the values used in the analysis were generated based on the official data available for a few County locations. The sources of data and methods used to generate the data are discussed below.

2.1 Precipitation

Weekly precipitation data were synthesized for each section using a combination of U.S. Weather Bureau maps and tables. Annual rainfall values were interpolated for each section from the isohyetal contours on the Washington State rainfall map (U.S. Weather Bureau, 1965). These contours are presented in Exhibit VI-1. Monthly rainfall rates were assumed to follow the same proportional distribution as that of Port Townsend. (i.e., if 8 percent of the annual precipitation occurs during a certain month in Port Townsend, 8 percent of the annual precipitation occurs in the section being considered in the analysis.)

Averages reported for Port Townsend (NOAA, 1978) were used as this is the only "official" data collection point in the County. Weekly average precipitation rates were synthesized through linear interpolation of the monthly distribution. Using this method as a representative, weekly average precipitation values were generated.

2.2 Direct Runoff

Few direct runoff data are available for Eastern Jefferson County. Experience in Western Washington indicates that some direct runoff is likely. In the Eastern Jefferson County Groundwater Characterization Study (Study), direct runoff is estimated as a percentage of rainfall, based on the Dunne and Black (1970) mechanism of runoff generation. In this mechanism, most runoff is produced from only part of each watershed. These variable source, runoff producing areas have perched or local water tables near or at the surface. They generally lie near streams or other surface water bodies and are more extensive during the wetter parts of the year.

[1] We use the term week to represent the one fourth month time period. Data are typically available in monthly and not weekly values and a smaller time period was desired in the analysis. *Weekly* or *week* is used to describe this period (7.0, 7.25, 7.5, 7.75 days depending on the month), in this report.

These areas generate runoff at rates of approximately 5 to 10 percent of precipitation.

Areas with altered or disturbed parts of the watersheds (such as paved areas or compacted bare mineral soil) can also contribute direct runoff through Hortonian overland flow (flow along the surface when the rainfall rate exceeds the soil's ability to accept infiltration). These areas are relatively small in much of the County as few areas are paved and rainfall is generally gentle with a rate usually below the maximum acceptance rate of the surficial soils.

Areas with exposed bedrock can contribute direct runoff at a much higher rate than the 5 to 10 percent of rainfall estimated for the non-bedrock areas. The higher run off rate would reduce the potential for recharge. The lower permeability of the rock would have an even greater effect on limiting recharge, however. The low permeability would limit recharge to a value in the range of the saturated hydraulic conductivity of the rock. This effect is further discussed below in Part D.

2.3 Evapotranspiration

Evapotranspiration (water evaporated from soil and transpired by plants) was estimated using the Blaney-Criddle method (USSCS, 1970). 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 meet the water demands of plants. When the soil is drier, the actual rate decreases below the potential rate.

In this analysis, the computerized the soil mass balance procedure was used to calculate the actual evapotranspiration rate on a weekly basis. In this analysis, monthly data, rainfall, and temperature are distributed over four quarters as described above. Weekly evapotranspiration was calculated according the following criteria:

When precipitation was equal to or greater than potential evapotranspiration:

AET = PET
When precipitation was less than potential evapotranspiration:
AET = PET (when SM/SMC > = 0.75)
or
AET = PET * 1.333 * (SM/SMC) (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).

The soil moisture holding capacity over each section was estimated based on soils data in the County soils atlas (USDA, 1975). The dominant soil type for each section was identified based on the general soil map in the atlas. The "available water capacity" (inches of water depth equivalent per inch of soil depth) was multiplied by the typical soil profile depth to generate the representative soil moisture holding capacity for each section used in the analysis. These values ranged from less than 3 to greater than 20 inches.

The choice of values for representative "crop factors" proved problematic. Much of the project site is vegetated by coniferous trees or cropland grasses. The published crop factors for the method include many irrigated crops, but not coniferous trees. Possible values have been proposed by several workers in the field. These values are based on analyses conducted in eastern Washington. They did not appear reasonable. 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) the grass crop factor for each section was used in this analysis.

2.4 Recharge Calculation

In most cases, the calculation of recharge was straightforward and followed the equation shown above in Part 2.A. In most situations, recharge was calculated by subtracting runoff evapotranspiration from precipitation. Change in storage was assumed to be zero over the long-term average and not used in the analysis.

In two situations, a different method was used. In areas where bedrock was at or very near the surface (generally the western part of the project area and in a few areas near Shine and Port Ludlow), bedrock has too low a permeability to accept the recharge passing through the soil. In these areas, the recharge would pond along the surface or near surface of the rock and flow toward shallow and local discharge areas. The water would then flow to local surface water bodies and not be available for groundwater recharge. In these areas a permeability-limited, maximum, recharge rate of 1 to 2 inches per year was assumed to be conservative (underestimate recharge). In some areas, fractures in the bedrock may allow higher recharge rates.

This recharge was not considered in this analysis in order to be conservative (underestimate recharge).

Some valley areas (such as the Chimacum or "Beaver" valley areas) may have either low permeability soils and/or lie in groundwater discharge areas. In these areas (identified by "muck" type soils) a 0 recharge rate was assumed. If the areas lie in discharge areas (data were insufficient to designate discharge areas) then the 0 recharge assumption is accurate. If the areas lie in recharge areas underlain by the low permeability soils, then a small amount of recharge is likely in these areas. A zero-recharge assumption was used to be conservative (underestimate recharge).

3. Results

Recharge results for each section are presented in Appendix Table A-2. Recharge rates vary throughout the County from 0 in discharge/low-permeability areas to almost 22 in/yr in areas with high rainfall rates and permeable soils. Bedrock areas have low recharge rates (1 to 2 in/yr) because of low permeability of the rock. The table presents recharge rates using two values for runoff (5 and 10 percent of precipitation) representing the expected range of runoff for the non-bedrock areas of the County. The table shows that doubling runoff causes recharge rates that vary by at most 2 inches.

The recharge rates for each section have been assigned to six categories (0 to 5 in/yr for category 1, 5 to 10 in/yr for category 2, etc). The rate category for each section is presented in Exhibit VI-2. The map (and Table VI-1) demonstrate that recharge rates are generally highest in the central part of the project area, with lower rates in the northeast and west parts. The lower rates in the northeast are generally due to the effects of lower precipitation (17 to 25 in/yr) compared with the central and southerly parts of the County where precipitation is higher (35 to 45+ in/yr).

By themselves, the recharge calculations act only to indicate the general areas where relatively higher and lower rates of recharge occur. They are significant in that they indicate where greater amounts of recharge are likely to reach underlying aquifers. The calculated recharge rates also serve as input to the water budget calculations discussed in Section VII.

The permeability of the Vashon Till that overlies much of the project area may limit recharge to deeper units to rates less than that calculated in this report, especially for the category 5 and 6 areas (greater than 20 inches per year). Studies on Island County (Pessl, et al, 1985) indicate the till has relatively high permeability (in some cases greater than 10^{-5} cm/sec) and should therefore have little effect on recharge rates.

Table VI-1

Recharge and Potential Additional Groundwater

			Low End of Range	High End of Range
REGION 1	Recharge	Total in gpm	5,100	6,200
(Gardner, SW Discovery Bay)		Total in MGD	7.3	8.9
	Yield	20-Percent Capture in MGD	1.5	1.8
		Current Use in MGD	0.1	0.1
		Potential Additional to 20 % in MGD	1.4	1.7
REGION 2	Recharge	Total in gpm	4,700	5,400
(Greater Pt. Townsend)		Total in MGD	6.8	7.7
	Yield	20-Percent Capture in MGD	1.4	1.5
		Current Use in MGD	0.4	0.4
		Potential Additional to 20 % in MGD	1.0	1.1
REGION 3	Recharge	Total in gpm	600	700
(Indian Island)		Total in MGD	0.9	1.0
	Yield	20-Percent Capture in MGD	0.2	0.2
		Current Use in MGD	0.0	0.0
		Potential Additional to 20 % in MGD	0.2	0.2
REGION 4	Recharge	Total in gpm	400	500
(Marrowstone Island)		Total in MGD	0.5	0.6
	Yield	20-Percent Capture in MGD	0.1	0.1
		Current Use in MGD	0.1	0.1
		Potential Additional to 20 % in MGD	0.0	0.0
REGION 5	Recharge	Total in gpm	9,700	13,600
(Western Foothills)		Total in MGD	13.9	19.5
	Yield	20-Percent Capture in MGD	2.8	3.9
		Current Use in MGD	0.3	0.3
		Potential Additional to 20 % in MGD	2.5	3.6
REGION 6	Recharge	Total in gpm	18,200	20,000
(Tri-Area and South)		Total in MGD	26.2	28.8
	Yield	20-Percent Capture in MGD	5.2	5.8
		Current Use in MGD	0.6	0.6
		Potential Additional to 20 % in MGD	4.7	5.2
REGION 7	Recharge	Total in gpm	1,700	18,800
(North of Dabob Bay)		Total in MGD	24.8	27.1
	Yield	20-Percent Capture in MGD	5.0	5.4
		Current Use in MGD	0.1	0.1
		Potential Additional to 20 % in MGD	4.9	5.4

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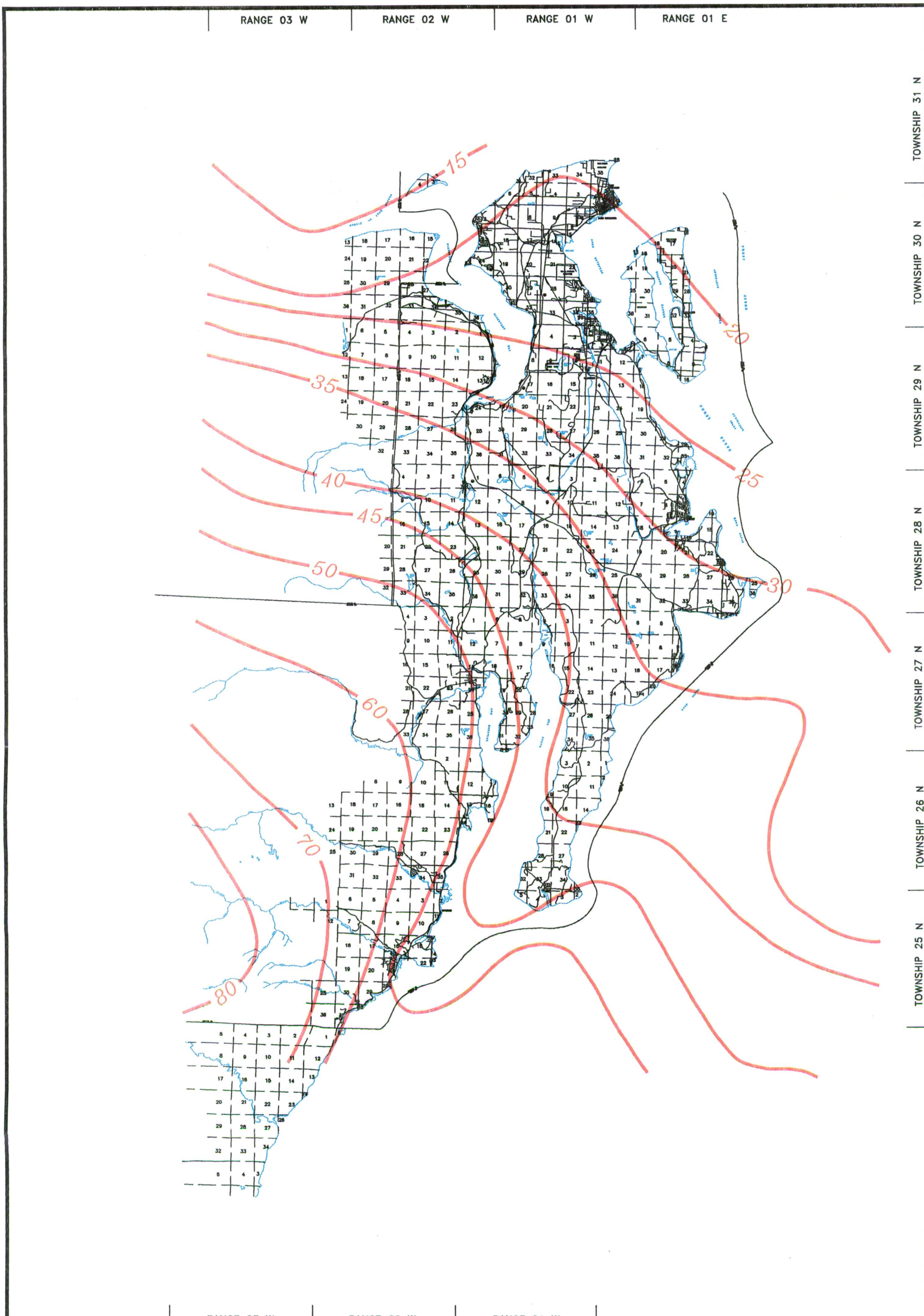
Table VI-1 (cont)

REGION 8	Recharge	Total in gpm	5,300	5,900
(Ludlow-Shine)		Total in MGD	7.6	8.5
	Yield	20-Percent Capture in MGD	1.5	1.7
		Current Use in MGD	0.1	0.1
		Potential Additional to 20 % in MGD	1.4	1.6
REGION 9	Recharge	Total in gpm	18,500	20,100
(Toandos Penninsula)		Total in MGD	26.7	29.0
	Yield	20-Percent Capture in MGD	5.3	5.8
		Current Use in MGD	0.1	0.1
		Potential Additional to 20 % in MGD	5.3	5.7
TOTAL		Potential Additional to 20 % in MGD	21.3	24.6

Note: Q to nearest 100 gpm or 0.1 MGD, actual value +/- 50 to 100 %

42780:tab6-1.xls



HORIZONTAL SCALE IN FEET

0 20,000 40,000

Average Annual Rainfall Depth in Inches (After USWB, 1965)

EXHIBIT VI-1
PRECIPITATION IN EASTERN JEFFERSON COUNTY

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.

Pacific Groundwater Group

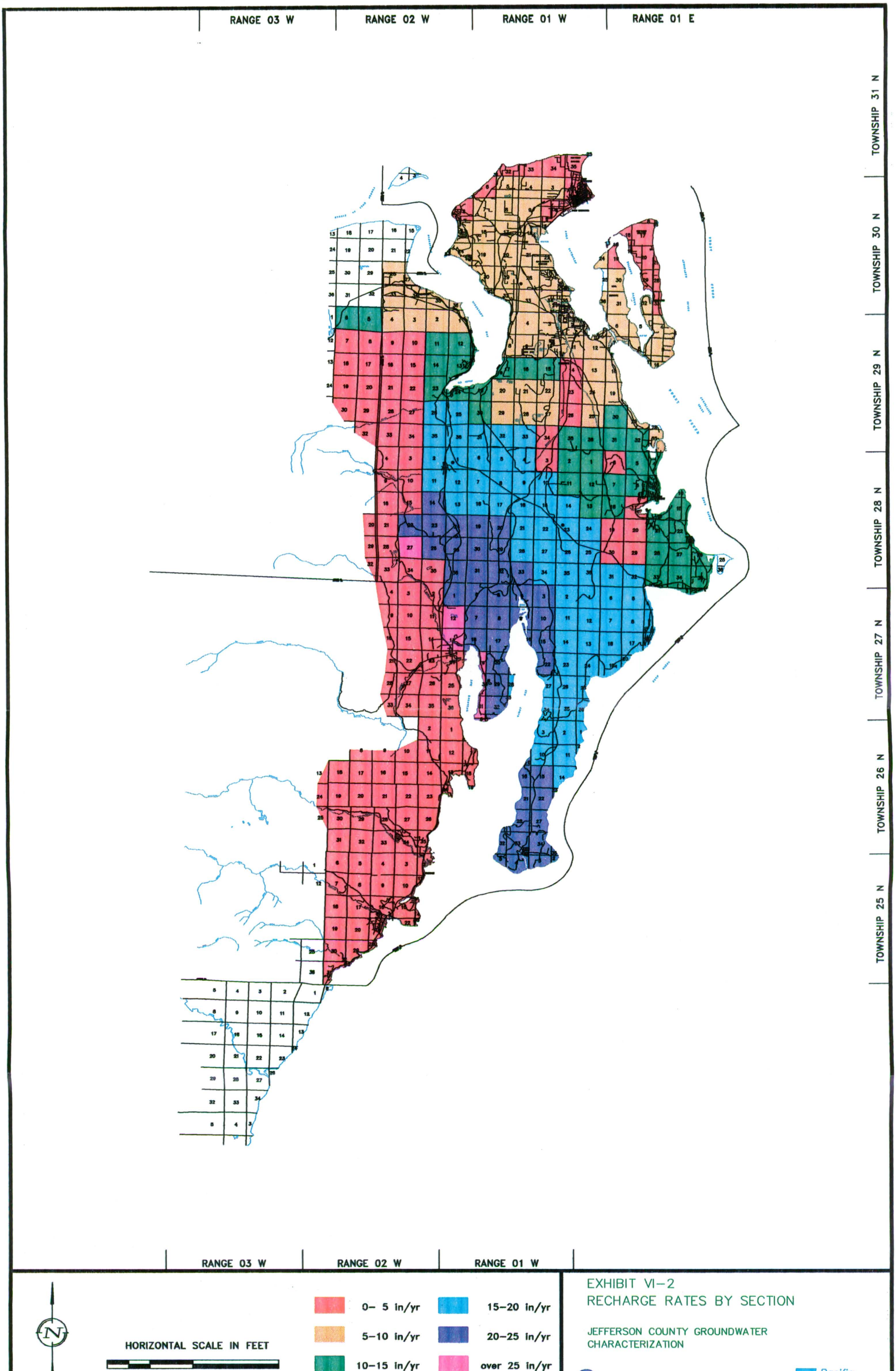


EXHIBIT VI–2
RECHARGE RATES BY SECTION

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.

Pacific Groundwater Group

SECTION VII

Section VII
Water Budget

1. Overview

The water budget estimates the major components of the hydrologic cycle. It indicates the approximate volumes of water that are flowing in and out of a region's hydrologic system through precipitation, evapotranspiration, runoff, groundwater recharge, human consumption, and natural discharge. The water budget serves as the "first-cut" basis for initial planning of groundwater use. By estimating the components of the hydrologic cycle, a water budget helps to define potential aquifer yield by indicating the general amount of "unused" groundwater in the system. By assuming a percentage of potential capture of the unused groundwater, an approximation of additional yield is generated.

Additional information in the form of water level, pumping, precipitation, and water quality data collected over time are needed to refine the conclusions generated during a water budget analysis. In general, if a conservative water budget analysis indicates that a significant proportion of the flow in a groundwater system is not used and is discharging to marine waters, additional development is likely possible with minimal to undetectable impacts such as saltwater intrusion into the existing system or stream flow decreases. Long-term data collection and analysis is recommended to verify that the impacts are indeed minimal.

A water budget analysis is considered controversial by some workers in the field. They argue that the inherent uncertainty in the estimate of each component of the water budget leads to an overall error in the estimates of water availability that makes the water budget unusable. Nonetheless, many water planners need to know the approximate quantities of water flowing through each component of the hydrologic cycle and the approximate quantities of water that may be considered for planning purposes. Thus, the results of a water budget analysis should be considered an approximate estimate suitable for planning purposes, but not accurate enough for detailed water allocation.

2. Water Budget Method and Assumptions

The water budget is based on the mass-balance principle: 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 this analysis it was assumed that long-term (multi-year) changes in the system are zero. This assumption helps to make the analysis conservative, i.e. tending to underestimate possible well yield. Reduction of storage volume could result in additional yields that are limited over time. The water removed from storage represents "mined" water that results in low water in the aquifer. The water budget represents an "average" year.

With the assumption that change in storage is zero (equilibrium conditions) the mass balance equation becomes (modified from Freeze and Cherry, 1979):

Inflow = Outflow

where:

Inflow = Natural Recharge + Human Induced Recharge + Underflow from outside the area of analysis

Outflow = Pumpage + Spring Discharge + Discharge to Marine and Surface Waters

The range in possible values of each of the hydrologic components in the mass balance analysis is high. A conservative (worst-case) analysis of the water balance resulting in the minimum estimated discharge requires using the higher end of the evapotranspiration range, the higher end of the runoff range, and the higher end of pumpage range. A best-case estimate resulting in the maximum estimated discharge would use the opposite: the lower end of the evapotranspiration range, the lower end of the runoff range, and the lower end of pumpage range.

Either approach could be misleading. For the purposes of this report a more "middle of the road" approach was used and values near the center of the range were utilized. This analysis is more likely to represent actual conditions. In any case, a site specific study is needed to better quantify yield.

2.1 Recharge/Withdrawal Area

The recharge/withdrawal area is the area over which the water budget is analyzed. Optimally, it should coincide with boundaries of the groundwater basin; the Eastern Jefferson County area should ideally be subdivided into a series of regions that are hydraulically independent from each other.

This subdivision into separate basins is typically accomplished through the generation of groundwater (potentiometric surface) contours. The contours demonstrate where groundwater flows from (recharge areas) and to (discharge areas). They also show the boundaries between the basins.

Groundwater potentiometric contour maps are produced by plotting water levels of wells within the same aquifer and contouring the elevation of the water levels. In the case of the Jefferson County (County) data, water levels were obtained from the well driller's logs for the County. In the process discussed above, one representative well log was selected from each section of the County (where available). Logs were selected that had both well numbers (to locate the well to the nearest 1/4 - 1/4 section), well depths and water levels. The wells were then plotted to the nearest 1/4 -1/4 section and the elevation of that point was selected for the elevation of the well head. Depth to water (as reported on the log) was then converted to elevation and plotted near the well.

Contouring was done by hand (no computerized contouring programs were used) as the method produced spot well water elevations that could only be approximate. Because of the uncertainty in well head elevation (estimated to within 50 feet in most cases), and the uncertainty in which aquifer the well was completed, the use of contouring by hand and "best professional judgment" produced the most meaningful results. In the northern and eastern parts of the County the contours helped to define the approximate boundaries of the basins.

In many other parts of the County, insufficient well data were available for complete and reliable contouring for identification of groundwater basin flow boundaries. In these areas, boundaries were assigned using best professional judgment and the understanding that boundaries could only serve as approximations. Areas such as stream valleys, topographic divides, and peninsula/island boundaries were all considered in assigning the boundaries to the various regions used in the water budget analysis. These areas are designated more for bookkeeping purposes than to define hydraulic boundaries.

Nine regions were selected for the analysis. In some cases, the regions are reasonable approximations of groundwater basins (e.g., Indian Island, Marrowstone Island, the greater Port Townsend region, the Toandos Peninsula, and the Ludlow Shine area). In other cases, few or no natural groundwater divides could be assigned from the data and the regions for the analysis are very rough approximations. The western foothills region contains many smaller groundwater basins, with the northern basins having no effect on the southern ones. For convenience, however, they were treated as one large region as few groundwater resources are located in this area. The on-land portions of each of the regions was estimated from topographic maps.

2.2 Natural Groundwater Recharge

Natural groundwater recharge within each section of each area was calculated as described in Section VI. The results of these analyses were transferred to the water budget analysis.

2.3 Human Induced Recharge

Additional recharge occurs through septic drainfield return flow and downward percolation of irrigation water. Sapik et. al. (1988) estimated human induced recharge in Island County based on groundwater consumption. They estimated human induced recharge as 30 percent of pumpage, while irrigation return was estimated as 11 percent of pumpage. Since some of the County uses surface water supply in non-sewered areas and these areas were difficult to readily map within budgetary restraints, no human-induced recharge was assumed as a conservative approach (i.e., underestimate recharge).

2.4 Pumpage

The amount of groundwater used in the project area was estimated by Economic and Engineering Services, Inc. (EES) based on 150 gallons per day per capita consumption (gpdpc), and population distribution within each region used in the assessment. Population estimates were obtained from the Jefferson County Coordinated Water System Plan document (EES, 1993). The 150 gpdpc is considered a conservative water usage. Actual usage may be less. (As little as 90 gpdpc was calculated for Island County for example.) Irrigation pumpage was not included in the assessment. Limited irrigation farming is practiced in the County.

2.5 Springs

Spring discharge is likely to be insignificant in the County. Spring discharge is largely confined to coastal cliff areas. Inland springs contribute to surface water runoff and are accounted for in the recharge analysis. Field observations of the coastal cliffs revealed generally localized, low yield springs (a few gpm). The overall effect on the water budget is small to unmeasurable. Spring discharge was assumed to be 0 in the analysis.

2.6 Discharge to Surface and Marine Waters

Discharge to surface and marine waters is the portion of total discharge that is not pumped from wells or flowing from springs. The usual method for quantifying natural discharge is by difference. Groundwater pumpage from wells is quantified and subtracted from the total amount of discharge (which under equilibrium conditions is equal to recharge). The difference is equal to the discharge to marine waters.

2.7 Additional Aquifer Yield

Only a portion of the undeveloped natural discharge can be used 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 ranged from 20 percent to 50 percent. A 20 percent capture ratio, based on our best professional judgment, was used in this estimate of additional groundwater available. This number was also used by the USGS in Drost (1979). Twenty percent is considered a conservative portion (least likely to result in undesirable impacts). It is the lowest value known to be used in a number of Northwest water resource studies. The actual percentage of groundwater discharge that could be "successfully" developed will depend on a number of factors beyond the scope of this project.

A capture ratio of 20 percent was used in this analysis. Sound development of additional water to a total equal to the 20 percent capture ratio will require proper placement of new wells and careful monitoring of water levels, pumpage, water quality, and precipitation. If water is developed in an indiscriminate or unplanned manner, the actual maximum development without environmental problems could be considerably less than the 20 percent of total recharge.

3. Results

3.1 Groundwater Flow Directions and Water Budget Calculation Areas

The results of the groundwater flow direction analyses are presented in Exhibit VII-1. The figure shows generalized water level (potentiometric surface) contours in regions having sufficient data for generalized contouring. The figure shows that groundwater generally flows from high-elevation areas away from the coast toward the marine shoreline or toward valley areas. The marine shoreline areas are the ultimate groundwater discharge areas, while the valley areas act as localized groundwater discharge areas for at least part of the year.

Groundwater elevation contours have only been generated for the parts of the County with sufficient data for water level analysis. Exhibit VII-1 shows that many parts of the County do not have sufficient data and are left blank. Based on existing understanding of the region's geology and on the groundwater contours generated in other parts of the County, it is believed that groundwater flow will follow the general pattern shown in the contoured areas: flow from the high elevation areas toward the valleys and coastal areas.

Using this understanding of groundwater flow, the County was divided into nine areas for water budget analyses. In three of these areas, there is sufficient data and/or hydrologic understanding to define reasonable hydrologic boundaries. These areas (with water budget calculation area number in parentheses) include:

- The "greater Port Townsend" area (2),
- Indian Island (3), and
- Marrowstone Island (4).

Four areas have some of their boundaries generally defined, while insufficient data is available for others. These include:

- The "Gardiner-Southwest Discovery Bay" area (1),
- The "Tri-Area and south" (6),
- The "Ludlow-Shine" area (8), and
- The "Toandos Peninsula" (9) area.

These areas have water level contours and marine shorelines that define some of their boundaries. They all have some areas without well defined boundaries. An arbitrary boundary was assigned to allow us to quantify recharge, water budget, and potential additional yield. Because the boundaries are arbitrary, the results of the analyses have an additional source of error beyond that associated with quantifying the components of the water budget. These boundary errors balance each other out in the "big picture." If yield in one area is overestimated because the actual basin size is less than that used in the calculation, the yield in the adjacent basin will be underestimated by a comparable amount. Its yield will have been "transferred" to the adjacent basin.

Two areas have been defined based on best professional judgment. The "western foot hills" area has been defined by most of the western part of the study area (Exhibit VII-1). This area consists primarily of bedrock uplands mantled by limited glacial deposits and lowland alluvial valleys that are limited in extent. The entire area is *not* hydraulically coupled. Withdrawal of groundwater from the northern part of this area has no measurable effect on the central and southern portions of this area. Groundwater effects are localized throughout this area. Rather, the area was designated as a "catch-all" area for the purpose of the water budget analysis. Recharge and well yields from this area are limited as bedrock forms the dominant geologic unit.

The area north of Dabob Bay (Region 7) has also been defined based on few data. It is defined as the area between the regions surrounding it that have better definition.

3.2 Water Budget Analysis and Additional Quantities Available

The results of the water budget analysis are summarized in Table VI-1. The analysis shows that approximately 20 to 25 mgd of additional groundwater withdrawal is potentially possible from Eastern Jefferson County. The range is indicative of the uncertainty in the data and analysis used in the calculation. It serves as a first-cut estimate for planning purposes. The actual amount that can be developed will depend on many factors, including: well placement, economics, the degree to which environmental effects are acceptable, and the political acceptance of the consequences of water availability on growth. Determination of what is acceptable (cost, fisheries impacts, population growth, etc.) is clearly beyond the scope of this report. The 20 to 25 mgd give a planning number, only, that will likely be different from the actual development amounts that will occur.

The potential additional groundwater withdrawal for each calculation region is also included in Table VI-1. All but two areas (discussed below) indicate that additional development of groundwater may be possible within the 20 percent "capture ratio" used in the analysis. These areas show 1 to 5+ mgd of potentially developable groundwater.

Several areas indicate that significant quantities of undeveloped groundwater are present in excess of the 20-percent capture ratio. These areas (and region number shown in Exhibit VII-1) include:

- The western foothills area (5),
- The Tri-area and south (6),
- The area north of Dabob Bay (7), and
- The Toandos Peninsula area (9)

These areas have relatively high amounts of recharge and small populations. Only limited groundwater has been developed in these regions. These areas have high rainfall rates and (except the western foothills area) and high recharge rates. Numerous wells appear feasible in these areas before the overall 20-percent capture ratio is reached.

Development in the areas indicating "additional yield," but at the low end of the range, should be approached carefully. These areas include:

- The Gardiner/Southwest Discovery Bay area (1),
- The greater Port Townsend area (2), and
- The Ludlow/Shine area (8).

Because of the inherent errors in the method of estimating undeveloped groundwater quantities, development in these areas may require additional studies to characterize water level trends, localized over-appropriation, interference with existing water rights, etc. The use of a conservative capture ratio helps to offset errors in the method and the potential for problems as the 20 percent of recharge is reached. Exceeding the 20-percent capture ratio could be problematic.

Two areas have very little to no additional groundwater over the 20-percent capture ratio. These areas include:

- Indian Island (3), and
- Marrowstone Island.

Marrowstone Island shows no surplus over the 20 percent capture ratio. The island has numerous wells and sustains a population of over 700 people. It also has a very low recharge rate as it lies in the driest part of the County. Additional development may potentially be possible at some locations on the island, but site specific analysis is strongly recommended before additional groundwater is developed. (The soon-to-be-released sea water intrusion study of the island reportedly indicates extensive salt water intrusion (Garrigues, 1993). Extensive intrusion suggests that the upper limit of groundwater development may have been reached.)

Indian Island shows a small surplus over the 20-percent capture ratio but only to the extent of about 0.2 mgd. Very little development has occurred on the island as it serves as primarily as a U.S. Naval facility. It too, has low recharge. Some additional development is potentially possible from the island but site specific studies are recommended before proceeding with development. Such development is unlikely as long as the island is used by the U.S. government.

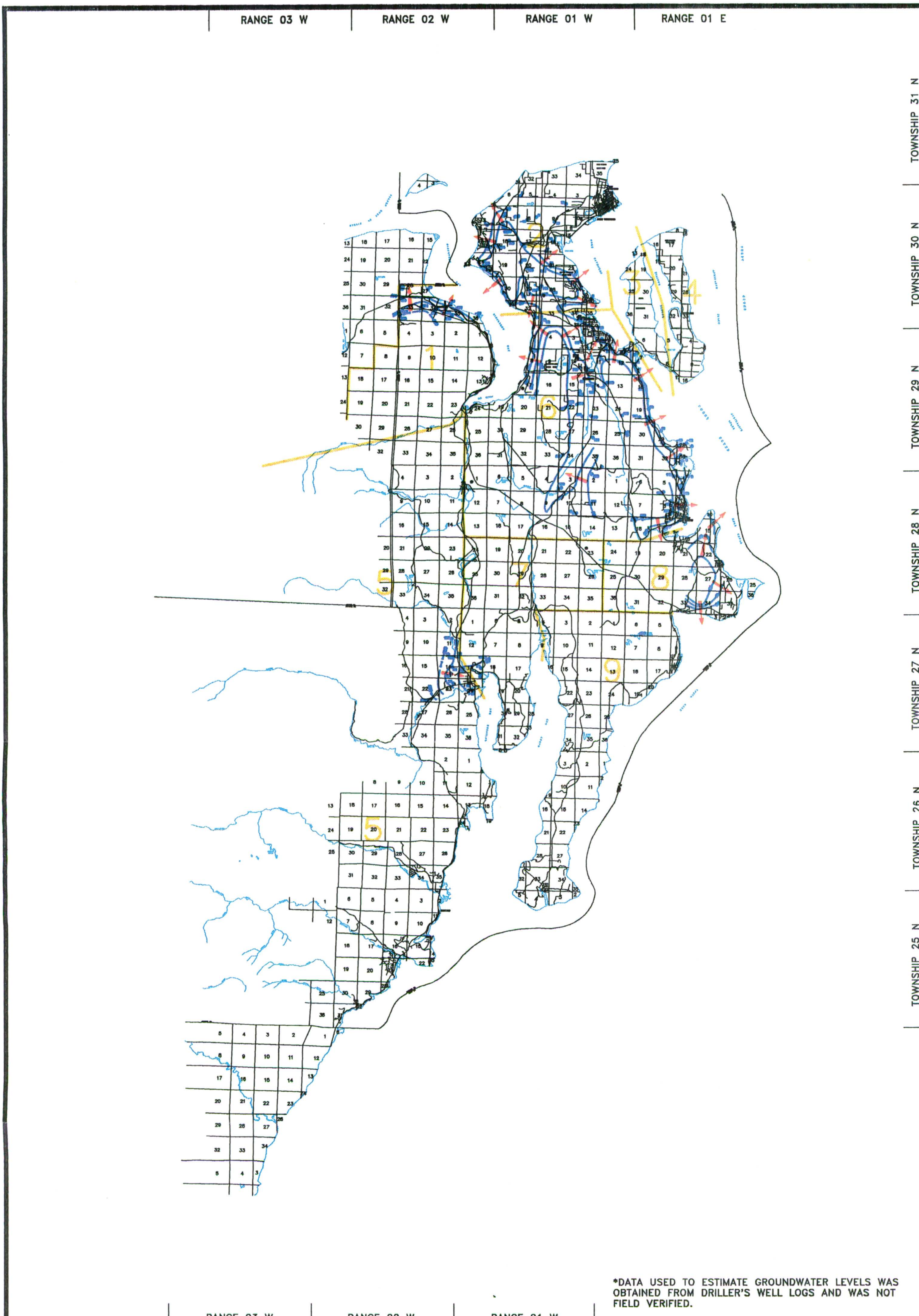
3.3 Significance in Jefferson County

The water budget analysis indicates that groundwater in addition to that currently used appears to be potentially developable. An estimated County-wide quantity of 20 to 25 mgd of development would bring consumption up to 20 percent of recharge. This volume is considerable in comparison to that currently being used (about 2 mgd) and compared to the population it could potentially sustain.

Assuming the 800 gallons per day per connection currently recommended by the Washington Department of Health, water availability is unlikely to be a limitation on growth in Eastern Jefferson County. If an average connection sustains four people (a likely over-estimate), then up to 100,000 additional people could theoretically by supplied by the undeveloped groundwater.

Actual consumption rates would likely be less as the 800 gpd includes provision for fire flow and is not based on the use of conservation practices that are likely to be employed in the future. The use of 150 gpd per person as used in the Eastern Jefferson County Groundwater Characterization Study or 90 gpd per person as indicated in the Island County Coordinated Water System Plan (EES, 1990) would lead to an even higher population number.

Full development of the 20 to 25 mgd is unlikely, however. Other factors such as cost to develop the additional water (discussed in Section X), acceptable levels of environmental deterioration, infrastructure costs, and/or other factors are likely to dominate over the physical availability of water. General economics suggests that people are willing to "pay" only so much (cost wise and environmentally wise) if other areas are available to live in with lower "costs." Clearly, water availability is not likely to be the controlling factor on growth.



HORIZONTAL SCALE IN FEET

0 20,000 40,000

Estimated Groundwater Level Contour in Feet MSL

Flow Path Direction

5 Recharge Area Boundary

EXHIBIT VII–1

GROUNDWATER LEVEL CONTOURS AND RECHARGE ASSESSMENT AREAS

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.

Pacific Groundwater Group

SECTION VIII

Section VIII
Groundwater Quality

1. Introduction

This chapter reviews available groundwater quality data from various parts of Jefferson County (County). Groundwater quality was assessed to identify the adequacy of data and any trends showing predictable water quality from locations that may be considered for water supply.

Four major categories of water quality problems were considered in the data review and analysis:

- Saline water,
- Nitrates,
- Iron and manganese, and
- Industrial or chemical contamination.

Saline water 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 the County. Saltwater 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: 1) reducing consumption and therefore the pumping rate at the well; 2) replacing the well with another at an inland location; or 3) 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 is 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. 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 should be excluded from consideration as targets for a regional groundwater supply.

Nitrate is a contaminant of concern because of known health effects. The Department of Health (DOH) has established a Maximum Contaminant Level

(MCL) of 10 mg/l. Ingestion of levels above 10 mg/l are known to result in methemoglobinemia, or "blue-baby" syndrome in small children. Nitrate can come from such sources as sewage (septic systems), fertilizers, feedlots, and natural mineral deposits.

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 plumbing. 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 known to have excess iron or manganese should be excluded from consideration for regional supply.

Industrial or chemical contamination has recently become a major groundwater quality concern. Contamination can result from spills, leaks, or dumps of industrial waste, chemicals, or fuels. Chemical contamination can also result from application of agricultural chemicals that are now considered dangerous or hazardous, especially if application rates were historically high or the chemical does not readily decompose. Older solid waste landfills can also be sources of contamination. Older landfills were not designed or constructed to keep contaminants out of the groundwater system. Many, until recently, have not been 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. However, locating regional supply wells in areas without industrial contamination is preferred.

2. Methods

Large amounts of water quality data for Jefferson County are not available. Limited information has been published in such documents as the Jefferson County Water Supply Bulletin (Grimstad and Carson, 1981), but widespread and comprehensive data reports do not exist. Within this context, the following data sources were examined in this study:

2.1 Inorganic Contaminants

Under Section 63 of the Growth Management Act, the County is requiring evidence of adequate water supply (water test results) prior to granting a building permit. However, this data is not kept in digital format, and is filed with the individual building permit files. Consequently, access to this information is difficult, and data are not easily analyzed or retrieved. Further, because the purpose of this data is to show "adequate" supply, the data is likely to be biased toward better water quality (poor results are not recorded).

For public water systems, the DOH's data system provides the best source of information on a variety of contaminants related to public health. Again, because this system is for public supplies, the aquifers and data reflected in the system are likely to be biased toward better water quality. Nevertheless, this data system represents the only available data for a regional assessment. Consequently, DOH records were queried for the following for the period of August 1988 to August 1993.

Nitrate	2 mg/l or above.
Iron	0.3 mg/l or above
Manganese	0.05 mg/l or above
Chloride	50 mg/l or above

For iron and manganese, the secondary DOH standards were used as search criteria. As indicated above, water supply with significant levels of iron and manganese can be used untreated, so the secondary standards represent a reasonable screening level to indicate problematic sources.

For nitrate, the 2 mg/l level was selected because it represents a conservative "early warning" level (10 mg/l is the health standard) and any reports at this level might indicate contamination and the need to investigate potential contaminant sources.

Chloride levels at 100 mg/l are considered by DOH as problematic. In this search, any reports greater than 50 mg/l were highlighted, again as early warning indicators of possible problems.

2.2 Organic Contaminants - Known and Potential Sources

Contaminant databases were obtained from the Department of Ecology (Ecology). Data files contained lists of sites within the County with contaminated soil, groundwater, or where chemicals had been released to the air. Data and reports involving known sources of contamination reviewed for this Eastern Jefferson County Groundwater Characterization Study (Study) are listed below.

- Washington State Department of Ecology, Toxics Cleanup Program, Leaking Underground Storage Tank (LUST) Site List. This list contains the names and addresses of sites located by County where an underground storage tank has reportedly leaked, the date of notification, the affected media, and status of the incident.

- Site Register - Washington State Department of Ecology, Toxics Cleanup Program - 1992 and 1993 Monthly Issues: This document lists known or suspected contaminated sites for Washington, and summarizes action on and status of the sites.

- U.S. Environmental Protection Agency, SARA Title III Facilities, Tier Two Reporters. This list contains the name, address, and facility identification number of owner/operators who have submitted a Tier Two form. The owner/operator of a facility where chemicals are present in quantities greater than threshold levels is required to submit annually a completed Tier I Emergency and Hazardous Chemical Inventory Form (Tier One). Under certain conditions, the Tier Two form may be submitted in lieu of Tier One. The Tier Two form requires more specific information about chemicals and their location within the facility, including the types and conditions of storage. Submittal of a Tier Two form does not imply that an unauthorized release of hazardous material has occurred at the site.

- Washington State Department of Ecology, State of Washington Solid Waste Facility Handbook, 1993. A comprehensive list of solid waste handling facilities that require permitting. Four hundred fifty-nine regulated facilities are classified by type of waste received.

- U.S. Environmental Protection Agency Region 10, Survey of Pesticides Used in Selected Areas Having Vulnerable Groundwaters in Washington State, 1987. This Study evaluates the potential for groundwater contamination from normal, commercial agricultural use of leachable pesticides.

2.3 Results

2.3.1 Natural Contaminants

Iron and Manganese: A survey of DOH records for the last five years indicates that there were only 21 reports of MCL exceedances for iron and manganese from the 153 public water systems in the County. Because these are public water systems, there is a bias toward better water quality.

Discussions with local purveyors, well driller's, and citizens indicates that the iron and manganese problem is more prevalent than these figures show. However, there has been no comprehensive documentation of the extent of these constituents in a broader context (e.g. private wells).

Nitrate: DOH records indicate there were no reports from any of the 153 water systems to indicate significant levels of nitrate. For the public water systems of the County, it appears the aquifers are being protected by natural confining layers, or the contaminant potential is not currently present.

Chloride: Of the 153 public water systems, only six reported levels of chloride above 50 mg/l. (DOH MCL is 250). As expected, these sources are mainly in areas where groundwater withdrawal might exceed recharge and saltwater intrusion could occur.

The results of this review of DOH data are shown on Table VIII-1.

There has been the documented saltwater intrusion and subsequent contamination of Marrowstone Island private domestic wells. Over the past two years, Ecology has been gathering data and analyzing the situation on the Island. At this time (September 1993), Ecology has not completed a report on their work. Such a report is expected to be issued as a Water Supply Bulletin in early 1994.

In addition, there have been several water quality studies which have documented high chloride levels in various private wells in Jefferson and Clallam Counties. These include Dion and Sumioka (1984), Forbes, et.al. (1993), Turney (1986), Van Denburgh and Santos (1965), and Walters (1971). These reports document chloride contamination in areas such as south Discovery Bay, the Quimper Peninsula, Marrowstone Island, Port Ludlow, Oak Bay, Mats-Mats, Shine, South Point, and Jackson Cove. Because of increased frequency and levels of chloride, the cause of chloride contamination has been linked to seawater intrusion at Shine, Mats-Mats, Oak Bay, and on Marrowstone Island. Common characteristics of wells with these chloride levels include:

- ❑ Locations less than 500 feet from the coastline.
- ❑ Bottom hole depths and intake elevations below sea level.
- ❑ Location in areas with previous intrusion history.
- ❑ Production from unconfined vs. confined aquifers.
- ❑ Locations in areas where well densities and aquifer withdrawal rates are high.

2.3.2 Induced Contamination from Human Activities (Anthropogenic)

A review of all contaminated site information resulted in Table VIII-2. This table shows that only ten leaking underground tanks have been reported and only seven contaminated sites are listed. Of these, clean-up has been completed on several. Where groundwater contamination has been confirmed, the effect has been local and there have been no threats to larger public supplies.

Jefferson County has only one sanitary landfill, and it is operating under the State's Minimum Functional Standards (Chapter WAC) with leachate control. No regional groundwater supplies are known to be potentially threatened by this site.

2.4 Potential Impact from Land Use Practices

The potential impact from land use practices depends on the practice itself, the local soils, geology, precipitation, and proximity to groundwater. For the practices themselves, commercial and industrial activities can represent the greatest potential for contamination because of the types and amounts of chemicals which are often associated with this class of activity.

On the other hand, intensive residential development with septics, fertilizer applications, and stormwater runoff and recharge, can represent a significant threat. With this threat category, density is a critical factor as well as natural features (soils, proximity to aquifers, etc.).

Agricultural activities can be threatening if they represent frequent use of pesticides and fertilizers. Similarly, livestock operations (feedlots and dairies) can represent a significant source of nitrate, and sometimes bacteriological contaminants.

Forest practices (Silvaculture) themselves have been the focus of controversy over the past few years. At issue, has been the effect of clear-cutting on habitat, and water quantity and quality. There have been cases where clear-cutting has been suspected of groundwater declines. However, as would be expected with the variety of site conditions, there is no conclusive correlation between the practice of clear-cutting and groundwater levels on a broad geographic scale.

In addition, herbicides are often used in forest management activities. Generally, proper application of these chemicals does not represent a risk to groundwater quality.

Use of land for transportation corridors does not, in itself, represent a risk to groundwater, with the exception of the use of herbicides in right-of-way maintenance. However, transport of hazardous materials along the corridors can represent a risk. If risk to groundwater is analyzed based on the number of spills or groundwater contamination events per mile, the probability of aquifer contamination is low from this land use activity.

3. Significance in Jefferson County

Because of the scarcity of data, and the source (public water system data), there is no opportunity to determine any geographical pattern to water quality parameters. However, for natural contaminants, general siting considerations can be deduced from natural characteristics such as the local geology, recharge, and land use as described elsewhere in this report. For example, iron and manganese can be expected where drilling occurs in older formations and more where more weathering has occurred. High chloride levels or effects of salt water intrusion can be expected in areas of lower recharge, relatively high pumping, and close proximity to marine water bodies.

Nitrate information, to-date, does not indicate contamination from septic systems. However, there is limited information. Specific studies are recommended in areas of high urbanization (and without sewers), and in areas of intensive farming or livestock production to further verify aquifer quality before use as a public supply.

Further, man induced hazardous material contamination events have had localized effects with no specific geographic pattern except that of generally being located in an urban/ industrial area or along a major transportation route.

A concerted effort should be undertaken in the County to either access available water quality information from all existing sources or undertake an extensive water quality monitoring and data development effort. Any effort to further acquire existing information will require extensive file searches and data input. In addition, the quality of the data will always be suspect because of the multiple sources or studies, sampling methodologies, and periods of sampling. Consequently, it may be desirable to pursue a monitoring and acquisition program from strategic and existing wells to better characterize the quality of the County's groundwater.

Table VIII-1
Summary of Elevated* Levels of Nitrate, Iron, Manganese, or Chloride
1988 to 1993

Number	System	Date	Parameter**	Level	MCL	Comments
3625L	ALCO 3	05/08/89	I	0.36	0.30	
0833N	BRIDGEHAVEN WATER SYSTEM	04/26/93	C	60	250	
0833N	BRIDGEHAVEN WATER SYSTEM	09/26/89	M	0.067	0.05	
0833N	BRIDGEHAVEN WATER SYSTEM	04/02/90	M	0.073	0.05	
0833N	BRIDGEHAVEN WATER SYSTEM	04/26/93	M	0.057	0.05	
586919	BRINNON BOOSTER CLUB	08/08/89	I	0.64	0.30	
109383	CAPM PARSONS	06/12/89	I	1.48	0.30	
FS127X	COLLINS CAMPGROUND	08/05/91	I	0.4	0.30	
32541D	HOOD CANAL SEAFOOD MARKET	04/29/91	C	55	250	
375006	KALA POINT WATER SYSTEM	03/09/89	C	165	250	
375006	KALA POINT WATER SYSTEM	03/09/89	M	0.173	0.05	
375006	KALA POINT WATER SYSTEM	04/01/89	M	0.154	0.05	
NP4507	KALAOCH CAMPGROUND	10/23/91	I	0.59	0.30	
13919	KINBERG WATER SYSTEM	08/26/92	I	1.59	0.30	
637009	OLYMPUS BEACH TRACTS, INC.	04/23/90	I	0.47	0.30	
637009	OLYMPUS BEACH TRACTS, INC.	06/29/90	I	0.37	0.30	
47629H	PLEASANT HARBOR MARINA	03/29/91	C	172	250	
69000R	PORT TOWNSEND, CITY OF	09/24/92	I	6.7	0.30	TRI CITY WELL
69000R	PORT TOWNSEND, CITY OF	09/24/92	M	0.45	0.05	TRI CITY WELL
FS756Y	QUILCENE ADMIN SITE	08/01/88	C	60	250	
FS756Y	QUILCENE ADMIN SITE	07/29/91	C	60	250	
FW585K	QUILCENE NATIONAL FISH HATCHERY	02/12/91	C	82	250	
813732	SOUND VIEW VILLA	02/05/90	I	0.84	0.30	
36705Y	JEFFERSON COUNTY WATER DIST. #1	04/26/93	M	0.069	0.05	
36705Y	JEFFERSON COUNTY WATER DIST. #2	05/16/91	M	0.076	0.05	
68700L	LUDLOW WATER CO.	02/28/89	M	0.052	0.05	
05820V	SHINE PLAT WATER SYSTEM	06/11/90	M	0.079	0.05	
602030	TALA POINT WATER SYSTEM	04/29/92	M	0.28	0.05	

* Department of Health Records - All reports of Nitrate exceeding 2 mg/l, Iron exceeding 0.3 mg/l, Manganese exceeding 0.05 mg/l, and Chloride exceeding 50 mg/l from 8/1/88 to 8/1/93.

**N = Nitrate
**C = Chloride
**M = Manganese
**I = Iron

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SECTION IX

Section IX
Aquifer Susceptibility And Vulnerability

1. Method and Overview

Aquifer "susceptibility" and "vulnerability" refer to a combination of conditions that indicate the general degree of protection from contamination offered by the hydrogeologic system. Aquifer susceptibility refers to the relative degree of natural protection offered by the physical system. Aquifer vulnerability refers to the combination of known and potential sources of contamination and their relationship to the natural protection (or lack of it) indicated by aquifer susceptibility. The end result is an indication of the relative potential for the groundwater to become contaminated at one location.

1.1 Aquifer Susceptibility

Aquifer susceptibility is controlled by a number of factors, the most significant being:

- The relative permeability of the geologic materials above the aquifer;
- The relative amount of moisture available to move contamination down from land surface to the aquifer;
- Direction of the vertical component of groundwater flow gradients (i.e., recharge - downward, or discharge - upward);
- The distance between the surface/near-surface (where contamination might originate) and the aquifer;
- The presence of overlying aquifers that would intercept the downward flow of contamination;
- Flow directions and rates in the overlying aquifer(s), if any; and
- Hydraulic connections between overlying aquifers (if any).

In the case of Eastern Jefferson County, many of these factors are not known in the detail needed to accurately quantify aquifer susceptibility. Only the first two factors on the list above can be readily quantified. The specific detail of groundwater flow gradients and the properties of overlying aquifers has not yet been quantified for Jefferson County (County) at many locations.

The first two factors listed above are generally the most significant for the evaluation of aquifer susceptibility, if the susceptibility of the uppermost aquifer is considered. If one assumes that water supply wells are, or could be, present in the uppermost aquifer, then this aquifer is the aquifer of concern for the analysis. The susceptibility of deeper aquifers is not indicated in such an analysis. In many cases the upper aquifer could be highly susceptible, while the underlying aquifer is protected by low permeability layers between the uppermost and deep aquifer. Only a site specific analysis would indicate if such conditions were present.

The direction of the vertical component of groundwater flow should ideally be considered in a susceptibility evaluation. Groundwater discharge conditions would generally keep contamination from flowing downward, even if the surface materials were permeable and conditions were wet. Surface contamination in this situation would tend to run off as surface water flow. By defining discharge and recharge areas of the County, some areas (specifically those in discharge areas) would automatically be designated as low susceptibility because of natural hydraulic control.

Water level data from many sets of shallow and deep wells placed close together at various locations throughout the County are needed to properly designate recharge and discharge zones. This information is not available now. However, the data that are available and general experience throughout the Puget lowlands indicates that most areas of the County are likely to be groundwater recharge areas. Generally, only valleys and areas near the marine coast act as discharge areas. With these assumptions, it is estimated that over 90 percent of the County acts as groundwater recharge areas. Therefore, it is conservative (tending to protect groundwater resources) to assume that all the County acts as a recharge area. Regions that are actually discharge areas would be placed in a susceptibility category that is too high. These areas will actually be more protective of groundwater than indicated in the analysis.

The susceptibility analysis presented in this report is based on the relative permeability of the surficial materials and the amount of groundwater recharge estimated for the area. Recharge was quantified as discussed previously in Section VI. The relative permeability was based on understanding of the material properties of surficial geology and the geologic distribution presented in Section IV. Relative susceptibility in three categories was designated by:

High: Beach sand and gravel deposits, Quaternary alluvium, Vashon recessional deposits (outwash, deltas, and ice-contact), Vashon advance outwash, undifferentiated stratified deposits - at all recharge categories.

Moderate: Artificial fill, Vashon lacustrine deposits, Vashon till (ablation and lodgment), "Kitsap Formation (older undifferentiated deposits), Possession and Double-Bluff tills (also mapped as "Salmon-Springs" till), and "pre-Salmon Springs" deposits (older undifferentiated deposits) - with recharge categories 5 (20 to 25 inches per year) and 6 (more than 25 inches per year).

All bedrock units - with recharge categories 4 (15 to 20 inches per year), 5 (20 to 25 inches per year) and 6 (more than 25 inches per year).

Low: Artificial fill, Vashon lacustrine deposits, Vashon till (ablation and lodgment), "Kitsap Formation (older undifferentiated deposits), Possession and Double-Bluff tills (also mapped as "Salmon-Springs" till), and "pre-Salmon Springs" deposits (older undifferentiated deposits) - with recharge categories 1 (0 to 5 inches per year), 2 (5 to 10 inches per year), 3 (10 to 15 inches per year) and 4 (15 to 20 inches per year).

All bedrock units - with recharge categories 1 (0 to 5 inches per year), 2 (5 to 10 inches per year), and 3 (10 to 15 inches per year).

Swamp, bog, and marsh deposits - at all recharge categories (these areas have high water table conditions because they are either located in a groundwater discharge area or because they are underlain by low-permeability materials).

An overlay analysis was conducted identifying zones within the County meeting the listed criteria using ARC/INFO computer software. A graphical display was then generated and a three-category map of the County prepared with the results. Because the analysis was based on the first two factors on the list above, the results are specific to the uppermost aquifer. Deeper aquifers may have lower susceptibility than that indicated by the analysis for that area.

1.2 Aquifer Vulnerability

Aquifer vulnerability is controlled by a number of factors, the most important being:

- ☐ Aquifer susceptibility,
- ☐ Known sources of contamination,
- ☐ Potential sources of contamination as defined by landuse (zoning), and

- ❑ Proximity to marine waters (i.e., potential for saltwater intrusion).

The first two factors indicate where an aquifer may be contaminated now and is therefore vulnerable. Areas in which contamination has occurred, and that offer low natural protection (high susceptibility), are vulnerable in that both a source and mechanism of contaminant transport are present.

The first, third, and fourth factors indicate where the aquifer could become contaminated in the future, and is, therefore, also vulnerable. Areas which have land use that are conducive to the generation of contamination, and that offer low natural protection (high susceptibility), are vulnerable in that both a potential source and mechanism of contaminant travel are present.

Areas with lower potential for the generation of contamination and with lower susceptibility have lower vulnerability. Naturally, areas with little potential for contamination generation, and that offer a high degree of protection (low susceptibility) have low vulnerability.

Sources of potential contamination were identified from County Assessors land use maps. These maps were prepared in conjunction with Jefferson County utilizing parcel maps and attributes. The information was compiled in a digital "ARC/INFO" format for overlay analysis.

Industrial areas, businesses, or farms that may potentially use or store hazardous materials, and high population density areas using septic drainfields, are examples of land use with potential sources of contamination.

Saltwater intrusion was also considered in the vulnerability assessment. Areas within 1,000 feet of wells with identified intrusion and areas within 1,000 feet of shoreline (where overpumping has the potential to induce saltwater intrusion) were all identified as potential sources of contamination.

The following specific criteria were used in the analysis to assess aquifer vulnerability.

High: Areas with high to moderate susceptibility with known sources of contamination.

Areas with high susceptibility with the following land uses: manufacturing, mills, wood products, stone and concrete products, metal products, ship and boat building, sanitary landfills, cemeteries, ports, airport hangers, gasoline service stations, auto and R.V. repair, and convenience marts (offering gasoline).

All areas within 1,000 feet of wells with saltwater intrusion (chloride concentration greater than 100 ppm).

Moderate: Areas with high susceptibility with the following land uses: unsewered housing with densities of greater than 1 unit per acre, farm buildings, garages/outbuildings

All areas within 1,000 feet of marine waters.

Low: All other areas not defined by criteria above.

Aquifer vulnerability was generated using an overlay analysis of aquifer susceptibility and landuse as defined above using ARC/INFO. A graphical display was then generated and a three-category map of the County prepared with the results.

Areas with known releases of contamination were both few and limited in extent. These releases consisted predominantly of petroleum product released from leaking tanks and small industrial spills (localized effects). Because of their relatively small extent, they were not included in the analysis as indicated above for the first entry of the high category. Based on current information, these sites and their known contamination are geographically insignificant and would be difficult to portray on the mapping scale used in this report.

2. Results

2.1 Susceptibility

Exhibit IX-1 shows the result of the aquifer susceptibility analysis. The exhibit shows that most of the County falls in the moderate or low categories. Most of the County is not highly susceptible to contamination.

The areas designated as "high" indicate the susceptibility to contamination of the uppermost aquifer. In these areas, the uppermost aquifer has little natural protection. The surficial geology allows rapid infiltration from the surface/near-surface with little natural attenuation or impediment. Deeper aquifers may be well protected by overlying low-permeability materials, but are not so designated by the analysis. No information on the deeper aquifers is given by the map.

Some moderate and low areas appear to be bounded by section lines. This effect is the result of the use of recharge categories to help define susceptibility. Since recharge is calculated on a sectional basis, this basis is carried through to the susceptibility map. The recharge numbers carry an inherent potential for error that makes it misleading to define rates for smaller areas. Susceptibility also carries this inherent error and imprecision. The section-based boundaries demonstrate the lack of precision in the analysis in the low and moderate categories. Because the analysis indicates relative susceptibility to contamination, the difference between moderate and low is less significant than the difference between high and other categories.

2.2 Vulnerability

Land use in Eastern Jefferson County is shown in Exhibit IX-2. This map demonstrates generalized land use, and not the detail actually used in the analysis. The detailed land use breakdown was used as input to the vulnerability analysis, but would require too large a single map or many small-scale maps for its presentation. The general map is included in this report to demonstrate general land use.

Two land uses predominate in Eastern Jefferson County: unimproved and residential. Other land uses occur only locally, generally near population centers. These land uses generally do not lead to the generation (or potential generation) of contamination, except in areas with unsewered residential housing at relatively high densities.

Exhibit IX-3 shows the results of the vulnerability analysis. The map shows that most of the County has a low vulnerability rating. Most of the County does not appear to be vulnerable to groundwater contamination.

Some localized areas of moderate and high vulnerability are indicated for the County. These areas generally have high unsewered residential density, commercial or industrial land use or lie near the marine coast.

2.3 Significance for Groundwater Development in Jefferson County

The vulnerability map indicates that aquifer vulnerability is not a significant control on the development of additional groundwater in the County. Most of the County falls in the low category. Much of the small total area that falls into the moderate or high category may have deeper aquifers that are less vulnerable, possibly in the low category. Only the uppermost aquifer in the high or moderate areas should be avoided where possible for the development of additional groundwater supplies.

The moderate areas within 1,000 feet of the marine shoreline should be avoided where possible for development of regional, groundwater-based, water supplies. These areas have the potential for saltwater intrusion, either at the new source or at existing wells in the area. Areas further inland have generally lower potential for intrusion and are preferred for additional development.

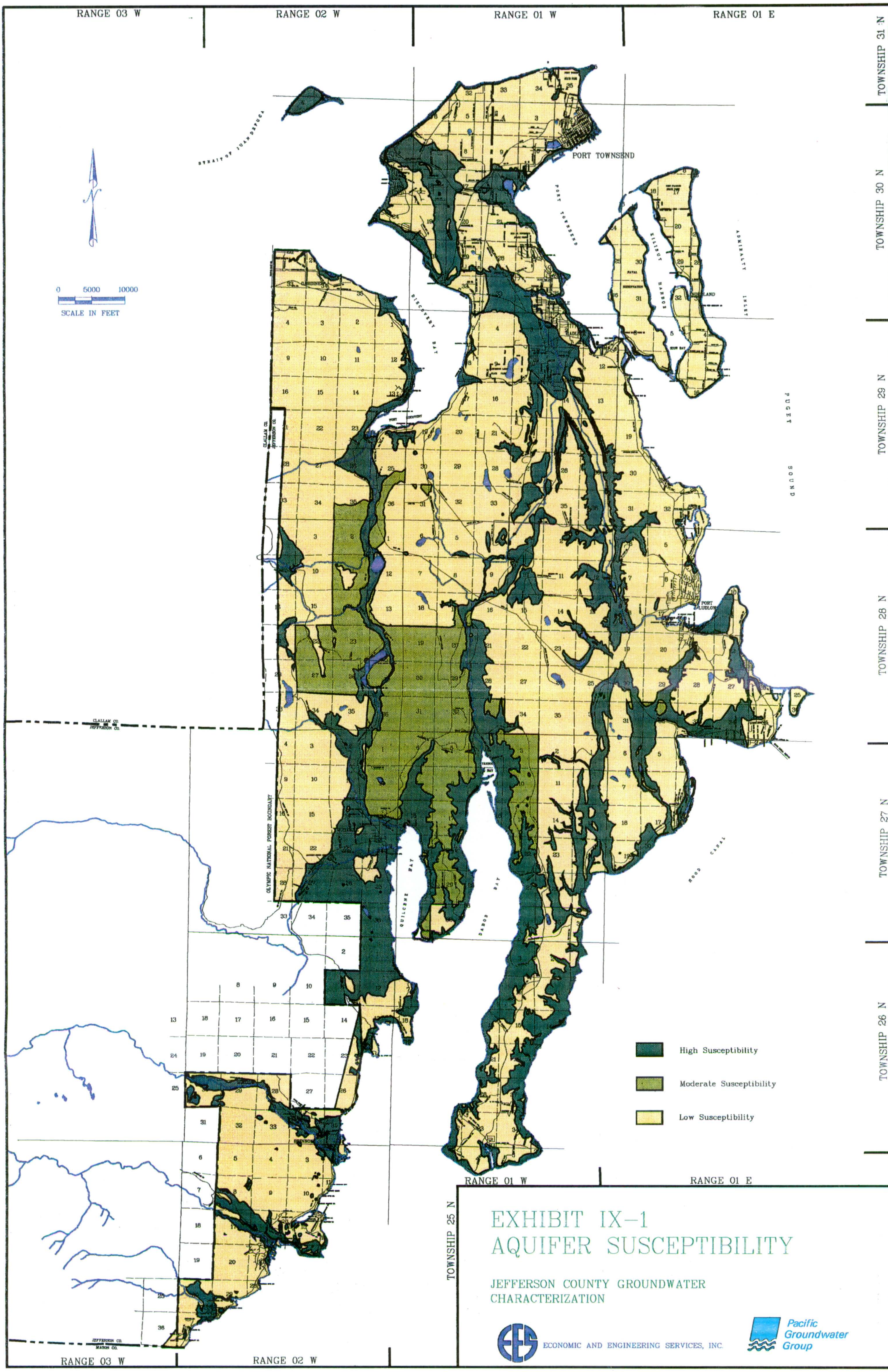

EXHIBIT IX–1
AQUIFER SUSCEPTIBILITY

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

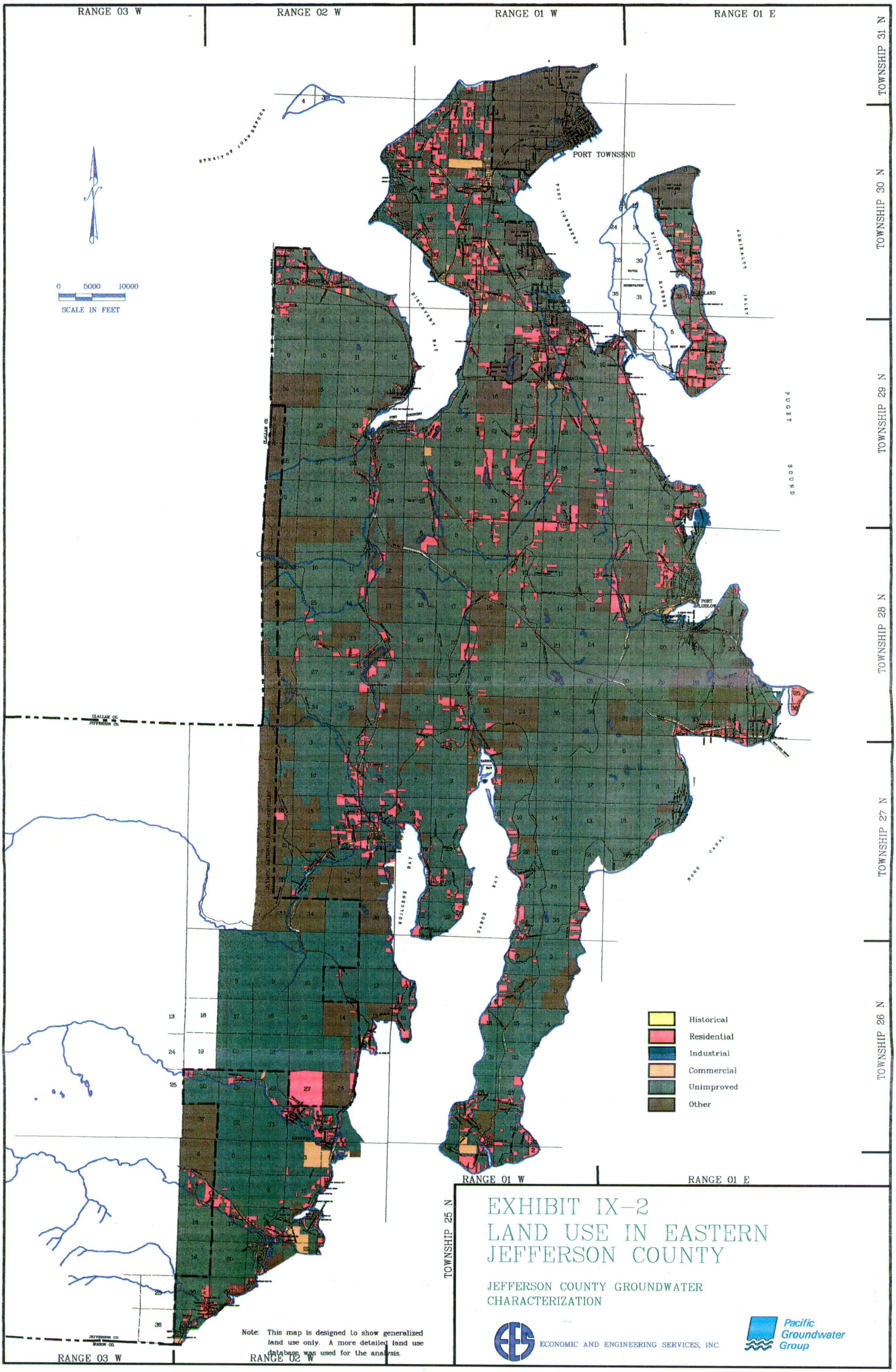

EXHIBIT IX-2
LAND USE IN EASTERN JEFFERSON COUNTY

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.

Pacific Groundwater Group

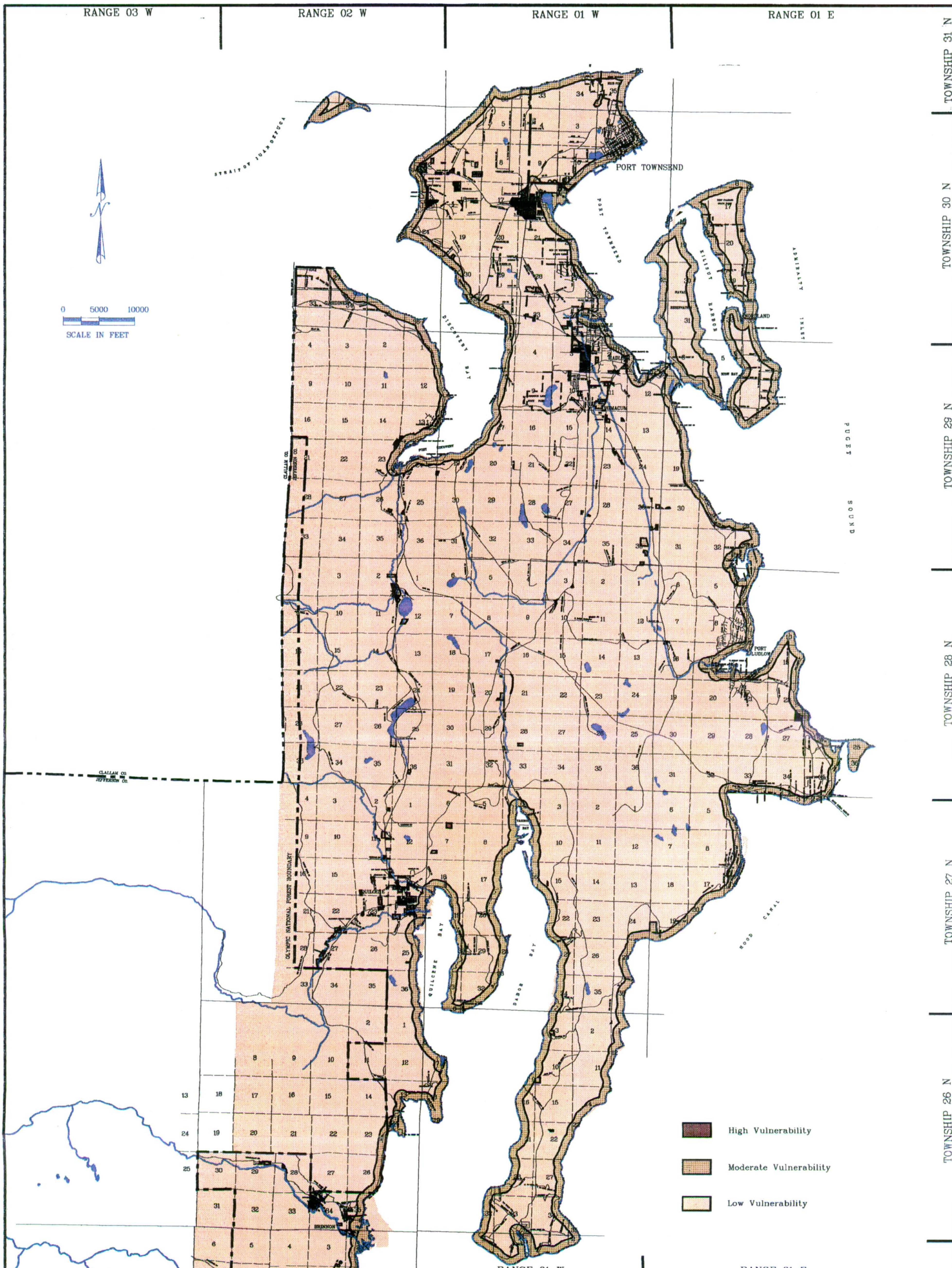

EXHIBIT IX–3
AQUIFER VULNERABILITY

JEFFERSON COUNTY GROUNDWATER CHARACTERIZATION

ECONOMIC AND ENGINEERING SERVICES, INC.

Pacific Groundwater Group

SECTION X

Section X
Additional Groundwater Development

1. Method and Overview

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 (discussed in Section III) were established for the Eastern Jefferson County Groundwater Characterization Study (Study). The preferred locations for development of additional groundwater would ideally meet all the criteria in the "high" desirability category. The results of the groundwater characterization discussed in the sections above are compared in this section to the criteria.

Based on these results, future development and costs are discussed in Sections V - IX. The numbers and depths of additional wells are estimated based on the aquifer statistics presented in Section VI, the possible well locations likely for development are discussed based on the results of Sections V through IX, and the costs for additional wells are estimated based on driller's estimates and experience in well installation and evaluations.

2. Groundwater Development and the Aquifer Ranking Matrix

2.1 Expected Well Yield

A regional supply aquifer is one capable of producing at least 500 gpm from a single well, and preferably 1,000 gpm or more. The well yield analysis indicated that average well yields in non-bedrock aquifers are 40 to 70 gpm and that only 6 percent of the wells surveyed met this criteria. In addition, no high-yield areas were delineated such that the location of a high yield well could be predicted.

Instead, only a few scattered high-yield locations were delineated on Exhibit V-1. Development of additional high-yield wells at inland locations should be considered near these wells in order to increase the probability of developing a high yield source. New wells located near the coast would require a saltwater intrusion assessment before the final well site was selected.

2.2 Expected Water Quality

A regional water supply aquifer 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 data available for water quality is limited. No area-wide problems were encountered for primary or secondary drinking water standards.

Numerous studies have documented high chloride levels in groundwater from private wells in Jefferson County (See Section VIII). These wells were noted for the following characteristics and should provide guidance for future production well siting.

- ❑ Locations less than 500 feet from the coastline.
- ❑ Bottom hole depths and intake elevations below sea level.
- ❑ Location in areas with previous intrusion history.
- ❑ Production from unconfined versus confined aquifers.
- ❑ Locations in areas where well densities and aquifer withdrawal rates are high.

Wells developed for a regional water supply are likely to meet the primary and secondary drinking water standards. The possibility exists, however, that some new wells may exceed iron or manganese standards, as the indicated by the limited data. No preferred areas were indicated to reduce this probability.

2.3 Expected Aquifer Yield

A regional supply aquifer should be capable of supplying a well or well field (two or more wells) of 2.0 mgd (about 1,400 gpm) or more without long-term depletion of the aquifer (water level declines or water quality deterioration). The water budget review indicated several areas with potential yields of groundwater in excess of the 20 percent capture ratio.

Based on this excess, three areas meet the high desirability criteria: 1) the "Tri-area" and southward; 2) the area north of Dabob Bay; and 3) the Toandos Peninsula area. Other areas meeting the medium criteria (1 to 2 mgd) include the Gardiner- Southwest Discovery Bay area, the Greater Port Townsend area, and the Ludlow-Shine area.

The Indian Island and Marrowstone Island areas fall into the "Low" desirability category for aquifer yield. Their additional groundwater development is close to, or equal to, zero.

Regional water supply is not recommended for the western foothills region, even though additional water appears developable from a total yield perspective. This area is underlain primarily by bedrock and would require a substantial number of wells.

2.4 Instream/Basin Closure

Regional water supply development can be problematic in areas with instream flow minimums that result in closures to further withdrawal during part or all of the year. A recent study by the U.S. Fish and Wildlife Service (1993) has listed several streams with mean flows less than the recommended minimums desirable for fish habitat. At the time of the preparation of this report, these recommendations had not led to stream or basin closures in Eastern Jefferson County. However, future rulings by the Department of Ecology (Ecology) may result in stream closures. Since there are no closures currently, all aquifers fall into the "high" desirability category. This situation could change.

2.5 Distance to Marine Water

Wells close to marine waters have a greater chance for saltwater intrusion than wells further inland. Development of new regional supply wells would ideally be located inland. If possible, new wells should be located more than one mile inland.

2.6 Depth to Static Water Level

New regional supply wells should have as high a static water level as possible to help reduce pumping costs. Ideally, the static water level would be less than 100 feet from ground surface. The average (both mean and median) static water level in the wells surveyed in this Study is less than 100 feet below ground surface. The relatively shallow average static level suggests a new regional supply well or wells will also meet the high desirability criteria.

Actual static water level will depend on site specific conditions. Wells sited at lower elevations will generally have a greater chance of shallower static water levels than wells started at higher elevations. Lower elevation wells are more likely to be completed in groundwater discharge areas where upward flow gradients will tend to cause groundwater to rise to higher levels in the well casing, compared to wells completed at higher elevations.

2.7 Geographic Location

The costs for delivering water to the end-users is a function of the distance between the source and the user. A highly desirable regional water supply source would be located near areas of higher population growth. Almost as desirable would be sources near existing distribution systems (such as the Little Quilcene - Port Townsend pipeline). This factor was not considered in this analysis.

2.8 Aquifer Vulnerability

The development of new groundwater sources for regional supply should be developed in areas with low vulnerability. If a supply well cannot be located in a low vulnerability region, then a moderate vulnerability should be acceptable because the criteria used to develop these categories are conservative (i.e., the medium category still provides much aquifer protection). A regional supply well should not be located in a high vulnerability area unless a site-specific study indicates the well will *not* be placed within the high-permeability geologic unit that helped produce the high vulnerability rating but *below* a low-permeability unit underlying the high-permeability zone. The aquifer must be protected by low-permeability sediments.

The aquifer vulnerability map (Exhibit IX-3) indicates that much of Jefferson County (County) is designated as low and moderate vulnerability. Any of these areas is acceptable for regional water supply development with the low vulnerability areas preferable.

2.9 Existing Water Use

A regional water supply well should be located as far as possible from areas of high groundwater use. Only regional groundwater use was addressed as part of this Study. These use amounts were incorporated into the water budget and aquifer yield criterion, discussed above. No site specific studies were conducted.

Before a new regional water supply well is placed, a site specific study addressing local groundwater use should be conducted. Such a study will help to find the preferred location for the well and may aid in obtaining a water right.

3. Additional Groundwater Development and Associated Costs

Review of the matrix and evaluation of the criteria above indicates that a large number of moderate to high yield wells will be needed to fully develop the groundwater resources of Eastern Jefferson County. Non-bedrock locations appear to be preferred, but little more can be said at this point about preferred locations within the non-bedrock areas. Development will likely occur near the areas where the water is needed, using a series of wells, both exploratory and production.

Typically, an eight-inch test well 200 to 400 feet deep will likely be drilled to assess the potential yield at that location. A production well may then either be drilled or developed from the test well. If successful, a water supply of 100 to 400 gpm may be obtained from the production well converted from the test well. If very successful, a larger-diameter production well would be developed on the site based on the test well result. If the drilling of each test well is guided by an area specific feasibility study, a success rate better than that indicated by the aquifer statistics (Tables V-1 and V-2) is likely. Assuming 1 out of 2 test/production wells indicate a potential yield of greater than 200 gpm (the tables indicate 1 out of 6 wells have potential yields of greater than 200 gpm) and that 1 out of 6 have yields of greater than 500 gpm (the tables indicate about 1 out of 20), then as many as seven wells will be needed per 1 mgd (approximately 700 gpm). Full development of the 20 to 25 mgd could potentially be accomplished by 140 to 175 wells. Assuming 150 wells for planning purposes and an average cost of $50,000 per well, a total well installation cost of $7.5 million would be required for well installation to fully develop the indicated potential of 20 to 25 mgd.

This cost estimate does not include pumps, control electricals, well houses, plumbing, transmission lines, and associated appurtenances which would likely be equal to the well installation costs. All the above costs are planning estimates and will likely vary. Site specific cost estimates would be made after a site specific feasibility study.

The actual development pattern may vary as entities in addition to the Jefferson County Public Utility District (PUD) may develop water systems. Expanded development in Eastern Jefferson County may lead to a number of water purveyors, each with its own needs and groundwater development strategies.

SECTION XI

Section XI
Data Gaps And Recommendations For Continuing Work

1. Data Inadequacies and Shortages

During the course of the project, several shortages or inadequacies in the existing data were noted. These data gaps produced limitations in the accuracy and extent of the conclusions drawn as part of the study. Some of the major data gaps are outlined below:

1.2 Well Log Database

Although almost 2,000 well logs were available in printed form for the use of the Eastern Jefferson County Groundwater Characterization Study (Study), their format and uncertainty on the locations of the listed well led to limitations in this analysis. Currently, the Jefferson County Public Utility District (PUD) has these logs in box files. The only method of accessing the information on these logs is through a manual search. In addition, the location of the well can only be identified to the nearest 1/4-1/4 section, if the well has been so labeled and if the driller carefully located the well based on survey information or topographic map. In many cases, the locations are clearly in error, as demonstrated by the fact that 5 percent of the wells analyzed as part of this well yield assessment plotted off shore based on this information. It is not known how many on-shore locations were also in error.

The solution is to develop a computerized data base with *all* the information on the log entered into the data base. Geologic information should be entered in an alpha-numeric format (not as a comment field) such that future analyses can generate geologic "stick logs" for analysis. It is strongly recommended that each well field should be located using a global positioning system (gps) and electronic altimeter to generate a unique identification and location for each well. The careful use of gps and altimeter allow the well to be given a position and elevation that will have an accuracy of ± 10 feet, or better. This accuracy will be sufficient for most future groundwater surveys.

The cost for the location equipment is approximately $1,000 to $1,500. A motivated and conscientious staff member should be able to field locate and enter 20 to 30 wells on a good day. Well database programs have been developed for other projects in the area and may be adapted to Jefferson County (County) at a reasonable cost.

1.2 Water Level Data

Very few usable water level measurements are available for wells in the project area. This information is needed to quantify groundwater flow directions, identify groundwater recharge and discharge directions, and assess continuity between various aquifers and bodies of surface water. Some well logs have water levels measured or estimated at the time of well drilling. These water levels can only be used as approximations as the data must be resolved into water level elevations before they are truly usable. The lack of known well head elevations makes the estimated water level depths (as reported on the logs) even less accurate when the well head or ground surface elevation must be estimated.

Water levels in selected wells should be measured and recorded on at least a semi-yearly basis in wells with known well head elevations and usable logs. This information can then be used to assess flow directions and over time, help assist in assessing long-term trends concerning water use, rainfall, and development.

1.3 Water Quality Information

Water quality information is limited for the County. Very few data are available, and these, like the well logs, are not available in electronic format. Data available from the Department of Health (DOH) were limited to a few water systems. Data from the USGS was only available from the Jefferson County Water Supply Bulletin (Grimstad and Carson, 1981). Additional data on chlorides were obtained from various reports on seawater intrusion. This report has summarized this information into a single document. This information can be used as part of future time-series analysis, but the data will have to be once again entered manually, as an electronic database has not been developed.

An electronic database, however, should be developed. The database should be consistent with existing and accepted formats used by the Department of Ecology (Ecology) and/or other regulatory entities, or be capable of easy translation both to and from these accepted formats. Data already existing in paper format should be entered. New data should be entered as it is generated. The database should be constantly updated. A regular source of funding and/or the data entry job should be assigned as part of a staff member's work assignment.

1.4 Deep Hydrogeologic Information

Very few wells have been drilled deeply in the northern and southern portions of the study area. These areas have potential for deep aquifers that could have high yields and little, if any, competition for their use. A

1,000+ foot test well was drilled on the northern end of the Miller Peninsula (in Clallam County). This test well indicated that deep layers of unexplored sediments probably underlie the northern portion of the Quimper Peninsula. Deep sediments are also likely beneath the Toandos Peninsula. Although, the need to explore and develop these areas does not appear to be a high priority at this time, knowledge of the groundwater potential in these areas would assist long range planning.

Test wells should be considered (at a priority below those listed above) in these areas. The wells should be logged by a professional hydrogeologist or geologist and pump-tested if promising aquifers are encountered during drilling.

2. Recommendations for Additional Work

2.1 Resource Expansion

The process begun with this project should be continued. This Study used only a limited amount of the existing data to characterize the groundwater resources of the County. Use of a more-complete data set and a more detailed analysis will help to refine the analysis and provide more specific planning and development information.

Specifically recommended high priority projects include:

- ❑ Development of a well log data base as described above;
- ❑ Field location and entering of existing well log data into the data base, as described above;
- ❑ Development of an on-going program to field locate and enter new well log data;
- ❑ Development of an on-going program to measure and record water levels, stream flow, precipitation, and withdrawal;
- ❑ Development of a water quality data base as described above;
- ❑ Entry of existing water quality data into the data base;
- ❑ Development of an on-going program to enter new water quality data; and
- ❑ Revision of this groundwater characterization report after the databases are up and running and sufficient data have been entered. The revised report would focus on improved definition of aquifers and identification of high yield areas. It would also better indicate water quality in the

various aquifers. The end result of this revised report would be a better understanding of the County's aquifers and where additional yield may be best obtained.

If budget limitations do not allow the completion of the above listed projects, the following should be undertaken to assist the PUD in its efforts to provide adequate water resources:

Site specific hydrogeologic analyses in the regions targeted for development of new groundwater sources for the PUD. These analyses would rely on paper well logs and no electronic logs as would be generated from the recommendations listed above. However, since the target areas would be smaller than the area addressed in this Study, a much higher percentage of the logs from the target area could be used in the Study, improving upon the region-wide understanding developed for this Study.

Lastly, the following work should be conducted after the above work has been completed:

Planning and completion of deep test well drilling programs, as described above.

2.2 Wellhead Protection

The federally mandated "Wellhead Protection" program, a separate but related project, must be undertaken in the near future by water purveyors who utilize groundwater as their source of supply. Each well in the PUD system, for example, will need an analysis of capture area, flow travel times, potential sources of contamination within the capture area, degree of hydrogeologic protection, and more. Much of this information would be an expansion of the information contained in this Study. The expansion would consist of a well-area-specific analysis in greater detail than that offered by this report. The information generated during a wellhead protection analysis would likewise help to augment an expanded regional groundwater characterization study.

SECTION XII

Section XII
Annotated Bibliography

The following references provided major input to this project. They can provide additional detail to the summary and overview provided in this report. A short description of the highlights is provided after each listing to aid the reader in selecting a reference for further study:

Birdseye, Richard U., 1976. Glacial and Environmental Geology of East-Central Jefferson County, Washington, Masters thesis submitted to North Carolina State University. Washington Department of Natural Resources Map No 76-26.

The purpose of this thesis was to prepare a detailed geologic map the east-central Jefferson County. The author describes the geologic history of the area and correlates the stratigraphy to surrounding areas. Based on this map the author provides interpretations regarding the region's economic and environmental geology.

Carson, Robert J., 1976. Geologic map of the Brinnon area, Department of Natural Resources, Div. of Geology and Earth Resources, Map No. 76-3.

The purpose of this map was to prepare a detailed geologic map the Brinnon area of Jefferson County. The author describes the geologic units of the area using nomenclature that correlates to the stratigraphy to surrounding areas.

Gayer, Jerome M., 1977. Quaternary and Environmental Geology of Northeastern Jefferson County, Washington. Masters thesis submitted to North Carolina State University.

The objective of this thesis was to investigate the Quaternary deposits of northeastern Jefferson County primarily through construction of a geologic map. Based on this map, the author provides interpretations of the surficial geology that have implications for future land-use activities. He describes the geologic history of the area and correlates the stratigraphy within the study area to surrounding areas.

Grimstad, P., and R.J. Carson, 1981. Geology and Ground-Water Resources of Eastern Jefferson County, Washington. Water Supply Bulletin No. 54.

This report summarizes the regional geologic and hydrologic character of Eastern Jefferson County. The authors describe the stratigraphy and geologic history of the study area and provide a geologic map. The map is compilation and simplification of the detailed maps listed in this annotated bibliography. In addition, the report contains a well location map and geologic sections based on selected borehole logs

from a well database of 374 wells. Water budgets are presented for the Port Townsend and Quilcene areas.

Hall, J.B. and K.L. Othberg, 1974. Thickness of Unconsolidated Sediments, Puget lowland, Washington. State of Washington, Department of Natural Resources, Division of Geology and Earth Sciences, Geologic Map GM-12.

This publication contains a thickness of unconsolidated sediments map (an isopach map) of the Puget Sound lowland. The isopach contours were constructed based on 280 oil and water well logs, surface exposures of bedrock, and subsurface seismic profiles. The contour interval is 400 feet.

Hanson, Kathryn L., 1977. The Quaternary and Environmental Geology of the Uncas-Port Ludlow area, Jefferson County, Washington. Masters thesis submitted to the University of Oregon, December 1977. Washington Dept. of Natural Resources Map No 76-20.

This thesis describes the Quaternary stratigraphy and geologic history of the Uncas-Port Ludlow area. The author correlates the glacial and interglacial deposits to the surrounding areas. In addition, geomorphic features, and the environmental and economic importance of the various geologic units are discussed. A substantial portion of this thesis work was the construction of a geologic map of the area.

Pessl, Fred Jr., D.P. Dethier, D.B. Booth, and J.P. Minard, 1989. Surficial Geologic Map of the Port Townsend 30- by 60-minute Quadrangle, Puget Sound Region, Washington, U.S. Geological Survey Map I-1198-F.

This 1:100,000 scale map provides a geologic map the of the area bounded by the Olympic Mountains and Vancouver to the west, and the Cascade Mountains to the east. In addition, the authors map the general distribution textures in areas of stratified sediments and provide lithologic logs of selected boreholes.

Purdy, Joel W., and J.E. Becker, 1992. South Aquifer Study, Port Ludlow/Shine Area, Prepared by Robinson & Noble, October 1992.

This report contains maps and hydrogeologic cross sections of the Port Ludlow/Shine area. The authors include a database of wells in the area and described the distribution of aquifers in the area. In addition they used a water balance approach to estimate potential yield from the principal water-bearing unit, the South Aquifer.

Yount, J.C., G.R. Dembroff, and G.M. Barats, 1985. Map showing depth to bedrock in the Seattle, 30' by 60' quadrangle, Washington, Map MF-1692.

This map presents depth to bedrock contours for part of the Puget Sound lowland extending from Seattle to Everett and from Eastern King County to Eastern Jefferson County. The contours are based on oil and water well logs, and logs

from geotechnical boreholes. Other data used for constructing contours includes information from marine seismic and aeromagnetic surveys and surface exposures of bedrock. The contour interval is variable and ranges from 10 to 100 meters. This map does not include the area of Eastern Jefferson County located north of the southern edge of Discovery Bay and Oak Bay.

Yount, James C. and H.D. Gower, 1991. Bedrock Geologic Map of the Seattle 30' by 60' quadrangle, Washington, U.S. Geological Survey Open File report 91-147.

This report includes a series of geophysical maps, geologic cross sections, and surficial geologic maps. These maps were used to construct a bedrock geologic map that contains information regarding depth to bedrock and bedrock structure such as folds and faults.

Washington State Department of Ecology, 1991. Well Logs for Eastern Jefferson County

The Washington State Department of Ecology files in Tumwater, Washington contain logs for many of the wells drilled in Eastern Jefferson County. About 2,000 logs are currently available for the area. More are being added as new wells are drilled. Each log is supposed to include the owners name, general well location, well depth, well diameter and casing information, water level and ground surface data, pumping test data, geologic log and driller's name and registration number. These logs are often incomplete, mislocated or have poor geologic interpretation (the well drillers are not trained as geologists although many are good at describing the material encountered). Nonetheless, they serve as the basic tool for interpreting subsurface conditions.

SECTION XIII

Sectoion XIII
References

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Sapik, D.B., G.C. Bortleson, B.W. Drost, M.A. Jones, and E.A. Prysch, 1988, Ground-water Resources and Simulation of Flow in Aquifers Containing Freshwater and Seawater, Island County, Washington, USGS WRI 87-4182, Tacoma. 67 p.

Thornthwaite, C.W. and Mather, J.R., 1955, The Water Balance, Laboratory of Climatology, Pub. No. 8, Centerton, 86p.

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Van Denburgh, A.S., and J.F. Santos, 1965. Ground Water in Washington: Its Chemical and Physical Quality. Water Supply Bulletin No. 24. Washington State Department of Conservation.

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APPENDIX

Table A-1

May 19, 1994

Well Data and Analysis for Jefferson County

Location Data							Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange		Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock, Shale, Dry Hole	Potential Well Yield gpm
25	1	W	3	A	1160942	258941	6	N	198	175	B	5	15	1.5	G	4
25	1	W	4	K	1154211	256362	6	S	217	200	B	30	1	3	S	300
25	1	W	13	G	1169996	246798	6	S	415	331	B	10	13	1	SG	30
25	1	W	26	N	1161951	233628	6	S	30	8	B	2	13	1	SH	2
25	1	W	20	R	1149812	239151	6	S	68	4	B	20	20	8	S	30
25	2	W	2	E	1130316	258075	8	S	56	13	P	60	1	4	SG	1000
25	2	W	3	B	1127764	259504	6	N	45	14	B	80	1	1	G	1000
25	2	W	7	K	1112183	251911	6	N	245	131	B	4	109	1.5	R	0
25	2	W	8	M	1114717	251781	6	N	56	35	P	10	11	2	G	10
25	2	W	10	K	1127661	251547	6	N	100	70	P	12	20	2	G	9
25	2	W	11		1132183	252097	6	N	78	63	B	10	1	1	G	80
25	2	W	14		1132084	246770	6	P	337	240	B	20	95	1	G	10
25	2	W	15	Q	1127574	244901	8	S	215	136	P	250	35	3	S	300
25	2	W	16		1121761	246999	10	S	83	6	P	568	2	4	SG	1000
25	2	W	16	Q	1122421	245019	6	N	175	31	P	30	35	72	G	60
25	2	W	17	B	1117251	249107	6	N	77	45	P	10	15	2	G	10
25	2	W	19	A	1113281	243916	6	N	31	23	B	25	1	1.5	G	100
25	2	W	21	D	1119683	243653	6	N	200	77	B	2	123	2	B	0
25	2	W	28	C	1120895	238322	6	N	91	59	B	8	11	2	G	10
25	2	W	29		1116372	236474	6	N	119	21	B	10	98	1	S	5
25	2	W	30	H	1113178	237263	6	P	260	88	B	2.5	50	2	S	4
25	2	W	31	M	1109118	230600	8	N	443	100	B	20	10	1	SH	300
25	2	W	32	D	1114286	233112	6	P	60	45	P	19	80	4	B	0

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange	Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock, Shale, Dry Hole	Potential Well Yield gpm
25	2 W	33		1121443	231001	9	N	34	21	B	25	3	1.5	G	50
26	1 W	3				6	S	164	60	P	25	15	2	S	90
26	1 W	5		1148950	288853	6	P	157	123	B	25	31	1	G	10
26	1 W	8	Q	1149434	281597	6	N	165	7	B	4	30		B	2
26	1 W	10	M	1157421	282724	36	P	15	6	P	6	6	2	G	5
26	1 W	12	E	1168042	283860	6	N	185	1	B	3	184	2	B	0
26	1 W	16	G	1154605	278858	6	N							D	0
26	1 W	18	D	1141372	280379	6	P	120	1	B	2	110	2	B	0
26	1 W	27	N	1157195	265581	6	N	470	440	B	12	1	2	SG	200
26	1 W	28	K	1154428	266969	6	P	360	352	B	30	2	2	S	60
26	1 W	34	Q	1159741	260288	6	S	316	295	B	32	3	4	SG	100
26	1 W	35		1164421	262187	6	N	76	57	B	10	10	0.5	S	10
26	2 W	11	C	1132473	285861	6	N	161	21	B	4	140	2	B	0
26	2 W	12	J	1140315	283116	6	N	229	112	B	15	116	1.5	R	2
26	2 W	13	A	1140108	280476	6	P	270	113	B	20	270	1.5	R	1
26	2 W	13	J	1140108	277836	6	S	52	37	B	10	13	2	SG	6
26	2 W	14	H	1134925	279257	6	N	32	5	B	18	7	2	SG	30
26	2 W	23		1132743	273312	6	P	65	3	P	6	62	3	B	1
26	2 W	24	E	1135963	273874	6	N	44	20	P	30	10	1	G	40
26	2 W	26	A	1134544	270005	6	P	400	34	P	12	336	2	R	1
27	2 W	27	N	1126246	297820	8	N	440	200	A	10	240	2	B	1
26	2 W	28	P	1121578	266255	6	N	60	44.5	B	25	15	1.5	G	10
26	2 W	33	A	1124059	264918	6	N	30	19	B	25	10	1.5	G	10

Table A-1
(Continued)

Location Data							Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange		Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock, Shale, Dry Hole	Potential Well Yield gpm
26	2	W	34	G	1127891	263491	6	N	66	38	B	20	20	1	G	10
27	1	E	3	A	1193290	321581	6	S	216	93	B	10	1	1.5	S	600
27	1	E	4	M	1184228	319057	6	S	109	51	B	26	4	4	S	200
27	1	E	5	H	1183055	320497	6	S	85	18	B	20	25	2	S	30
27	1	E	9		1186081	314436		S	274	201	P	69	12	1.5	SG	200
27	1	E	13	N	1199206	306843	8	S	389	322	B	20	1	1	SG	700
27	1	E	16		1185959	309162	6	S	116	97	B	60	13		S	40
27	1	E	19	L	1174901	303470	6	N	198	122	B	30	1	2	G	1000
27	1	E	20	D	1178736	305990	6	S	175	145	B	15	20	2	S	10
27	1	W	1	N	1168758	318100	6	N	75	62	B	10	4	1	SG	20
27	1	W	4	M	1153107	319751	6	S	34	22	B	3	1	2	S	20
27	1	W	5	G	1150474	321164	6	N	180	32	B	5	148	8	SH	3
27	1	W	7	N	1142444	313345	6	N	100	10	B	2	1	0.5	SH	90
27	1	W	13	Q	1171141	307540	6	N	30	6	B	30	20	1.5	G	20
27	1	W	16	M	1152868	309199	6	N	20	6	B	5	1	3	G	40
27	1	W	17	A	1151579	311945	6	N	67	38	B		10	2	G	0
27	1	W	17		1149599	309965	6	S	117	93	B	15	1	2	S	200
27	1	W	18	Q	1144983	308081	6	N	134	70	B	20	20	2	SG	30
27	1	W	19	B	1144869	306771	6	S	43	32	B	11	4	3	SG	20
27	1	W	19	G	1144869	305451	6	S	219	158	P	15	35	1	S	10
27	1	W	20	D	1147490	306667	6	N	327	304	B	10	1	6	SG	100
27	1	W	21	N	1152724	302601	6	S	81	48	B	40	22	1.5	SG	30
27	1	W	24	K	1171028	303587	6	S	270	170	P	30	51	4	S	30

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange	Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock,Shale, Dry Hole	Potential Well Yield gpm
27	1 W	25	B	1170929	300962	6	S	41	27	B	15	3	1	S	40
26	1 W	27	N	1157195	265581		N	470	440	B	12	1	2	S	200
27	1 W	29	E	1147340	300069	6	N	253	163	B	5	43	1.5	G	5
27	1 W	28	A	1156517	301281	6	N	272	20	A	40	260	2	SH	20
27	1 W	29	E	1147340	300069	6	N	216	100	P	5	40	4	SG	7
27	1 W	30	R	1146059	297533	6	S	35	6	B	20	30	2	SG	10
27	1 W	31	H	1145904	294894	6	S	248	195	A	20	45	2	S	10
27	1 W	32		1149141	294130	6	P	40	30	B	24	6	1	G	20
27	1 W	36	F	1169522	294381	6	N	116	50	B	20	3	1	SG	200
27	1 W	36	P	1169522	291741	6	S	120	107	P	15	4	4	S	20
27	2 W	6	A	1114667	323070	6	S	32	2	B	40	20	8	SG	30
27	2 W	10	K	1129125	314898	6	N	38	21	B	4	11	1	G	3
27	2 W	11	A	1135771	317463	6	S	114	56	B	10	42	8	SH	7
27	2 W	12	D	1137134	317386	6	N	145	93	B	2	1	1.5	SH	50
27	2 W	13	P	1138364	308168	6	S	51	5	B	40	12	2	SG	80
27	2 W	14	B	1134369	312208	8	S	72	22	S	52	26	3	SG	50
27	2 W	16	K	1123740	309729	6	P	45	17	B	35	30	1	SG	20
27	2 W	20	C	1117065	307214	6	N	34	6	B	60	4	1	SG	200
27	2 W	21	P	1122348	303161	6	N	25	5	B	40	1		G	400
27	2 W	22	Q	1128972	303076	12	P	27	10	P	300	1		SG	1000
27	2 W	22	R			6	S	106	12	B	47	70	2	SG	30
27	2 W	23	C	1132961	306952	6	S	85	72	B	35	1	2	SG	200
27	2 W	24	B	1139584	306865	8	S	62	10	P	264	53	4.5	SG	100

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange	Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock, Shale, Dry Hole	Potential Well Yield gpm
27	2 W	25	J	1140790	298956	6	S	178	132	P	40	1	48	G	900
27	2 W	27	M	1126246	299140	6	N	24	12	P	35	8	7	G	30
28	1 E	4	M	1184992	350685	6	S	89	31	P	21	11	2.5	SG	60
28	1 E	5	P	1181237	349581	6	S	154	145	B	20	10	3	S	9
28	1 E	7		1176617	346428	6	S	37	33	B	8	3	2	SG	5
28	1 E	8	P	1181076	344271	12	S	315	159	P	94	51	18	SG	100
28	1 E	9		1186816	346044	6	S	76	30	B	30	5	2	S	100
28	1 E	13	F	1170627	341909	6	N	60	29	B	20	20	1.5	SG	20
28	1 E	15	Q	1192418	338585	6	S	69	38	P	5	18	1	SG	4
28	1 E	16		1186679	340759	6	S	83	26	B	25	11	1.5	S	60
28	1 E	17	F	1180927	341611	6	N	47	15	B	3.5	15	3	G	4
28	1 E	18	F	1175803	341779	6	S	44	22	B	4.5	25		S	2
28	1 E	19	P	1175657	333838	6	S	105	65	B	4	30	2	S	3
28	1 E	21	R	1188538	333515	8	S	432	362	P	200	1	24	S	1000
28	1 E	21		1186558	335495	8	S	503	366	P	303	74	15	SG	300
28	1 E	21		1186558	335495	8	S	46	8	P	60	34	6.5	SG	30
28	1 E	22		1191651	335349	6	N	376	65	B	17	30	13	SG	90
28	1 E	23	J	1198711	334562	6	S	88	3	B	38	28	1.5	S	60
28	1 E	24	P	1201137	333137	6	N	47	32	B	5	6	4	SG	6
28	1 E	26	N	1163815	328780	6	S	109	72	B	30	10	2	SG	60
28	1 E	27	G	1192210	330783	6	N	297	115	B	18	30	2	G	50
28	1 E	27	G	1192210	330783	10	S	408	315	P	100	38	24	S	100
28	1 E	33	M	1184354	324336	6	N	80	F	B	3	45	4	SG	3

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange		Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock,Shale, Dry Hole	Potential Well Yield gpm
28	1	E	33	P	1185674	323016	6	N	98	54	P	14	1	4	S	300
28	1	E	34	M	1189457	324227	8	S	273	162	P	150	54	8	SG	200
28	1	E	35	L	1195852	324114	6	S	253	200	B	3	40	6	S	2
28	1	W	1	D	1169620	353861	6	S	151	109	B	12	13	2	S	20
28	1	W	2	C	1165701	353964	6	S	117	100	B	13	6		SG	20
28	1	W	2	N	1164381	350004	6	S	47	8	A	30	42	1	SG	10
28	1	W	3	K	1161738	351408	6	N	189	F	B	10	1	4	SG	900
28	1	W	4	K	1156421	351477	6	N	225	40	B	12	40	2	SH	30
28	1	W	6	J	1147048	351594	6	S	202	183	B	12	1	1	SG	100
28	1	W	8	L	1149627	346224	6	N	187	136	B	12	20	1	SG	20
28	1	W	10	P	1160271	344770	6	S	149	97	B	10	23	1	S	10
28	1	W	11	L	1165546	346005	6	S	233	207	B	15	5		S	40
28	1	W	12	A	1173420	348542		N	120	30	B	36	3	1	SG	500
28	1	W	15	B	1161455	343422	6	S	341	253	B	17	13	2	SG	60
28	1	W	16	N	1153516	339537	6	N	47	3	B	7	1		S	200
28	1	W	20		1150079	336304	6	P	23	F	B	3	28		SH	1
28	1	W	21	D	1153406	338208	6	N	57	32	P	3	22	3	S	2
28	1	W	22	H	1162650	336805	6	S	81	28	B	1	44	8	S	1
28	1	W	29	H	1151974	331696	6	N	77	21	B	0.5	34		SH	0
28	1	W	30		1144679	331112	6	S	91	19	B	30	45		S	20
28	1	W	32	K	1150567	325110	6	N	187	F	F	5	8		SH	60
28	1	W	33	D	1153211	327662	12	P	44	18	P	50	15	1	SH	40
28	1	W	34	N	1158465	323605	6	N	97	56	B	40	20	1.5	G	40

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange	Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock,Shale, Dry Hole	Potential Well Yield gpm
28	2 W	2	J	1136363	351722	6	N	24		B	20	4		G	60
28	2 W	13	N	1137524	339740	6	N	240		B	3	1		SH	400
28	2 W	14	H	1136155	342456	6	S	26	3	B	15	6	2	SG	30
28	2 W	22	B	1129435	338582	6	N	38	15	B	8	23	1.5	G	4
28	2 W	23	Q	1134756	334543	6	N	81	2	B	10	10	3	G	40
28	2 W	25	Q	1140011	329204	6	N	305	5	B	1	205	0.5	SH	1
28	2 W	26	B	1134678	333236	6	N	335	144	B	2.5	176	4	SH	1
28	2 W	36	D	1137295	327903	6	N	40	17	B	40	13	2	G	40
29	1 E	3		1193191	383186	6	S	53	39	B	14	1	2	SH	100
29	1 E	4	C	1187518	385329	6	P	73	44	B	4	30	1	SH	2
29	1 E	4		1188178	383349	6	P	22	1	B	3	1		B	6
29	1 E	6	P	1177264	381666	6	P	54	0	F	0.3	10		B	0
29	1 E	7		1177723	378337	8	S	50		B	30	40	2	SG	20
29	1 E	7	M	1175743	377677	6	N	44	1	B	7	25	2	G	6
29	1 E	8	J	1184870	377520	6	N	112	82	B	5	22	0.5	G	3
29	1 E	9	D	1186016	379990	6	S	125	122	B	15	7		SG	3
29	1 E	10		1193032	377838	6	S	24	14	B	9	24		S	2
29	1 E	11	D	1196042	379656	8		112	19	P	55	71	4	SG	40
29	1 E	11	Q	1198682	375696	6	P	180	179	B	2	30	1	G	0
29	1 E	15	K	1193508	371799	6	S	96	80	B	20	10	2	S	20
29	1 E	17	A	1184654	374834	6	S	56	35	B	7	15	4	S	5
29	1 E	18	Q	1178180	371045	6	N	135	74	B	10	56	0.15	SH	5
29	1 E	19	R	1179304	365729	6	S	95	92	B	20	20	2	S	2

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange	Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock, Shale, Dry Hole	Potential Well Yield gpm
29	1 E	28	N	1185362	360003	6	S	31	4	P	12	30	26	SG	5
29	1 E	29	R	1184240	360222	6	P	56	20	B	6	135	1	B	0
29	1 E	31	A	1178933	359046	6	N	81	60	B	5	81	2	SH	1
29	1 E	32	H	1184052	357539	6	P	100	40	B	5	80	1.5	B	0
29	1 E	33	N	1185168	354678	6	S	47	2	B	7	7	1	SH	20
29	1 W	2	R	1169450	381925	16	P	87	71	P	200	21	168	SH	80
29	1 W	3	K	1162865	383366	12	P	48	45	P	400	1		G	600
29	1 W	3	K	1162865	383366	12	P	180	38	P	720	20		SG	1000
29	1 W	5	A	1153581	386252	6	S	199	74	B	5	20	2	S	20
29	1 W	8	B	1152047	380891	6	P	100	68	P	7	70	2	SH	2
29	1 W	9	A	1158683	380786	6	S	42	4	P	15	35	4	SG	8
29	1 W	10	R			6	N	100	35	B	25	55	1.5	G	10
29	1 W	12	H	1174493	379133	6	P	64		B	4	100	2	SH	1
29	1 W	13	P	1171658	371183	6	P	278	26	B	20	40	0.5	S	60
29	1 W	14	N	1165092	371296	6	S	110	13	B	34	43	6	SG	40
29	1 W	15	F	1161133	374032	6	S	36	2	B	45	15	1	SG	50
29	1 W	16	A	1158464	375435	5	S	33	10	B	2	23		SG	1
29	1 W	17		1151155	373535	6	N	180	120	B	35	10	1.5	G	100
29	1 W	19	M	1143609	367587	6	N	95	32	P	50	50	3	SH	30
29	1 W	22	R	1163576	366068	12	P	50	F	P	250	11		SH	600
29	1 W	22		1161596	368048	6	N	84	F	B	20	44	1	SG	20
29	1 W	23	F	1166222	368617	6	S	76	39	A	30	37		SG	20
29	1 W	24	L	1171468	367188	10	P	50	24	P	200	2		SG	1000

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange	Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock, Shale, Dry Hole	Potential Well Yield gpm
29	1 W	25	L	1171285	361867	6	P	29	21	B	50	1	2	SG	200
29	1 W	26	M	1164719	361973	5	S	19	3	P	14	10	1.5	SG	10
29	1 W	27		1161412	362720	6	S	89	40	B	40	10		S	100
29	1 W	27	E	1159432	363380	6	S	247	233	B	7	3	3.5	S	20
29	1 W	30		1145392	362909	6	N	151	8	B	24	1		B	300
29	1 W	31		1145218	357576	6	N	43	5	P	3	17	1	SG	3
29	1 W	32	H	1152553	358181	6	N	284	80	B	3	200	2	B	0
29	1 W	33	R	1157898	355482	6	N	251	168	B	5	42	1	G	5
29	1 W	34	E	1159259	358053	6	S	195	118	B	20	5	2	SH	200
29	1 W	35	Q	1167185	355328	6	S	163	131	B	15	9	5	SH	30
29	1 W	36	Q	1172428	355224	6	S	20	2	B	15	6	1	S	20
29	2 W	3	D	1128311	386820	6	N	29	11	B	6	1	1.5	G	50
29	2 W	4		1124995	385006	6	N	330	140	B	60	80	1	B	10
29	2 W	12		1140733	379151	6	S	78	58	B	5	20	4.5	SG	3
29	2 W	13	Q	1141143	371743	6	S	86	65	B	25	6	1	SG	40
29	2 W	23	A	1136889	370390	6	N	115	A	B	12	105	1	SH	7
29	2 W	24	G	1140901	368977	6	S	108	82	B	5	19	3	SG	3
29	2 W	25	M	1138058	362306	6	S	70	20	B	60	10	1	SH	200
29	2 W	26	E	1132718	363690	6	N	140	10	B	10	130	1.5	R	1
30	1 E	8		1152094	410358	6	S	240	185	B	18	2	3	S	200
30	1 E	9	N	1186877	407612	6	N	70	60	P	7	5	1.5	SG	7
30	1 E	18	J	1180489	403903	6	N	195	142	B	20	3	2.5	G	200
30	1 E	17		1183647	404423	6	S	265	224	B	20	2	4	S	200

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange	Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock,Shale, Dry Hole	Potential Well Yield gpm
30	1 E	18		1178509	404563	6	S	91	83	B	10	5		S	8
30	1 E	19		1178380	399386	6	S	108	98	B	5	6	2	S	4
30	1 E	20	F	1182865	399901	6	S	136	127	B	10	1	0.5	S	50
30	1 E	20	P	1182865	397261	6	S	64	63	P	30	1	0.5	S	20
30	1 E	21	N	1186616	397100	6	S	75	70	P	15	6	1	SG	6
30	1 E	23		1198580	398870	6	S	82	74	B	5	1	2	S	20
30	1 E	28		1188477	393889	6	S	103	93	B	6	10	3	S	3
30	1 E	28	D	1186497	395869	6	S	99	94	B	8	1	3	SG	20
30	1 E	29	K	1184060	393391	6	S	40	38	B	6	1	4	G	6
30	1 E	29		1183400	394051	6	S	32	23	P	20	12	4	SG	8
30	1 E	29	A	1153838	396727	6	S	118	107	B	3	7	3	SG	2
30	1 E	32	D	1181281	390785	6	N	185	16	P	7	1		SH	600
30	1 E	33		1188341	388650	8	S	158	100	P	158	28	5.5	S	200
30	1 W	5	E	1150231	416293	6	S	265	207	B	12	30	2	S	10
30	1 W	6	L	1146216	415094	6	S	156	130	B	14	14	3	S	10
30	1 W	7	M	1144787	409811	6	S	125	11	B	22	8	2	SG	200
30	1 W	8	F	1151434	411018	6	S	274	181	B	13	60		S	10
30	1 W	9		1188857	409592	6	S	314	288	B	10	3	2	S	40
30	1 W	10		1162882	410131	6	S	233	182	A	30	1	1	S	800
30	1 W	16	P	1156693	403054	6	S	245	190	B	40	1	2	S	1000
30	1 W	17	H	1153983	405775	6	S	245	197	B	20	16	4	S	30
30	1 W	18	M	1144694	404569	8	S	273	258	P	184	19	12	SG	70
30	1 W	18		1146674	405229	6	N	178	145	A	30	1	1	G	500

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange		Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock, Shale, Dry Hole	Potential Well Yield gpm
30	1	W	20	M	1149952	399256	6	N	152	77	B	20	20	3	SH	40
30	1	W	21		1157269	399821	6	S	276	242	N	15	29		S	9
30	1	W	22	Q	1163271	397769	8	S	250	190		11	33	39	S	10
30	1	W	25	N	1171086	392346	6	N	92	72	B	20	15	0.5	G	10
30	1	W	26	N	1165826	392462	6	S	171	147	P	50	16	2	S	40
30	1	W	27		1162504	394531	8	S	458	322	P	203	77	10	SG	200
30	1	W	28	C	1156529	396613	6	N							D	0
30	1	W	29	G	1152518	395407	6	P	223	157	P	3	125	4	S	1
30	1	W	31	B	1147080	391668	6	S	145	133	B	10	1	1	S	60
30	1	W	33	M			8	S	143	93	P	30	23	24	SG	30
30	1	W	34	J	1164357	388645	6	N	146	102	P	20	24	4	SG	20
30	1	W	35		1167651	389186	6	S	147	125	P	40	5	8	S	90
30	2	W	12	Q	1142124	408637		P	203	168	B	60	7		SG	200
30	2	W	13	R	1143335	403397		P	311	250	B	60	5		SG	400
30	2	W	24	C	1140601	402165	6	S	300	230	B	10	50	1.5	S	7
30	2	W	27	M	1128539	394710	6	N	128	65	P	20	33		SG	20
30	2	W	28		1125219	395575	8	S	314	108	P	258	112	13	SG	200
30	2	W	28	P	1124559	393595	10	S	222	134	P	100	8	4	SH	600
30	2	W	32	N	1117853	388528	6	S	125	122	B	12	1	0.5	S	20
30	2	W	33	H	1127093	390979	6	P	96	69	B	5	23	3	SG	3
30	2	W	34		1130416	390143	6	P	136	6	B	2	130	1	SH	1
30	2	W	35	F	1135080	390640	6	N	50	12	B	7	50		SH	3
31	1	W	18	B	1147995	439106	6	S	222	136	B	10	50	2	SG	9

Table A-1
(Continued)

Location Data						Well Data				Pump Test Data				Hydrogeologic Data	
Town-Ship	ange		Sec	Sub	Approximate Location State Plane Coords N	E	Dia in	Scrn Perf, or None	Depth Top Water Zone ft	Depth to Water ft	Pump, Bail, or Air Lift	Rate gpm	Draw-down ft	Period hrs	Aquifer: Sand, Gravel Basalt, Rock, Shale, Dry Hole	Potential Well Yield gpm
31	1	W	28		1157831	426148	6	S	127	106	B	20	2	2	SH	100
31	1	W	33	G	1158383	421479	6	N	30	9	B	12	30	1.5	SG	4
31	1	W	34	G	1163785	421360	6	S	20	10	B	30	5	1	SG	30

Table A-2 May 19, 1994

Recharge in Jefferson County by Section

Location Data			Input Data					Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
25	1W	2	5	5	3.8	46	15%	21.75	108	19.90	99	5
25	1W	3	5	5	3.8	45	45%	20.97	312	19.21	286	5
25	1W	4	5	5	3.8	44	60%	20.21	401	18.51	367	5
25	1W	5	5	5	3.8	44	20%	20.21	134	18.51	122	5
25	2W	2	5	1	3.5	47	50%	2.00	33	1.00	17	1
25	2W	3	5	1	3.5	51	100%	2.00	66	1.00	33	1
25	2W	4	5	1	3.5	59	100%	2.00	66	1.00	33	1
25	2W	5	5	1	3.5	62	100%	2.00	66	1.00	33	1
25	2W	6	5	1	3.5	68	100%	2.00	66	1.00	33	1
25	2W	7	5	1	3.5	68	100%	2.00	66	1.00	33	1
25	2W	8	5	1	3.5	62	100%	2.00	66	1.00	33	1
25	2W	9	5	1	3.5	59	100%	2.00	66	1.00	33	1
25	2W	10	5	1	3.5	45	100%	2.00	66	1.00	33	1
25	2W	11	5	1	3.5	47	20%	2.00	13	1.00	7	1
25	2W	14	5	1	3.5	47	10%	2.00	7	1.00	3	1
25	2W	15	5	1	3.5	48	90%	2.00	60	1.00	30	1
25	2W	16	5	1	3.5	51	100%	2.00	66	1.00	33	1
25	2W	17	5	1	3.5	60	100%	2.00	66	1.00	33	1
25	2W	18	5	1	3.5	66	100%	2.00	66	1.00	33	1
25	2W	19	5	1	3.5	66	100%	2.00	66	1.00	33	1
25	2W	20	5	1	3.5	59	100%	2.00	66	1.00	33	1
25	2W	21	5	1	3.5	50	50%	2.00	33	1.00	17	1
25	2W	22	5	1	3.5	48	25%	2.00	17	1.00	8	1
25	2W	23	5	1	3.5	48	5%	2.00	3	1.00	33	1
25	2W	28	5	1	3.5	50	20%	2.00	13	1.00	7	1

Table A-2

(Continued)

Location Data			Input Data					Recharge Rate	Recharge Amount	Recharge Rate	Recharge Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
25	2W	29	5	1	3.5	49	80%	2.00	53	1.00	26	1
25	2W	30	5	1	3.5	62	100%	2.00	66	1.00	33	1
25	2W	31	5	1	3.5	60	70%	2.00	46	1.00	23	1
25	2W	32	5	1	3.5	58	10%	2.00	7	1.00	3	1
26	1W	1	9	5	3.8	38	30%	16.22	161	14.80	147	4
26	1W	2	9	5	3.8	39	100%	16.93	560	15.47	512	4
26	1W	3	9	5	3.8	39	80%	16.93	448	15.47	409	4
26	1W	5	7	5	3.8	47	5%	22.52	37	20.60	34	6
26	1W	6	7	5	3.8	48	5%	23.30	39	21.34	35	6
26	1W	7	5	1	3.5	47	45%	2.00	30	1.00	15	1
26	1W	9	9	5	3.8	40	10%	17.64	58	16.15	53	5
26	1W	10	9	5	3.8	39	95%	16.93	532	15.47	486	4
26	1W	11	9	5	3.8	39	100%	16.93	560	15.47	512	4
26	1W	12	9	5	3.8	38	5%	16.22	27	14.80	24	4
26	1W	13	9	5	3.8	39	5%	16.93	28	15.47	26	4
26	1W	14	9	5	3.8	39	75%	16.93	420	15.47	384	4
26	1W	15	9	5	3.8	40	100%	17.64	583	16.15	534	5
26	1W	16	9	5	3.8	41	50%	18.37	304	16.82	278	5
26	1W	18	5	1	3.5	46	40%	2.00	26	1.00	13	1
26	1W	21	9	5	3.8	41	45%	18.37	273	16.82	250	5
26	1W	22	9	5	3.8	41	95%	18.37	577	16.82	528	5
26	1W	23	9	5	3.8	40	5%	17.64	29	16.15	27	5
26	1W	27	9	5	3.8	43	90%	19.47	579	18.18	541	5
26	1W	28	9	5	3.8	43	80%	19.47	515	18.18	481	5
26	1W	29	9	5	3.8	43	10%	19.47	64	18.18	60	5

Table A-2

(Continued)

Location Data			Input Data					Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
26	1W	32	9	5	3.8	44	40%	20.21	267	18.51	245	5
26	1W	33	9	5	3.8	44	100%	20.21	668	18.51	612	5
26	1W	34	9	5	3.8	44	100%	20.21	668	18.51	612	5
26	1W	35	9	5	3.8	45	15%	20.97	104	19.21	95	5
26	2W	1	5	1	3.5	50	95%	2.00	63	1.00	31	1
26	2W	2	5	1	3.5	54	100%	2.00	66	1.00	33	1
26	2W	3	5	1	3.5	58	100%	2.00	66	1.00	33	1
26	2W	4	5	1	3.5	60	100%	2.00	66	1.00	33	1
26	2W	5	5	1	3.5	62	100%	2.00	66	1.00	33	1
26	2W	6	5	1	3.5	63	100%	2.00	66	1.00	33	1
26	2W	7	5	1	3.5	64	100%	2.00	66	1.00	33	1
26	2W	8	5	1	3.5	63	100%	2.00	66	1.00	33	1
26	2W	9	5	1	3.5	61	100%	2.00	66	1.00	33	1
26	2W	10	5	1	3.5	58	100%	2.00	66	1.00	33	1
26	2W	11	5	1	3.5	53	100%	2.00	66	1.00	33	1
26	2W	12	5	1	3.5	49	100%	2.00	66	1.00	33	1
26	2W	13	5	1	3.5	49	75%	2.00	50	1.00	25	1
26	2W	14	5	1	3.5	53	100%	2.00	66	1.00	33	1
26	2W	15	5	1	3.5	58	100%	2.00	66	1.00	33	1
26	2W	16	5	1	3.5	61	100%	2.00	66	1.00	33	1
26	2W	17	5	1	3.5	63	100%	2.00	66	1.00	33	1
26	2W	18	5	1	3.5	65	100%	2.00	66	1.00	33	1
26	2W	19	5	1	3.5	67	100%	2.00	66	1.00	33	1
26	2W	20	5	1	3.5	64	100%	2.00	66	1.00	33	1
26	2W	21	5	1	3.5	61	100%	2.00	66	1.00	33	1

Table A-2

(Continued)

Location Data				Input Data				Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
26	2W	22	5	1	3.5	58	100%	2.00	66	1.00	33	1
26	2W	23	5	1	3.5	61	100%	2.00	66	1.00	33	1
26	2W	24	5	1	3.5	48	20%	2.00	13	1.00	7	1
26	2W	26	5	1	3.5	50	95%	2.00	63	1.00	31	1
26	2W	27	5	1	3.5	55	100%	2.00	66	1.00	33	1
26	2W	28	5	1	3.5	60	100%	2.00	66	1.00	33	1
26	2W	29	5	1	3.5	64	100%	2.00	66	1.00	33	1
26	2W	30	5	1	3.5	68	100%	2.00	66	1.00	33	1
26	2W	31	5	1	3.5	68	100%	2.00	66	1.00	33	1
26	2W	32	5	1	3.5	64	100%	2.00	66	1.00	33	1
26	2W	33	5	1	3.5	60	100%	2.00	66	1.00	33	1
26	2W	34	5	1	3.5	54	100%	2.00	66	1.00	33	1
26	2W	35	5	1	3.5	50	50%	2.00	33	1.00	17	1
27	1E	2	8	5	3.8	32	5%	12.54	21	11.38	19	3
27	1E	3	8	5	3.8	32	5%	12.54	21	11.38	19	3
27	1E	4	9	5	3.8	33	15%	12.98	64	12.03	60	4
27	1E	5	9	5	3.8	34	100%	13.38	442	12.69	419	4
27	1E	6	9	5	3.8	35	100%	14.09	466	13.09	433	4
27	1E	7	9	5	3.8	35	100%	14.09	466	13.09	433	4
27	1E	8	9	5	3.8	34	100%	13.38	442	12.69	419	4
27	1E	9	9	5	3.8	34	30%	13.38	133	12.69	126	4
27	1E	16	9	5	3.8	34	30%	13.38	133	12.69	126	4
27	1E	17	9	5	3.8	34	95%	13.38	420	12.69	398	4
27	1E	18	9	5	3.8	35	100%	14.09	466	13.09	433	4
27	1E	19	9	5	3.8	36	90%	14.80	440	13.46	400	4

(Continued)

Location Data			Input Data					Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
27	1E	20	9	5	3.8	35	20%	14.09	93	13.09	87	4
27	1W	1	9	5	3.8	36	100%	14.80	489	13.46	445	4
27	1W	2	9	5	3.8	37	100%	15.51	513	14.13	467	4
27	1W	3	9	5	3.8	40	100%	17.64	583	16.15	534	5
27	1W	4	9	5	3.8	42	100%	18.74	620	17.49	578	5
27	1W	5	7	5	3.8	43	100%	19.47	644	18.18	601	5
27	1W	6	7	2	5.2	45	100%	20.04	663	18.25	603	5
27	1W	7	7	2	5.2	45	100%	20.04	663	18.25	603	5
27	1W	8	7	5	3.8	44	100%	20.21	668	18.51	612	5
27	1W	9	7	5	3.8	42	45%	18.74	279	17.49	260	5
27	1W	10	9	5	3.8	40	100%	17.64	583	16.15	534	5
27	1W	11	9	5	3.8	37	100%	15.51	513	14.13	467	4
27	1W	12	9	5	3.8	36	100%	14.80	489	13.46	445	4
27	1W	13	9	5	3.8	36	100%	14.80	489	13.46	445	4
27	1W	14	9	5	3.8	38	100%	16.22	536	14.80	489	4
27	1W	15	9	5	3.8	40	95%	17.64	554	16.15	507	5
27	1W	16	9	5	3.8	41	10%	18.37	61	16.82	56	5
27	1W	17	7	5	3.8	44	100%	20.21	668	18.51	612	5
27	1W	18	7	2	5.2	47	100%	21.63	715	19.67	650	5
27	1W	19	7	5	3.8	47	35%	22.52	261	20.60	238	6
27	1W	20	7	5	3.8	45	90%	20.97	624	19.21	571	5
27	1W	21	7	5	3.8	40	5%	17.64	29	16.15	27	5
27	1W	22	9	5	3.8	40	80%	17.64	467	16.15	427	5
27	1W	23	9	5	3.8	38	100%	16.22	536	14.80	489	4
27	1W	24	9	5	3.8	37	100%	15.51	513	14.13	467	4

Table A-2

(Continued)

Location Data				Input Data				Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
27	1W	25	9	5	3.8	37	55%	15.51	282	14.13	257	4
27	1W	26	9	5	3.8	38	100%	16.22	536	14.80	489	4
27	1W	27	9	5	3.8	39	50%	16.93	280	15.47	256	4
27	1W	28	7	5	3.8	39	10%	16.93	56	15.47	51	4
27	1W	29	7	5	3.8	45	100%	20.97	693	19.21	635	5
27	1W	30	7	5	3.8	47	20%	22.52	149	20.60	136	6
27	1W	31	7	5	3.8	47	45%	22.52	335	20.60	307	6
27	1W	32	7	5	3.8	45	70%	20.97	485	19.21	444	5
27	1W	33	7	5	3.8	44	5%	20.21	33	18.51	31	5
27	1W	34	9	5	3.8	39	50%	16.93	280	15.47	256	4
27	1W	35	9	5	3.8	38	100%	16.22	536	14.80	489	4
27	1W	36	9	5	3.8	37	60%	15.51	308	14.13	280	4
27	2W	1	5	2	5.2	47	100%	21.63	715	19.67	650	5
27	2W	2	5	6	2.9	49	100%	2.00	66	1.00	33	1
27	2W	3	5	6	2.9	51	100%	2.00	66	1.00	33	1
27	2W	4	5	6	2.9	52	100%	2.00	66	1.00	33	1
27	2W	5	5	6	2.9	53	100%	2.00	66	1.00	33	1
27	2W	6	5	6	2.9	54	100%	2.00	66	1.00	33	1
27	2W	7	5	6	2.9	56	100%	2.00	66	1.00	33	1
27	2W	8	5	6	2.9	54	100%	2.00	66	1.00	33	1
27	2W	9	5	6	2.9	53	100%	2.00	66	1.00	33	1
27	2W	10	5	6	2.9	52	100%	2.00	66	1.00	33	1
27	2W	11	5	6	2.9	51	100%	2.00	66	1.00	33	1
27	2W	12	5	2	5.2	48	100%	22.42	741	20.42	675	6
27	2W	13	5	2	5.2	50	100%	24.00	794	21.92	725	6

Table A-2

(Continued)

Location Data			Input Data					Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
27	2W	14	5	6	2.9	52	100%	2.00	66	1.00	33	1
27	2W	15	5	6	2.9	53	100%	2.00	66	1.00	33	1
27	2W	16	5	6	2.9	54	100%	2.00	66	1.00	33	1
27	2W	17	5	6	2.9	56	100%	2.00	66	1.00	33	1
27	2W	18	5	6	2.9	58	100%	2.00	66	1.00	33	1
27	2W	19	5	6	2.9	60	100%	2.00	66	1.00	33	1
27	2W	20	5	6	2.9	59	100%	2.00	66	1.00	33	1
27	2W	21	5	6	2.9	56	100%	2.00	66	1.00	33	1
27	2W	22	5	6	2.9	54	100%	2.00	66	1.00	33	1
27	2W	23	5	6	2.9	53	100%	2.00	66	1.00	33	1
27	2W	24	5	6	2.9	50	100%	2.00	66	1.00	33	1
27	2W	25	5	1	3.5	50	100%	2.00	66	1.00	33	1
27	2W	26	5	1	3.5	54	100%	2.00	66	1.00	33	1
27	2W	27	5	6	2.9	56	100%	2.00	66	1.00	33	1
27	2W	28	5	6	2.9	59	100%	2.00	66	1.00	33	1
27	2W	29	5	6	2.9	60	100%	2.00	66	1.00	33	1
27	2W	30	5	6	2.9	61	100%	2.00	66	1.00	33	1
27	2W	31	5	6	2.9	62	100%	2.00	66	1.00	33	1
27	2W	32	5	6	2.9	61	100%	2.00	66	1.00	33	1
27	2W	33	5	6	2.9	60	100%	2.00	66	1.00	33	1
27	2W	34	5	6	2.9	59	100%	2.00	66	1.00	33	1
27	2W	35	5	6	2.9	54	100%	2.00	66	1.00	33	1
27	2W	36	5	1	3.5	50	100%	2.00	66	1.00	33	1
28	1E	4	6	5	3.8	27	45%	9.09	135	8.39	125	3
28	1E	5	6	5	3.8	28	100%	9.78	323	8.77	290	3

Table A-2

(Continued)

Location Data				Input Data				Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
28	1E	6	6	4	21	29	100%	0.00	0	0.00	0	1
28	1E	7	6	5	3.8	30	100%	11.16	369	10.07	333	3
28	1E	8	6	5	3.8	29	100%	10.47	346	9.42	311	3
28	1E	9	6	5	3.8	28	50%	9.78	162	8.77	145	3
28	1E	10	8	5	3.8	28	20%	9.78	65	8.77	58	3
28	1E	15	8	5	3.8	28	85%	9.78	275	8.77	247	3
28	1E	16	8	5	3.8	29	30%	10.47	104	9.42	93	3
28	1E	17	8	6	2.9	30	80%	2.00	53	1.00	26	1
28	1E	18	6	5	3.8	31	100%	11.85	392	10.72	355	3
28	1E	19	8	6	2.9	32	100%	2.00	66	1.00	33	1
28	1E	20	8	6	2.9	31	100%	2.00	66	1.00	33	1
28	1E	21	8	5	3.8	30	100%	11.16	369	10.07	333	3
28	1E	22	8	5	3.8	29	90%	10.47	312	9.42	280	3
28	1E	26	8	5	3.8	30	60%	11.16	221	10.07	200	3
28	1E	27	8	5	3.8	31	100%	11.85	392	10.72	355	3
28	1E	28	8	5	3.8	31	100%	11.85	392	10.72	355	3
28	1E	29	8	6	2.9	32	100%	2.00	66	1.00	33	1
28	1E	30	8	6	2.9	33	100%	2.00	66	1.00	33	1
28	1E	31	8	5	3.8	34	100%	13.38	442	12.69	419	4
28	1E	32	8	5	3.8	33	100%	12.98	429	12.03	398	4
28	1E	33	8	5	3.8	32	100%	12.54	415	11.38	376	3
28	1E	34	8	5	3.8	32	100%	12.54	415	11.38	376	3
28	1E	35	8	5	3.8	31	95%	11.85	372	10.72	337	3
28	1W	1	6	5	3.8	30	100%	11.16	369	10.07	333	3
28	1W	2	6	5	3.8	31	100%	11.85	392	10.72	355	3

Table A-2

(Continued)

Location Data				Input Data				Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
28	1W	3	6	4	21	33	100%	0.00	0	0.00	0	1
28	1W	4	6	5	3.8	34	100%	13.38	442	12.69	419	4
28	1W	5	6	5	3.8	35	100%	14.09	466	13.09	433	4
28	1W	6	6	5	3.8	36	100%	14.80	489	13.46	445	4
28	1W	7	6	5	3.8	37	100%	15.51	513	14.13	467	4
28	1W	8	6	5	3.8	36	100%	14.80	489	13.46	445	4
28	1W	9	6	5	3.8	35	100%	14.09	466	13.09	433	4
28	1W	10	6	5	3.8	34	100%	13.38	442	12.69	419	4
28	1W	11	6	5	3.8	32	100%	12.54	415	11.38	376	3
28	1W	12	6	5	3.8	31	100%	11.85	392	10.72	355	3
28	1W	13	6	5	3.8	32	100%	12.54	415	11.38	376	3
28	1W	14	6	5	3.8	34	100%	13.38	442	12.69	419	4
28	1W	15	6	5	3.8	35	100%	14.09	466	13.09	433	4
28	1W	16	6	5	3.8	36	100%	14.80	489	13.46	445	4
28	1W	17	6	5	3.8	38	100%	16.22	536	14.80	489	4
28	1W	18	6	5	3.8	39	100%	16.93	560	15.47	512	4
28	1W	19	7	5	3.8	40	100%	17.64	583	16.15	534	5
28	1W	20	7	5	3.8	40	100%	17.64	583	16.15	534	5
28	1W	21	7	5	3.8	38	100%	16.22	536	14.80	489	4
28	1W	22	7	5	3.8	36	100%	14.80	489	13.46	445	4
28	1W	23	7	5	3.8	35	100%	14.09	466	13.09	433	4
28	1W	24	8	5	3.8	33	100%	12.98	429	12.03	398	4
28	1W	25	8	5	3.8	34	100%	13.38	442	12.69	419	4
28	1W	26	7	5	3.8	35	100%	14.09	466	13.09	433	4
28	1W	27	7	5	3.8	38	100%	16.22	536	14.80	489	4

Table A-2

(Continued)

Location Data			Input Data					Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
28	1W	28	7	5	3.8	39	100%	16.93	560	15.47	512	4
28	1W	29	7	5	3.8	40	100%	17.64	583	16.15	534	5
28	1W	30	7	2	5.2	43	100%	18.52	612	17.21	569	5
28	1W	31	7	2	5.2	44	100%	19.27	637	17.54	580	5
28	1W	32	7	2	5.2	42	100%	17.78	588	16.51	546	5
28	1W	33	7	5	3.8	40	100%	17.64	583	16.15	534	5
28	1W	34	7	5	3.8	38	100%	16.22	536	14.80	489	4
28	1W	35	7	5	3.8	36	100%	14.80	489	13.46	445	4
28	1W	36	8	5	3.8	35	100%	14.09	466	13.09	433	4
28	2W	1	7	5	3.8	37	100%	15.51	513	14.13	467	4
28	2W	2	5	5	3.8	38	100%	16.22	536	14.80	489	4
28	2W	3	5	6	2.9	38	100%	2.00	66	1.00	33	1
28	2W	4	5	6	2.9	39	100%	2.00	66	1.00	33	1
28	2W	5	5	6	2.9	39	100%	2.00	66	1.00	33	1
28	2W	6	5	6	2.9	39	100%	2.00	66	1.00	33	1
28	2W	7	5	6	2.9	42	100%	2.00	66	1.00	33	1
28	2W	8	5	6	2.9	42	100%	2.00	66	1.00	33	1
28	2W	9	5	6	2.9	41	100%	2.00	66	1.00	33	1
28	2W	10	5	6	2.9	40	100%	2.00	66	1.00	33	1
28	2W	11	5	5	3.8	39	100%	16.93	560	15.47	512	4
28	2W	12	7	2	5.2	38	100%	15.22	503	13.78	456	4
28	2W	13	7	2	5.2	40	100%	16.66	551	15.14	501	4
28	2W	14	5	5	3.8	43	100%	19.47	644	18.18	601	5
28	2W	15	5	6	2.9	44	100%	2.00	66	1.00	33	1
28	2W	16	5	6	2.9	45	100%	2.00	66	1.00	33	1

Table A-2

(Continued)

Location Data				Input Data				Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
28	2W	17	5	6	2.9	45	100%	2.00	66	1.00	33	1
28	2W	18	5	6	2.9	45	100%	2.00	66	1.00	33	1
28	2W	19	5	6	2.9	47	100%	2.00	66	1.00	33	1
28	2W	20	5	6	2.9	47	100%	2.00	66	1.00	33	1
28	2W	21	5	6	2.9	47	100%	2.00	66	1.00	33	1
28	2W	22	5	5	3.8	46	100%	21.75	719	19.90	658	5
28	2W	23	5	5	3.8	44	100%	20.21	668	18.51	612	5
28	2W	24	7	2	5.2	43	100%	18.52	612	17.21	569	5
28	2W	25	7	2	5.2	45	100%	20.04	663	18.25	603	5
28	2W	26	5	5	3.8	46	100%	21.75	719	19.90	658	5
28	2W	27	5	5	3.8	48	100%	23.30	770	21.34	705	6
28	2W	28	5	6	2.9	48	100%	2.00	66	1.00	33	1
28	2W	29	5	6	2.9	49	100%	2.00	66	1.00	33	1
28	2W	30	5	6	2.9	49	100%	2.00	66	1.00	33	1
28	2W	31	5	6	2.9	52	100%	2.00	66	1.00	33	1
28	2W	32	5	6	2.9	51	100%	2.00	66	1.00	33	1
28	2W	33	5	6	2.9	50	100%	2.00	66	1.00	33	1
28	2W	34	5	6	2.9	49	100%	2.00	66	1.00	33	1
28	2W	35	5	6	2.9	47	100%	2.00	66	1.00	33	1
28	2W	36	7	2	5.2	46	100%	20.83	689	18.95	627	5
29	1E	4	4	7	4.8	22	75%	5.24	130	4.48	111	2
29	1E	5	4	7	4.8	23	40%	5.90	78	5.10	67	2
29	1E	6	3	7	4.8	23	90%	5.90	176	5.10	152	2
29	1E	7	6	5	3.8	24	20%	7.34	49	6.50	43	2
29	1E	8	3	7	4.8	23	40%	5.90	78	5.10	67	2

Table A-2

(Continued)

Location Data			Input Data					Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
29	1E	9	4	7	4.8	23	90%	5.90	176	5.10	152	2
29	1E	16	4	7	4.8	23	20%	5.90	39	5.10	34	2
29	1E	17	4	7	4.8	23	5%	5.90	10	5.10	8	2
29	1E	18	6	5	3.8	24	50%	7.34	121	6.50	108	2
29	1E	19	6	5	3.8	25	60%	8.01	159	7.13	141	2
29	1E	29	6	5	3.8	26	40%	8.67	115	7.76	103	2
29	1E	30	6	5	3.8	27	100%	9.09	301	8.39	277	3
29	1E	31	6	5	3.8	28	100%	9.78	323	8.77	290	3
29	1E	32	6	5	3.8	27	100%	9.09	301	8.39	277	3
29	1E	33	6	5	3.8	26	60%	8.67	172	7.76	154	2
29	1W	1	6	7	4.8	23	25%	5.90	49	5.10	42	2
29	1W	2	6	3	3.5	24	95%	7.57	238	6.73	212	2
29	1W	3	6	3	3.5	24	100%	7.57	250	6.73	223	2
29	1W	4	6	3	3.5	24	100%	7.57	250	6.73	223	2
29	1W	5	6	3	3.5	25	40%	8.23	109	7.36	97	2
29	1W	7	6	3	3.5	27	15%	9.32	46	8.61	43	3
29	1W	8	6	5	3.8	26	45%	8.67	129	7.76	115	2
29	1W	9	6	5	3.8	26	100%	8.67	287	7.76	257	2
29	1W	10	6	5	3.8	25	100%	8.01	265	7.13	236	2
29	1W	11	6	3	3.5	25	100%	8.23	272	7.36	243	2
29	1W	12	6	5	3.8	24	100%	7.34	243	6.50	215	2
29	1W	13	6	5	3.8	25	100%	8.01	265	7.13	236	2
29	1W	14	6	4	21	26	100%	0.00	0	0.00	0	1
29	1W	15	6	5	3.8	27	100%	9.09	301	8.39	277	3
29	1W	16	6	5	3.8	27	100%	9.09	301	8.39	277	3

Table A-2

(Continued)

Location Data				Input Data				Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
29	1W	17	6	5	3.8	28	80%	9.78	259	8.77	232	3
29	1W	18	6	5	3.8	29	5%	10.47	17	9.42	16	3
29	1W	19	6	5	3.8	30	80%	11.16	295	10.07	266	3
29	1W	20	6	5	3.8	25	100%	8.01	265	7.13	236	2
29	1W	21	6	5	3.8	24	100%	7.34	243	6.50	215	2
29	1W	22	6	5	3.8	23	100%	6.68	221	5.89	195	2
29	1W	23	6	4	21	23	100%	0.00	0	0.00	0	1
29	1W	24	6	5	3.8	22	100%	6.02	199	5.27	174	2
29	1W	25	6	5	3.8	23	100%	6.68	221	5.89	195	2
29	1W	26	6	4	21	24	100%	0.00	0	0.00	0	1
29	1W	27	6	5	3.8	24	100%	7.34	243	6.50	215	2
29	1W	28	6	5	3.8	25	100%	8.01	265	7.13	236	2
29	1W	29	6	5	3.8	26	100%	8.67	287	7.76	257	2
29	1W	30	6	5	3.8	27	100%	9.09	301	8.39	277	3
29	1W	31	6	5	3.8	35	100%	14.09	466	13.09	433	4
29	1W	32	6	5	3.8	34	100%	13.38	442	12.69	419	4
29	1W	33	6	5	3.8	33	100%	12.98	429	12.03	398	4
29	1W	34	6	4	21	31	100%	0.00	0	0.00	0	1
29	1W	35	6	5	3.8	30	100%	11.16	369	10.07	333	3
29	1W	36	6	5	3.8	29	100%	10.47	346	9.42	311	3
29	2W	1	1	3	3.5	25	90%	8.23	245	7.36	219	2
29	2W	2	1	3	3.5	25	100%	8.23	272	7.36	243	2
29	2W	3	1	3	3.5	26	100%	8.89	294	7.98	264	2
29	2W	4	1	3	3.5	26	100%	8.89	294	7.98	264	2
29	2W	5	1	3	3.5	27	100%	9.32	308	8.61	285	3

Table A-2

(Continued)

Location Data			Input Data					Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
29	2W	6	1	3	3.5	27	100%	9.32	308	8.61	285	3
29	2W	7	1	6	2.9	29	100%	2.00	66	1.00	33	1
29	2W	8	1	6	2.9	28	100%	2.00	66	1.00	33	1
29	2W	9	1	6	2.9	28	100%	2.00	66	1.00	33	1
29	2W	10	1	6	2.9	27	100%	2.00	66	1.00	33	1
29	2W	11	1	3	3.5	27	100%	9.32	308	8.61	285	3
29	2W	12	1	3	3.5	27	100%	9.32	308	8.61	285	3
29	2W	13	1	3	3.5	28	80%	10.00	265	9.00	238	3
29	2W	14	1	5	3.8	29	100%	10.47	346	9.42	311	3
29	2W	15	1	6	2.9	30	100%	2.00	66	1.00	33	1
29	2W	16	1	6	2.9	31	100%	2.00	66	1.00	33	1
29	2W	17	1	6	2.9	32	100%	2.00	66	1.00	33	1
29	2W	18	1	6	2.9	33	100%	2.00	66	1.00	33	1
29	2W	19	1	6	2.9	35	100%	2.00	66	1.00	33	1
29	2W	20	1	6	2.9	34	100%	2.00	66	1.00	33	1
29	2W	21	1	6	2.9	34	100%	2.00	66	1.00	33	1
29	2W	22	1	6	2.9	33	100%	2.00	66	1.00	33	1
29	2W	23	1	5	3.8	32	100%	12.54	415	11.38	376	3
29	2W	24	6	5	3.8	31	50%	11.85	196	10.72	177	3
29	2W	25	6	5	3.8	33	100%	12.98	429	12.03	398	4
29	2W	26	1	5	3.8	34	100%	13.38	442	12.69	419	4
29	2W	27	1	6	2.9	35	100%	2.00	66	1.00	33	1
29	2W	28	1	6	2.9	36	100%	2.00	66	1.00	33	1
29	2W	29	1	6	2.9	36	100%	2.00	66	1.00	33	1
29	2W	30	1	6	2.9	37	100%	2.00	66	1.00	33	1

Table A-2

(Continued)

Location Data			Input Data					Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
29	2W	31	1	6	2.9	38	100%	2.00	66	1.00	33	1
29	2W	32	1	6	2.9	38	100%	2.00	66	1.00	33	1
29	2W	33	1	6	2.9	38	100%	2.00	66	1.00	33	1
29	2W	34	1	6	2.9	37	100%	2.00	66	1.00	33	1
29	2W	35	1	5	3.8	36	100%	14.80	489	13.46	445	4
29	2W	36	6	5	3.8	35	100%	14.09	466	13.09	433	4
30	1E	8	4	7	4.8	19	10%	3.27	11	2.84	9	1
30	1E	17	4	7	4.8	19	100%	3.27	108	2.84	94	1
30	1E	18	4	7	4.8	20	25%	3.93	32	3.24	27	1
30	1E	19	3	7	4.8	21	45%	4.58	68	3.86	57	1
30	1E	20	4	7	4.8	20	85%	3.93	110	3.24	91	1
30	1E	21	4	7	4.8	20	25%	3.93	32	3.24	27	1
30	1E	28	4	7	4.8	20	40%	3.93	52	3.24	43	1
30	1E	29	4	7	4.8	21	45%	4.58	68	3.86	57	1
30	1E	30	3	7	4.8	22	80%	5.24	139	4.48	118	2
30	1E	31	3	7	4.8	23	85%	5.90	166	5.10	143	2
30	1E	32	4	7	4.8	22	40%	5.24	69	4.48	59	2
30	1E	33	4	7	4.8	21	45%	4.58	68	3.86	57	1
30	1W	1	2	3	21	20	20%	0.00	0	0.00	0	1
30	1W	2	2	3	21	20	95%	0.00	0	0.00	0	1
30	1W	3	2	3	3.5	20	100%	4.97	164	4.29	142	2
30	1W	4	2	3	3.5	20	100%	4.97	164	4.29	142	2
30	1W	5	2	3	3.5	20	100%	4.97	164	4.29	142	2
30	1W	6	2	3	3.5	19	75%	4.33	107	3.69	92	1
30	1W	7	2	3	3.5	20	100%	4.97	164	4.29	142	2

Table A-2

(Continued)

Location Data			Input Data					Recharge				
								Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
30	1W	8	2	3	3.5	21	100%	5.61	186	4.90	162	2
30	1W	9	2	3	3.5	21	100%	5.61	186	4.90	162	2
30	1W	10	2	3	21	21	80%	0.00	0	0.00	0	1
30	1W	11	2	3	21	20	25%	0.00	0	0.00	0	1
30	1W	15	2	3	3.5	22	20%	6.25	41	5.51	36	2
30	1W	16	2	3	3.5	22	100%	6.25	207	5.51	182	2
30	1W	17	2	3	3.5	21	100%	5.61	186	4.90	162	2
30	1W	18	2	3	3.5	21	100%	5.61	186	4.90	162	2
30	1W	19	2	3	3.5	22	100%	6.25	207	5.51	182	2
30	1W	20	2	3	3.5	23	100%	6.91	228	6.12	202	2
30	1W	21	2	3	3.5	23	100%	6.91	228	6.12	202	2
30	1W	22	2	3	3.5	23	45%	6.91	103	6.12	91	2
30	1W	24	3	7	4.8	22	25%	5.24	43	4.48	37	2
30	1W	26	2	7	4.8	23	20%	5.90	39	5.10	34	2
30	1W	27	2	3	3.5	23	80%	6.91	183	6.12	162	2
30	1W	28	2	3	3.5	23	100%	6.91	228	6.12	202	2
30	1W	29	2	3	3.5	23	100%	6.91	228	6.12	202	2
30	1W	30	2	3	3.5	23	80%	6.91	183	6.12	162	2
30	1W	31	2	3	3.5	24	20%	7.57	50	6.73	45	2
30	1W	32	2	3	3.5	24	65%	7.57	163	6.73	145	2
30	1W	33	2	3	3.5	24	100%	7.57	250	6.73	223	2
30	1W	34	2	3	3.5	23	100%	6.91	228	6.12	202	2
30	1W	35	2	3	3.5	23	45%	6.91	103	6.12	91	2
30	1W	36	3	3	3.5	23	25%	6.91	57	6.12	51	2
30	2W	12	2	3	3.5	19	70%	4.33	100	3.69	85	1

(Continued)

Location Data				Input Data				Recharge Rate	Amount	Rate	Amount	
Town-Ship	Range	Section	Ass'mnt Region	Soil Ass'n	Ave. SMC in of H2O	Precip. in/yr	Percent of Section as Land	Runoff = 5% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Runoff = 10% of Precip. or Inf. Limited by Bedrock in/yr	gpm	Recharge Category
30	2W	13	2	3	3.5	21	70%	5.61	130	4.90	113	2
30	2W	24	2	3	3.5	22	55%	6.25	114	5.51	100	2
30	2W	27	1	3	3.5	23	15%	6.91	34	6.12	30	2
30	2W	28	2	3	3.5	22	95%	6.25	196	5.51	173	2
30	2W	33	2	3	3.5	24	100%	7.57	250	6.73	223	2
30	2W	34	1	3	3.5	24	100%	7.57	250	6.73	223	2
30	2W	35	1	3	3.5	24	80%	7.57	200	6.73	178	2
30	2W	36	1	3	3.5	24	20%	7.57	50	6.73	45	2
31	1W	32	2	3	3.5	19	40%	4.33	57	3.69	49	1
31	1W	33	2	3	3.5	19	55%	4.33	79	3.69	67	1
31	1W	34	2	3	3.5	19	85%	4.33	122	3.69	104	1
31	1W	35	2	3	3.5	19	85%	4.33	122	3.69	104	1

Table A-3

Eastern Jefferson County Groundwater Demand By Region

Area	Geographic Location	Population (1990)	Population (1993)	Significant Water Purveyor	Assumed GPCD	Estimated Water Use (MGD in 1993)	Estimated Percent Demand on GW*	Estimated Groundwater Demand (MGD)	Peak Day (MGD) (Factor 2.5)
1	Gardiner-Southwest Discovery Bay	363	390	PUD #1	150	0.06	100%	0.06	0.15
2	Greater Port Townsend	9458	10155	PT/PUD #1	150	1.52	26%	0.40	0.99
3	Indian Island	57	61	PT	150	0.01	0%	0.00	0.00
4	Marrowstone Island	737	791	Fort Flagler (PT)	150	0.12	80%	0.09	0.24
5	Western Foothills	1806	1939		150	0.29	100%	0.29	0.73
6	Tri-Area and South	5793	6220	Port Ludlow/PUD #1	150	0.93	62%	0.58	1.45
7	North Dabob Bay	453	486		150	0.07	100%	0.07	0.18
8	Ludlow/Shine	681	731	Port Ludlow/Bywater Bay	150	0.11	100%	0.11	0.27
9	Toandos Peninsula	382	410	WD #3	150	0.06	100%	0.06	0.15
Total Eastern Jefferson County Population			21185	Totals		3.18		1.66	4.16
1992 County Population Estimate(CWSP)			22536	1992 County-wide Groundwater Demand Estimate (CWSP)					4.38

*Population Served by Surface Water Distribution Estimated and Subtracted