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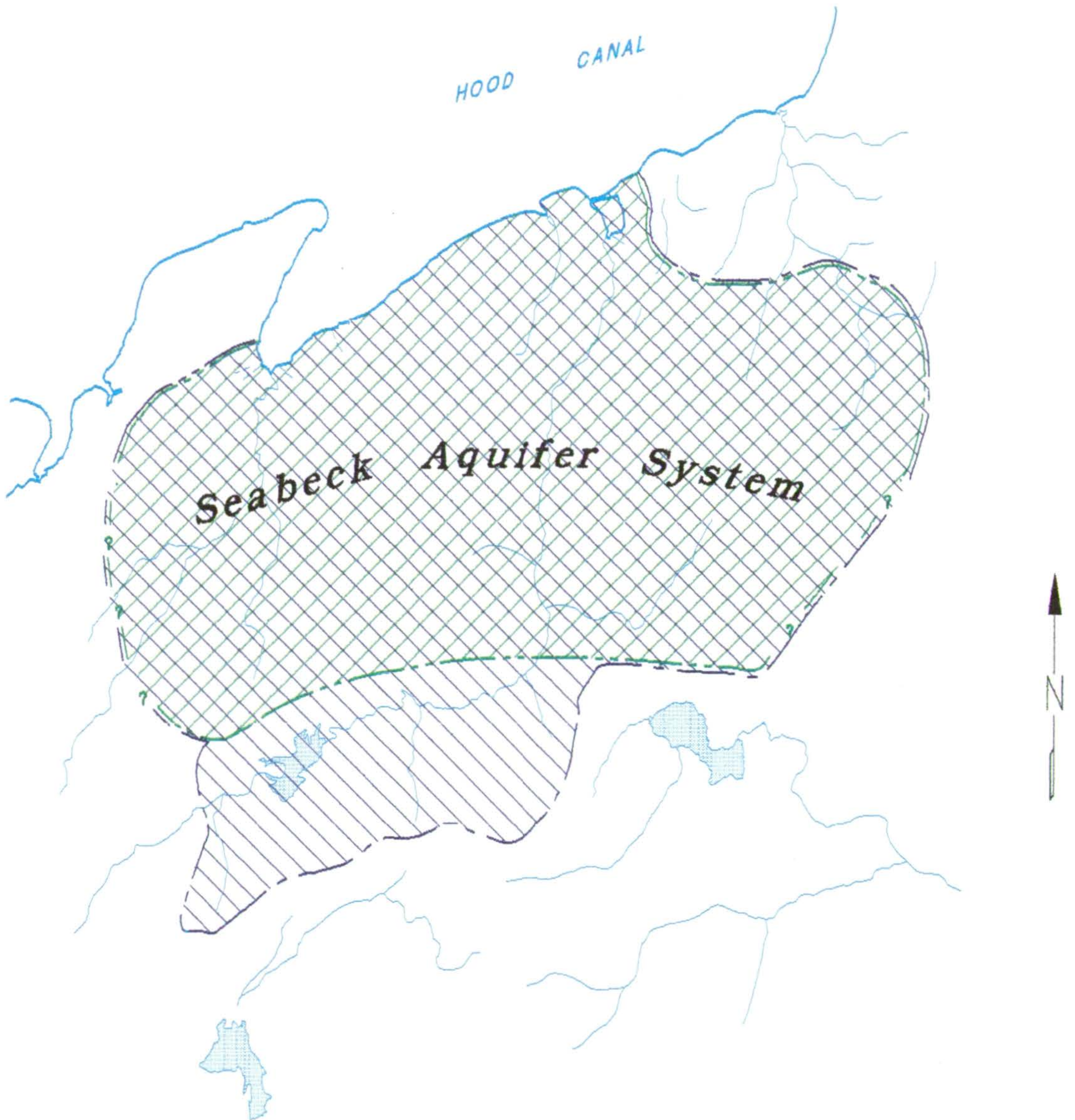
1996 Seabeck aquifer protection plan

96190589

# SEABECK AQUIFER PROTECTION PLAN
# PUBLIC UTILITY DISTRICT #1 OF KITSAP COUNTY

**April 1996**

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*Funded in part by **Washington State Department of Ecology** Centennial Clean Water Fund Grant #G9300318*

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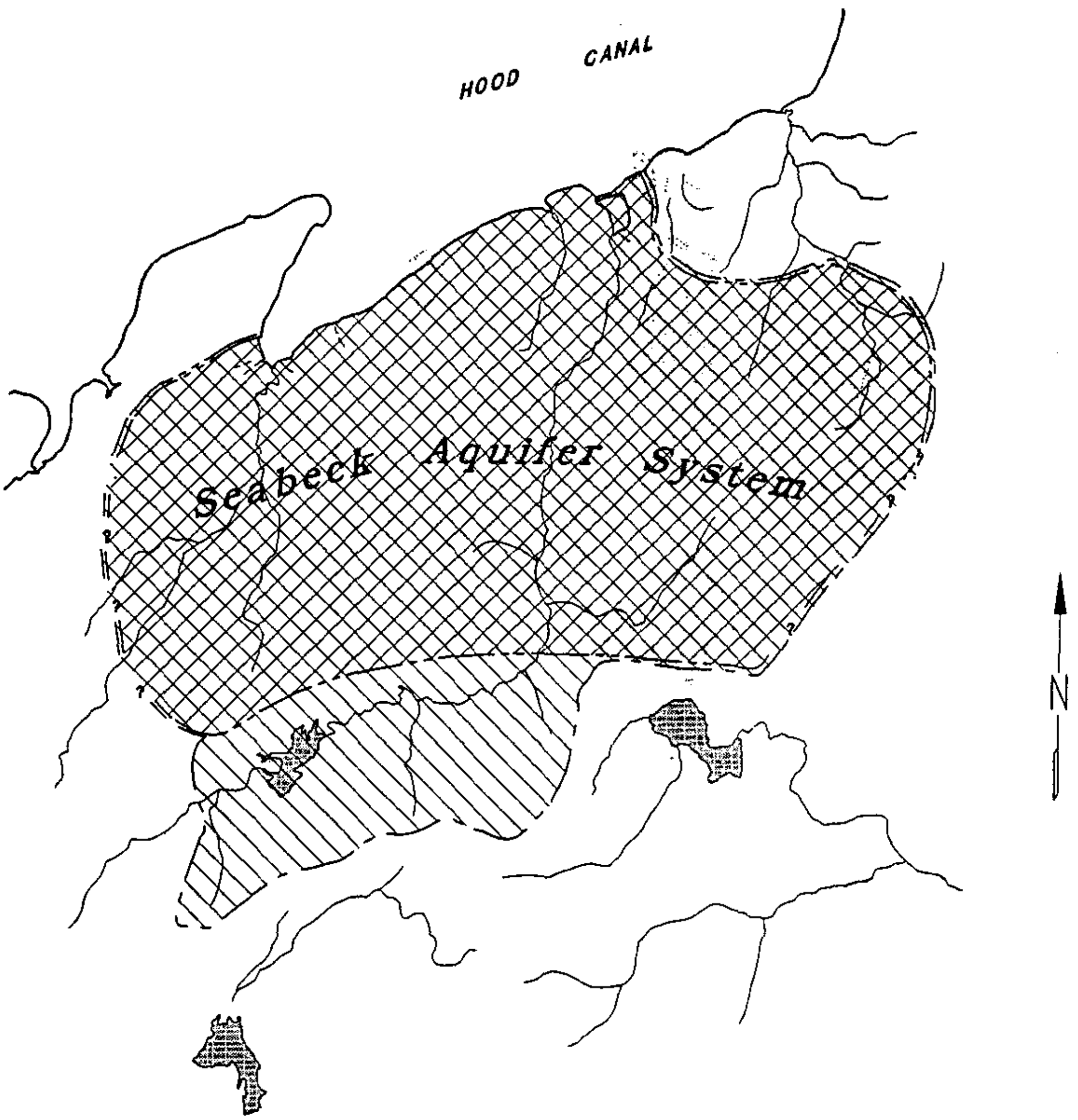



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1. EXECUTIVE SUMMARY

# PUBLIC UTILITY DISTRICT # 1 OF KITSAP COUNTY
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# EXECUTIVE SUMMARY

The Public Utility District #1 of Kitsap County (KPUD) developed an Aquifer Protection Plan to identify and protect the ground water resources in the Seabeck area. The plan was developed under the auspices of the Washington Department of Ecology Centennial Clean Water Funds Grant program Grant No. G900318. The study was divided into three primary areas of interest: 1) aquifer identification and characterization, 2) existing and potential contamination hazard identification, and 3) protection strategies and implementation tasks.

Aquifer identification and characterization were accomplished in order to develop explicit protection plans for the area. Aquifer definition included specific aquifer delineation, determination of ground water flow directions, and demarcation of aquifer recharge areas. Local and regional hydrogeology was evaluated using topographic, climatic, stratigraphic, and surficial geology data collected for a 27-square-mile area. A conceptual model was developed of both the aquifer system and the overlying and underlying geologic units. This model allowed for the specific definition and delineation of the Seabeck Aquifer System.

Once the Seabeck Aquifer System was delineated, existing and potential contamination sources were identified and the risks to the aquifer were evaluated. The review and identification of potential and known contamination threats consisted of evaluation of contaminant site databases developed by the EPA and Washington State Department of Ecology. Current and historic land use in the area was also examined. No existing threats to the aquifer were identified. However, several potential threats were found. All of the potential risk categories are considered minor and manageable. Those land use activities which pose a potential threat to the aquifer, in order of risk, are: 1) medium density residential development, 2) low density residential development, 3) transportation corridors, 4) industrial/commercial sites, 5) forestry practices, and 6) mining practices. Water quality in the Seabeck Aquifer System is generally high. Threats to the aquifer system appear to be typical of rural residential/forested land use and are relatively minor. Continued development under the existing county zoning designations can be managed in such a way that it will adequately protect the water quality of the Seabeck Aquifer System.

The protection plan includes 18 potential implementation tasks and a monitoring plan. The monitoring plan consists of a ground water monitoring network of 18 wells located throughout the aquifer area. This network will serve to generate basic information regarding the hydrogeology of the aquifer and also serve as a sentinel well network to alert the KPUD of existing contamination. The overall success of the protection plan is based upon monitoring of the system, active data collection and management by the District, and cooperation with those state and local agencies which regulate potential contaminants. The recommendations presented in this document provide for continuing assessment of risks and for updating this planning document. The critical piece of this plan is the development of an aquifer protection steering committee which will provide guidance and impetus to a continuing planning process. The steering committee will oversee the management of the aquifer area and see that the long-term commitment to protecting the existing water quality and quantity of the aquifer is maintained.

2. SEABECK AQUIFER PROTECTION PLAN

## Introduction

Kitsap Public Utility District (KPUD) and its consultant team have performed a hydrogeologic evaluation of the Seabeck Aquifer System and have inventoried the potential hazardous materials sites in the local area. The Seabeck Aquifer Protection Plan and associated studies were funded in part by the Department of Ecology Centennial Clean Water Funds Grant G9300318. The goal of the study is to provide a sufficient understanding of the ground water system, develop a plan to protect the integrity of the existing water quality of the aquifer, to manage the activities in proximity to the aquifer recharge area in order to prevent contamination where possible, and to affect a timely and appropriate response to possible contamination events. The overall plan incorporates the recommendations presented in this section, the Aquifer Protection Plan Implementation Tasks identified in the subsequent section, and the Ground Water Monitoring Plan developed in the Monitoring Program Section.

The Seabeck Aquifer System lies within a portion of Kitsap County identified as the Seabeck subarea. This subarea is one of eighteen study areas identified in the County's Ground Water Management Plan Volume III Draft (1995) and in the Kitsap County Initial Basin Assessment Draft (1995) (see Figure 1).

The subarea contains five major stream drainages (Little Beef, Johnson, Anderson, Big Beef and Seabeck). These drainages generally flow from south to north, from elevations near 400 feet above sea level to discharge points along Hood Canal. The subarea covers approximately 27 square miles (about 7% of the County) and is largely forested or covered with other natural vegetation. Two main transportation routes traverse the Seabeck area on the north and south edges of the basin, one along Hood Canal and the other passing from the Wildcat Lake area through the community of Camp Union. Two other routes traverse the subarea from north to south. The upper reaches of the streams in the subarea contain some marsh plateaus. The only large lake in the area is William Symington Lake, an artificial reservoir located in the Big Beef drainage.

## Protection Plan Philosophy

The information collected to date indicates that the quality and quantity of the ground water in the Seabeck Aquifer System are very good and constitute a valuable regional resource. Presently, development in the subarea does not appear to have had any negative impact on the region's water quantity and quality; however, future longer-term testing and monitoring is needed to provide a better assessment of the relationship between the resource and land use changes. The monitor plan developed as a portion of this study will provide a network of wells to collect the hydrogeologic data necessary to evaluate long-term changes in water quantity and quality. These wells will also serve as sentinel wells to provide warnings regarding emergent contamination of the ground water resource.

At the present time, the Seabeck subarea is sparsely developed but could be subjected to increased development in the future. Because the Seabeck Aquifer System represents a substantial, long-term resource for the County, the development of a plan to protect its integrity is prudent. Additionally, the expense incurred by the KPUD to develop and distribute this water represents a substantial investment which would be wasted should the resource become unusable.

The KPUD recognizes that responsible surface development can occur without harming the ground water resource if the development is managed according to appropriate guidelines. The Seabeck Aquifer Protection Plan is not designed to preclude development in the area, but it does identify and recommend management actions to avoid potential threats to the aquifer. Where practical, the plan allows for mitigation of threats.

## Seabeck Subarea Hydrogeology

Within the Seabeck subarea, three aquifer systems have been defined: the perched aquifer system, the Seabeck Aquifer System, and the bedrock aquifer system. A thorough description of the hydrogeology of the area may be found in the Hydrogeology Section. Brief summaries of the aquifer systems are given below.

### Perched Aquifer System

Perched aquifers occur where the downward movement of water is impeded by less permeable layers within the vadose zone, causing local areas of saturation with non-saturated sediments beneath them. In the Seabeck subarea, perched aquifers occur discontinuously, generally at elevations 100 feet above mean sea level (MSL). The majority of the wells in the upland areas are completed within these local aquifers. Springs occur where perched aquifers intercept the land surface, particularly on the high banks along Hood Canal and in steep valleys cut by streams in the upland areas.

## Seabeck Aquifer System

The Seabeck Aquifer System has been defined as a large, highly stratified, heterogeneous series of permeable strata containing water with a concordant water table which occurs between approximately 100 feet above MSL and 270 feet below MSL. Figure 2 shows the extent and recharge area of the Seabeck Aquifer System as currently defined. The Seabeck Aquifer System represents a major source for domestic supply.

At any one location, the thickness of the Seabeck Aquifer System does not exceed 250 feet and averages about 200 feet. The top of the aquifer is interpreted to be the point where permeable materials, excluding perched zones, become saturated. The elevation of the aquifer top ranges from 100 feet above MSL in the southern portion of the aquifer area, to approximately MSL in the northern portion. The bottom of the aquifer has only been identified at four points in the Seabeck subarea. From these points, it appears that the bottom elevation ranges from 130 to 270 feet below MSL. A 60-day test of a production well in the Seabeck Aquifer System indicated that the aquifer-wide transmissivity is 50,000 gpd/ft with a storage coefficient of 0.0098 (Purdy, 1994).

### *Seabeck Aquifer System Recharge Area*

The recharge area for the Seabeck Aquifer System, shown on Figure 2, is the area that directly overlies the aquifer plus the area of the Big Beef Creek drainage which is underlain by bedrock. The bedrock area is included because the bedrock provides a catchment area to precipitation, a portion of which contributes aquifer recharge once the water reaches the aquifer sediments. With this interpretation, the area contributing recharge to the Seabeck Aquifer System encompasses approximately 20 square miles (12,800 acres).

## Bedrock Aquifer

The bedrock aquifer forms a minor ground water source in the Seabeck subarea, serving only a few domestic users. It exists as interconnected fracture zones within the mostly basalt bedrock. The bedrock aquifer system is only significant in the southern portion of the Seabeck subarea. The small number of wells completed in the bedrock generally show limited yields.

## Seabeck Subarea Hazard Inventory

### Population/Land Use

The Seabeck subarea, with an estimated 135 persons/square mile (1990 census), has one of the lowest population densities in the County. Based upon current county estimates, the anticipated population increase is expected to average 1% per year by the year 2014.

The Seabeck subarea contains approximately 95 percent forested or natural cover. The intent of future zoning under the proposed County Comprehensive Plan (1994) is to keep this area in rural and forested land uses. At a building rate of 1 percent, development of the area with an average one unit per 2.5-acre density would result in an additional 4 percent of the surface area being affected by parcel development by the year 2014.

### Contaminant Source Inventory

An inventory of known and potential contaminant sources for the Seabeck subarea was conducted utilizing existing Department of Ecology databases and by conducting a "windshield" survey of the area. The Ecology databases list both known and potential sources of hazardous material and contain records for operational and leaking underground storage tanks, hazardous waste generators, and confirmed or suspected contaminated sites. A comprehensive description of the inventory process is included in the Hazard Inventory Section.

The database search found no known or potential direct threats to the aquifer. A single, potential indirect threat was identified: the operational underground tanks at a gas station in Camp Union. It is located outside the direct recharge area of the aquifer system, just southeast of William Symington Lake. The "windshield" survey confirmed that there are few current threats to the aquifer. There are no industrial sites upgradient of the aquifer area, higher density development is limited to the area around William Symington Lake, hazardous material usage is limited to the Camp Union gas station, and major transportation routes skirt the recharge area. Development along the Hood Canal shoreline is located downgradient from the major supply wells and, at this time, does not represent a serious threat to the source of supply.

The inventory of hazards to the Seabeck Aquifer have been classified as follows:

<u>Known Sources:</u>

- Septic Tanks
- Pesticide/Herbicide Application
- Agricultural Practices
- Silvaculture Practices

Potential Sources:

Transportation of Hazardous Material
Operational Underground Tanks
Storage of Hazardous Materials
Disposal of Household Hazardous Materials

It should be strongly noted that, at the present time, there is no indication that any of the above known or potential sources have served to degrade the quality of ground water in the Seabeck subarea.

## Seabeck Subarea Hazard Assessment Ranking

The methodology for prioritizing and ranking contaminant risks in the Seabeck subarea was based on the October 1991 EPA guidance document entitled, "*Managing Ground Water Contamination Sources in Wellhead Protection Areas: A Priority Setting Approach.*" The guidance methodology provided a general framework for risk evaluation. Final risk ranking was based upon the confidence level of the data and information collected during the hazard inventory. Ranking the apparent risks to the aquifer allowed the development of prioritized management plans and ground water protection tasks.

The threat of contamination to the Seabeck Aquifer System, based upon the hazard inventory, were classified and ranked using the following categories, listed in order of importance:

Proximity of the hazard to the recharge area
Existing or potential threat
Toxic nature of the contaminant
Vulnerability of the aquifer
Site specific characteristics within the aquifer recharge area

When assessed according to the above risk prioritization factors, the hazards to the Seabeck Aquifer System were ranked from highest to lowest risk. It should be stressed that all the hazards are considered minor and manageable. These minor hazards are:

1) Residential Development - Medium and Low Densities[1]: The primary threat to the water quality of the Seabeck Aquifer System is the planned surface development within the recharge area. Residential development has several potential water quality problem sources, including septic tanks and drainfields, residential application of herbicides, pesticides and fertilizers, and nitrate contamination resulting from "hobby" farming activities.

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[1] As of April 1996: Medium density = 1 du/5 acres, and low density = 1 du/10 acres.

2) Operating Underground Storage Tanks: The threats to the water quality of the Seabeck Aquifer System from this source include the gas station in the community of Camp Union and the presence of below-ground residential fuel oil storage tanks.

3) Small Capacity RCRA Sites: Water quality in the Seabeck Aquifer System is potentially threatened by hazardous substances utilized in small or home-based businesses. The Hazard Inventory noted several home businesses (vehicle repair shops) and a feed store, adjacent to the gas station in Camp Union, which could possess or utilize hazardous materials in the course of doing business.

4) Forest/Agricultural Practices: Forest and agricultural practices which may present a risk to ground water quality are certain tree harvesting operations and the application of herbicides, pesticides, and fertilizers. As these practices are generally performed under specific permits, or are performed by a licensed operator, the magnitude of the risk is small. However, the level of application of these practices within the Seabeck subarea is unknown.

5) Transportation/Spill Response: Unpredictable but possible sources of contamination are accidents occurring during the transport of hazardous materials through the aquifer recharge area. The Aquifer Protection Plan has developed a specific action plan for notification and response activities in the case of an accidental hazardous material spill. This plan is detailed in the Emergency Spill Response sub-section.

## Kitsap County Ground Water Management Plan

There are two primary avenues for development of plans, policies, and programs to protect the integrity of the Seabeck Aquifer System: the Kitsap County Ground Water Management Plan (GWMP) and the development of site-specific programs for the Seabeck subarea.

Kitsap County has been developing a Ground Water Management Plan over the last several years. This on-going work has involved thousands of hours of effort and has included substantial citizen input. The draft Plan contains many issue papers written to guide the development of management options for the county. It has evaluated the risks of general contamination of the ground water in the County and has made recommendations for controlling potential contamination-producing activities. Although the GWMP has not been concluded, the chances for the overall success of the Seabeck Aquifer Protection Plan will be greatly enhanced through the adoption of the GWMP. The development of the site-specific plan for the Seabeck subarea, detailed below, is predicated upon the eventual approval of the GWMP.

## Seabeck Aquifer Protection Plan

The following plan was designed to balance the protection of the existing ground water quality and quantity of the Seabeck Aquifer System with the future development of the land surface. The plan is based upon the following tenets:

1) The hydrology of the Seabeck subarea should be systematically monitored to identify potential changes in water quality or quantity parameters.

2) Land use activities which may bring significant quantities of potential contaminants into the recharge area should be closely monitored and controlled.

3) A comprehensive recharge enhancement program should be implemented to allow for better management of the overall ground water resources of the Seabeck Aquifer System.

4) Public education programs should be developed to inform the general public and appropriate governmental agencies on the presence of the aquifer and to solicit their participation in the protection program.

The following proposal describes the development and implementation methods recommended for the Seabeck Aquifer Protection Plan.

1) <u>Recognition of the Seabeck Aquifer System as a Critical Recharge Area.</u>

The KPUD could propose to Kitsap County that the Seabeck Aquifer System Recharge Area be formally designated as a Critical Recharge Area (CRA) under the proposed GWMP Critical Area Ordinance (CAO) guidelines. This identification would serve to classify the area for specific controls under the Growth Management Act and County Comprehensive Plan to preclude land uses involving hazardous materials in sufficient quantities to pose an unacceptable threat to the aquifer or other practices (e.g., deep quarries, landfills) which increase the vulnerability of the aquifer to contamination.

2) <u>KPUD Hydrogeologic Site Assessment and Evaluation</u>

As one of the requirements associated with the designation of the Seabeck Aquifer System Recharge Area under the CAO, appropriate county agencies could require KPUD and other purveyors with major wells in the aquifer to comment on any permit application which involves regulated hazardous materials within the CRA. At this time, the two agencies which regulate the use of hazardous substances are the Kitsap County Department of Community Development (KDCD) and the Bremerton-Kitsap County Public Health Department (BKCHD).

For land use proposals which involve the introduction of significant quantities of hazardous substances into the designated recharge area, the County could require the submittal of a Hydrogeologic Site Assessment (HSA). The HSA should evaluate the risks to the aquifer that may occur as a result of the proposed land use. The HSA should be submitted to the KPUD, which will coordinate comment by affected Group A water purveyors on the advisability of prohibiting the proposed activity or the need for conditioned use within the CRA. At a minimum, the HSA should include:

- Soil and ground water analyses
- Full description of proposed use
- An inventory of hazardous materials to be utilized
- An identification of the maximum quantity of each material allowed on the site
- Listing of contaminant handling facilities and procedures
- Spill response plan
- Descriptions of employee training
- Proposed mitigation

At this time, there are six categories of permits for which the KPUD should seek review authority and comment. These are:

| *Permit* | *Regulatory Agency* |
|---|---|
| Conditional Use Permit | KDCD |
| Determination of Non-Significance | KDCD |
| Solid Waste Siting | BKCHD |
| Home Business | KDCD |
| Community Septic System[2] | BKCHD |
| County Zoning Change | KDCD |

3) Seabeck Aquifer Recharge Management and Enhancement Evaluation

The KPUD recognizes that maintenance and enhancement of the quantity of recharge to the Seabeck Aquifer System is an integral component of the comprehensive protection plan. At the present time, the quantity of ground water in the aquifer system has been estimated using available water level, stream flow, and climatic data. These estimates demonstrate an apparent surplus of water in excess of the present production capabilities of the wells in the aquifer.

[2] KPUD and BKCHD are working out program elements for Large On-site Septic System Management. This program does not include single family septic systems which are currently the responsibility of BKCHD. Single family septic systems, under current zoning, are not considered a threat to ground water. By the year 2000, BKCHD will require all on-site systems to have established maintenance and monitoring programs.

Because quantity aspects of the Seabeck Aquifer System must be an integral part of the ground water management program, it is recommended that the KPUD identify recharge management and enhancement practices for the aquifer system. This effort could be initiated following the adoption of the Kitsap County Ground Water Management Plan, which addresses ground water recharge management on a county-wide basis. Aspects of land use which impact ground water recharge and should be addressed include residential housing, logging, road building, construction of impervious surfaces, storm water diversion, alteration of fisheries habitat, and modification of wetlands. Subsequent recharge studies should incorporate technical input from Kitsap County Department of Community Development, Washington Department of Fisheries, Washington Department of Natural Resources, Washington Department of Ecology, Tribal Fisheries, and Kitsap Department of Public Works.

4) <u>Emergency Spill Response</u>

KPUD could coordinate the Aquifer Protection Plan with the agencies responsible for hazardous material spill-response in the County. These agencies are the Kitsap County Fire Districts, the Kitsap County Sheriff, and the Washington State Patrol. The location and reasons for the CRA should be explained to these agencies and an agreement reached with them to assure that appropriate aquifer protection measures are included for spills within the CRA. At a minimum, this arrangement should include the immediate notification of KPUD in case of an accidental spill and an agreement with the response team to contain, rather than dilute and disperse, the contaminant.

5) <u>Public Education</u>

The most effective long-term protection of the Seabeck Aquifer System will result from the education of the local residents, landowners, and regulatory agencies on the ramifications of land use practices. Prior to and following adoption of the plan, open forums should be held to educate and receive comments from the general public. After adoption, people living in the area should be informed of the requirements developed under the Seabeck Aquifer Protection Plan. Direct contact with timber companies and other agricultural land owners should be periodically accomplished to reinforce the use of Best Management Practices, particularly for the application of herbicides, pesticides, and fertilizers.

The KPUD could develop "Critical Aquifer Recharge Area" signs and post them along roads throughout the CRA to alert people of the need to protect the area and remind the local residents of the protection plan. Finally, KPUD could actively support and advertise the Small Quantity Hazardous Waste Disposal Program sponsored by Kitsap County. They could notify CRA residents of this program and assure that disposal locations are convenient to the area residents.

# KITSAP COUNTY WASHINGTON

Subarea Boundaries for Kitsap County Initial Basin Assessment (Draft 1995)

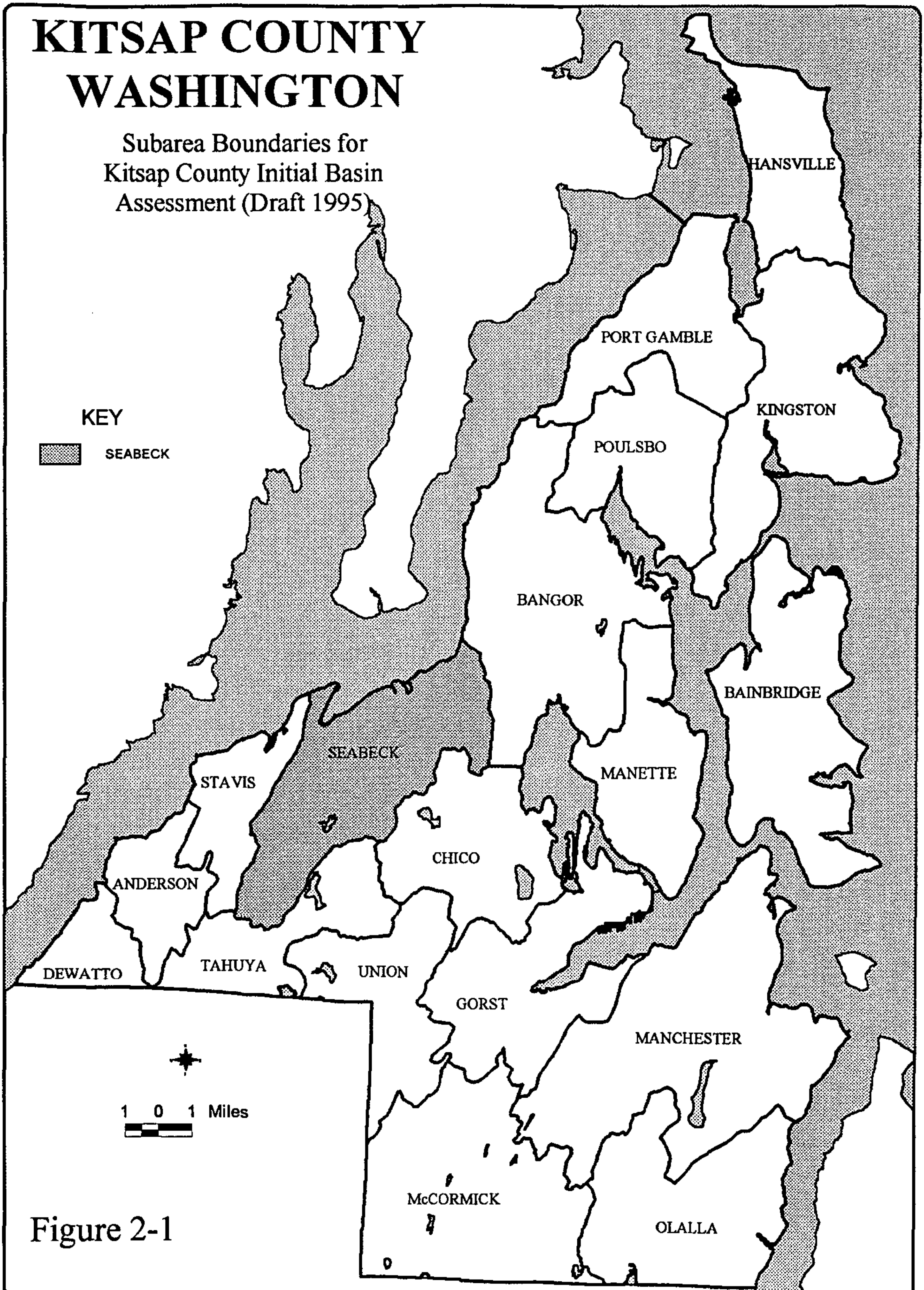


Figure 2-1

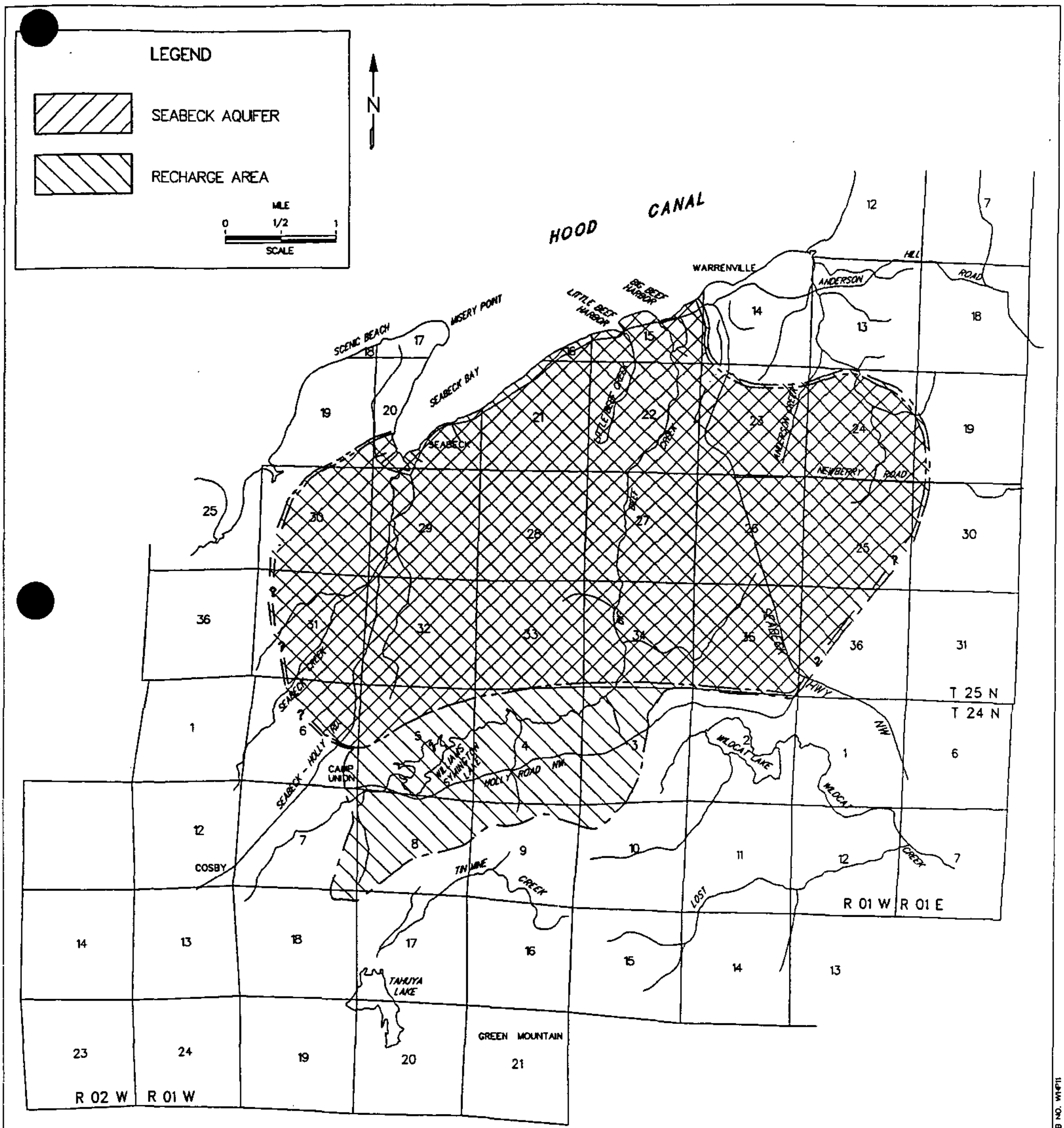


FIGURE 2-2
SEABECK AQUIFER SYSTEM BOUNDARIES AND RECHARGE AREA
SEABECK AQUIFER PROTECTION PLAN
ROBINSON & NOBLE, INC.
APRIL 1996. JOB NO. WH-P11
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3. IMPLEMENTATION TASKS

In order to accomplish the protection of the aquifer area in an orderly and cost-effective manner, the KPUD could adopt the implementation tasks listed below. To achieve the maximum effectiveness in the Aquifer Protection Plan (APP), a cooperative effort should be established and/or continued between the District, state and local agencies which regulate potentially harmful activities within the area, and other purveyors who have designated protection areas in Kitsap County. The tasks have been ordered in their possible implementation priority. The costs for the implementation of each of these tasks are variable depending upon the level of effort deemed appropriate by KPUD and the Implementation Steering Committee (discussed below).

Task 1: Create and operate an Aquifer Protection Plan Implementation Steering Committee. This committee would strive to focus the applicable state and local programs to the Aquifer Protection Area (APA), review management strategies, incorporate new data, evaluate new requirements, oversee educational programs, and evaluate new approaches to aquifer protection. The Implementation Steering Committee (ISC) could also seek to coordinate environmental education projects with appropriate County agencies to help focus efforts on the APA.

This ISC could meet, at a minimum, on a quarterly basis initally following Plan implementation and establish an appropriate, subsequent meeting schedule. The group would be responsible for the oversight of activities within the APA. It should seek to focus public awareness on the protection area and solicit county and state funding for ground water protection-oriented studies and activities. The ISC should include representatives of KPUD, Silverdale Water District, Bremerton-Kitsap County Health Department, Kitsap County Planning Department, Washington Department of Ecology, Tribal governments, Upper Hood Canal Watershed Management Committee and local interest groups.

Task 2: Establish formal communication with first responders. The initial function of this task is to update and inform local emergency response organizations on the APA location. Emergency spill response should include notification of the local water purveyors for any spill response within the protection area. First response communication should, at a minimum, be established with local fire departments, the county sheriff, and the Washington State Patrol.

Task 3: Communicate the extent of the Aquifer Protection Area to County Planning. Kitsap County Department of Community Development could consider the APA in their designations of critical area regulations, susceptibility mapping, and development permitting. Additionally, the existence and extent of the APA should be communicated to local industrial/commercial site owners.

Task 4: Consider seeking designation of the Aquifer Protection Area as a "special protection area". There are numerous special designations the District may wish to seek to protect the APA. The ISC could evaluate the protection offered by these various designations and seek the most appropriate protection designations for the APA. If the County Critical Areas Ordinance permits designating the area as a Critical Recharge Area, that designation should be pursued.

Task 5: If designated as a Critical Recharge Area, locate "Critical Aquifer Recharge Area" signs at the Aquifer Protection Area boundary along transportation corridors. KPUD should design "Critical Aquifer Recharge Area" signs and locate them throughout the APA, especially at the boundaries of the area.

Task 6: Assure that the hydrogeologic impacts of land use within the Aquifer Protection Area are adequately evaluated during the Washington State Environmental Policy Act (SEPA) process. The District could request Kitsap County Department of Community Development and Bremerton-Kitsap County Health Department to require a hydrogeologic evaluation for any proposed land use which presents a significant threat within the APA. Additionally, the District should agree upon a Memorandum of Understanding with these agencies requiring KPUD and other affected Group A water system purveyors to comment on the effects such land use will have on the ground water system. Designation of the area as a Critical Aquifer Recharge Area will be the first step toward gaining such an agreement.

Task 7: Conduct and periodically evaluate ground water monitoring according to the Aquifer Protection Plan ground water monitoring plan. The water quality monitoring plan should concentrate upon analyses of chloride, nitrate, pesticides, herbicides, and volatile organic compounds. Additionally, the ISC could establish early warning values for each of these parameters that will allow for timely action in the event of increasing concentrations. The ISC could also participate in developing and managing a regional ground water data program to assure that an adequate regional database is developed.

Task 8: Encourage requirement of new septic system as-builts to be recorded in a Geographic Information System database. The District could request Kitsap County to require as-built data from the septic design professional for septic systems be recorded in a GIS database for new systems within the APA. Additionally, the District should support the implementation of laws and regulations requiring the proper inspection and maintenance of septic systems.

Task 9: Work with responsible parties to assess adequacy of storm water systems. This task includes evaluation of the adequacy of the existing storm water detention facilities, establishing joint priority of storm water upgrades, and seeking maximum infiltration of storm water. KPUD may also wish to consider promoting research on the impacts of storm water discharge from residential areas and promote the evaluation of possible storm water detention, retention, and routing toward areas where storm water may be infiltrated into the ground water system. Additionally, KPUD should encourage the periodic water quality monitoring of surface water within the APA by the County.

Task 10: Promote and coordinate public education programs. KPUD should promote and coordinate educational programs, initially concentrating on the following areas to the following audiences:

- household, hazardous material use, storage, and disposal - all local residents
- the impact of septic systems on the Aquifer Protection Area - all local residents
- proper septic tank maintenance and hazardous waste disposal - all local residents
- the potential hazards of underground tanks - exempt underground tank owners
- methods of leak detection for underground tanks - exempt underground tank owners
- closure procedures for underground tanks - owners of exempt underground tanks
- ground water recharge enhancement - public agencies and all local residents

Task 11: Inventory forest ownership and management practices. KPUD could inventory forest ownership throughout the APA and evaluate management practices used on those lands. The practices evaluated could include the extent and time of harvesting, the type of harvesting used, reforestation schedules, and uses of herbicides and pesticides.

Task 12: Encourage development and use of Best Management Practices. Owners of large land parcels, such as large residential developments, schools, golf courses, parks, mining operations, and forest areas, could be encouraged to develop and use best management practices. The KPUD could also request that County, State, and private landowners utilize special vegetation management practices designed to protect water quality.

Task 13: Survey pesticide and herbicide use; work with the Washington State University Cooperative Extension Office and Kitsap County using available data to modify future ground water monitoring and APP-related education programs. Data collected through the APP should be used to guide which water quality analyses are to be performed for the monitoring network samples. This data can also be used in the education of the public on the handling and disposal of hazardous materials.

Task 14: Support Kitsap County well drilling inspection authority. KPUD should support the well construction inspection authority of Kitsap County. This regulatory body should provide better inspection of wells drilled within the APA than can be accomplished solely by Ecology.

Task 15: Review annual Superfunds Amendment and Reauthorization Act Title III reports. Review of these reports could be conducted by the ISC and be designed to document and inventory chemicals used in the APA. This review can be used to guide future ground water monitoring and APP-related education programs.

Task 16: Inventory abandoned or unused wells in the Aquifer Protection Area. The KPUD could attempt to locate and inventory decommissioned, abandoned, and unused wells. Owners of these wells should be notified of the potential liability such wells cause and be educated on proper well abandonment procedures.

Task 17: Develop data on the number and size of exempt underground tanks within the aquifer recharge area. To help with this task, the ISC may wish to incorporate the assistance of local fuel oil distribution firms in the distribution of literature and data on the proper servicing of existing tanks and the proper abandonment of unused tanks. Additionally, these firms, as transporters of fuel oil within the APA, should be educated concerning proper emergency response to accidental spills.

# 4. HYDROGEOLOGY

# HYDROGEOLOGIC CHARACTERIZATION OF THE SEABECK AQUIFER SYSTEM FOR PUD #1 of KITSAP COUNTY

June, 1995

by

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## TABLES



## ILLUSTRATIONS



## APPENDICES

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June, 1995

## INTRODUCTION

Test well drilling in the area near Seabeck has demonstrated the existence of a laterally extensive and relatively thick aquifer. The aquifer, which has been designated the Seabeck Aquifer System (Figure 1), is encountered from approximately 100 feet above to 250 below sea level and has areal extent of approximately 20 square miles. Kitsap County Public Utility District #1 currently has three test wells and one production well completed in the Seabeck Aquifer. Protection of the quality and the quantity of the ground water in the aquifer is a primary concern of the KPUD. As part of the commitment from the KPUD to the management of the Seabeck Aquifer, a Seabeck Aquifer Protection Planning Program was initiated. The planning effort is being funded in part through a grant from the Centennial Clean Water Fund (Grant Agreement No. G9300318). The aquifer protection plan's principal goals are to identify and evaluate the recharge area; evaluate the potential for impacts on the quantity and quality of water in the aquifer as a result of surface development and other human activity; and develop methods and protocols to effectively monitor, manage, and protect the surface and ground water systems related to the aquifer. Toward that end, this hydrogeologic study was commissioned. Although some aspects of other pertinent hydrogeologic features in the area have been addressed, the primary focus of this evaluation is the Seabeck Aquifer. This report essentially concentrates on the hydrogeology of the Seabeck Aquifer and is intended to be integrated into the overall Aquifer Protection Plan as the other components of that plan become available.

This report documents a hydrogeologic evaluation of the Seabeck Aquifer System based on existing data. The report includes discussion of the definition, geologic framework, and hydrogeologic parameters of the Seabeck Aquifer. In addition, analytical computer modeling techniques were applied to provide insights into the water budget of the aquifer system. Using the computer-based, analytical model, which is based on average aquifer-wide parameter values, effects of the proposed withdrawal from KPUD's Seabeck Aquifer wells have been investigated. The report provides an overview of the aquifer system as currently understood and makes recommendations for further data collection and resource investigation to enhance resource management in the future.

## PREVIOUS WORK

Studies pertaining to the Seabeck area include several regional or subregional ground water studies of Kitsap County. The study of the geology and ground water resources of Kitsap County performed by Sceva (1957) collected and interpreted basic data in the area up to that date. The report included information on wells in the county, as well as geologic maps and cross-sections. *Water resources and geology of the Kitsap Peninsula and certain adjacent islands* (Water Supply Bulletin No. 18) by Garling and others (1965) included a county-wide analysis of all aspects of the water resources. This assessment included an evaluation of previous work, a compilation of existing precipitation, stream flow, and surface water data, and geologic and hydrologic mapping. A Masters thesis by Deeter (1979) described in detail the glacial stratigraphy and surface geology of Kitsap County including all of the current study area. A cursory summary of ground water availability on Kitsap County was accomplished by Hansen and Bolke (1980) as part of the county impact definition associated with the building of the Naval Facility at Bangor immediately north of our study area.

Numerous hydrogeologic studies pertinent to the Seabeck Aquifer have been conducted by consultants. The first of these was accomplished in 1980 when Robinson & Noble supervised the drilling and testing of two test wells and one production well for the University of Washington at the Big Beef Creek Fisheries Research Center. Four aquifers were discovered in the course of that project which were designated simply Aquifers A, B, C, and D. Aquifer C, located 225 to 265 feet below MSL, was shown to have characteristics that make it one of the best aquifer zones ever identified on the Kitsap peninsula. Production Well 1, completed in Aquifer C, was tested at 2,000 gpm for 72.5 hours. The aquifer as it exists beneath the Fisheries Center has an implied transmissivity of 165,000 gpd/ft. The work at this site brought a focus to all subsequent work in the western Kitsap area, and the combined aquifer system of Aquifers A, B and C was eventually named the Seabeck Aquifer System after it was found to be laterally extensive.

As part of Grant No. 1 portion of the Kitsap County Ground Water Management Plan (GWMP), which was completed in 1991, 27 principal aquifer systems in Kitsap County were identified. The "Big Beef Aquifer system" was the only significant aquifer identified in the West Kitsap Subarea. At that time, the aquifer definition was based solely upon information available from the University of Washington Fisheries Facility wells on Big Beef Creek. As defined in the GWMP, the Big Beef Aquifer system was located 100 to 250 feet below sea level, within the "Qg4" unit which is a hydrostratographic layer defined in the course of that study. At the time of the report, the lateral extent of the Big Beef Aquifer was unknown but was suspected to extend a greater distance to the south and west. Further test drilling in the area was recommended to further describe the stratigraphic and hydrologic conditions which define the aquifer system.

To better define the lateral extent of the previously identified Big Beef Aquifer, a test drilling project was implemented in October, 1990. The program began with the drilling of Seabeck Well 1 (25N/1W-21N, AAA235). Well 1 is located approximately one mile southeast of the previously assumed boundary of the Big Beef Aquifer. The intention of the drilling plan was to determine if the permeable materials of the Big Beef Aquifer (Aquifer C) extended to that point, and to determine if any other water bearing zones existed at the location. Well 1 was drilled to a total depth of 649 feet (320 feet below mean sea level). A deep zone from 591 to 604 feet (262 to 275 feet below MSL) was tested and found to have no substantial production potential. It was concluded that the explicit sediments of the Big Beef Aquifer (Aquifer C) did not extend to the Well 1 site. However, a shallower water bearing zone, at 429 to 450 feet (100 to 120 feet below MSL), was encountered and tested. Testing, which was performed at 325 gpm, indicated a potentially productive aquifer. This zone was named the Seabeck Aquifer and correlated to "Aquifer B" of the Big Beef Fisheries study.

Seabeck Well 2 (25N/1W-22E, AAC799), located approximately 5,600 feet northeast of Well 1, was drilled to 500 feet (231 feet below MSL). This well did not encounter the Big Beef Aquifer, either. As in Well 1, Well 2 was completed in an aquifer above the elevation of the Big Beef Aquifer. Well 2 is completed in a productive water-bearing zone located 50 to 80 feet below MSL. This aquifer has been correlated to "Aquifer A" at the Big Beef facility. The well was tested at rates up to 910 gpm, with some indication that the well may be capable of producing up to 1500 gpm.

Seabeck Well 3 (25N/1W-28F, AAA980), located approximately 2,000 feet south of Well 1, was drilled with the intention of converting it into a production well. Well 3 is completed in an aquifer believed to be equivalent to the Big Beef Aquifer B, similar to Well 1. The well was drilled to a total depth of 630 feet (190 feet below MSL) and completed between 510 and 617 feet below ground (70 to 177 feet below MSL). The well was tested and rated at 600 gpm.

After the drilling and testing of Seabeck Wells 1, 2 and 3, the interpretation of the information led to the grouping of the Big Beef Aquifers A, B, and C as the Seabeck Aquifer System. Hereafter, the water bearing zones from approximately 100 feet above to 250 feet below sea level are considered hydraulically interconnected and will be referred to as the Seabeck Aquifer System. An interim report for the Seabeck Aquifer Protection Study written by Kaminsky (1994) (Appendix A) gave a preliminary overview of the Seabeck Aquifer System.

From June 1 to August 1, 1994, a 60-day constant-rate pumping test was conducted on KPUD's Seabeck Well 3. The testing provided valuable information on the Seabeck Aquifer System (see Appendix B). The testing allowed an excellent opportunity to take close-order, accurate measurements over a large area and time span. Results of the test showed:

- An aquifer-wide decline in water levels was documented. This decline was apparently a seasonal fluctuation and occurred at a rate of approximately 0.6 feet in 60 days.
- Pumping of Well 3 at an average rate of 584 gpm for 60 days induced drawdown interference in addition to the seasonal decline in all of the wells monitored.

- Drawdown and recovery data showed that the Seabeck Aquifer System can maintain a production level of 600 gpm from Well 3 for an extended period with no apparent residual affect on the system's water levels. The recovery trend shows that interference observed during the test was a function of classic well hydraulics, and that the aquifer water levels returned to the expected non-stress levels.
- Water chemistry was stable and of excellent quality throughout the pumping period.
- There was no evidence of saltwater intrusion.

Based on the results of this testing, a conservative aquifer production rate of approximately 1,400 gpm was estimated. A rate of 1,000 gpm was suggested as the initial amount to be used for planning purposes for KPUD's Seabeck wells in order to maintain a yet more conservative production rate until longer-term responses could be observed.

In December, 1994, Seabeck Well 4 was drilled to 650 feet and completed from approximately 100 to 126 feet below MSL. The well was tested at a rate of 200 gpm with approximately 33 feet of drawdown. The completion elevation, types of materials encountered during the drilling, and the testing data all indicate that Well 4 is completed within the Seabeck Aquifer System (Sebren, 1995).

In summary, many ground water studies outside the analysis performed for this project have been conducted in the Seabeck area. Current understanding is that the water bearing zones from approximately 100 feet above to 250 feet below sea level are all hydraulically interconnected on a regional scale. The various names assigned to the water bearing zones (Aquifers A, B, and C, Big Beef Aquifer system, Seabeck Aquifer) have all been grouped as the Seabeck Aquifer System.

## DATA BASE

As part of the Kitsap County Ground Water Plan (1991), a data base consisting of information regarding well construction, geologic logs, water levels, owner and water rights, was developed for the entire county. The information in the database was acquired from several sources. Well construction and water level data for approximately 2,900 wells were transferred from the USGS WATSTOR computer system. Data from approximately 350 wells were upgraded and information for approximately 450 new wells was added. These 800 "high quality" data points were compiled from Robinson & Noble's files, various reports by other consultants, files maintained by the Kitsap County Environmental Health Department, Nicholson Well Drilling, and USGS publications and unpublished data. Since the completion of the initial GWMP data base effort, KPUD has been adding field-verified wells to the database and have tagged these wells with a unique well identification number. The field verification and tagging of wells by KPUD personnel includes a GPS (Global Positioning Satellite) reading to establish Latitude/Longitude and an altimeter reading of the well's elevation relative to mean sea level.

As part of this project, that portion of the KPUD database pertinent to the area of the Seabeck Aquifer was examined and cross-checked to verify the accuracy of the information. At this time, the KPUD database contains information on 325 wells in the 33 sections initially included in the study. The information in the database was cross-checked with DOE well logs, KPUD field notes, and consultant reports.

## PHYSICAL SETTING

### TOPOGRAPHY

Topography of the Subarea reflects typical erosional and depositional effects of glaciated terrains such as elongated hills and valleys. Some features are unique to the area. For instance, the tops of the hills in the Seabeck area are of higher elevation, mostly over 500 feet, than in the north and east parts of the county. These hills are cut by deep, steep-walled stream valleys that stretch several miles inland from the shoreline. The valley of Big Beef Creek is easily the deepest and longest valley in the county. The southern part of the study area also includes the steep, basalt bedrock hills which form the north flanks of Green and Gold Mountains. Here elevations reach up to 1,291 feet, with the top of Green Mountain, south of the study area, reaching 1,639 feet.

### RAINFALL

Based on the isohyetal map in Garling and others (1965), the precipitation over the area that contributes to the Seabeck Aquifer varies from 47 to 70 inches (1946-1960 average), a large variation for such a small area. An isohyetal map of the distribution of precipitation over Kitsap County is also presented in the GWMP report (Exhibit II-15) using regional precipitation data. This map was used for the analyses of the Seabeck Subarea. The precipitation rates for the GWMP map are higher than indicated by the isohyetal map of Garling and others (1965) based on rates during 1946 to 1960.

Precipitation in the Seabeck area is controlled by the rain shadow of the Olympic Mountains and generally decreases to the north and east. The majority of the annual precipitation in the area falls during the months of October through April. The highest precipitation occurs along the northern flanks of Green Mountain, in response to the orographic effects of those higher elevations. Precipitation data has been recorded at several stations in and in proximity to the recharge area of the Seabeck Aquifer (see Table 1). The station with the longest period of record in the region is the NOAA station at Bremerton. This station has had four locations since its inception in 1899, the two most recent of these being pertinent to the purpose of this investigation. The station was moved on April 17, 1952, from the Bremerton Ship Yard to its present location near the Highway 16- Kitsap Way Exit.

From January, 1958 to October, 1991, a station located near Scenic Beach was monitored by a local resident, Frank Munroe. Another station with significant data is located near Silverdale and monitored by Henry Aus, the District Engineer for Silverdale Water District, from November, 1989, to present. The annual precipitation from these three stations are shown on Figure 2. In addition to these, three relatively new stations are located within the area significant to the Seabeck Aquifer: Scenic Beach, Apex Airport and Lake Symington. In total, there are 6 stations currently being monitored in and near the Seabeck Aquifer capture zone. Basic information for these 6 active stations, as well as for the inactive Munroe station are listed below in Table 1.

Table 1. Current and historical precipitation stations in the Seabeck area.

| Station name | Location | Period of record | Average annual rainfall | Responsible party |
|---|---|---|---|---|
| NOAA Bremerton | T24N/1E-16K | 1952- | 51.46[1] | Bremerton Fire Station |
| Henry Aus | 25N/1E-5G | Nov. 1989- | 42.32[2] | Henry Aus |
| Lake Symington | 24N/1W-4G | Oct. 1990- | 54.49[3] | City of Bremerton |
| Scenic Beach | 25N/1W-19H | Apr. 1994- | -- | |
| Apex Airport | 25N/1E-15E | Aug. 1994- | -- | USGS |
| Jim Crouch-Silverdale | 25N/1E-11F | Jun. 1994- | -- | Jim Crouch |
| Frank Munroe-Scenic Beach | 25N/1W-19B | 1958-Oct. 1991 | 59.93[4] | Frank Munroe |

1 1953 through 1994 (42 years) average at the current location.
2 1990 through 1994 (5 years) average.
3 1991, 1992 and 1994 (3 years) average.
4 1958 through 1990 (33 years) average

## SURFACE WATER FEATURES

### Lakes

Natural ponds and marshes of less than 5 acres occur in the Seabeck area along the shoreline and in the upper reaches of Big Beef Creek. A majority of these are interconnected, at least seasonally, with flowing reaches of Big Beef Creek. Only a few named lakes are found in the area. The largest lake in the subarea is William Symington Lake, an artificial impoundment of Big Beef Creek created for recreational purposes. William Symington Lake covers a surface area of approximately 60 acres. A small pond of 2.3 acres, named Sprague Pond, is located on the glaciated upland in 25/1W-33N (Wolcott, 1961). Several small, unnamed open water features are indicated on the USGS topographic maps for the area. In addition to open water features, there are several marshes in the area. Major among these are Big Beef Ponds at the headwaters of Big Beef Creek.

### Streams

Garling and others (1965) sequentially numbered the streams on Kitsap Peninsula. Ten of these designated streams and ephemeral creeks flow within the expected catchment which recharges the Seabeck Aquifer System. The five major surface water drainage basins are, from west to east: Seabeck Creek (#117), Little Beef Creek (#120), Big Beef Creek (#121), Johnson Creek (#123), and Anderson Creek (#124). Minor streams numbered 115, 116, 118, 119 and 122 (Spring Creek) are ephemeral streams with limited drainage basins of less than 0.1 square miles. The streams and their basins are shown on Figure 3.

Seabeck Creek (#117) drains an area of 5.2 square miles along the western margin of the study area. The basin is a long feature reaching south more than 3 miles. It drains the lowland shoulder on the west flank of Green Mountain and flows into Seabeck Bay which, in consort with Misery Point, forms the most dominant feature of the coastline within the study area.

Little Beef Creek (#120) is a single-channel, short drainage feature which has only 0.78 square miles of catchment. It parallels the lowest reach of Big Beef Creek about one half mile to the west. Little Beef Creek has a recorded low flow of 0.5 cfs.

Big Beef Creek (#121) is the largest of the surface water feature within the study area. It occupies a drainage area of 14.1 square miles and drains an estimated 28,400 acre feet of water per year from that area. The drainage basin is a long and narrow feature which drains northward from its headwaters on the western flank of Green Mountain to its mouth at Big Beef Harbor where it flows into Hood Canal. The stream falls a total of 480 feet over a total distance of approximately 9 miles. Below William Symington Lake the creek falls 380 feet in 5 miles. At the headwaters, Big Beef Creek is a series of interconnected marshes and ponds.

Johnson Creek (#123) drains a 0.81 square mile area along Hood Canal and is essentially a single channel feature which reaches about one mile inland. No flow information is available for Johnson Creek except for the spot measurement of 0.05 cfs on August 27, 1947. Johnson Creek is ephemeral with periods of no flow.

Anderson Creek (#124) occupies a small, nearly circular drainage basin of 4.9 square miles in the lowland portion of the northeast study area. It exhibits a more dendritic pattern of drainage than the other four drainages discussed. Other than the low flow of 2.07 cfs on September 18, 1947 listed in Garling and others (1965), only miscellaneous measurements at different points of the stream have been recorded. These have been accomplished as part of habitat monitoring in the area[1].

Documented stream flow data for the streams numbered 115, 116, 118, 119, and 122 (Spring Creek) is limited to measurements on August 3, 1961, from Garling, and others (1965). The existence of these streams within such limited catchment basins indicate that they are spring-fed. Low flow measurements demonstrate that the base-flow of these streams are augmented by capture of ground water from outside their minuscule basins (Garling and others, 1965).

The estimated catchment areas and lowest recorded flow for all the streams as taken from Garling (1965) are presented in Table 2.

1 Personal communication from Roger Tabor, WDFW to Joel Purdy, R&N, 1995.

Table 2. Spot measurements of low flow given in Garling and others (1965) for the ten streams within the Seabeck area.

| Stream (Garling designation) | Drainage area ($mi^2$) | Stream flow (cfs) | Date of measurement |
|---|---|---|---|
| #115 | 0.1 | Dry | August 3, 1961 |
| #116 | 0.04 | 0.07 | August 3, 1961 |
| Seabeck Creek (#117) | 5.2 | 0.27 | August 19, 1958 |
| #118 | 0.02 | 0.01 | August 3, 1961 |
| #119 | 0.04 | 0.03 | August 3, 1961 |
| Little Beef Creek (#120) | 0.78 | 0.5 | August 3, 1961 |
| Big Beef Creek (#121) | 14.1 | 3.91 | August 20, 1958 |
| Spring Creek (#122) | 0.07 | 0.5 | August 3, 1961 |
| Johnson Creek (#123) | 0.81 | 0.05 | August 27, 1947 |
| Anderson Creek (#124) | 4.89 | 2.07 | September 18, 1947 |

Of the five major creeks discussed above, only Big Beef Creek has continuous instream flow records. Since 1969, the US Geologic Survey has had an active gaging station (#12069550) on Big Beef Creek located in 25N/1E-22K. Since 1982, the station has been recording daily discharge from June through October only. Figure 4 shows the annual discharge of Big Beef Creek at the station and precipitation at the Scenic Beach (F. Munroe Station) over the time period of 1969 through 1980 when the stream gage station was monitored year-round. During this time period, the average annual flow was 38.7 cfs (27,965 af/yr). During the entire period of record from October, 1969 to September, 1994, the maximum recorded flow was 658 cfs on January 16, 1974, and the minimum flow was 2.2 cfs on August 13, 1990.

Besides Big Beef Creek, no other long-term stream flow record exists for the streams in the study area. Miscellaneous stream flow data have been collected as part of ambient habitat monitoring being conducted in the area by Washington Department of Fish and Wildlife[2] and by the Northwest Indian Fisheries Council (Lestelle and others, 1993). This information consists of spot flow measurements at various times of the year as part of stream habitat investigations. Although they provide some insight, these records are not generated on a consistent basis and are, therefore, inadequate to characterize the historical, annual and seasonal flow patterns of these streams. A

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[2] Personal communication from Roger Tabor, WDFW to Joel Purdy, R&N, 1995.

station has been established by KPUD on Stavis Creek to the southwest. However, the length of record is insufficient for meaningful interpretation. Further, the gage station has recently been washed out and will have to be reestablished. Effort has been made to establish a gaging station on Seabeck Creek. So far, definition of and access to an adequate site has not been attained.

# HYDROGEOLOGY

## GEOLOGIC SETTING

### Stratigraphy

The Seabeck study area lies within the Puget Sound Lowland as part of a large glacial drift plain formed by multiple glaciations over the area. This history of glacial erosion and deposition separated by long periods of non-glacial erosion and deposition has created a complex mixture of highly variable unconsolidated sediments. The depositional and erosional dynamics are magnified in the Seabeck area by the presence of the massive bedrock feature of Green and Gold Mountain. This has increased the complexity of the sedimentary record. This complex geology has been mapped in the study area by several investigators (Sceva, 1957; Molenaar in Garling, and others 1965; Deeter, 1979). A schematic cross-section of the subsurface geology as interpreted for this study is presented as Figure 5.

Tertiary volcanic deposits (Tv) crop out in the southern part of the study area. The consolidated volcanics, mostly basalt, form the practical lower limit to the ground water systems of the study area. Though the fractures of the rock can produce water sufficient for minor domestic use, it is not a significant component of the regional ground water resource. Undifferentiated, older (pre-Double Bluff), non-glacial and glacial deposits (Qu) overlie the bedrock within the study area. These units are found exclusively below sea level. Because of a lack of data, these older deposits could not be correlated with the regional stratigraphy. Overlying the older deposits is a glacial unit referred to as the Double Bluff Drift (Qdb). This unit is encountered in the study area from sea level to as much as 200 feet below sea level. The Double Bluff ranges from 50 to 200 feet thick and consists predominantly of glacial till, and sand and gravel deposits. The permeable sections of the Double Bluff have significant water resource potential and comprise the lower zones of the Seabeck Aquifer System. Above the Double Bluff Drift, the Kitsap Formation (Qk) is generally found; this is a non-glacial deposit of compact silt, clay, sand and peat layers. Thickness of the Kitsap Formation varies from a few feet to 100 feet. Overlying the Kitsap Formation are deposits from a glacial episode, referred to as the Possession Drift (Qps). These glacial deposits of till, and sand and gravel, range from 50 to 150 feet in thickness and are generally found between 50 to 300 feet above sea level in the central portion of the subarea. There is a discontinuous non-glacial deposit above the Possession Drift. This fine-grained deposit is often identified by a distinct thick peat layer and has been correlated to the Discovery Formation (Qd) of Noble (1990). The peat is generally found approximately 300 feet above MSL. Overlying the Discovery Formation are the deposits of the Vashon Glaciation, the youngest glacial event in the area.

At the base of the Vashon deposits is the Lawton Clay (Qvl). This thick, fine-grained formation of compact clay and silt was deposited in pro-glacial lakes as the glacier advanced south and blocked the Strait of Juan De Fuca. Overlying the Lawton Clay are the Vashon advance outwash deposits (Qva), predominantly fine to medium sand and gravel with thin silt layers. These deposits have been mapped by several investigators in the valley walls of Big Beef, Anderson and Seabeck Creeks. These deposits have been given different names through the years (Puyallup Sand by Sceva; Vashon advance and Colvos Sand by Molenaar; and Esperance Sand late phase and early phase by Deeter). The evidence from inland well logs suggests that the Vashon advance unit(s) previously mapped in the creek valleys is not as thick as expected or, in some cases, is absent as one gets further away from the valleys.

The tops of the hills in the subarea are mapped as mostly Vashon Till (Qvt), a compact, poorly sorted mixture of clay, silt, sand and gravel. This formation was deposited directly by the thick ice sheet which occupied the area during the Vashon glaciation. Glacial striations found at the top of Green Mountain indicate that the glacier overrode that feature which has an elevation 1,639 feet. In some portions of the Seabeck area Vashon recessional deposits (Qvr) of well-sorted, medium to coarse sand were deposited on top of the till as the ice sheet receded. The nomenclature of regional stratigraphy as used in this report is given below:

| | Stratigraphic unit | Cross-section symbol |
|---|---|---|
| Vashon Drift-- | Recessional Outwash | Qvr |
| | Till | Qvt |
| | Advance outwash (Esperance Sand) | Qva |
| | Lawton Clay | Qvl |
| Discovery Formation (non-glacial) | | Qd |
| Possession Drift | | Qps |
| Kitsap Formation (non-glacial) | | Qk |
| Double Bluff Drift | | Qdb |
| Pre-Double Bluff undifferentiated (non-glacial) | | Qu |
| Tertiary volcanic rocks (basalt) | | Tv |

**Cross-sections**

Six cross-sections were constructed as part of the geologic interpretation performed for this study. After laying out the well logs on the cross-sections, correlations were made where obvious geologic boundaries existed. Reliable regional correlations were able to be made in some cases, especially where important marker units, such as peat or thick clay, were present. The cross-section traces are indicated on Figure 6.

Anomalous deposits occur in the study area. A thick sand unit was encountered at the southern end of cross-section A-A' (Figure 7). This sand unit was interpreted to be cut-and-fill deposits of Vashon-age Esperance Sand. Nowhere else in the Seabeck area was found as thick a sequence of sand. In the area around Warrenville, on cross-sections C-C', D-D' and F-F' (Figures 9, 10, and 12, respectively), a very thick deposit of clay and silt was encountered. Here the clay is found from 300 feet above to 200 feet below MSL. This occurrence was interpreted to be an ancestral lake deposit. The unit appears to cross-cut deposits of pre-Vashon glaciations, so is most likely a Vashon pro-glacial lacustrine deposit, i.e. Vashon Lawton Clay (Qvl).

Static water levels were plotted on the strip log of each well shown on the cross-sections. The highly permeable, water-bearing zones are delineated as the most productive areas of the Seabeck Aquifer System and are shown as stippled on the cross-sections.

Boundaries of aquifers, controlled by permeability, can cross-cut the stratigraphic layers which are controlled by depositional relationships. In general, however, aquifers occupy the outwash deposits of glacial sequences, and the fine-grained deposits of non-glacial sequences commonly act as separating layers (aquitards) between aquifers.

## AQUIFER CHARACTERIZATION

Within the Seabeck area, three aquifer systems have been defined: the bedrock aquifer, the perched aquifers, and the Seabeck Aquifer System. These aquifers systems are further discussed below.

### Bedrock Aquifer

The bedrock aquifer is a minor source in the Seabeck area, only serving some domestic users. It exists as interconnected fracture zones within the mostly basalt bedrock. The bedrock aquifer is only significant in the southern portion of the Seabeck study area where little to no sediments overlie the rock. A small number of wells are completed in the bedrock. They generally show limited yields. Though the total underflow through the basalt has not been determined, well tests in conjunction with regional calculations suggest that the bedrock represents a very minor component of the regional ground water resource.

**Perched Aquifers**

Perched aquifers occur where the downward movement of water is impeded by a less permeable layer causing local areas of saturation with non-saturated sediments beneath them. In the Seabeck area, perched aquifers occur discontinuously, generally at elevations above 100 feet MSL. The majority of the wells in the upland areas are completed in permeable zones within these local aquifers. Springs occur where the perched aquifers intercept the land surface, particularly on the high banks along the Hood Canal and in steep valleys cut by the streams in upland areas. The perched aquifer system is controlled by the occurrence of permeable materials overlying fine-grained deposits. The less permeable, fine-grained deposits are generally the non-glacial units in the area. Since these deposits, such as the Discovery Formation, are discontinuous, as can be seen in the cross-sections, the perched aquifers are also discontinuous. The total amount of discharge from the perched aquifers to the streams has not been quantified. However, the baseflow of Big Beef Creek suggests that the perched aquifers contribute up to 4 cfs (4 in/yr over the catchment to that stream).

**Seabeck Aquifer System**

One major objective of this study was to more accurately determine the boundaries of the Seabeck Aquifer System. For this study, an aquifer is defined as a permeable zone of a geologic unit that can transmit economically significant quantities of water to wells. Economically significant quantities of water, for the purpose of this report, is that amount that can supply a moderate-sized water supply system, say, greater than 50 gpm. Previous work (Kaminsky, 1994) showed that on a regional scale, local and discontinuous water-bearing zones which may appear isolated from one another are actually interconnected on a regional scale. The Seabeck Aquifer System is defined as a large, highly stratified, heterogeneous series of permeable strata of similar head, which occur between approximately 100 feet above MSL and 270 feet below MSL (Kaminsky, 1994). Figure 1 shows the boundaries of the Seabeck Aquifer System.

The north and south boundaries of the Seabeck Aquifer System are fairly well-defined. The practical northern boundary is the shoreline of the Hood Canal, even though the aquifer likely extends a short distance into Hood Canal where it discharges as leakage through the recent bottom deposits of the canal. The southern boundary is defined by the bedrock contact which occurs as the subsurface projection of Green Mountain where it intercepts the sediments of the aquifer. Projecting the angle of the top of the basalt encountered in several drilled wells, the contact with Seabeck Aquifer units appears to subcrop at an elevation of about sea level on a line approximately paralleling the baseline between townships 24N and 25N.

The east and west boundaries of the Seabeck Aquifer System are less well-defined. The northeast boundary of the aquifer is controlled by the presence of a thick sequence of clay and clayey silt, sands and gravels, which tend to obstruct the flow of water to the east. The amount of subsurface information for the western boundary is limited. The wells that exist west of the boundary as drawn are completed at depths above the Seabeck Aquifer. Due to this lack of data, the actual western-southwestern extent of the aquifer is poorly defined.

Seabeck Aquifer System parameters

*Recharge area*

The recharge area for the Seabeck Aquifer, shown on Figure 13, is that area that lies directly over the aquifer plus the area of the Big Beef drainage which is underlain by bedrock. This additional area is included because it is assumed that the precipitation that falls on the bedrock runs down hill as subflow through the forest floor with a portion entering the ground water system as recharge once unconsolidated sediments are reached. With this interpretation, the area contributing recharge to the Seabeck Aquifer System is approximately 20 square miles (12,800 acres).

*Aquifer top and bottom elevations*

The Seabeck Aquifer occurs between 100 feet above and 270 feet below MSL. However, at any one location the thickness does not exceed 250 feet and averages 200 feet. The top of the aquifer is interpreted to be the point where the permeable materials become saturated, excluding the perched zones. This elevation ranges from 100 feet above MSL in the southern portion of the aquifer to approximately MSL in the northern portion. At Well 3 the upper limit of the aquifer occurs at approximately 25 feet above MSL.

The bottom of the aquifer has only been identified at four points. From this information, it appears that the bottom ranges from 130 to 270 feet below MSL. The bottom of the aquifer at Well 3 occurs at approximately 175 feet below MSL. For the purpose of analytical modeling, the top and bottom elevations of the aquifer system at Well 3 were used. The overall thickness used in that analysis was, therefore, 200 feet, which agrees with the conceptual model of the system.

*Hydraulic conductivity*

The aquifer parameters of the Seabeck Aquifer System are derived from results of the testing of six wells in the northern part of the study area. The transmissivity and storage coefficient values calculated from the test data are given below in Table 2. The transmissivity ranges from 30,000 gpd/ft at Well 1 and Big Beef Fisheries Test Hole 2 (TH-2) to 90,000 gpd/ft at Well 3. The storage coefficients range from 1.6 x $10^{-4}$ to 9.8 x $10^{-3}$. Analysis of a 60-day test of Well 3 (Appendix B) yields an apparent transmissivity value of 50,000 gpd/ft and a storage coefficient of 9.8 x $10^{-3}$. The storage coefficient was calculated after correcting for the 0.6 ft of water level decline during the 60-day test attributed to the seasonal trend.

Table 3. Aquifer parameters of Seabeck area wells.

| Aquifer parameter | Testing source | Values (data source) |
|---|---|---|
| Transmissivity ranges | Well 1 | 24,500 to 30,600 (drawdown plot)<br>36,000 (recovery plot)<br>88,000 (Well 3 1-day test) |
| | Well 2 | 73,000 (drawdown plot)<br>76,000 to 86,000 (recovery plot) |
| | Well 3 | 32,000 (1-day drawdown plot)<br>79,000 (1-day recovery plot)<br>86,000 (60-day test drawdown) |
| | Aquifer | 88,000 (1-day Well 3 testing dist. vs. dd.)<br>50,000 (60-day Well 3 distance vs. dd) |
| Storage coefficient ranges | Well 3 | $1.7 \times 10^{-4}$ (1-day Well 3 test)<br>$6.5 \times 10^{-3}$ (60-day Well 3 test)<br>$9.8 \times 10^{-3}$ (60-day Well 3 test, 0.6 ft removed) |
| Thickness ranges | Well 2 | 87 feet (-26 to -113 MSL) |
| | Well 1 | 172 feet (+45 to -127 MSL) |
| | Well 3 | 202 feet (+27 to -175 MSL) |

Considering that, after 60 days of pumping of Well 3, the assumptions of a homogeneous, confined, and infinite aquifer may no longer be valid, the aquifer parameters calculated from the latter portion of that test may be suspect. However, the implied values of transmissivity (50,000 gpd/ft) and storage coefficient ($9.8 \times 10^{-3}$) reflect approximate, aquifer-wide values of apparent, *average* characteristics of the Seabeck Aquifer System. Sensitivity analyses of the analytical model, discussed later, tends to corroborate this assumption.

Using an average aquifer thickness of 200 feet and an average transmissivity of 50,000 gpd/ft, the aquifer hydraulic conductivity is 250 gpd/ft$^2$. This hydraulic conductivity value was used as the average for the Seabeck Aquifer System in subsequent analytical modeling.

*General flow system of the Seabeck Aquifer*

The dynamics of the movement of water into and out of the study area can be simplified to a few basic relationships. Precipitation which falls on the area and is not lost to evapotranspiration is called the effective precipitation. The effective precipitation becomes either runoff, a surface water component, or percolates vertically to become saturated flow, a ground water component. The percentage of water that becomes either component is a function of the geology of the catchment area.

The southern portion of the Seabeck Aquifer catchment (recharge) area is dominated by rock and tends to escort water along the land surface until it either reaches a surface drainage or until it reaches sediments of sufficient permeability to allow vertical percolation to the ground water systems. Much of the surface geology of the area is dominated by glacial till or bedrock that causes a large percentage of effective precipitation to run off as surface flow.

In the northern portion of the recharge area a greater percentage of effective precipitation does move vertically and becomes ground water recharge. When vertical ground water flow is impeded by lower permeability material, such as silt or clay, a perched aquifer can be formed. The sediments of the area which lie above an elevation of 100 feet contain an abundance of lenses of low permeability material that form the perched aquifers of the area. The geologic logs of wells in the area show many regionally variable water level elevations reflected by the perched aquifers. Some of the perching layers are of substantial lateral extent and provide significant storage of water. Where this is the case, and the perching unit reaches a valley wall or a sea cliff, water drains from the aquifer as springs. When the edge of the perching unit is reached, water can drain off of the edge and continue its vertical migration through the non-saturated materials which lie below the perching layer. The complex subsurface geology of the Seabeck area suggest that water encounters several successive perched layers before encountering the underlying sediments of the Seabeck Aquifer.

Once the water reaches a zone of regional saturation, it becomes part of the regional ground water flow. The Seabeck Aquifer represents the only identified aquifer of the area that carries a significant amount of water on a regional scale. The water level gradient for this aquifer shows that the system is recharged on the upland area and that the water flows essentially northward to discharge at depth along the coast of Hood Canal. This is typical of many coastal aquifers of the Puget Sound Basin.

The surface water of the basin is captured in the drainage channels of the streams discussed above. During the winter, stream flow is a function of storm runoff, and the flows are relatively large. The distribution of these flows is dictated by storm patterns and, to a lesser degree, changes in land use over the area. The primary land use impact in the Seabeck area is that of logging since only a minor amount of the area has been converted to residential use.

As stated above in the discussion of the Perched Aquifers, some water discharges from that ground water system into the streams. This water provides much of the baseflow of the streams through the drier months of the summer and early fall. Though it is possible that some water discharges from the Seabeck Aquifer to the lower reaches of the major streams, the pattern of the potentiometric surface of that aquifer does not indicate a substantial discharge signature correlative to the streams.

The bedrock does not carry significant amounts of water from the system nor does it import significant amounts of water. The permeability of the rock is dependent on fractures within the rock and, for that reason, is substantially lower than the permeabilities that dictate the flow of water through the sequence of glacial and interglacial sediments which overlie the rock. It is safe to assume that nearly all of the water that falls on the subarea is accounted for in the unconsolidated components of the subsurface or in the surface water features of the subarea.

A database of 334 wells were used to develop a potentiometric surface map for the Seabeck Aquifer System. All wells completed between 100 feet above to 300 feet below sea level were selected as possible Seabeck Aquifer System wells. This group included 132 wells. This group of wells was further refined to exclude wells if shown to be completed in the relatively shallow, perched aquifers. Most of the eliminated wells occurred in the hills in the northern portion of the study area which have completion elevations similar to the outcroppings of small springs in the area. Finally, 85 wells (Appendix C) were used to construct a potentiometric surface map of the Seabeck Aquifer System, shown on Figure 14. The contour lines are drawn between points of equal hydraulic head (water level elevation) using the contouring program SURFER.

The overall ground water flow pattern is from south to north with minor local variations near the shoreline. The map shows that the hydraulic gradient (the difference in water levels along a line perpendicular to the contours) is generally consistent at approximately 40 feet per mile.

Monitoring of wells has shown that the water levels in the area have seasonal fluctuations of at least 1.5 feet (Purdy, 1994). Water levels in wells are also influenced by tidal fluctuations to varying degrees, depending on depth and distance from the shoreline. The water levels are also influenced by short-term effects of barometric change and longer-term reflections of erratic precipitation patterns. Because these fluctuations tend to be introduced randomly in this data set, these influences have little effect on the overall shape and pattern of the defined potentiometric surface.

# ANALYTICAL GROUNDWATER MODEL

## Model design

There are essentially two types of mathematical ground water flow models, numerical modeling in which the equations which dictate flow are solved using discrete values and simultaneous solutions; and analytical, modeling in which the solutions to the equations are facilitated through simplifying assumptions and then solved directly. Numerical modeling requires a substantial amount of data in order to accurately define the discrete solutions. Since that level and quality of data is not available, only an analytical model could be applied to the Seabeck Aquifer System. An analytical model was developed to simulate the ground water flow production on the aquifer system. The analytical model was calibrated to match the observed potentiometric surface using the reported precipitation (recharge) conditions. It then was used to simulate the drawdown effects of the pumping of KPUD's Seabeck wells. Results are presented later in this report as a predicted potentiometric water surface in the form of a contour map.

## SURFER and QuickFlow software packages

Two software packages were used in developing the analytical computer model, SURFER and QuickFlow. SURFER is a high resolution, two- and three-dimensional graphing program distributed by Golden Software, Inc. SURFER was used to take irregularly spaced water level data and create regularly spaced grid data. The grid data was then used to create a contour map.

QuickFlow distributed by Geraghty & Miller, Inc., is an interactive model which simulates two-dimensional, steady-state and transient ground water flow. The program has two modules. The steady-state module simulates ground-water flow in a horizontal plane utilizing analytical functions developed by Strack (1989). The transient module simulates ground water flow using equations developed by Theis (1935) for confined aquifers, and by Hantush and Jacob (1955) for leaky aquifers.

## Simulation of effects on the Seabeck Aquifer from pumping of Well 3

Boundary conditions

To simulate the hydraulic effects of discharge from wells using the equations of Theis (1935), several assumptions must be made regarding the aquifer. The aquifer is assumed to have infinite areal extent; have uniform thickness throughout; is uniformly confined between impermeable formations; is horizontal; and the aquifer is homogeneous and isotropic with respect to hydrogeological parameters. Under these assumptions, the simulation of the effects of the pumping of Well 3 on the water levels of the Seabeck Aquifer System can be accomplished without consideration of boundary conditions. Considering the results of the 60-day test, and the conceptual definition of the lateral extent of this aquifer system, the assumptions are valid for simulation of regional responses.

Aquifer parameters

The following aquifer parameter values, which have been discussed above, were used in the analytical model:

| | |
|---|---|
| Top and bottom elevation: | +25 ft to -175 feet MSL |
| Thickness: | 200 ft |
| Hydraulic conductivity: | 250 gpd/ft$^2$ (50,000 gpd divided by 200 ft) |
| Storage coefficient | $9.8 \times 10^{-3}$ |

Drawdown effects

Using the QuickFlow program, the predicted steady-state drawdown of Well 3 pumping at 585 gpm for 60 days was generated and the resultant potentiometric surface contoured (Figure 15). A calibration table (Table 4) and a scatter plot (Figure 16) were developed for this model run. The calibration table shows that the modeled drawdown closely approximates the observed (target) drawdown in the nearest wells, Well 1 (r= 2,000 ft) and Guava (r=3,100 ft), and the farthest well, TH-2 at Big Beef (r= 8,200 ft). The model overestimates the drawdown in four of the monitor wells. There are plausible explanations for this overestimation which are consistent with both the conceptual model of the system and the limitations of the analytical modeling method. The wells could be located in areas of the aquifer which have greater permeability; Well 2 is a demonstrated example of this situation. Or, the fact that the four wells are located higher in the aquifer where the effects of vertical anisotropy in the aquifer, which cannot be simulated in an analytical model, would cause a dampened drawdown response to pumping that the modeled result would not predict. These discrepancies are relatively minor, and the result of the simulation demonstrates that the model sufficiently reflects the conditions observed during the 60-day test to predict general response on a regional scale.

Table 4. Calibration table of analytical model simulation of drawdown effects of Well 3 after 60 days of pumping at 585 gpm.

| Well name | Target dd (ft) | Modeled dd (ft) | Error (ft) | Absolute error (ft) | Error squared (ft) |
|---|---|---|---|---|---|
| Well 1 | 4.4 | 4.21 | 0.19 | 0.19 | 0.036 |
| Guava | 3 | 3.14 | -0.04 | 0.04 | 0.02 |
| Seab. CC | 1 | 2.29 | -1.29 | 1.29 | 1.66 |
| Collier | 3.4 | 2.21 | 1.19 | 1.19 | 1.42 |
| Well 2 | 0.9 | 1.49 | -0.59 | 0.59 | 0.35 |
| Smith | 0 | 0.99 | -0.99 | 0.99 | 0.98 |
| TH-2 | 0.4 | 0.80 | -0.40 | 0.40 | 0.16 |
| mean = -0.29<br>standard deviation = 0.44<br>mean absolute error = 0.68<br>root mean squared error = 2.15 | | | | | |

**Simulation of the effects on the Seabeck Aquifer from pumping multiple wells**

The analytical model described above was applied to simulate the effects of pumping the four KPUD wells. Kitsap County PUD has four water right applications for 1,500 gpm each. A well has been drilled and tested at each site. For the model simulation, each well was pumped for 100 days and the drawdown effects contoured. The 100-day duration was used because it is the length of time generally used to rate production wells. The pumping rates used in the simulation were the rated capacity for each existing well (Well 1 = 325 gpm, Well 2 = 1,000 gpm, Well 3 = 600 gpm, Well 4 = 200 gpm). The interference effects at TH-2 at Big Beef were compiled and compared.

Successive runs of the analytical model were conducted by theoretically pumping the four KPUD wells in order of increasing magnitude of interference at TH-2. Starting with Well 3, the wells were sequentially pumped at the rated capacity and the additive drawdown effect at Test Hole 2 (TH-2) at the Big Beef Creek Fisheries was compiled for each run. Seabeck Well 3 was pumped at 600 gpm for 100 days. The resulting drawdown cone, shown on Figure 17, resulted in drawdown interference at TH-2 of 1.3 feet after 100 days. Note that the model overestimated the drawdown response at TH-2 for pumping Well 3 for 60 days. Therefore, the computed drawdown should be considered a conservative estimation.

The next run, shown on Figure 18, computed the drawdown interference caused by the pumping of Wells 1 and 3 concurrently. The combined pumping rate of 925 gpm caused a predicted drawdown at TH-2 of 2.02 feet after 100 days. For the third run, Wells 1, 3, and 4 were pumped. The drawdown cone is shown on Figure 19. The combined pumping rate of the three wells was 1,125 gpm. The predicted drawdown interference at TH-2 for this run was 2.45 feet. The fourth run using the model to simulate drawdown effects was with all four wells pumping. The combined pumping rate for Wells 1, 2 , 3, and 4 was 2,125 gpm. The predicted drawdown interference, shown in Figure 20, indicates 8.72 feet of drawdown at TH-2. This dramatic increase in drawdown effects at TH-2 from the previous run is caused by the close proximity of Well 2 to TH-2, and Well 2's high pumping rate of 1,000 gpm.

## RECHARGE

### Analytical modeling the recharge rate of the Seabeck Aquifer

The rates of flow within a ground water system are defined primarily by the aquifer transmissivity and hydraulic gradients. The flow rate in a steady-state system can be determined using the modified form of the Darcy equation:

$$Q = T\, i\, w$$

where $Q$ is discharge through a given width of an aquifer (gpd), $T$ is the aquifer transmissivity (gpd/ft), $i$ is the hydraulic gradient of the aquifer (ft/mile), and $w$ is the width of the aquifer (mile). Because the aquifer structure is constant, the W and T values are constant. Therefore, a given gradient in the aquifer implies a specific value for Q. Assuming a steady-state condition, the inflow (recharge) equals the outflow (discharge). Therefore the equation becomes:

$$\text{Recharge} = T\, i\, w$$

For this exercise, a unit width for $w$ and a hydraulic gradient of 40 ft/mile for $i$, taken from the potentiometric surface map, were held constant. The value for $T$ was varied between 25,000 to 100,000 gpd/ft to bracket the average aquifer transmissivity of 50,000 gpd/ft calculated from the 60-day test of Well 3 and the recharge rate that gives a 40 ft/mi gradient was determined.

Utilizing the QuickFlow analytical model, a line sink was used to simulate the aquifer's zero-head boundary and uniform recharge was applied at rates to match the hydraulic gradient. A sensitivity analysis for the Seabeck Aquifer System was conducted and the results are given below on Table 5. The results of the analysis show that the recharge rate ranged from 4 to 16.5 in/yr depending on the transmissivity values. Using 50,000 gpd/ft, the transmissivity calculated from the 60-day test, the recharge rate for the entire recharge area is calculated to be 8.25 inches/yr.

Table 5. Steady-state, uniform recharge sensitivity analysis using thickness as 200 feet (top +25 ft, bottom -175 MSL) and a storage coefficient of 9.8 $10^{-3}$. Given is the hydraulic gradient for each analysis. The actual hydraulic gradient for the Seabeck Aquifer System is 40 ft/mi.

| | Transmissivity (gpd/ft) | Recharge rate [1] (in/yr) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | 8.25 | 10 | 13 | 15 | 16.5 |
| Gradient (ft/mi) | 25,000 | **39.1** | -- | 96 | -- | 141 | -- |
| | 50,000 | 20.2 | **40.2** | 48.8 | -- | 71.4 | -- |
| | 80,000 | 12.9 | -- | 31.1 | **39.7** | 45.3 | -- |
| | 100,000 | 10.4 | -- | 25.2 | -- | 36.6 | **40.4** |

[1] As applied evenly over entire recharge area.

The relationship of the Seabeck Aquifer System to the streams in the area is best known from a 1980 drilling project at the fisheries at the Big Beef Creek. During the drilling program, a water bearing unit at a depth of 50 feet (elevation approximately 15 ft below MSL), presumed to be the Seabeck Aquifer, showed a water level nearly 20 feet above the surface of the creek at that site. The existence of a confining unit of up to 21 feet thick near the creek bed surface indicates that the Seabeck Aquifer is not in direct continuity with Big Beef Creek at that site. The fact that the head in the aquifer is highly confined suggests that the confining unit is laterally extensive. However, if leakage occurs between the aquifer and the stream, then the driving head would be 20 feet. For the purpose of discussion, a hypothetical analysis was developed for the amount of leakage between the aquifer and creek.

Test Holes 1 and 2 and Production Well 1 at Big Beef Creek all encountered a clay unit at approximately 10 feet below MSL. The Seabeck Aquifer lies immediately below this layer. Therefore, at this site the ground water has to leak upward through a confining unit with a small vertical conductivity. Applying Darcy's law:

$$Q = KiA$$

where $Q$ is the discharge rate, $K$ is hydraulic conductivity, $i$ is hydraulic gradient, and $A$ is the area of vertical flow. Hydraulic conductivity of clays typically range from $10^{-2}$ to $10^{-5}$ gpd/ft$^2$ (Freeze and Cherry, 1979). Hydraulic gradient is defined by the change in head, $dh$, divided by the distance between the two measuring points, $dl$. The change in head at TH-2 is the static water level elevation (38 ft MSL in June, 1994) in the well minus the water level of the creek (28 ft MSL), which equals 10 ft. The distance between the measuring points is the creek level (28 ft MSL) and the top of the Seabeck Aquifer (-10 ft MSL), which equals 38 ft. Therefore, the vertical hydraulic gradient under pre-stress conditions in the summer at TH-2 is 10 ft/38 ft (~0.25). For this case, the effective area, A, can be assumed to be equal to the area of the creek channel and an area to either side until the head in the lateral sediments is sufficient to counter the upward gradient of the Seabeck Aquifer System (i.e. 10 ft or less). For this calculation, we assume the effective width is 500 ft. For each mile of the stream under the above condition, the area would equal 2,650,000 $ft^2$ (500 ft x 5280 ft). Inserting the values, the equation becomes:

$$Q = KiA$$

| High range assuming $10^{-2}$ gpd/ft$^2$ | | Low range assuming $10^{-5}$ gpd/ft$^2$ |
|---|---|---|
| $= (10^{-2}\ gpd/ft^2)(0.25)(2,650,000\ ft^2)$ | or | $= (10^{-5}\ gpd/ft^2)(0.25)(2,650,000\ ft^2)$ |
| = 6625 gpd | | = 6.6 gpd |
| = 0.01 cfs | | = 0.00001 cfs |

This calculation, based on conditions at TH-2, indicates that the Seabeck Aquifer System, if leaking to Big Beef Creek at all, is contributing less than 0.01 cfs to as little as 0.00001 cfs per mile of creek. The lowest recorded flow since 1969 is 2.2 cfs, or 1.4 million gallons per day. This means that either the Seabeck Aquifer System contributes insignificant ground water base flow of Big Beef Creek, or the conditions observed at TH-2 are not typical for the creek/aquifer interactions. Since the head in the aquifer is a regional phenomenon, the assumed head conditions of TH-2 seem reasonable. It also seems likely that the perched aquifers are the source of base flow for Big Beef Creek and, by analogy, for other creeks in the area.

Upstream the conditions are less well known. It is recommended that the creek should be investigated to determine gaining and/or losing reaches of the creek and the relationship to ground water baseflow, whether from perched aquifers or the Seabeck Aquifer System.

Our analysis indicates that the pumping of Well 3 at its maximum rated capacity continuously for 60 days causes only a small amount of drawdown interference (0.4 ft) in the Seabeck Aquifer System near Big Beef Creek (Purdy, 1994). It is unlikely that this drawdown could have an effect on the baseflow of Big Beef Creek.

## WATER QUALITY

### GROUND WATER QUALITY

The water quality information available for the Seabeck Aquifer is from the previous hydrogeologic studies discussed earlier. Complete inorganic analyses were done for Aquifers D and C (Seabeck Aquifer) at the Big Beef Fisheries and for KPUD's Seabeck Wells 1, 2, 3, and 4. The results showed that for all parameters the water meets the standards set by EPA and Washington

DOH. The chloride and nitrate concentrations are at background levels of less than 5 mg/l and 0.2 mg/l, respectively, for all samples. The iron, manganese, and hardness concentrations are low and specific conductivity, and total dissolved solids values are likewise low. Overall, the water quality is excellent and consistent between well locations for which data is available.

During the 60-day testing of KPUD's Well 3 in the summer months of 1994, chloride and conductivity were monitored in four other monitoring wells. The results showed that the chloride was at background levels in these wells and the chloride and conductivity levels remained stable throughout the testing period.

## WATER RIGHTS ASSESSMENT

### GROUND WATER RIGHTS

The water right records used in this study are from the Department of Ecology's WRIS database for the Water Resource Inventory Area (WRIA) 15. Appendix D is the compilation of the surface and ground water rights for the area encompassing the Seabeck Aquifer System boundaries and the drainage basins which overlie the aquifer. Appendix D lists information such as location of withdrawal, priority date, owner, type of use, and instantaneous and annual quantities allocated. Table 6 shows the totals of all ground water rights in the Seabeck area. This total represents all known water right holders whether actively used or not. The allocation totals on Table 6 do not include approximately 300 private domestic users in the area who are served by exempt wells. Also not listed are 391 water right claims in the area (both surface and ground water claims). These claims are not water rights but could become valid in adjudication process.

Table 6. Certified, permitted and applied-for ground water rights reported by the Department of Ecology Northwest Regional Office in the following sections in the study area: 24N/1W- 1 through 9; 25N/1W-13 through 36. Not included in the water right summary are 391 claims in the same area.

| GROUND WATER RIGHTS | | | | |
|---|---|---|---|---|
| | Certificates and Permits | | Applications | |
| | Qi (gpm) | Qa (af/yr) | Qi (gpm) | Qa (af/yr) |
| KPUD | -- | -- | 6,000 | -- |
| ALL OTHERS | 5,238 | 4,158 | 702 | -- |
| Seabeck Study Area TOTAL | 5,238 | 4,158 | 6,702 | |

Although the source aquifer could not be determined for every ground water right, the known users of the Seabeck Aquifer System were totaled. The ground water users that are known to withdraw from the Seabeck Aquifer are the Big Beef Fisheries, other fisheries, and domestic wells along the Hood Canal shoreline. These users have total water rights of approximately 3,000 af/yr. This is approximately 72% of the total allocation of 4,158 af/yr in the study area.

Of the ground water right applications listed on Table 6, KPUD has four applications totalling 6,000 gpm. Not all of the KPUD applications appear in the DOE records. This could be a result of mis-location or could reflect a lag in entering information into the water right database. The omissions are being corrected. These applications represent the four Seabeck wells. The total rated capacities of KPUD's four Seabeck wells is 2,125 gpm. The remaining ten applications, totalling 702 gpm, are designated for multiple domestic usage. Two of the applications, totalling 350 gpm, are by Central Kitsap School District for two elementary schools in the area.

## SURFACE WATER RIGHTS

Of the 27 surface water rights in the Seabeck area, 20 are consumptive surface water rights (see Appendix D) with an instantaneous total of 0.474 cfs and an annual total of 43.5 af/yr. Four of the larger streams in the Seabeck area have multiple allocations. Table 7 lists the consumptive water rights assigned to the streams.

Table 7. Certified surface water rights for consumptive use on streams in the study area.

| SURFACE WATER RIGHTS | | | | |
|---|---|---|---|---|
| | Number of Rights | Qi (cfs) | Qa (af/yr) | DOE low flows |
| Seabeck Creek | 5 | 0.07 | 5 | -- |
| Big Beef Creek | 6 | 0.174 | 7 | 14 to 4 cfs[3] |
| Johnson Creek | 3 | 0.04 | 1 | -- |
| Anderson Creek | 4 | 0.17 | 30.5[2] | 3 to 1 cfs[4] |
| Other creeks | 2 | 0.02 | -- | -- |
| TOTALS | 20 | 0.474[1] | 43.5 | |

1 Water right total does not include a water right on Anderson Creek for 5.56 cfs for fire protection

2 Includes a water right of 30 af/yr for irrigation use that is likely inactive

3 Big Beef Creek was closed to further appropriation on 8-27-54. Period of closure is May 15 through October 31.

4 Anderson Creek period of closure is June 1 through October 31.

It appears from the water rights totals that the consumptive water rights on the streams are a small percentage of the stream flows. On Big Beef Creek the maximum instantaneous rate for the water right holders of 0.174 cfs is 8% of the lowest recorded flow (2.2 cfs) in Big Beef Creek since 1969. Note that the allocated instantaneous rate for Anderson Creek does not include a 5.56 cfs water right for fire protection. Without this right the total maximum instantaneous surface water right for the area is 0.474 cfs. The annual quantity is inflated by a 1950 surface water right for 30 af/yr for irrigation use located in 25N/1W-13C. This right is 69% of the annual surface water allocation in the area. The property is referred to on the Metzker map as Sunset Farms. The property is now a small development served by Sunset Farms Water, a Class A system with 18 hookups served by ground water right G1-22376C for *Qi* of 30 gpm and *Qa* of 16 af/yr. Therefore, this surface water right is likely to be inactive.

The non-consumptive uses of the streams are not listed in Table 7, but are presented in Appendix D. Two major non-consumptive uses, Symington and UW Fisheries, are located on Big Beef Creek. The water right for annual use of 670 af/yr held by Symington of Seattle is designated for recreation and beautification use. This water right allows for the impounding of water in Lake Symington located approximately 4.5 miles upstream from the mouth of Big Beef Creek. The water right for 11 cfs (instantaneous) held by the Big Beef Fisheries is designated for fish propagation.

One other non-consumptive user is W. W. Wade on Johnson Creek. His total of 0.75 cfs for two water rights are designated for fish propagation. Since these water rights are non-consumptive, they do not affect the total flow of the creek, with the possible exception of minor increases in evaporation.

## WATER AVAILABILITY

### Water balance

In the GWMP report for Kitsap County (1991), a water budget analysis was applied to the West Kitsap Subarea using the water balance equation:

Recharge = Precipitation - Storm runoff - Evaporation.

This method of calculation presumes a steady-state condition. That is, there are no significant changes in the amount of water stored in the system. Values for the components of the water balance were given as ranges of regional estimates. As part of the Seabeck Subarea assessment, which is a parallel study to this effort, a water budget analysis of the Big Beef Creek basin was performed for the period from 1970 to 1980, at which time year-round stream flow data is available. Based on the hydrologic and hydrogeologic characteristics of the Seabeck Subarea, we believe that Big Beef Creek is likely to be representative of the other major basins in the Seabeck area. Results from the water budget analysis of the Big Beef Creek basin were, therefore, used to characterize the flows of the entire Seabeck area.

The precipitation rate within the Seabeck Subarea is highly variable. According to the isohyetal map presented by Garling and others, 1965 (Plate 4), which is based on the average precipitation from 1946 to 1960, the precipitation rate is approximately 50 in/yr at the mouth and 70 in/yr at the head of the basin with an average of 60 in/yr. According to the isohyetal map of the GWMP report (Exhibit II-15), the precipitation rate is approximately 60 in/yr at the mouth and 75 in/yr at the head of the basin with an average of 67 in/yr. The higher rate is also indicated by the average precipitation rate at the Munroe Station. From 1970 to 1980 (the time span of the water budget analysis of the Big Beef Creek basin), the average rate at the Munroe Station was 61.2 in/yr. The following water budget analysis of Big Beef Creek basin uses an average annual precipitation of 67 in/yr.

Evapotranspiration cannot be directly measured. For this analysis, evapotranspiration for the basin was calculated utilizing the Thorthwaite method (Dunne and Leopold, 1978). The Thorthwaite method estimates the potential evapotranspiration based on soil thickness, temperature and latitude. Assumptions of soil moisture holding capacity and estimations of evaporation and sublimation based on temperature and latitude must be made. Temperature data from 1970 to 1980 at the Bremerton station were used to calculate the potential evapotranspiration of the Seabeck subarea. An evapotranspiration value of 25 in/yr was calculated. A difference between potential and actual evapotranspiration occurs when evapotranspiration exceeds precipitation and is a function of soil moisture depletion. Depending on the range of assumed soil moisture holding capacity, the calculated actual evapotranspiration ranged from 21 in/yr to 16 in/yr. The rate of 21 in/yr was used in order to maintain a conservative estimate of the resource.

Runoff was determined using data collected by the USGS at the Big Beef Creek gage. The average total annual flow from the Big Beef Creek basin for the years 1970 to 1980 was 27,965 af/yr. Since the drainage area above the stream gage is 13.80 $mi^2$, or 8,832 acres, 27,965 af/yr converts to an average discharge equivalent to 3.17 ft/yr, or 38 in/yr over the catchment area. A component of this annual flow of 38 in/yr is derived from the ground water as baseflow to the creek. The baseflow was determined by assuming that the lowest monthly flow for each year represents the ground water flow exclusively. Based on this, the ground water component of stream flow was found to average 4.3 in/yr over the catchment. This would imply that the average amount of runoff generated in Big Beef Creek between 1970 and 1980 is equivalent to 34 in/yr over the catchment area. Since Big Beef Creek is assumed to be similar to the other drainages in the area, discharge for them can be estimated using the relationship established for Big Beef Creek.

Returning to the initial equation for definition of Recharge:

$$\begin{aligned}
\text{Recharge} &= \text{Precipitation - Evapotranspiration - Storm runoff} \\
&= 67 \quad - \quad 21 \quad - \quad 34 \\
\text{Recharge} &= 12 \text{ in/yr}
\end{aligned}$$

This value is the approximate amount of recharge that would be expected to reach the ground water system during the average year.

To determine the amount of ground recharge that reaches the Seabeck Aquifer System, the budget of the shallow perched aquifers must be examined. Recharge to the ground water system enters the shallow perched aquifers and discharges either to surface water features or passes vertically through the perched systems and infiltrates to deeper ground water systems. Springs are evident in the Seabeck area where the perched aquifers intersect the land surface along valley cuts and sea cliffs. The actual amount of discharge from the perched aquifers cannot be directly measured. However, the geologic information for the area considered with the implications of water level data for the perched and Seabeck Aquifer Systems imply that the baseflow of the streams is derived, for the most part, from the perched aquifers. Based on the Big Beef Creek baseflow, the perched aquifers likely discharge an average of about 4 in/yr to the surface water features. The remainder of the 12 inches of annual recharge percolates to the deeper aquifers. Based on this, the water balance indicates an average recharge rate of 8 in/yr to the Seabeck Aquifer System. This is in agreement with the recharge indicated in the analytical modeling discussed earlier. Since the modeling effort was developed to match the implications of observed water levels in the aquifer, it represents an independent method for estimating recharge. The fact that both types of analysis suggest the same magnitude of recharge to the Seabeck Aquifer System, is encouraging.

The agreement between the recharge rate indicated utilizing the water balance approach and the recharge rate arrived at using the analytical model (the gradient-implied approach), suggests that a rate of 8 in/yr is reasonable. If the rate of 8 in/yr is the average amount of ground water that naturally discharges into Hood Canal from the Seabeck Aquifer System (approximately 20 $mi^2$, or 12,800 acres), then a total of 8,533 af/yr, or 5,290 gpm is indicated as the annual aquifer discharge.

## MONITORING NETWORK

The Seabeck Aquifer Protection Plan called for a monitoring network and the drilling of up to 3 monitor wells in the Seabeck Aquifer. However, as the study progressed, it was evident that there was a need for additional monitoring in the upland areas and not the shoreline areas as previously thought. Since it would be necessary to drill the monitoring wells in the upland areas at least 500 feet deep, the expense was prohibitive to drilling even one monitoring well. Therefore, it was decided that existing wells would be used instead. The resulting monitoring network will encompass more area and more wells than was initially proposed. The monitoring network will be expanded to include other wells in the Seabeck area. The process of selecting and locating these wells will begin in May, 1995.

Currently there are 9 wells in the Seabeck Aquifer being monitored by KPUD. The 9 wells include all four of the KPUD's Seabeck wells, TH-2 at Big Beef Fishery, and four other domestic and purveyor wells. Water level records for the KPUD wells date from their construction. The monitoring of the other wells was initiated in April, 1994 as part of the 60-day testing of Well 3.

The monitoring network will be implemented to acquire information on the water levels, withdrawal rates and water quality. The water levels will be measured to monitor the seasonal and annual trends of the Seabeck Aquifer System. The water quality analyses will monitor drinking water standard constituents with an emphasis on parameters such as chloride and conductivity which are indicators of salt water intrusion.

## SUMMARY AND CONCLUSIONS

Using previous hydrogeologic studies, an extensive database of well log information, pump test data, geologic cross-sections, and a potentiometric surface map, a conceptual model of the hydrogeologic characteristics of the Seabeck Aquifer System was developed. Current understanding is that the water bearing zones from approximately 100 feet above to 250 feet below sea level are all hydraulically interconnected on a regional scale and can be grouped as the Seabeck Aquifer System. The flow pattern within the Seabeck Aquifer is generally northward, perpendicular to the shoreline of Hood Canal.

An analytical model was developed to reflect the relationship between recharge rates, gradient, and transmissivity of the aquifer system, and to simulate drawdown responses of the Seabeck Aquifer System when pumping stresses are applied. The model indicates that the recharge rate is approximately 8 in/yr. This is in agreement with independent calculations using a mass balance approach. If the entire recharge area of the Seabeck Aquifer System (approximately 20 $mi^2$, or 12,800 acres) is considered, 8 in/yr is equivalent to a ground water underflow of 8,533 af/yr, or 5,290 gpm.

Total water rights in the Seabeck area (an area larger than the recharge area of the Seabeck Aquifer System), amount to 4,202 af/yr (4,158 af/yr ground water plus 43.5 af/yr surface water). This total includes all users whether in the Seabeck Aquifer or not. Approximately 85 wells are presumed to be completed in the Seabeck Aquifer. These wells, including the major production wells, account for a total allocation of approximately 3,000 af/yr. Any dramatic increase in withdrawal from this system should be phased in and monitored closely. To that end, it has been recommended that the current monitoring program be expanded to include several existing domestic wells in the area.

The analytical model predicts that the pumping of all four of the KPUD's Seabeck wells at their maximum rate continuously for 100-days will induce 8.7 feet of drawdown interference in TH-2. The geologic conditions in conjunction with water level data indicate that the Seabeck Aquifer System is not in direct continuity with Big Beef Creek and that, by analogy, is probably not a significant component of base flow for the other streams of the area. The perched aquifers appears to be the source of base flow to the surface waters of the study area. A detailed investigation of the flow rates and hydrogeologic characteristics of several locations along Big Beef Creek would determine the areas of the creek where ground water is entering the creek and may provide a better understanding of the hydrogeologic relationship with the streams.

## RECOMMENDATIONS

From the hydrogeologic study of the Seabeck Aquifer System, several recommendations can be made to improve the understanding of this complex region.

- We recommend that the continuous monitoring of the Kitsap PUD's Seabeck Wells 1, 2, 3 and 4 continue indefinitely. This will contribute to the understanding of the seasonal variations observed in earlier monitoring efforts.

- We recommend that the monitoring of Big Beef Creek Fisheries Test Hole 2 be continued indefinitely. Previous information has not been continuous, and the lack of year-round data is a shortfall of analysis at this site. In addition, production records from the Fisheries Production Well 1 should be kept and reviewed regularly.

- We recommend that the current monitoring effort be expanded to include a larger area by adding several existing wells to the monitoring network. Several wells located upgradient (south) of KPUD's wells and a few additional domestic wells along the shoreline should be added to develop a more comprehensive regional monitoring network.

- During periods of low flow in the late summer months, the Big Beef Creek should be investigated by walking the channel with close attention to changes in stream flow rates, spring lines along the valley walls, and the relationship of the geology to the valley. A major goal of the investigation would be to determine which areas are contributing ground water baseflow to the stream. This type of survey may also be of value on the un-gaged streams of the area.

- The predicted drawdown effects in the Seabeck Aquifer System are small along Big Beef Creek. However, the stress on the aquifer (pumping of KPUD's wells) should be introduced in increments and the effects should be monitored thoroughly. The impact of each incremental increase should be analyzed and understood before any subsequent pumping increases occur.

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# FIGURES

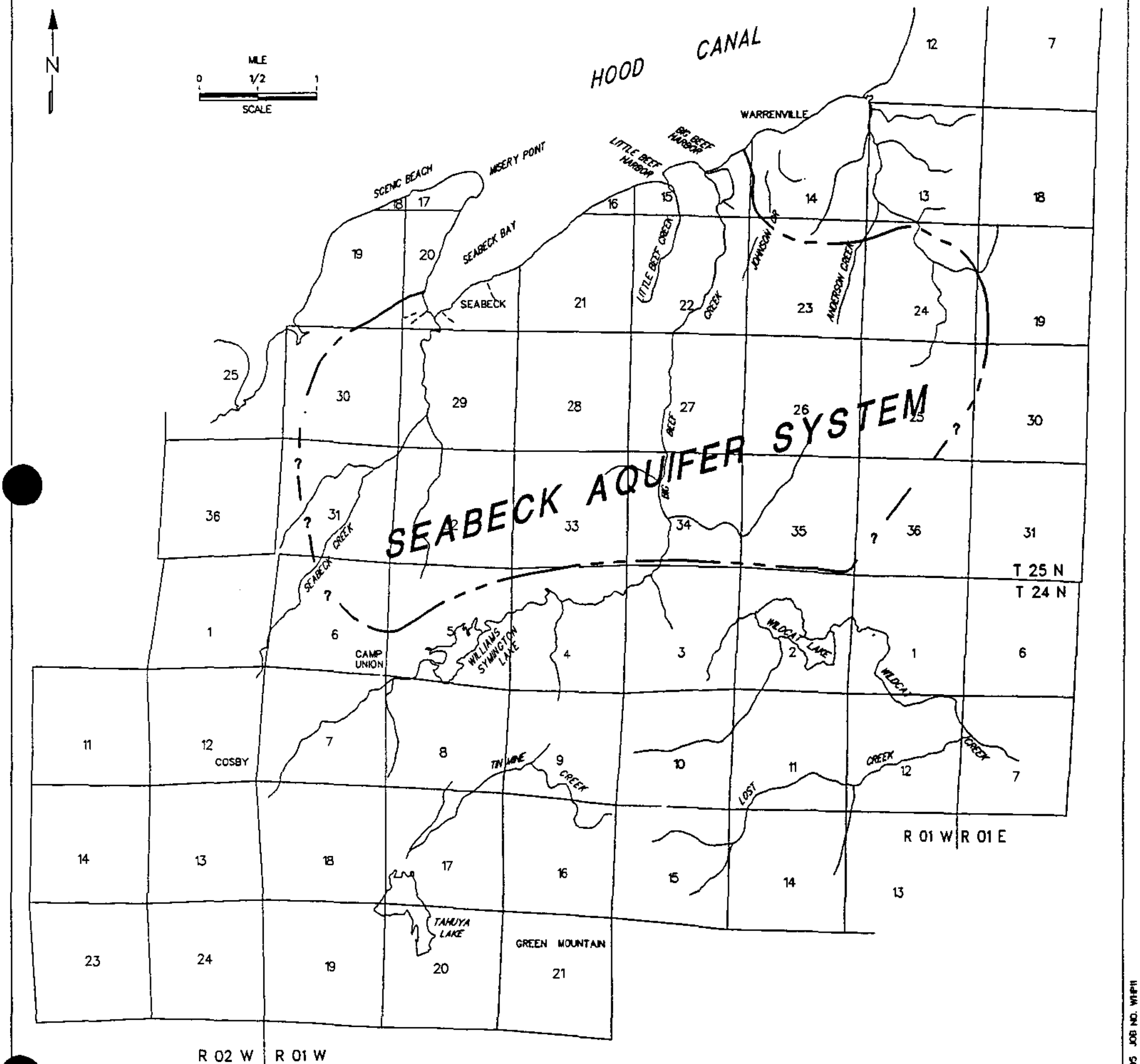


FIGURE 1
STUDY AREA, SEABECK AQUIFER SYSTEM BOUNDARY
SEABECK AQUIFER SYSTEM CHARACTERIZATION
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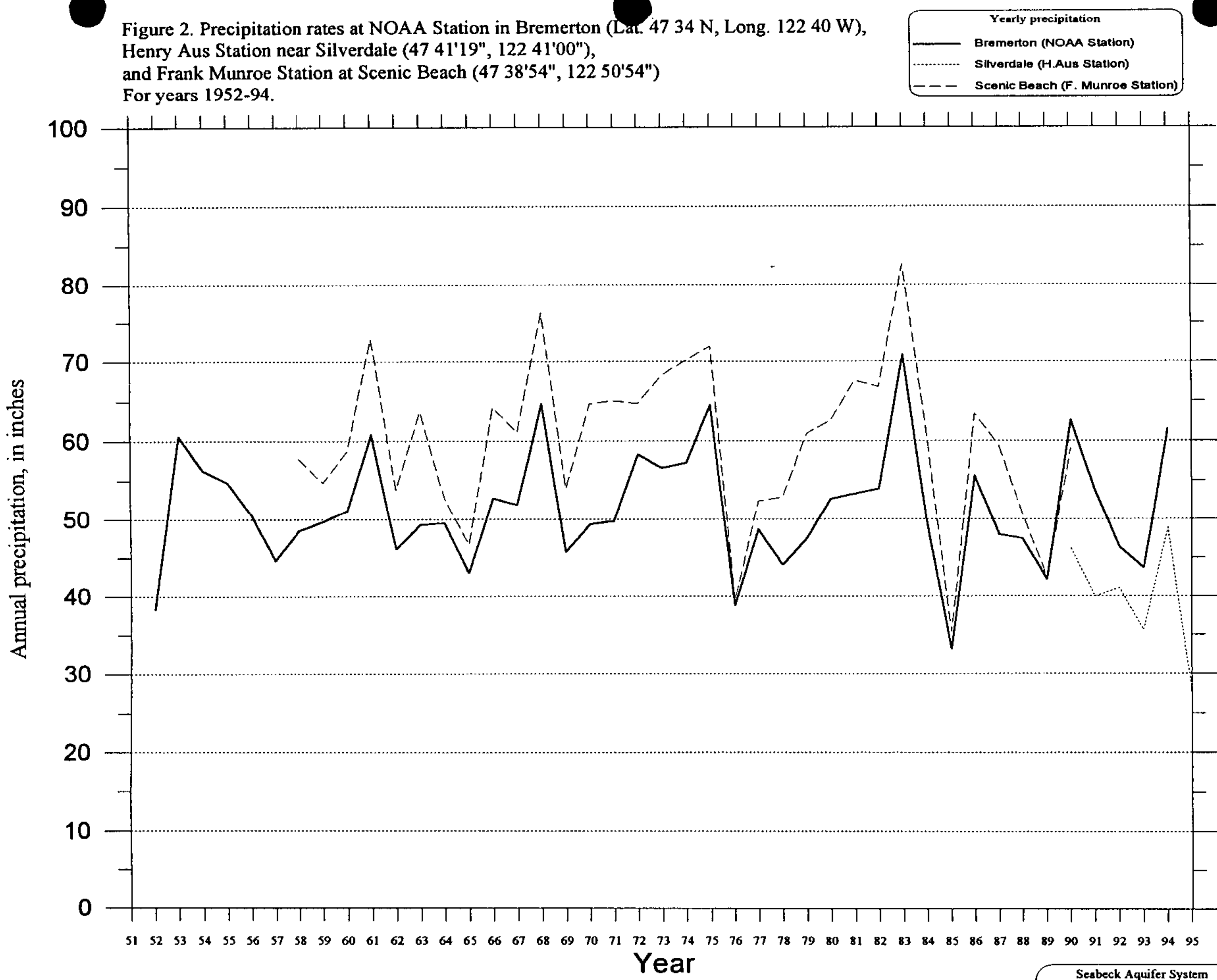
Figure 2. Precipitation rates at NOAA Station in Bremerton (Lat. 47 34 N, Long. 122 40 W),
Henry Aus Station near Silverdale (47 41'19", 122 41'00"),
and Frank Munroe Station at Scenic Beach (47 38'54", 122 50'54")
For years 1952-94.

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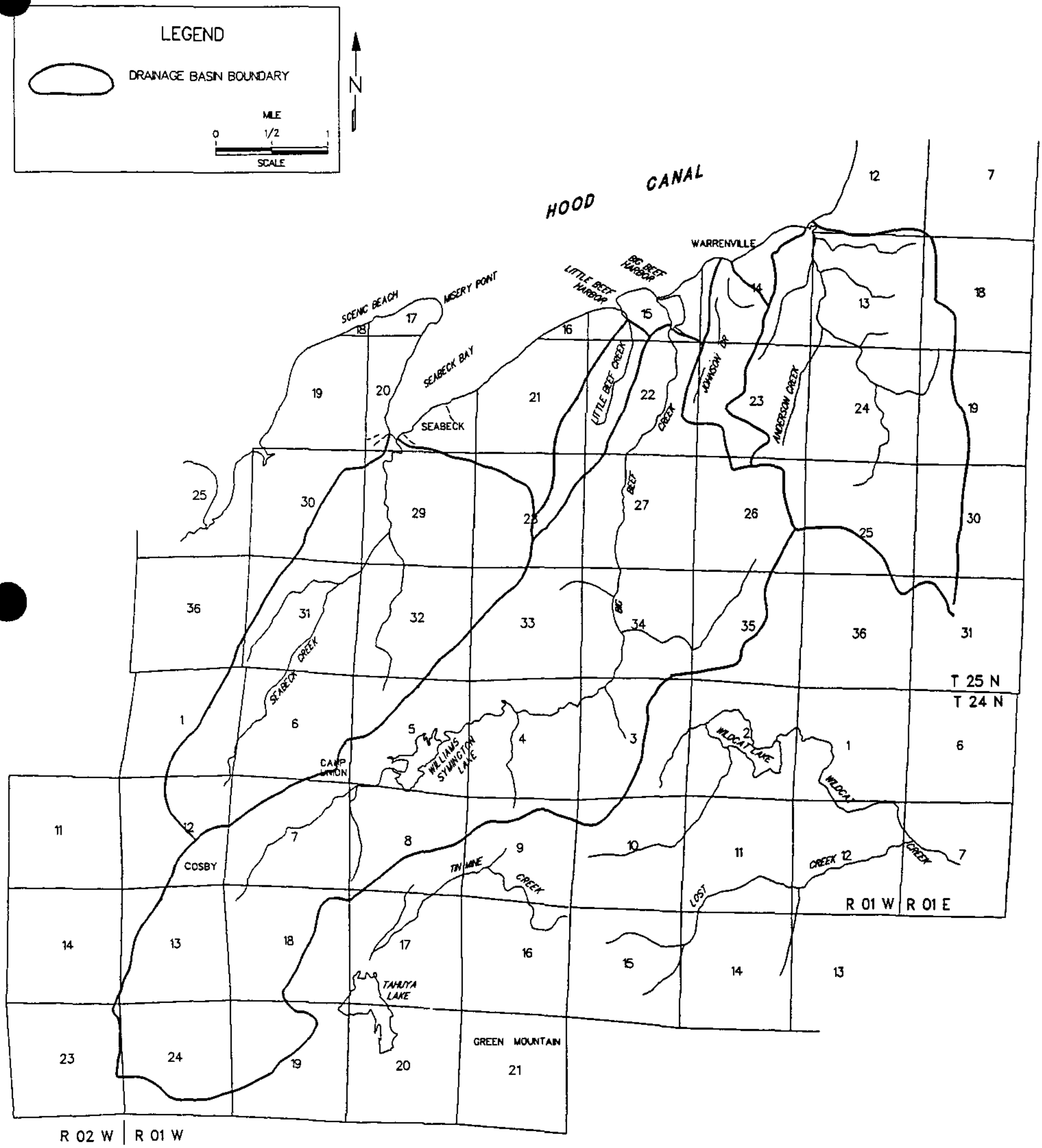


FIGURE 3

DRAINAGE BASINS OF MAJOR STREAMS IN THE SEABECK AREA

SEABECK AQUIFER SYSTEM CHARACTERIZATION

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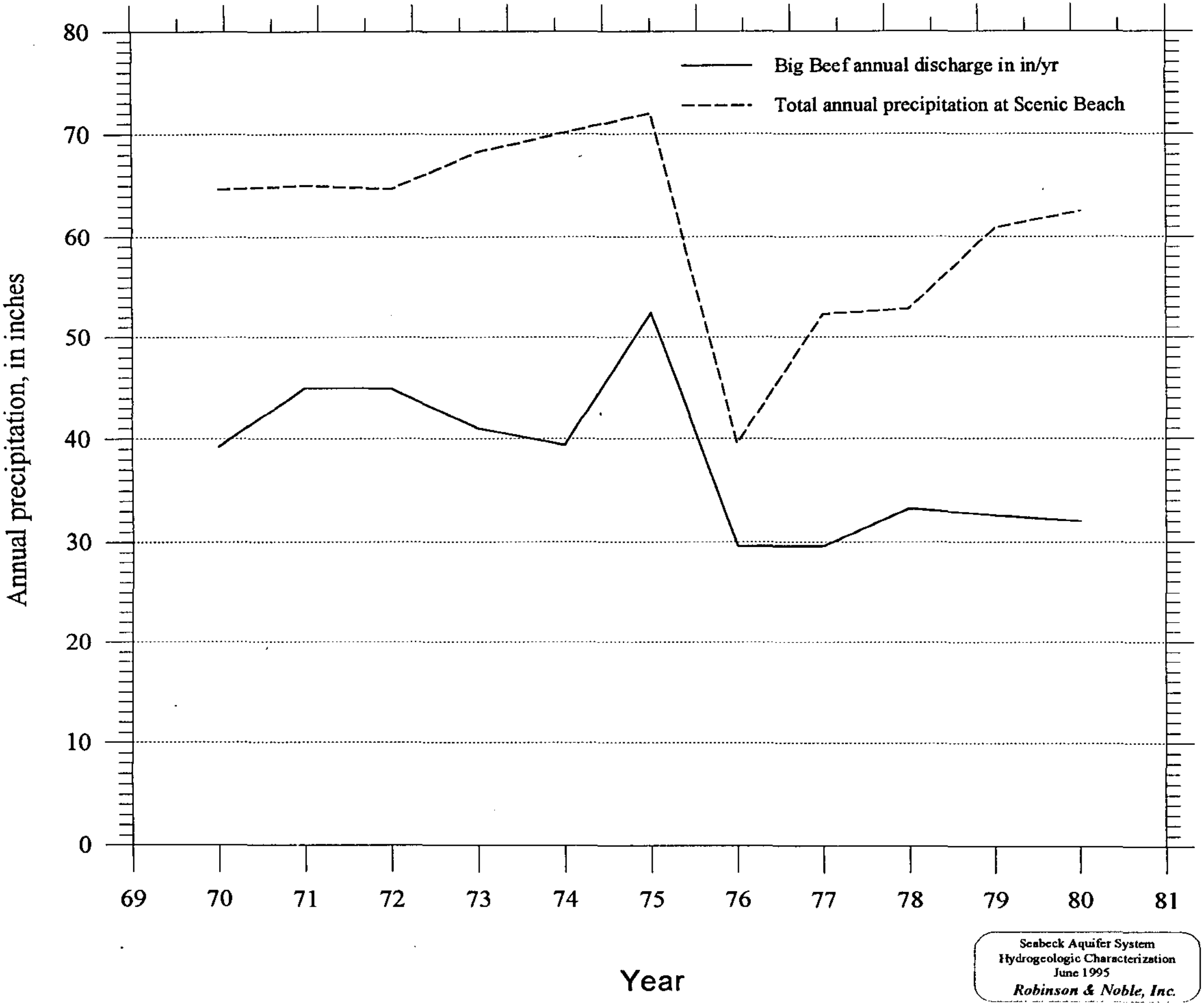
JUNE 1995 JOB NO. WH-P11

Figure 4. Plot of annual precipitation in inches at the Frank Munroe Station at Scenic Beach and annual discharge from Big Beef Creek in inches over catchment area, from 1970 to 1980.

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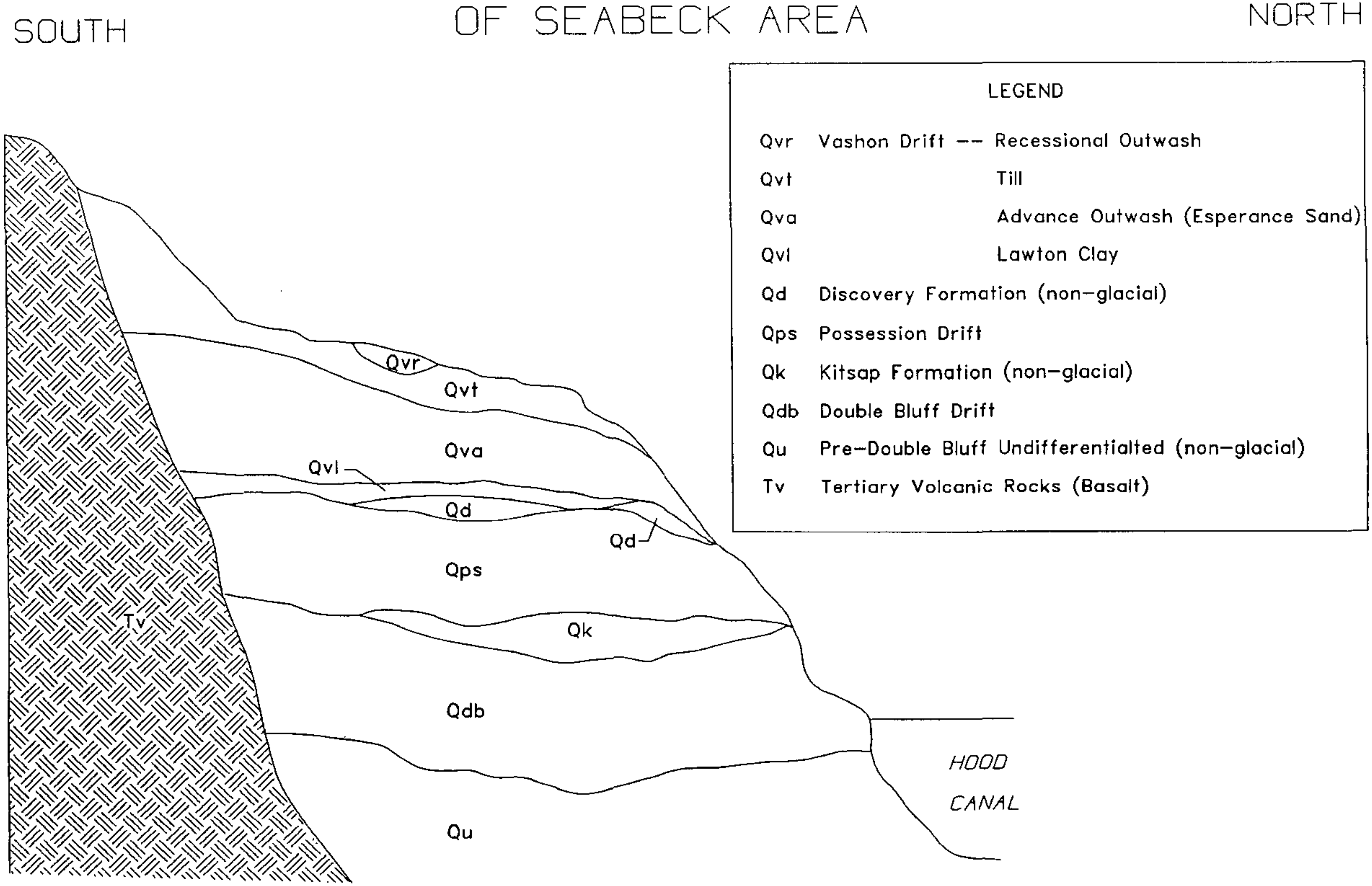
# SCHEMATIC CROSS-SECTION OF SEABECK AREA




LEGEND

| | | |
|---|---|---|
| Qvr | Vashon Drift -- | Recessional Outwash |
| Qvt | | Till |
| Qva | | Advance Outwash (Esperance Sand) |
| Qvl | | Lawton Clay |
| Qd | Discovery Formation (non-glacial) | |
| Qps | Possession Drift | |
| Qk | Kitsap Formation (non-glacial) | |
| Qdb | Double Bluff Drift | |
| Qu | Pre-Double Bluff Undifferentialted (non-glacial) | |
| Tv | Tertiary Volcanic Rocks (Basalt) | |

FIGURE 5
SCHEMATIC STRATIGRAPHIC SECTION
SEABECK AQUIFER SYSTEM CHARACTERIZATION

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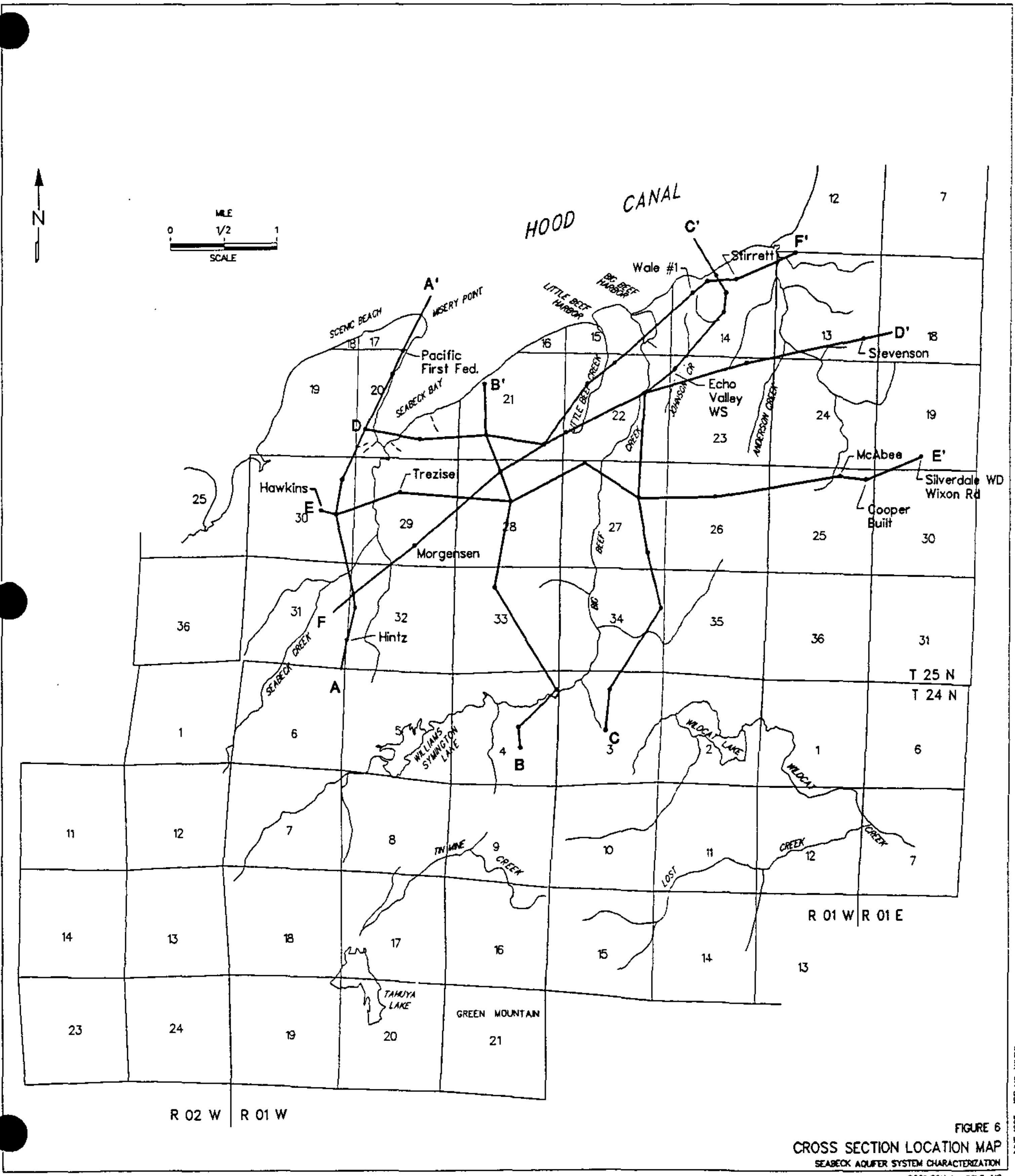
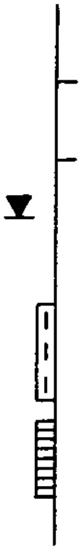



FIGURE 6
CROSS SECTION LOCATION MAP
SEABECK AQUIFER SYSTEM CHARACTERIZATION
ROBINSON & NOBLE, INC.

# CROSS SECTION LEGEND

## SYMBOLS

| | |
|---|---|
| AAA232 | DOE UNIQUE ID# |
| Well 2 | WELL NAME |



| | |
|---|---|
| (tick marks) | LITHOLOGIC INTERVAL AND IDENTIFIER |
| ▼ | PRE-STRESS STATIC WATER LEVEL |
| (open box) | PERFORATED INTERVAL |
| (hatched box) | SCREENED INTERVAL |
| 12/7 | PUMPING RATE (GPM)/ DRAWDOWN (FT) |

## LITHOLOGY

| | | | |
|---|---|---|---|
| 1 | GRAVEL | | |
| 2 | SAND & GRAVEL | | |
| 3 | SAND | vf | VERY FINE |
| | | f | FINE |
| | | m | MEDIUM |
| | | c | COARSE |
| 4 | CLAY, SILT, SAND & GRAVEL MIX | | |
| 5 | SILT, CLAY | | |

## UNITS

| | |
|---|---|
| Qvr | VASHON DRIFT RECESSIONAL OUTWASH |
| Qvt | VASHON DRIFT TILL |
| Qva | VASHON DRIFT ADVANCE OUTWASH (ESPERANCE SAND) |
| Qvl | VASHON DRIFT LAWTON CLAY |
| Qd | DISCOVERY FORMATION (NON-GLACIAL) |
| Qps | POSSESSION DRIFT |
| Qk | KITSAP FORMATION (NON-GLACIAL) |
| Qdb | DOUBLE BLUFF DRIFT |
| Qu | PRE-DOUBLE BLUFF UNDIFFERENTIATED |
| Tv | TERTIARY VOLCANIC ROCK (BASALT) |

## LITHOLOGIC MODIFIERS / EXAMPLES

| LITHOLOGIC MODIFIERS | | EXAMPLES | |
|---|---|---|---|
| / | MIXED, EQUAL AMOUNTS | 3/5 | SAND & SILT |
| , | MIXED, IN LAYERS | 3,5 | SAND WITH SILT LAYERS |
| . | MIXED, NON-EQUAL AMOUNTS | 3.5<br>5.3 | SILTY SAND<br>SANDY SILT |
| W/ | OCCASIONAL | 3 W/5 | SAND WITH OCC. SILT |
| Pt | PEAT NOTED | | |

## SCALE

VERTICAL SCALE 1:1,200

HORIZONTAL SCALE 1:24,000

VERTICAL EXAGGERATION = 20

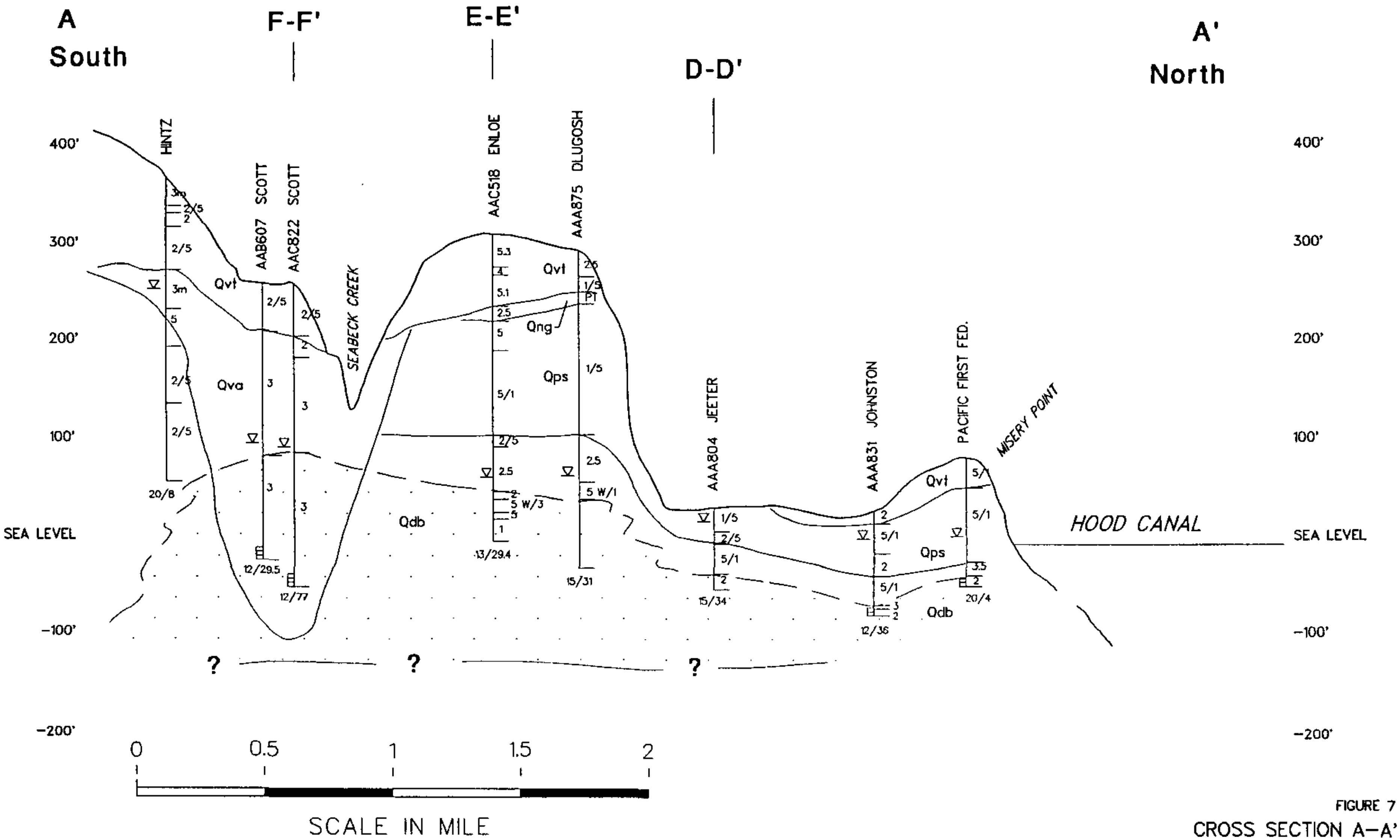



FIGURE 7

CROSS SECTION A–A'

SEABECK AQUIFER SYSTEM CHARACTERIZATION

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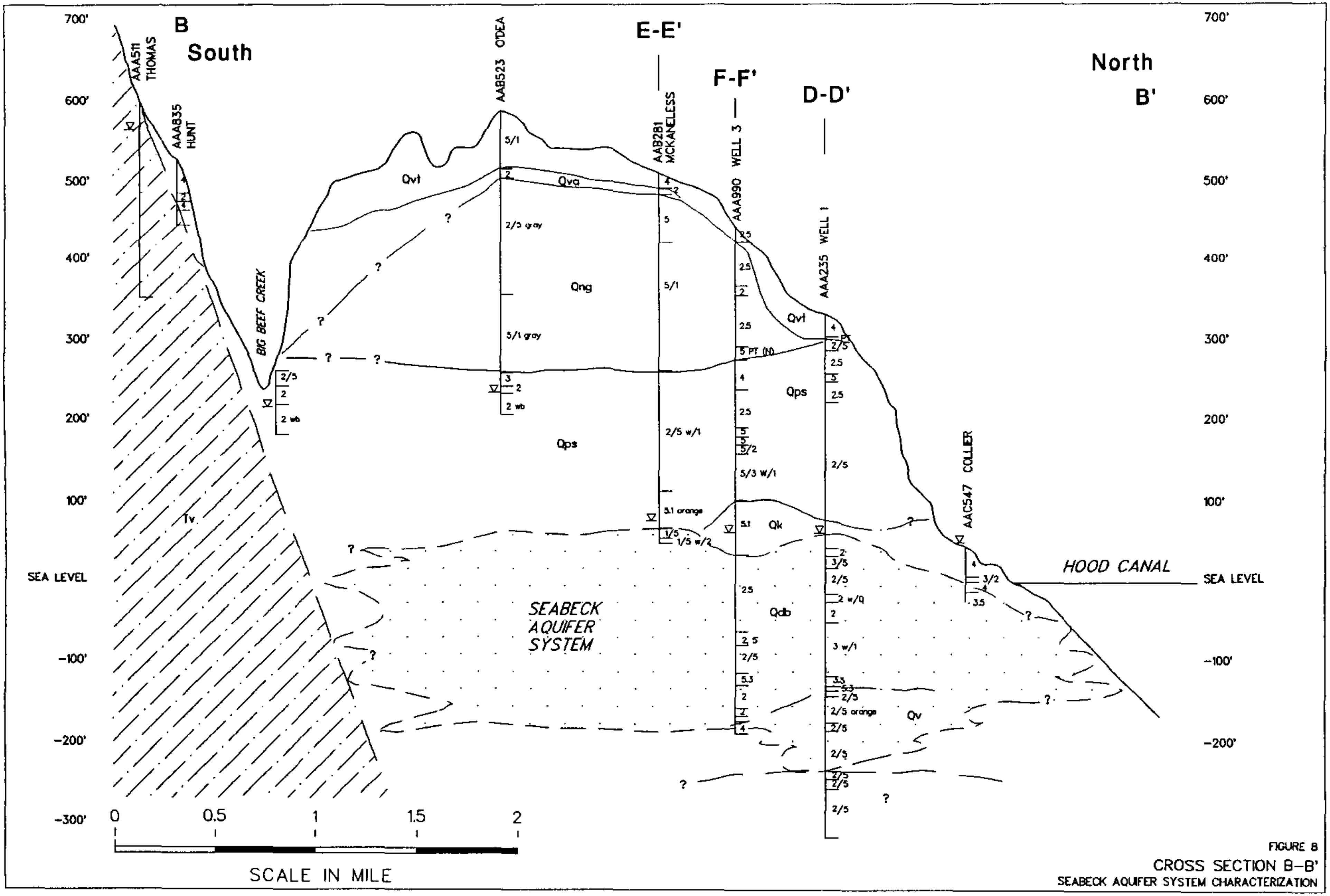


FIGURE 8

CROSS SECTION B–B'

SEABECK AQUIFER SYSTEM CHARACTERIZATION

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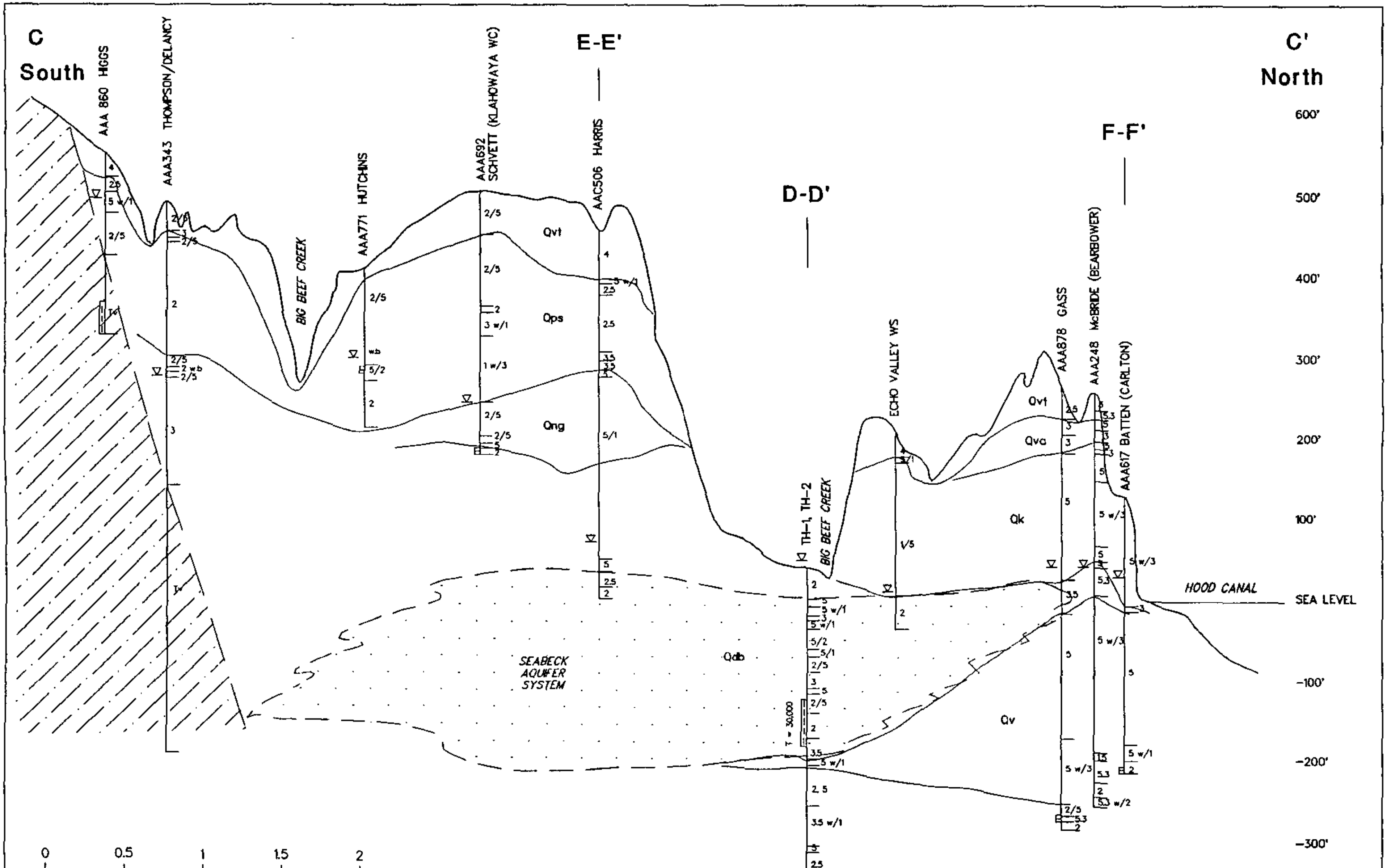


FIGURE 9
CROSS SECTION C–C'
SEABECK AQUIFER SYSTEM CHARACTERIZATION

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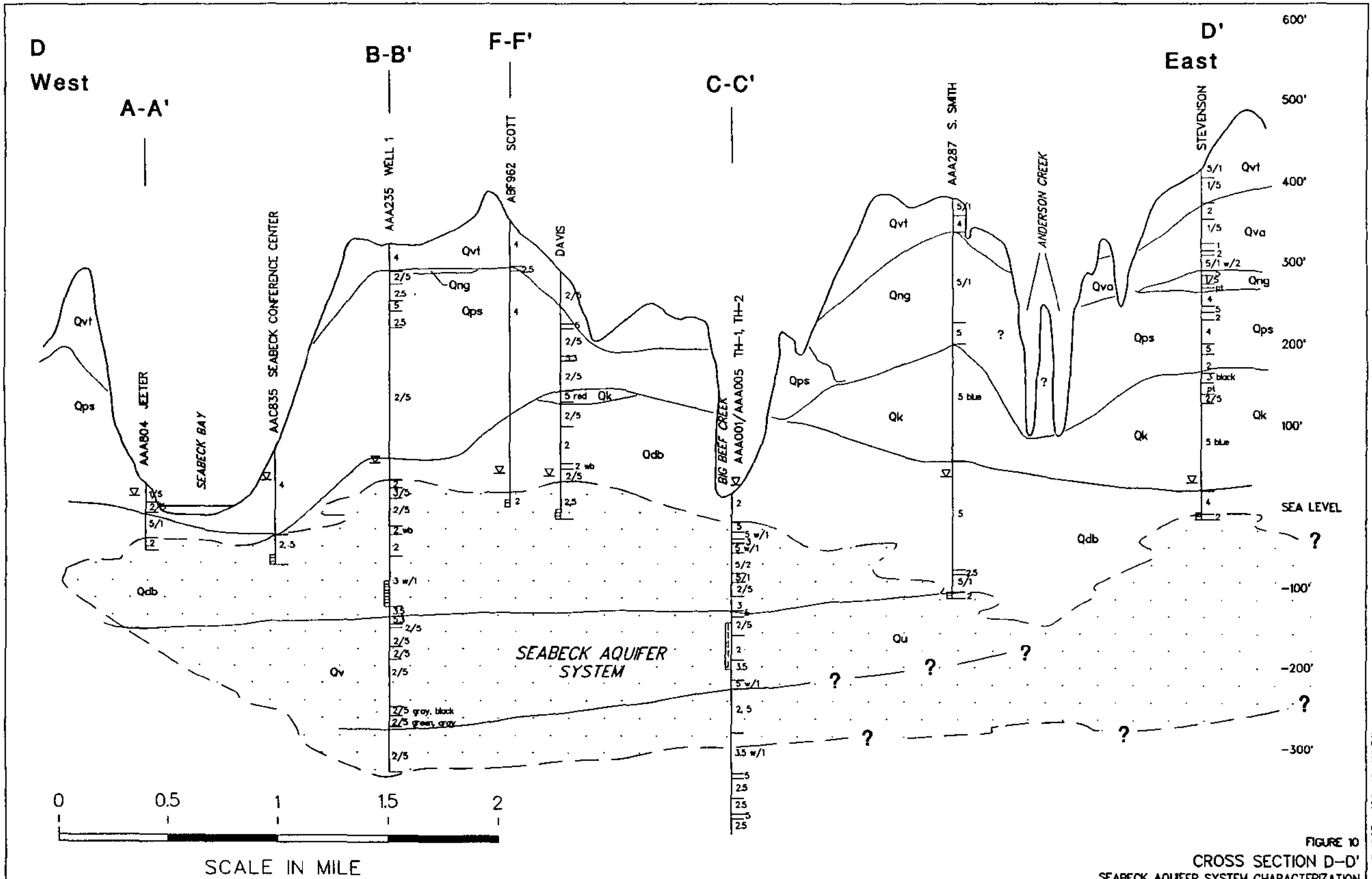


FIGURE 10
CROSS SECTION D-D'
SEABECK AQUIFER SYSTEM CHARACTERIZATION

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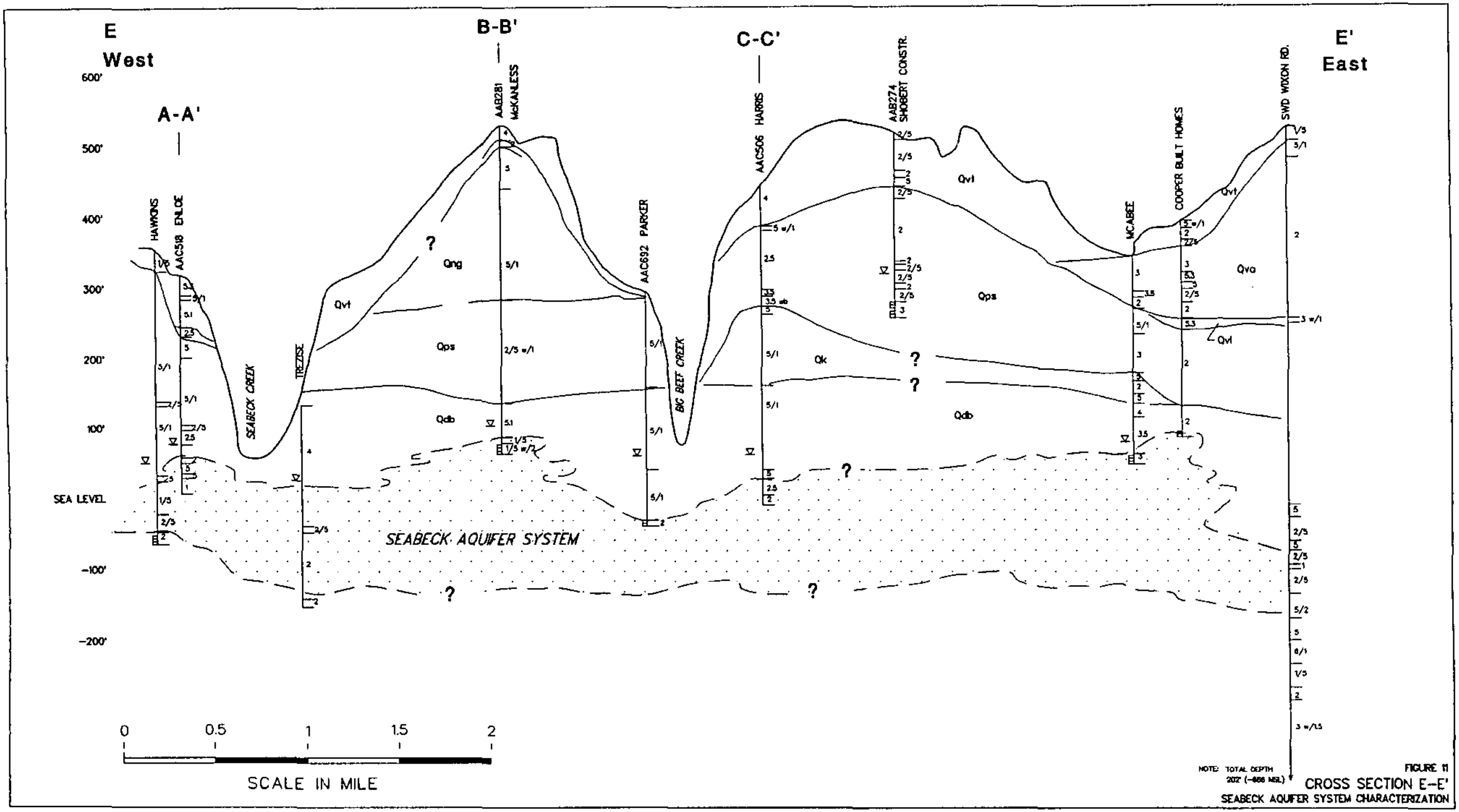


FIGURE 11
CROSS SECTION E–E'
SEABECK AQUIFER SYSTEM CHARACTERIZATION
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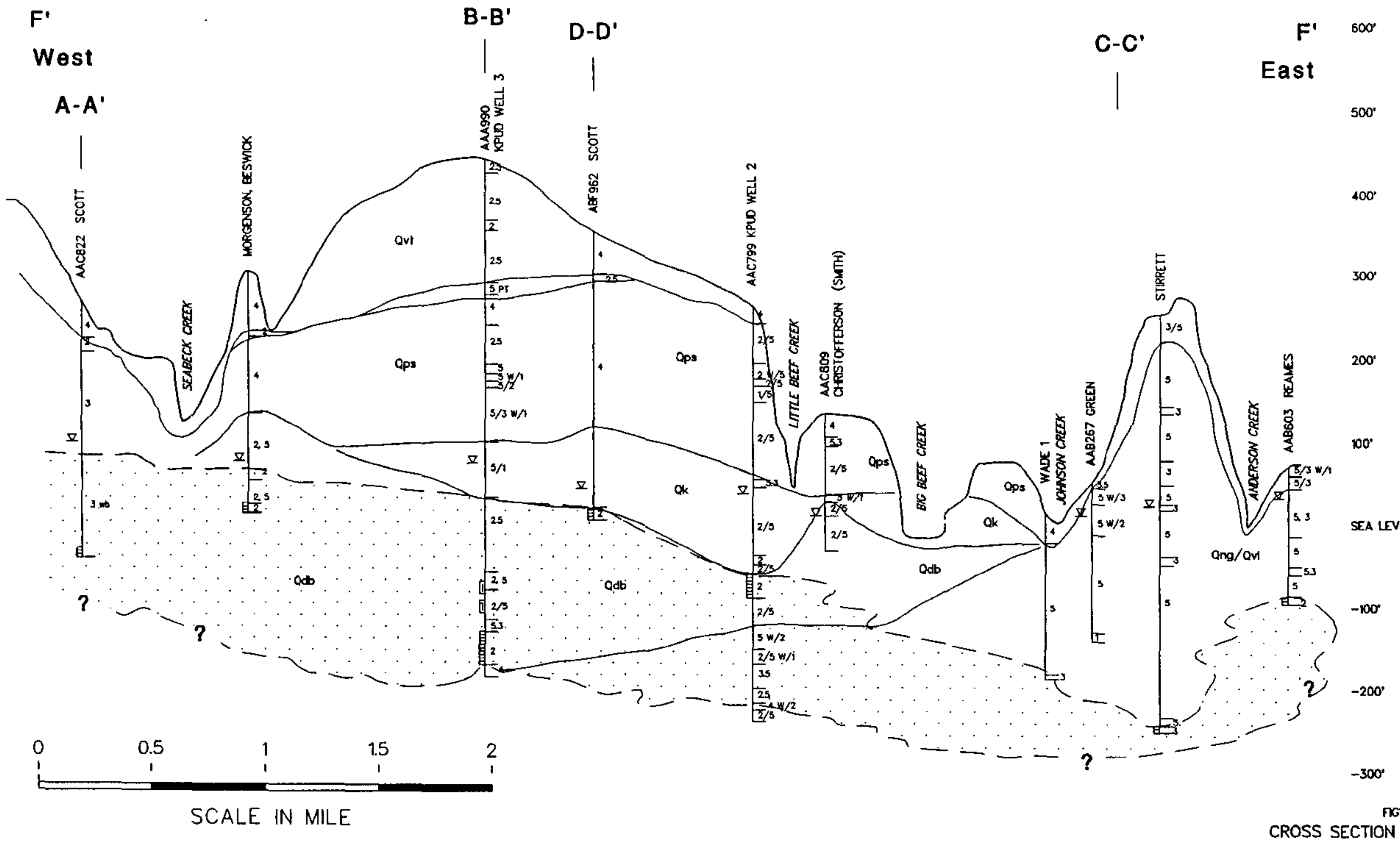


FIGURE 12
CROSS SECTION F–F'
SEABECK AQUIFER SYSTEM CHARACTERIZATION

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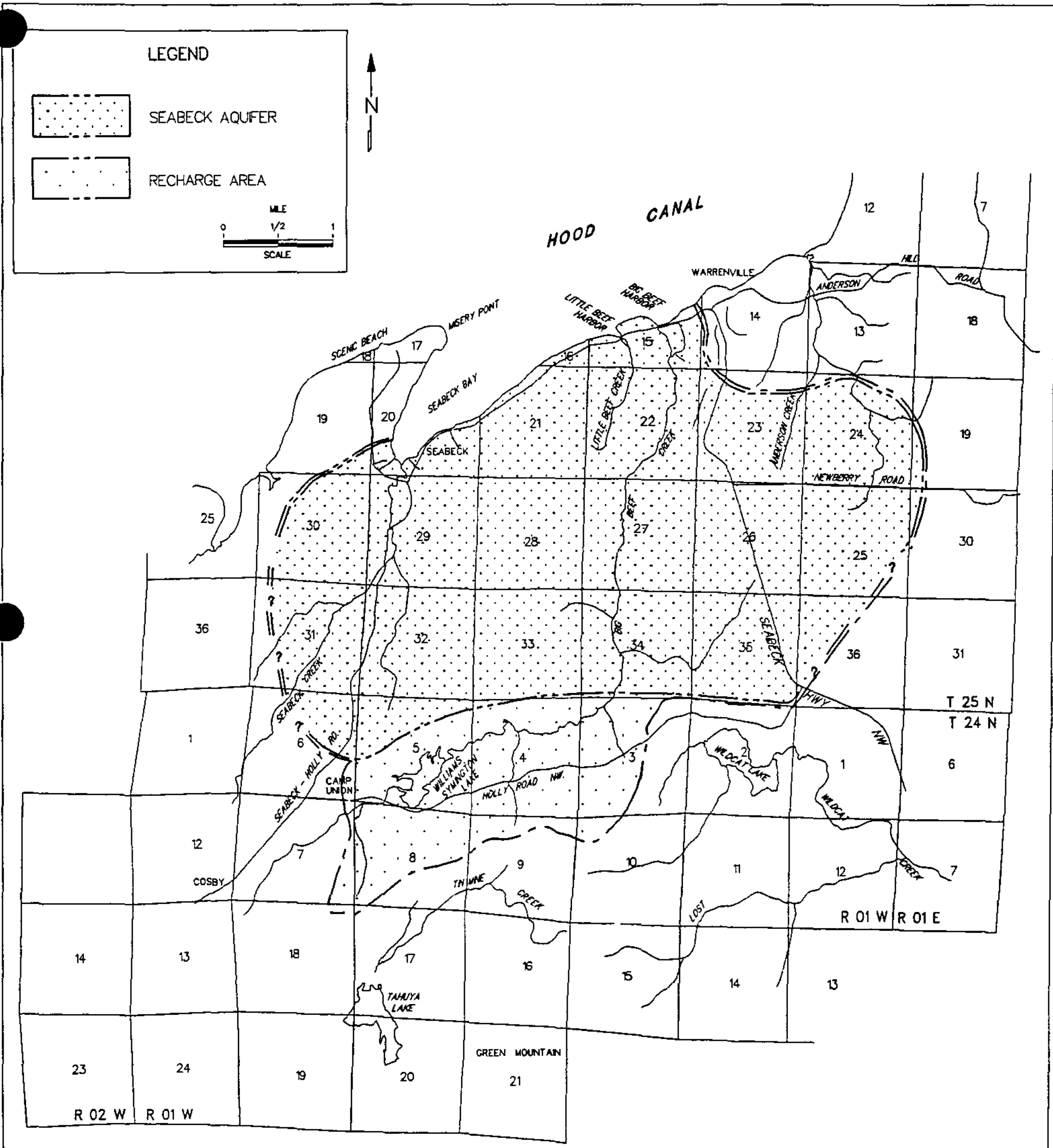


FIGURE 13
RECHARGE AREA OF THE SEABECK AQUIFER SYSTEM
SEABECK AQUIFER SYSTEM CHARACTERIZATION
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**Figure 14. Potentiometric surface map of the Seabeck Aquifer System.**

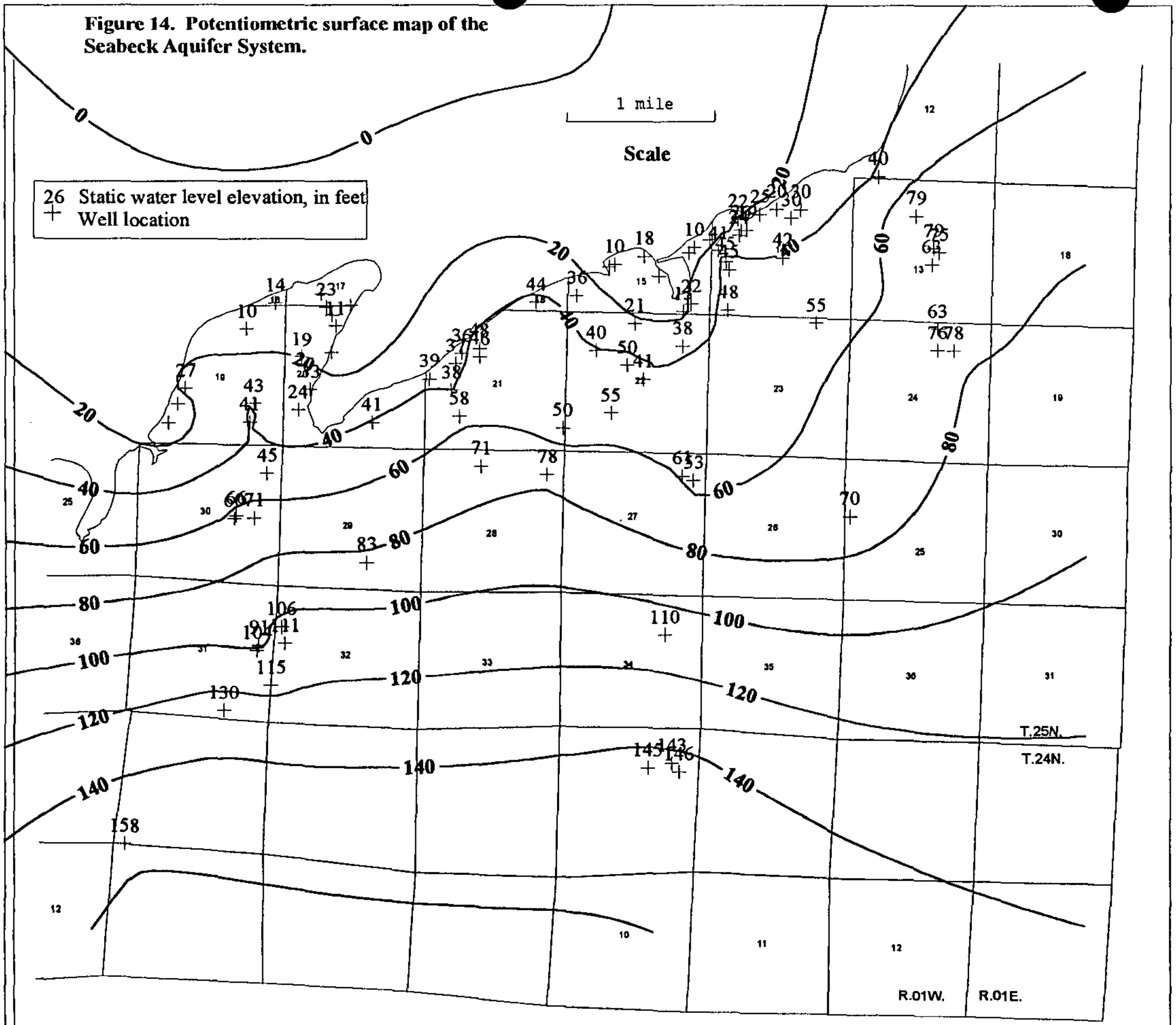

Figure 15. Predicted drawdown interference (in feet) from pumping Well 3 at 585 gpm for 60 days.

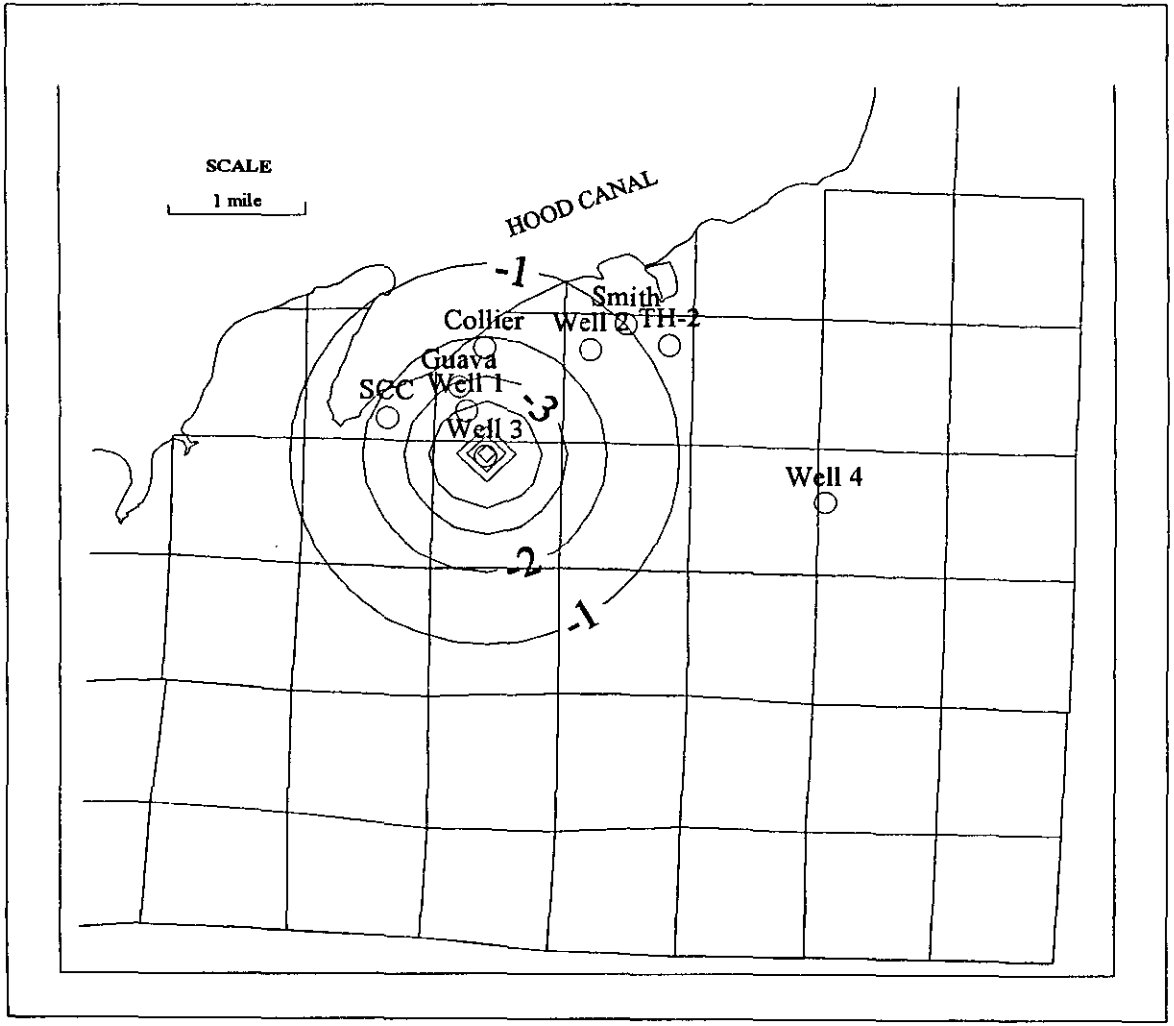


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Figure 16. Scatter plot for drawdown interference during the 60-day test of Well 3 compared to the computed drawdown. (k = 33.4 ft/day, S = 0.0098).

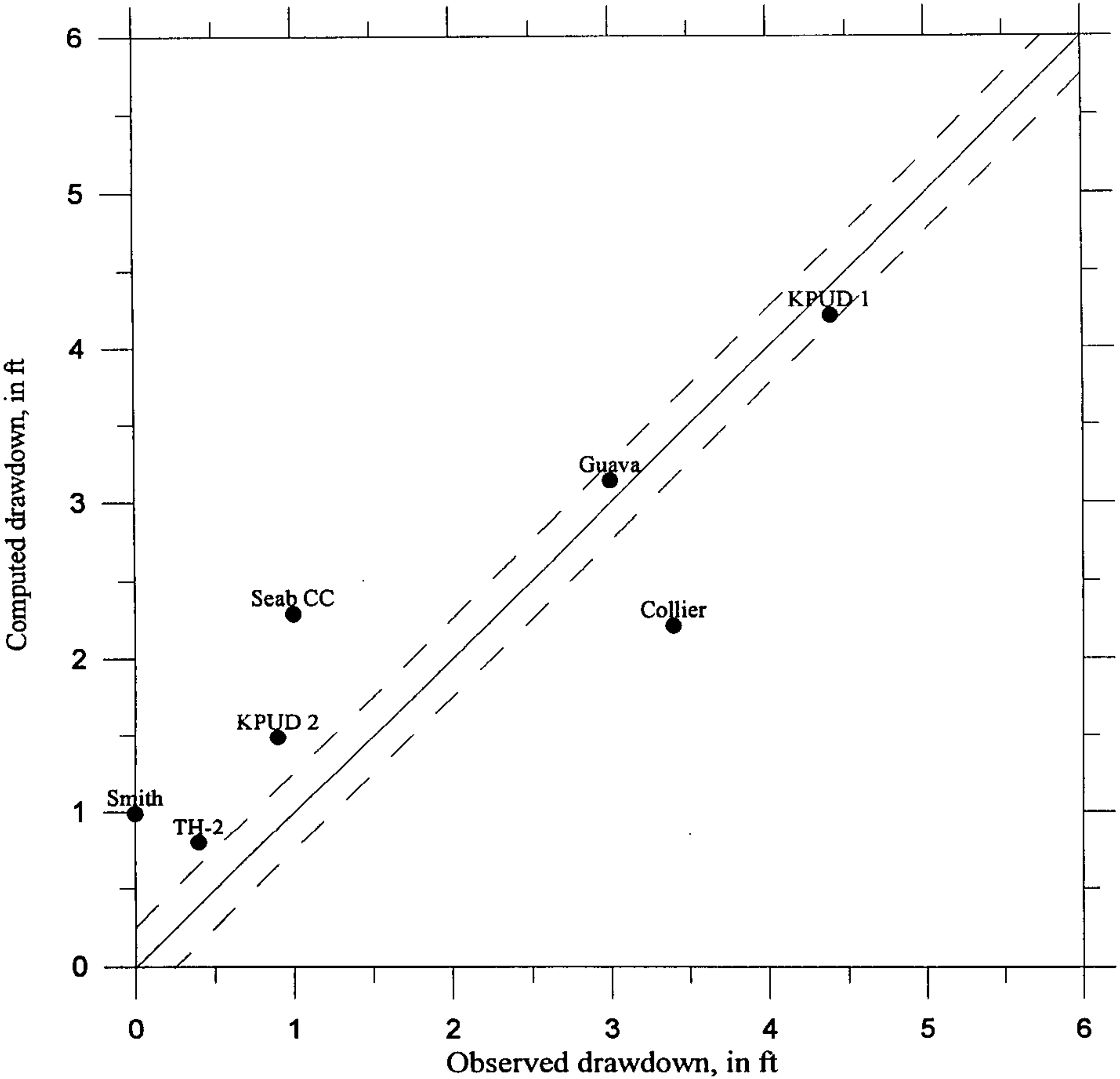


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Figure 17. Predicted drawdown interference from pumping of Well 3 at 600 gpm for 100 days. k=33.4, S=0.0098

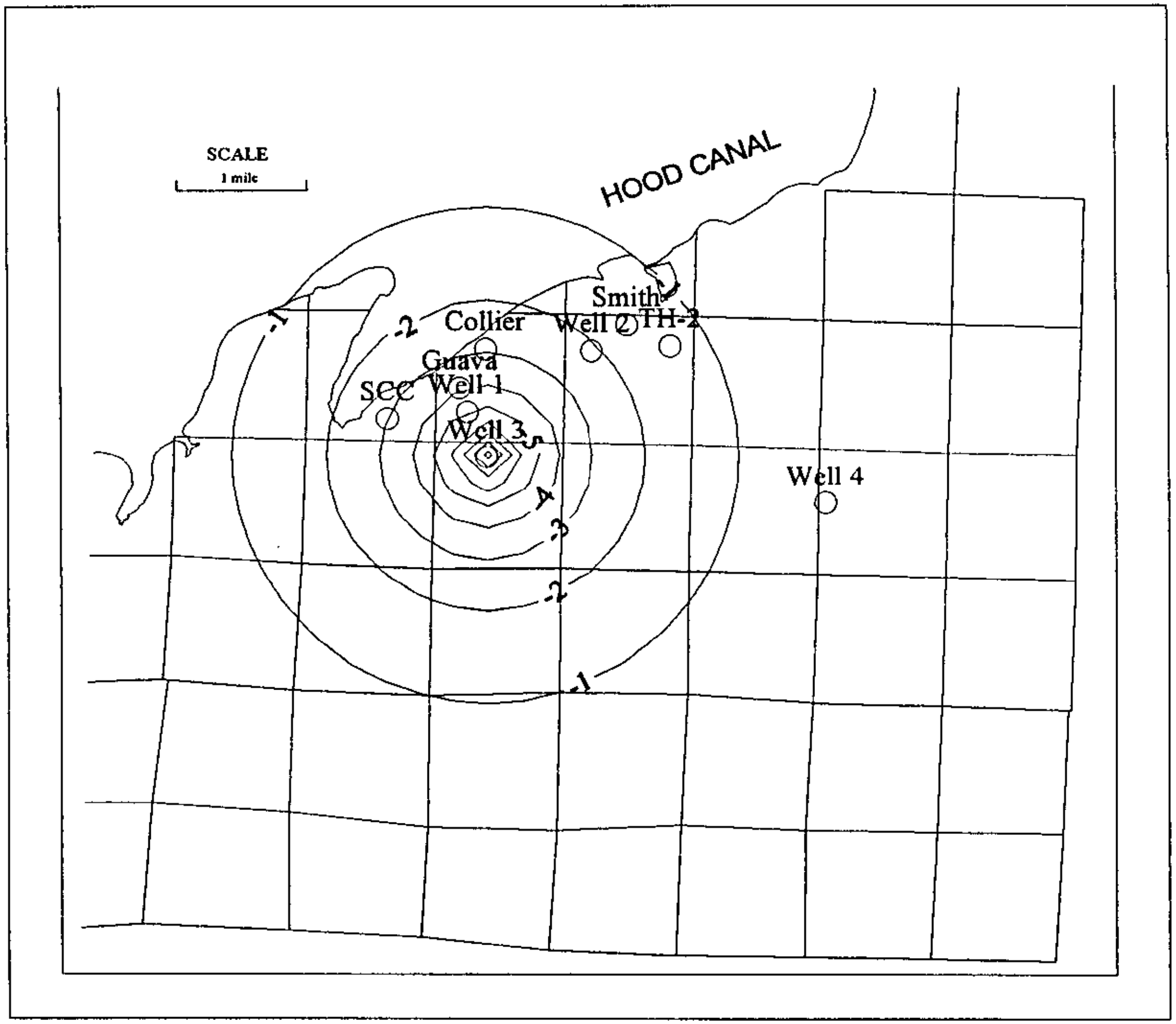


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Figure 18. Predicted drawdown interference from pumping Well 1 at 325 gpm and Well 3 at 600 gpm for 100 days. k= 33.4, S=0.0098

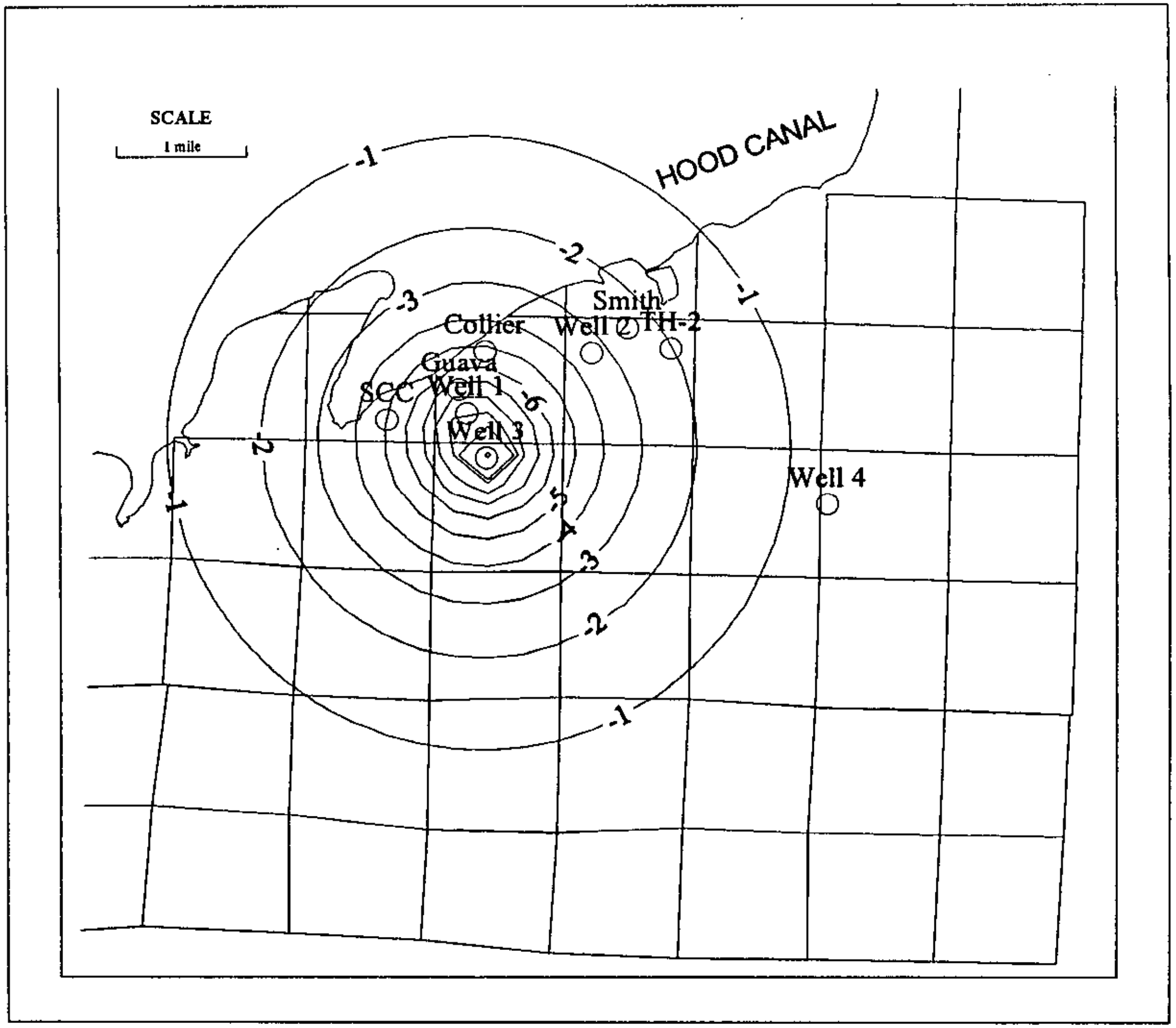


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Figure 19. Predicted drawdown interference (feet) from pumping of Well 1 at 325 gpm, Well 3 at 600 gpm, and Well 4 at 200 gpm for 100 days. k= 33.4, S= 0.0098

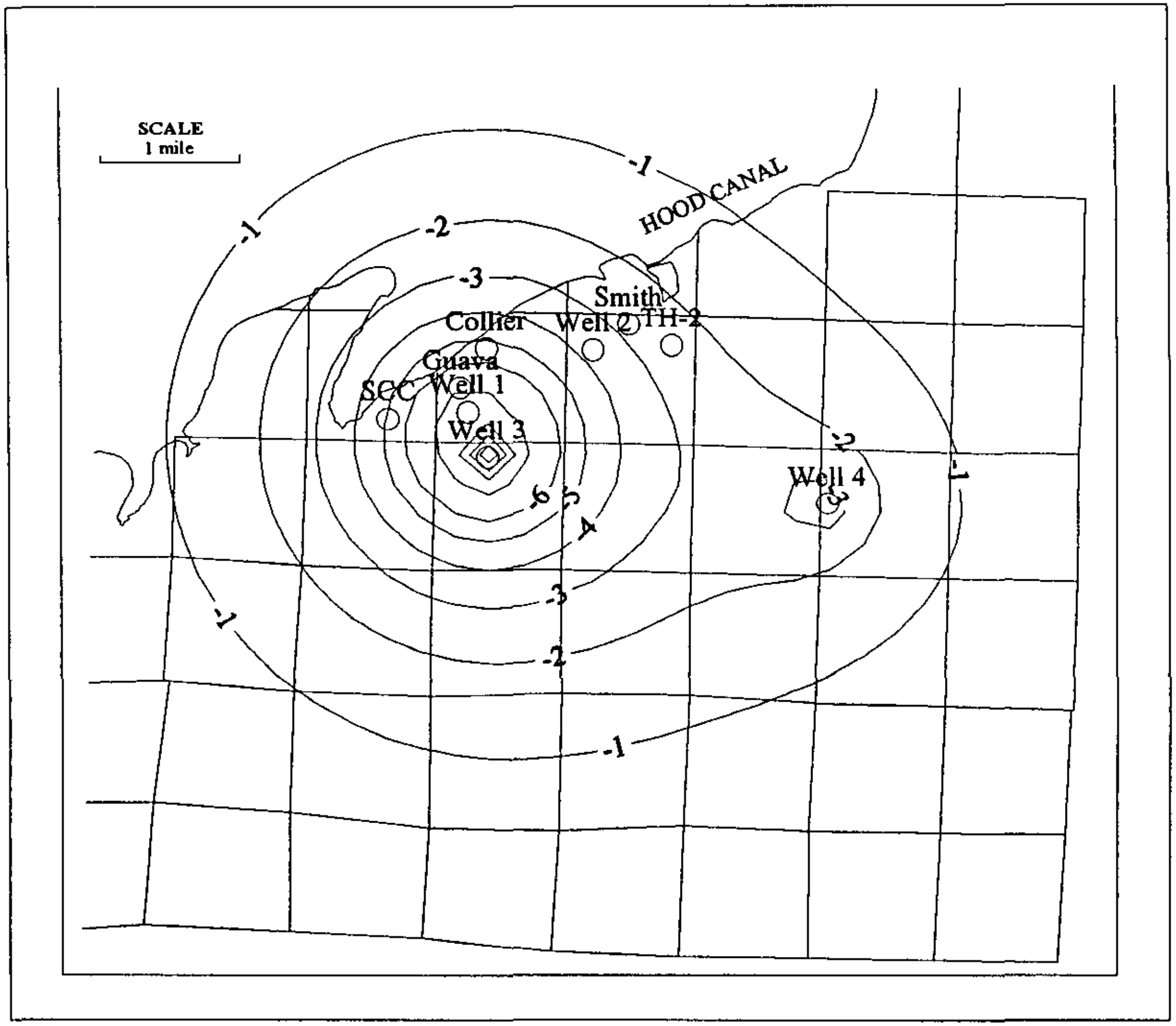


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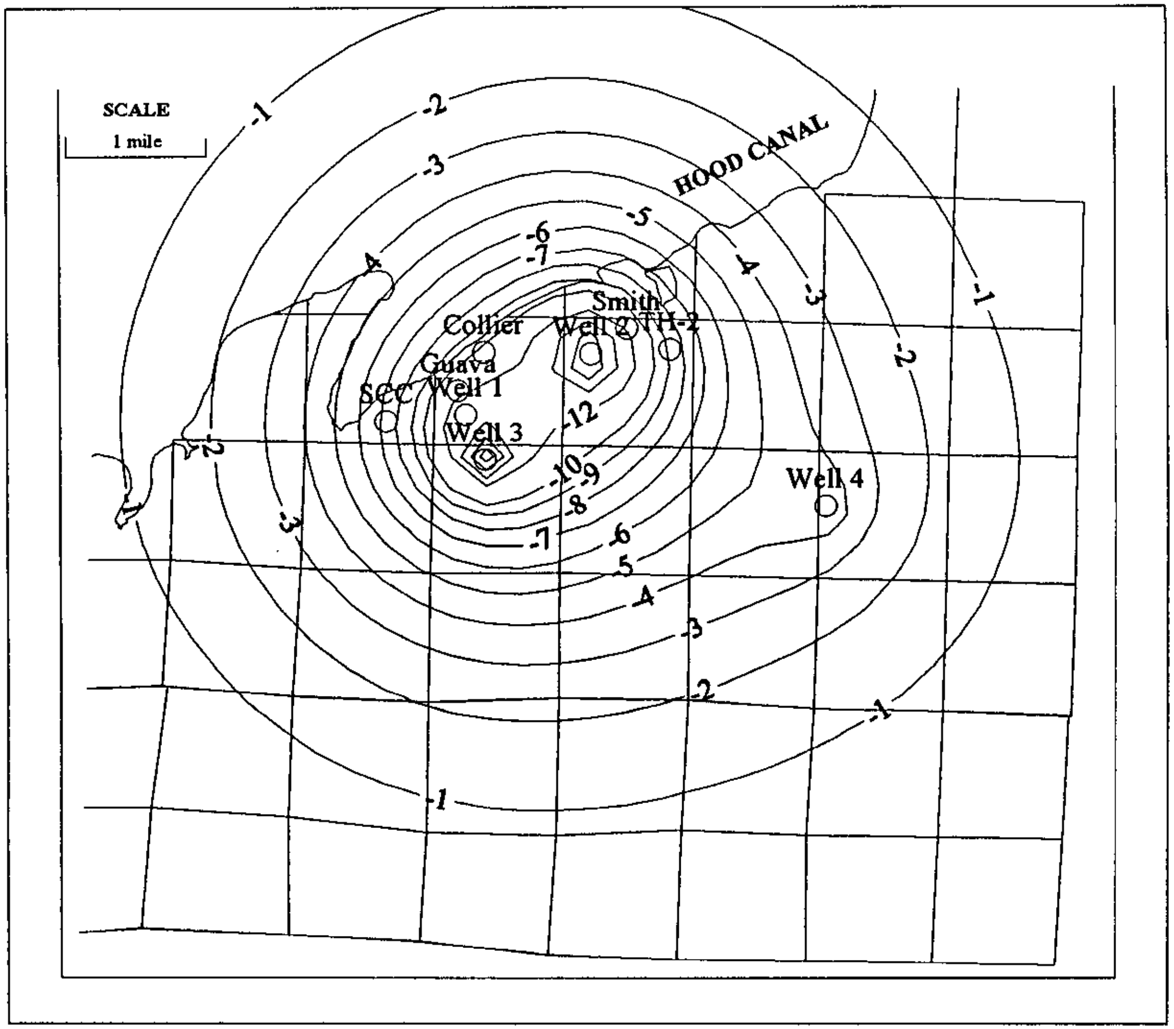
Figure 20. Predicted drawdown interference (in feet) from pumping Well 1 at 325 gpm, Well 2 at 1000 gpm, Well 3 at 600 gpm, and Well 4 at 200 gpm for 100 days. k=33.4, S=0.0098

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# APPENDIX A

***Recommendations-in-progress report for the Seabeck Aquifer Protection Study***

# *Recommendations-in-Progress Report*
# *for the*
# *Seabeck Aquifer Protection Study*

*June 1994*

*by*

*J. F. Kaminsky*

*Prepared by:*

**Robinson & Noble, Inc.**
5915 Orchard Street West
Tacoma, Washington 98467

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*for the*
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June 1994

## Introduction

As a module of the Seabeck Aquifer Protection Study, this report summarizes the available data collected thus far, and makes recommendations with respect to the Seabeck Aquifer Protection Plan. This report includes: 1) the findings of an extensive well database search and update; 2) the selection of candidate wells for further study; 3) representative hydrogeologic cross-sections; delineation and redefinition of the Seabeck Aquifer; 4) the nature of flow in the aquifer with respect to discharge and recharge areas by construction of a regional flow map.

## Well database

Robinson & Noble were provided KPUD database dumps for the parcel of land delineated by Robinson & Noble as the study area (Figure 1). The study area was defined by Robinson & Noble as the area of land that would reasonably be expected to fully contain the Seabeck Aquifer, and also provide sufficient surrounding buffer space to accurately define the edge of the aquifer. The database dump consisted of T. 24N, R. 1W Sections 3 through 6; T. 25N, R. 1W, Sections 13 through 35.

**KPUD database.** The provided database records were reportedly of the best quality and were only provided in the dump because they were thought to be accurate and were field-checked as such. After several days of searching through the provided records, it became apparent the database was unreliable for several reasons. These reasons are as follows:

1. Numerous wells do not appear to be in a location commensurate with the reported land surface datum. For example, a well might have a listed land surface elevation and be located in a section which does not even contain terrain low of high enough to include such an elevation. This of course could be a function of the wrong location rather than of a error in land surface datum.

2. Erroneous Latitude - Longitude listing. These wells have erroneous data that presumably are the result or errors in data entry. Besides the uncertainty of locating the well, one of the more serious problems that arises from this error is static water levels that appear well below sea level because of the terrain in which the reported lat - long plots them in. This causes problems in modeling flow in the aquifer.

3. Mixed decimal Latitude - Longitude listing and degrees, minutes, seconds listing. While the location may be accurate, this error creates problems in locating well by plotting programs. There is currently no database field to identify which wells are listed with the decimal format or degrees, minutes, seconds. The result in some cases is that wells plot in the wrong section or even worse, plot in the middle of Hood Canal.

4. Multiple entries for the identical well. This error appears to the be the result of the same data unwittingly being entered for two different wells or for the same well with different owner names. Table 1 lists wells identified thus far.

Table 1. Duplicate Entries present in KPUD database.

| First site ID | First local name | Duplicate site ID | Duplicate local name |
|---|---|---|---|
| 473935122455601 | ? | AAA248 | Private McBride (Bearbower) |
| 473921122454901 | ? | AAA521 | Private Sicks |
| 473841122474201 | KPUD | AAC799 | KPUD Seabeck Test well 2 |
| 473854122441101 | ? | AAA056 | Private Demers |
| 473802122460602 | ? | AAA048 | Private Wallace |
| 473749122453001 | Private Powers | AAA289 | Private Powers |
| 473747122483601 | ? | AAB281 | Private Aronhalt (McKaneless) |
| 473746122503401 | ? | 473746122503402 | ? |

5. Erroneous or missing names in the local name field. This problem could be easily dealt with if entries are limited to the current owner (if available) and the original name that appeared on the original log. No other entries are needed and only serve to confuse the database user when present.

***R&N Database***. Because the above errors caused confusion in some cases, a parallel spread-sheet based database was begun. This database only consists of owner name, local ID, depth, land surface, static water level and screen elevation. This database is not designed to replace the KPUD database. It was designed to be used as working tool with space for comments regarding problems with the well location, or other information. This database was also designed to quickly identify wells at certain target screen elevations to screen out wells to be used for cross-sections, etc., which could be quickly accomplished by normal column and row arithmetic functions. This database appears as a appendix to this document.

The procedure for accomplishing the R&N database was as follows. First, all paper copy of well logs were assembled for the study region. These logs came from Robinson & Noble well log repositories, Robinson & Noble job files, Nicholson Drilling, Inc. job files, and Kitsap PUD files. These well logs were compared to the database dump provided by Kitsap PUD. Each well log that was not included in the Kitsap PUD database was noted as such, photocopied, and sent to Kitsap PUD for entry into the database. The remaining well logs were compared to the information contained in the Kitsap PUD database dump for accuracy and completeness. Locations for these wells were also cross-checked by owner name with the Metsker land ownership maps for the region. Wells were then plotted on a USGS quadrangle to check location and land surface elevation associated with that location. When an accurate location was indicated, static water level was then checked to ensure a reasonable number. In some case, the calculated static water level elevation was far below sea level, resulting in flagging the location as uncertain. The result of the above procedure is a spreadsheet of each well that has some sort of hardcopy documentation (DOE log, USGS report log, etc.) of location, depth and water level. The hand plotted map was then used to acquire a general feel for the distribution of wells in the region and to pick wells for cross-sections.

## Cross-section construction

***Procedure.*** Because of a relatively low number of deep wells that had reliable land surface and location data, cross-section locations were limited. Specifically, three north-south sections (lines A-A', B-B', and C-C'), two east-west sections (lines D-D' and E-E'), and one southwest-northeast section (line F-F') were constructed (refer to Figures 6-12 in final report: Purdy, 1995). The cross-sections were laid out on 7-1/2 minute USGS quadrangle with a horizontal scale of 1-inch to 2,000 ft. The vertical scale used for the sections is 1 inch to 100 ft (20 x vertical exaggeration). Each well was scaled to the cross-section using the actual horizontal distance from the preceding well. In doing so, a bend in each cross-section occurs at every well. At each well, a strip log of geology was constructed from the data reported in the drillers well report associated with each well. The driller's formation picks were strictly followed, although some interpretation was used when terms such as "hardpan" appeared in the log. Hardpan was interpreted as any dry dirty clay-bound sand and gravel, regardless of origin.

After laying out strip geology on the cross-sections, correlations were made where obvious geologic boundaries existed. It was assumed, for example that the driller could determine the difference between clay and sand or sand from sand and gravel. Reliable regional correlations were able to be made in some cases, especially were large thicknesses of clay were reportedly present. Less success was had when mixed silts, sands, and gravels were reported.

Static water levels were plotted on the strip log of each well. In most cases, static water level elevations matched what could be expected for that particular region. However, in some cases, especially near the shoreline with Hood Canal, static water level was too far below sea level to be anywhere near accurate. As alluded to earlier, inaccurate static water level are probably a function of poor location data rather than an improperly reported static water level.

**Cross-section analysis**

***General.*** Although it would be desirable to have several more cross-sections, analysis of the existing cross-sections leads to some interesting conclusions. Previously, analysis of data sets associated with the drilling of the three KPUD Seabeck test wells and the University of Washington Big Beef Fisheries test wells led to an assumption that the so-called Seabeck

Aquifer was a separable hydrostratigraphic unit that was intercalated between a series of other aquifers defined on the presence of clay-bearing strata at the Big Beef test wells (Table 2). While this system of categorization seemed to work fairly well in a geologic sense for the Big Beef drilling project, the relationships it depends on become unreliable with distance from Big Beef Fisheries.

**Table 2.** Seabeck area aquifer nomenclature.

| Big Beef Fisheries designation | Depth below sea level | Seabeck Well 3 report designation |
|---|---|---|
| Aquifer "A" | 35 to 155 ft | not encountered |
| Aquifer "B" | 135 to 215 ft | Seabeck Aquifer |
| Aquifer "C" | 225 to 265 ft | Big Beef Aquifer |
| Aquifer "D" | 410 to 485 ft | not explored for |

Based on data collected at the aforementioned wells, the Seabeck Aquifer was thought to be the water-bearing zone occurring between approximately sea level and 200 below MSL. The lower boundary of the Seabeck Aquifer was drawn at a notable orange-orange/red to brown clay about 5 feet thick. The upper boundary was drawn at the brown clay separating the Aquifer "A" and Aquifer "B" at Big Beef Fisheries, but was undefined elsewhere. Aquifer testing at the Big Beef Fisheries Production Well 1 (PW-1) which was completed in Aquifer "C" showed that aquifers "A" through "D" responded to the imposed stress. This situation, coupled with the fact that hydraulic head measurements in piezometers completed in aquifers "A" through "D" are all within 5 feet of each other, indicate that there is little justification for the divisions as presented in Table 1.

***Redefinition of the Seabeck Aquifer.*** Analysis of the available data indicates that a much broader definition of the Seabeck Aquifer is warranted. The data show that the Seabeck Aquifer is better defined as a large, highly stratified heterogeneous series of permeable strata of similar head, which occur between approximately 100 ft above MSL to 270 ft below MSL. Locally, this series likely consists of small, thin water bearing zones which may appear isolated from one another on a small scale. Static water level in this aquifer system is generally between MSL and 100 feet above MSL.

***Extent of the Seabeck Aquifer.*** The Seabeck Aquifer is laterally extensive, appearing to be as large as 15 sq. miles in area. In general, thicknesses of the aquifer range from 200 to 300 ft. However, this thickness is for the entire packet of water bearing strata, and therefore includes local impermeable or low-permeable materials. It is stressed that the 200 to 300 ft estimate for aquifer thickness is not necessarily water bearing throughout.

The southern and northern boundaries of the aquifer are well-defined. The southern terminus appears to be against steeply north-dipping Tertiary basalt which comprise the Green Mountain highlands to the south of the Seabeck Area. Projecting the attitude of dip based on the top of basalt encountered in several drilled wells, the contact with Seabeck Aquifer units appears to subcrop at an elevation of about sea level on line approximately paralleling the baseline between townships 24N and 25N. The northern practical boundary is the shoreline with Hood Canal.

The east and west boundaries are less well-defined. The eastern extent of the aquifer seems to be controlled by the presence of a thick sequence of clay and clayey silts, sands, and gravels. This sequence clearly delineates the northeastern corner of the aquifer, but becomes less apparent with distance to the south. However, well control in the east-central and southeastern portion of the Seabeck study area is poor at Seabeck Aquifer depths. It is entirely possible that the central portion of the aquifer may extend to the region marked by the principal meridian between R. 1W and R.1E, based on the lack of Seabeck-type water bearing units in the Silverdale Water District deep well at Wixon Road.

The eastern boundary is not clearly marked by a major lithologic change. However, water levels appear to wrap back around the Green Mountain highland just west of Seabeck Creek. This change may also be a function of well placement.

**Analysis of static water levels**

***Flow net Analysis***. A flow net was constructed using water level data from wells thought to be completed in the Seabeck Aquifer (refer to Figure 14 in final report: Purdy, 1995). A flow net consists of flow lines drawn to show general directions of ground water movement from areas of recharge to areas of discharge. Flow lines are conceptual abstractions based on assumptions of water flow and aquifer characteristics. In a theoretical homogenous and isotropic aquifer, flow lines are perpendicular to equipotential lines, which are lines of equal hydraulic head.

Analysis of the flow net constructed for the Seabeck Aquifer shows ground water is moving in a northerly direction, discharging, for the most part, into Hood Canal. Along this boundary, there also exists at least two area of concentrated discharge. One of these regions of concentrated discharge is the Seabeck Bay area, the other appears to be the region near Little Beef and Big Beef Harbors. These areas, marked by the pronounced curvature of equipotential lines, may not be the result of natural heterogeneities in the aquifer. Rather, the distorted equipotential lines may delineate area of higher ground water usage.

The flow net also indicates that the area of recharge lies to the south, perhaps even as far as Green Mountain. However, the physical extent of the Seabeck Aquifer is thought to be much less than that. The Seabeck Aquifer is likely recharged by water moving horizontally and downward through fractures in the basaltic rocks lying to the south. This water enters Seabeck strata either directly, or indirectly by downward leakage from higher aquifers being recharged by water originating in the basalt.

*Areas for further ground water exploration.* By analysis of the flow net, areas that are promising for further ground water development can be readily identified. One of the more favorable areas, almost perfectly outlined by the three KPUD wells (numbers 1, 2, and 3), lies in the eastern portion of Section 21 and the western portion of Section 22. This area of the aquifer is characterized a lower hydraulic gradient, which may be indicative of a zone of greater transmissivity. Another larger area of promising ground water supplies is the area between Big Beef Creek and Anderson Creek. This is also an area of lower hydraulic gradient. However, the geology at Seabeck Aquifer depths appears to change to more clay-rich strata as one approaches the area of Section 14. Therefore, the likelihood of having to complete a well in material with a less than desirable transmissivity is probably greater.

## Implications for new KPUD Seabeck Aquifer monitoring wells

Monitoring wells are needed to monitor natural trends in head, water quality, and the effect on water levels due to seasonal changes in ground water utilization. Several factors must be weighed before placing a well in order that the most beneficial information can be generated. A primary use of the well should be identified (e.g., water quality, observation, etc.). Secondly, can the well be placed to help further delineate aquifer boundaries.

*Water quality monitoring wells.* At the minimum, at least two wells whose primary responsibility would be water quality monitoring, are suggested to be placed in the two areas of concentrated discharge. Because these two areas show a landward deflection of equipotential lines, all other things being equal, water quality degradation due to salt water intrusion should occur in these areas first. Secondarily, these wells can also observe head in the aquifer. Monitoring of secondary water quality analyses should done on a monthly basis for the first few months and then possibly dropped to a biannual basis if no problems are detected. Both of these wells should be screened in the first permeable zone below sea level.

Because there are no manufacturing facilities or landfills in the area, regular monitoring for primary water quality contaminants is unwarranted.

***Observation wells.*** Several observation wells whose primary responsibility would be to monitor long-term changes in aquifer water levels are suggested. Ideally, these wells should be placed in areas not already under heavy ground water production, but up-gradient from those area which are. Three such wells are suggested for the southern boundary of the aquifer. These wells would be placed to help further delineate the thickness and extent of the aquifer, and to monitor up-gradient head closer to the recharge zone. Suggested areas for placement are along the northern portions of Sections 31 through 35 in Township 25N.

# APPENDIX B

*Interpretation of a 60-day pumping test on*
*PUD #1 of Kitsap County's*
*Seabeck Well 3*

# INTERPRETATION OF A 60-DAY PUMPING TEST ON PUD #1 OF KITSAP COUNTY's SEABECK WELL 3

October, 1994

by

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Prepared by

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## ATTACHED ILLUSTRATIONS



## APPENDIX

**INTERPRETATION OF A 60-DAY PUMPING TEST OF PUD #1 OF KITSAP COUNTY's SEABECK WELL 3**

October, 1994

# INTRODUCTION

To better understand the long-term capabilities and regional characteristics of the Seabeck Aquifer System, the naming of which is discussed below, a 60-day pumping test was conducted on Kitsap Public Utility District No. 1's Seabeck Well 3. Considering that the combined peak capabilities of Seabeck Wells 1, 2 and 3 could be as much as 2,425 gallons per minute, the ability of the aquifer system to sustain that level of production needed to be evaluated. Well 3 was tested at an average of 584 gpm for 60 days. Several wells were monitored before, during and after the pumping period and the information was collected and evaluated. Based on the evaluation of the pumping test, coupled with the compilation of geologic data, the capacity and extent of the aquifer system has been estimated. The following report will be included as supplement in the Seabeck Aquifer Protection Study currently in progress.

# PROJECT SUMMARY

## NAMING OF THE SEABECK AQUIFER SYSTEM

The description of the aquifers in the Seabeck area has evolved over the years. In 1980, two test wells and one production well at the Big Beef Creek Fisheries Research Center encountered four productive water bearing zones and were designated, from shallow to deep, as Aquifers A, B, C, and D. Aquifer C was considered one of the most productive in Kitsap County. As part of the Ground Water Management Plan (GWMP) in 1991, these aquifers were grouped into the Big Beef Aquifer system. Evaluation of a 3-hole test drilling program for the PUD from 1991 to 1993 showed that the target Aquifer C did not extend a great distance from Big Beef

Creek, however Aquifers A and B did. Aquifer B was then referred to as the Seabeck Aquifer and its extent was estimated. The long-term testing of KPUD's Seabeck Well 3 and the work currently being done on the Seabeck Aquifer Protection Study show that regionally there was no basis for the separation of the aquifers. Consequently, all the aquifers found at the Fisheries Center and by the PUD wells should be combined and referred to as the Seabeck Aquifer System.

## TESTING RESULTS

The 60-day test of KPUD's Seabeck Well 3 has provided valuable information on the Seabeck Aquifer System. The testing allowed an excellent opportunity to take close-order, accurate measurements over a large area and time span. Results of the test showed:

- Pumping of Well 3 at an average rate of 584 gpm for 60-days induced drawdown interference in all the wells monitored.
- Drawdown and recovery data showed that the Seabeck Aquifer System can maintain a production level of 600 gpm from Well 3 for an extended period with no apparent residual affect on the system's water levels. The recovery trend shows that interference observed during the test was a temporary condition and that aquifer water levels returned to the expected non-stressed level.
- Water chemistry was stable and of excellent quality throughout the pumping period.
- There was no evidence of saltwater intrusion.

Based on the testing results and the on-going aquifer protection study, a conservative production rate of approximately 1,400 gpm was estimated as the capacity of the aquifer system between Wells 1, 2 and 3. A rate of 1,000 gpm should be used for initial planning purposes for KPUD's Seabeck wells.

# REDEFINITION OF SEABECK AQUIFER SYSTEM

Since 1980, the boundaries of the various aquifers in the Seabeck area have been estimated and re-estimated. Past boundaries were based on site-specific studies in the area. Currently, a detailed study specifically intended to define the aquifer boundaries, is being conducted. Figure 1 shows the progression of the defined boundaries. A synopsis of the previous and on-going studies follows.

## PREVIOUS STUDIES IN THE AREA

### Big Beef Creek Fisheries study

In 1980, Robinson & Noble supervised the drilling and testing of two test wells and one production well for the University of Washington at the Big Beef Creek Fisheries Research Center. Four aquifers were discovered and designated Aquifers A, B, C, and D. Aquifer C, located 225 to 265 feet below MSL, was shown to have characteristics that make it among the best aquifer zones identified on the Kitsap peninsula. Production Well 1, completed in Aquifer C, was tested at 2,000 gpm for 72.5 hours. The aquifer at the site has an implied transmissivity of 165,000 gpd/ft.

### Kitsap County GWMP

As part of Grant No. 1 of the Kitsap County Ground Water Management Plan (GWMP), 27 principal aquifer system areas were identified. The only major aquifer identified in the West Kitsap subarea was named the Big Beef Aquifer system. It was identified at Big Beef Creek east of Seabeck. This aquifer system area was based solely upon the Big Beef Fisheries wells.

According to the GWMP, the Big Beef Aquifer was located 100 to 250 feet below sea level (Aquifer C), within the "Qg4" unit. At the time of the report, the Big Beef Aquifer's extent was unknown but was thought to extend a greater distance to the south and west. Further test drilling in the area was recommended to define the stratigraphic and hydrologic conditions of the system.

**KPUD drilling and testing in the Seabeck area**

In October, 1990 exploration drilling began on Seabeck Well 1 (25N/1W-21N, AAA235). Well 1 was located approximately one mile southeast of the previously assumed boundary of the Big Beef Aquifer. The intention of the drilling plan was to determine if the Big Beef Aquifer extended in that direction and to determine the characteristics of any other water bearing zones at the location. Well 1 was drilled to a total depth of 649 feet (320 feet below mean sea level). A deep zone from 591 to 604 feet (262 to 275 feet below MSL) was tested and found to not have a substantial production potential. It was concluded that the Big Beef Aquifer (Aquifer C) did not extend to Well 1. However, a shallower water bearing zone, at 429 to 450 feet (100 to 120 feet below MSL) was encountered and tested. The testing at 325 gpm indicated a potentially productive aquifer. This zone was named the Seabeck Aquifer and correlated to the "Aquifer B" of the Big Beef study.

Next, Seabeck Well 2 (25N/1W-22E, AAC799), located approximately 5,600 feet to the northeast of Well 1, was drilled to 500 feet (231 feet below MSL). It did not encounter the Big Beef Aquifer. As in Well 1, Well 2 was completed in an aquifer above the Big Beef Aquifer. Well 2 is completed in a productive water-bearing zone located 50 to 80 feet below MSL. This aquifer has been correlated to "Aquifer A" at the Big Beef facility. The well was tested at rates of 910 and 720 gpm, showing indications that the well is capable of producing up to 1500 gpm.

Seabeck Well 3 (25N/1W-28F, AAA980), located approximately 2,000 feet south from Well 1, was drilled as a production well and is completed in the equivalent of Big Beef Aquifer B. The well was drilled to a total depth of 630 feet (190 feet below MSL) and completed from 510 to 542 feet and from 576 to 617 feet below ground (70 to 177 feet below MSL). The well was tested and rated at 600 gpm.

### Aquifer Protection Study

An on-going aquifer protection study is currently being conducted in the Seabeck area. As a result of this investigation, the previously separately named aquifers were all included in the designated Seabeck Aquifer System. Response from testing at Big Beef Fisheries, and detailed cross-sections and potentiometric surfaces in the study area imply a interconnected system of permeable zones separated by discontinuous impermeable layers. The study shows that, regionally, there is no basis for naming individual aquifers as the water bearing zones from 100 above to 300 feet below sea level all appear to be interconnected hydraulically. Thus, the Seabeck Aquifer System was defined.

## GEOLOGY

The surficial geologic formations in the Seabeck area consist of unconsolidated glacial deposits of the Vashon glaciation. Most of the Seabeck area is covered by Vashon Till which drapes the surface as a veneer of approximately 10 to 100 feet thick. Below the till are advance outwash deposits mapped as Esperance Sand by Deeter, 1979. These deposits are thicker here than in other parts of Kitsap County. Esperance Sand, consisting of sand and gravel and siltbound sand and gravel, has been mapped on the surface in places and interpreted from well logs to be from 200 to 400 feet thick. At approximately sea level, non-glacial deposits are encountered in some wells. These 10 to 60 feet thick clay and silt layers mark the lower limit of Vashon deposits, and have been designated Kitsap Formation by Molenaar (Garling, and others, 1965) and Whidbey Formation by Deeter, 1979. Below these non-glacial deposits are yet older glacial deposits consisting of layers of siltbound sand and gravel with some layers of clean sand and gravel. These deposits exist in discontinuous layers with highly variable permeabilities.

## HYDROLOGY

Nearly all the wells in the area, including the wells monitored during this test, are completed in the permeable zones of the formations located from approximately 100 feet above to 270 feet below sea level, both above and below the Kitsap/Whidbey Formation. These formations constitute the Seabeck Aquifer System. Units of highly permeable, clean sand and gravel of less than 50 feet thickness have been encountered in the area, but generally the deposits in the area consist of siltbound sand and gravel, typically hundreds of feet thick. Within these siltbound sand and gravel deposits are thin, highly permeable zones which occur between discontinuous impermeable layers. These discontinuous, permeable zones within the siltbound sequences appear to be the most productive zones in the aquifer system.

Potentiometric surface maps from the Seabeck aquifer protection study indicate the ground water generally flows perpendicularly toward the shoreline. The general flow is northwesterly, discharging to Hood Canal. Long-term monitoring of KPUD's Well 1 has shown that the water levels in the area have seasonal fluctuations of at least 1.5 feet. Water levels in wells are also influenced by tidal fluctuations to varying degrees, depending on depth and distance from the shoreline. These influences had to be taken into account and made interpretation of the test data more difficult.

Based on the KPUD's Wells 1, 2 and 3 and the three wells at the Big Beef Creek Fishery, transmissivity values in the area vary from 30,000 to 165,000 gpd/ft. Storage coefficient values range from 0.0001 to 0.0065, indicating the Seabeck Aquifer System is confined.

Within the area delineated as the Seabeck Aquifer System, there are four surface drainage basins. The largest basin is Big Beef Creek, with a drainage area of approximately 14.1 square miles. The others are, from east to west: Anderson Creek, 4.89 square miles; Little Beef Creek, 0.78 square miles; and Seabeck Creek, 5.2 square miles. A stream gage on Big Beef Creek is seasonally monitored by the US Geologic Survey. This gage is currently monitored from June to October. The historic record is further discussed in detail below.

## TESTING OF WELL 3

### WELL 3 DATA

Well 3, drilled to 630 feet, was completed June 11, 1993 with 40 feet of screen and 24 feet of perforations. The completion elevations are from 70 to 177 feet below sea level. The well was tested at 600 gpm with 73.5 feet of drawdown after 24 hours. Well 3 was rated at 600 gpm and a permanent pump was installed. At the time of the completion of Well 3, a long-term testing and monitoring program was proposed to determine the long-term effects of pumping from the Seabeck Aquifer System. A long-term test was started on June 1, 1994.

Prior to the testing period, two storage tanks were built and Well 3 was put online to serve approximately 7 connections system. Additional connections will be added in the future. The well was outfitted with a water level pressure transducer and flow meter. A second water level transducer was installed on May 23, 1994 and water level readings were recorded using a data-logger. The data, shown on Figure 2, shows tidal fluctuations of approximately 0.2 feet and the periodic pumping episodes caused by system demand. On June 1, 1994 at 10:30 AM, the pump was turned on at an initial rate of 610 gpm. As the water level drew down from the pre-test static of 371.91 feet, the pumping rate decreased slightly and stabilized at 596 gpm after 120 minutes. The drawdown data (Figure 3) show that for the first 10 days of pumping the rates of drawdown were less than that of the original 24-hour testing at the time of construction. After approximately 10 days the shape of the curve is influenced by a seasonal decrease in aquifer water levels (discussed below). The spikes and gaps in the drawdown data were caused by power failures, the second one lasted for approximately nine hours.

After 60 days of pumping, a decision was made to end the test. By the end of the pumping period the water level in Well 3 was at 431.4 feet, for a total drawdown of 59.2 feet. The average pumping rate over the 60-day test was 584 gpm. Therefore, the 60-day specific capacity of Well 3 is 9.8 gpm/ft of drawdown. This value is higher than the 24-hour specific capacity 8.2 gpm/ft of the original test. The higher specific capacity is likely caused by natural development of the well during regular operation of the system. The well was making small amounts of sand during the beginning of the 60-day test. Transmissivity at the well was calculated to be 86,000 gpd/ft based on the curve from 100 to 1000 minutes. This value is within range of transmissivity calculated from the original test recovery data.

## MONITORING WELLS

During the testing of Well 3, seven other wells were monitored (see Figure 4). The study intent was to monitor as large an area as feasible utilizing wells completed in the same aquifer as Well 3. KPUD's Seabeck Wells 1 and 2 and Big Beef TH-2 were monitored continuously prior to the pumping of Well 3 and are today still actively recording water levels. Four other wells, selected based on their location, completion depth, and accessibility, were also monitored during the testing. The Smith, Guava, Seabeck Conference Center, and Collier wells, located from 2,000 to 8,200 feet from Well 3, were measured periodically during the monitoring period. All the wells monitored experienced some degree of drawdown interference from the pumping of Well 3. Each well is discussed below in order of distance from Well 3.

The monitoring period, for the purpose of this discussion, was from April 19 to September 16, 1994. The start of the monitoring in each well was when equipment was first installed in each well. The end of the monitoring in each well was based on the recovery of the wells and, in part, because of required scheduling for analysis of the results.

**Seabeck Well 1**

Seabeck Well 1, located 2,000 feet away in SW ¼ SW ¼ of Section 21, has a completion elevation of 88 to 120 feet below sea level. Well 1 is equipped with a Stevens GS-93 data logger which started recording on April 19, 1994. This system uses a float and data logger which records the water levels at specified intervals. It is planned that the equipment is to remain active indefinitely. The water level record from April 19 to September 16 is shown on Figure 5. The pre-test water levels show tidal fluctuations, as well as, sharp, short-lived declines caused by the intermittent pumping of Well 3. The pre-test data also show an overall declining water level trend at the rate of approximately 1 foot per 80 days. The plot shows that water levels responded quickly to pumping by drawing down approximately 2.5 feet and continuing to draw down at a consistent linear trend of 1 foot per 35 days. At the end of the 60 days of pumping, Well 1 had a water level approximately 5 feet below the pre-test static. When the pumping of Well 3 stopped, the water level in Well 1 rose approximately 2.6 feet within the first day of recovery. At the end of the recording period on September 16, the water level was approximately 1.6 feet below the pre-test static. However, if the pre-test seasonal decline is projected to the end of the record, the residual drawdown at Well 1 is approximately 0.3 feet.

**Guava Well**

The Guava Well, located approximately 3,100 feet to the south in the NW ¼ SW ¼ of Section 21, is completed at an elevation of 52 to 62 feet below sea level. The Guava Well, serving about 5 homes, was equipped with an electric sounder with a fixed reference. The plot of the Guava Well (Figure 6) shows drawdown interference of approximately 3.6 feet. After pumping stopped at Well 3, the water level recovered in a period of two days to within 1.1 feet of the pre-test static. By the end of the monitoring period, the water level was 2.5 feet below pre-test static, indicating a seasonal(?) trend of decreasing water levels. It should be noted that due to the fact that the Guava Well was in intermittent domestic service at the time of monitoring, there were several times when no water level measurement was taken; and that all of the water levels recorded were at some point of recovery from pumping in the well. Because of this, fewer water levels were taken and the record is a bit erratic.

**Seabeck Conference Center Well**

The Seabeck Conference Center Well, located approximately 4,400 feet to the northeast in the SW ¼ SE ¼ of Section 20, is completed at an elevation of 54 to 64 feet below sea level. The well is inactive and was equipped with an electric sounding line. The drawdown interference (Figure 7) in the Conference Well is less defined than at the above mentioned wells, but is still evident. The total interference was approximately 1.6 feet. Interestingly, after Well 3 was shut off, the Conference Well had only 0.5 feet of recovery and showed a water level that is slightly higher than expected from projecting the pre-test seasonal decline.

**Collier Well**

The Collier Well, located approximately 4,700 feet to the north of Well 3 in the NE ¼ NW ¼ of Section 22, is completed at an elevation of 22 to 28 feet below sea level. The Collier Well, at an elevation of 40 feet, has a flowing artesian condition. The well was equipped with a 0 to 10 psi pressure gage. Readings were taken after venting the air column from the well. The pressure readings were converted from psi to feet of water by multiplying by 2.31. Due to its proximity to the shoreline, the well experienced large fluctuations caused by tidal influences. This, coupled with problems in the gage reading procedures early in the monitoring period, caused the water level record for this well to be erratic. In addition, the bentonite seal was unstable during the monitoring period. The seal bulged at the surface and was repaired on May 31, and thereafter, showed additional minor movement. With this in mind, the Collier Well (Figure 8) showed apparent drawdown interference of approximately 4.0 feet, with the initiation of the interference happening approximately 3 days after Well 3 was turned on. The well showed a similar recovery response after Well 3 was turned off. At the end of the monitoring period, the water level in the Collier Well was approximately 2 feet below the pre-test static.

**Seabeck Well 2**

Kitsap PUD's Seabeck Well 2, located approximately 5,600 feet to the northeast in the SW ¼ NW ¼ of Section 22, is completed at an elevation of 50 to 81 feet below sea level. The well was equipped with a Stevens GS-93 data logger measuring every 5 minutes (see Figure 9). The pre-test data, as in Seabeck Well 1, showed a general trend of decreasing water levels. The decline was at a rate of approximately 1 foot per 100 days. The drawdown interference in this well is less apparent than the previously mentioned wells, but is noticeable. After approximately 10 days of pumping, the well experienced a drop in water level. At the end of the pumping, the water level in Well 2 had declined 1.5 feet from the pre-test static. After the Well 3 was turned off, Well 2 showed a rise in water level until just before the end of the monitoring period, with the level being approximately 0.7 feet below the pre-test static. However, if the pre-test trend of decline is projected to the end of the monitoring period, Well 2 had no residual drawdown.

**Smith Well**

The Smith Well, located approximately 7,800 feet to the northeast in the NE ¼ NW ¼ of Section 22, is completed at an elevation of 5 to 25 feet below sea level. The well was equipped with an electric sounding line. The total change in water level in the Smith Well (Figure 10) was apparently 0.6 feet. However, based on the shape of the data plot, most, if not all, of the 0.6 feet could be seasonal decline. At the end of the monitoring period, the water level continued to be 0.6 feet below the pre-test static.

**Big Beef TH-2**

Test Hole 2 at the Big Beef Creek Fisheries Research Center, located 8,200 feet to the northeast in the NE ¼ NE ¼ of Section 22, is completed with multiple piezometers measuring two aquifer zones. During the test the completion zone at 133 to 187 feet below sea level was monitored. The 8-inch casing, sticking 17 feet in the air, was equipped with a Stevens Type-F float recorder. The continuous record was gathered throughout the monitoring period. The water level plot (Figure 11), from data with the diurnal tidal fluctuations removed, shows an apparent drawdown interference of 1.0 feet. The plot also shows a recovery trend after the pumping of Well 3 stopped. At the end of the monitoring period the water level was 0.6 feet below the pre-test static.

## MONITORING WELL OVERVIEW

Figure 12 was developed to allow for a visual comparison of the water levels of each monitoring well during the monitoring period. Figure 12 shows the monitoring wells in descending order of proximity to Well 3. It clearly shows that the beginning and end of the pumping period becomes less apparent with distance from the well. This dampened response is very evident when comparing the record for KPUD's Wells 1 and 2. These two wells were monitored continuously and therefore have a much more detailed record than the other wells. The irregular patterns seen in the Guava and Collier wells are the result of tidal fluctuations and periodic use of the wells.

## BIG BEEF CREEK HISTORICAL RECORDS

In addition to analysis of the testing of Well 3, the historical flow of Big Beef Creek was examined. Since 1969, the US Geologic Survey has had an active gaging station (#12069550) on Big Beef Creek upstream from Big Beef TH-2. Since 1982 the station has been recording daily discharge from June through October only, the time of lowest flow. Since 1982, summer mean monthly flows have ranged from 2.48 to 21.9 cfs. Figure 13 shows the lowest mean monthly discharge, those with flows less than 5 cfs. The plot possibly can be interpreted as showing a declining trend in discharge for the lowest of the flows. However, if the minimum flows (Figure 14) are examined instead of monthly discharge, historic records show earlier times with comparable low flows.

## PRECIPITATION

Figure 15 is a plot based on the precipitation at the Bremerton NOAA station. It is presented as cumulative departure from the average yearly precipitation, a method not commonly used and one that requires some explanation. For the selected period of record the total amount of rain divided by the number of years gives the average annual amount, which was 50.8 inches during the period of January, 1969 through September, 1994. As such, positive departures (more than 50.8 inches per year) show a graphical rise and negative departures a graphical decline. The total data set shows long-term trends. It should be noted that the record from the Bremerton station is not complete; it is missing several months of data during this time span. These months were given a value of either the historical average for that month, or the amount measured by Henry Aus at his station in Silverdale (active since November, 1989). Figure 15 shows that the last two years have been drier than normal. From current records, 1994 also appears to be a dry year.

When comparing Figures 13 and 14 with Figure 15 there appears to be a somewhat tenuous correlation between precipitation and minimum and lowest mean flows. Since 1983, the peak point of positive cumulative departure (Figure 15), there has been an overall drier than normal trend. The lowest monthly mean flow (Figure 13) shows a trend toward decreased flow over the same time span. The monthly minimum flow (Figure 14) shows a less obvious trend. Another factor, which could significantly affect the flows in the creek, is that there is a dam at Lake Symington upstream from the gage.

# WATER QUALITY

As part of the testing, the water quality of Well 3 and the monitoring wells were examined with special emphasis on identifying any possible trends indicating salt water intrusion. Samples were taken from each monitoring well, except Wells 1 and 2 and the Guava Well, at three time intervals during the pumping test: on the first day; after 45 days; and at the end of the 60-day test. The samples were run in Robinson & Noble's in-house laboratory for conductivity and chloride, two indicators of salt water intrusion, with the following results:

Table 1. Water quality results during the 60-day test of Well 3

| Well | Conductivity (µmhos/cm) | | | Chloride (ppm) | | |
|---|---|---|---|---|---|---|
| | 1 day | 45 day | 65 day | 1 day | 45 day | 60 day |
| KPUD Well 3 | 114 | 110 | 110 | ≤2.5 | 2.5 | 2.5 |
| Seabeck Conference Center | 92 | 75 | 74 | ≤2.5 | 2.5 | 2.5 |
| Collier | 117 | 118 | 115 | ≤2.5 | 2.5 | 2.5 |
| Smith | 122 | 119 | 121 | ≤2.5 | 2.5 | 2.5 |
| Big Beef PW-1 | 145 | 142 | 145 | 12.5 | 12.5 | 12.5 |

The above results show consistent values, with no trend toward salt water intrusion.

# HYDROLOGY DISCUSSION

The 60-day test of KPUD's Seabeck Well 3 has provided valuable information on the Seabeck Aquifer System. The monitoring shows that both seasonal and tidal effects occur throughout the system. The results of the monitoring data shows that wells completed at various depths located large distances away have drawdown interference from a single well pumping. The water quality monitoring has shown that no salt water intrusion was induced. Based on the amount of drawdown in the monitoring wells, the test had no effect on surface water bodies.

## TIDAL AND SEASONAL FLUCTUATIONS

The fluctuations of water levels caused by tidal influences is quite obvious when examining close-order measurements or the continuous water level data of the monitoring wells. The magnitude and timing of the fluctuations are dependent on the well's distance from the shoreline. From a previous study, the Big Beef TH-2, located approximately 1500 feet from Big Beef Harbor, has a fluctuation of 0.6 feet, or 5% of magnitude of Seabeck tides. The lag time between Seabeck tides and aquifer tides at TH-2 is approximately 2 ¼ hours. From this study, Well 3, located approximately 4,000 feet from Hood Canal, was found to have a total fluctuation of 0.3 feet.

The seasonal fluctuation is more difficult to quantify. To do this, the entire historical record at Well 1 was examined. As stated above, based on the pre-test static water levels from April 19 to June 1, 1994, a trend of a 1 foot decline per 80 days is evident. The trend during the same time period in 1993 at Well 1 showed a 1 foot decline per 130 days. In 1991 and 1992 it was approximately 1 foot per 30 days and 1 foot per 120 days respectively. Not only does the rate of decline change from year to year, but is different from well to well. The Well 1 record also shows seasonal increasing trends during November through May so that overall there is a balance.

The influence of tidal and seasonal fluctuations has caused difficulty in quantifying the absolute drawdown interference from the pumping of Well 3. The magnitude of the tidal fluctuation varies from well to well based on distance from shoreline. The magnitude of seasonal declines can only be projected and estimated based on this limited history.

## DRAWDOWN INTERFERENCE

To display the drawdown interference relationship, two plots, Figures 16 and 17, were developed. The first is the semi-logarithmic plot of distance versus drawdown. A line was drawn that represents the best fit of the data ignoring the Collier data. The reason for eliminating the Collier point is that it was measured using a different method (pressure gage), measuring procedures were altered after the pumping began, and the surface seal was unstable during the monitoring period. Based on Figure 16 the apparent aquifer transmisssivity and storage coefficient calculate as 49,300 gpd/ft and 0.0065 respectively. These values indicate a productive, confined (artesian) aquifer.

The drawdown interference in the monitoring wells is also presented on Figure 17 which shows the relative distance from Well 3, screen depth, static water level, and total depth drilled. This figure shows that the wells are completed at various depths within a range of 5 to 187 feet below sea level. The shallower wells, (Smith, Seabeck Conference Center, and Well 2) generally show a less than expected drawdown interference (see Figure 16). A compilation of well statistics on each well monitored during the test is presented below in Table 2.

Table 2. Compilation of monitoring well statistics.

| Well | Location | Elevation MSL | Screen elevation [1] | SWL elev.[2] | Distance from Well 3 | Draw-down[3] |
|---|---|---|---|---|---|---|
| Well 3 | 25N/1W-28C | 440 | -70 to -177 | 70 | -- | 59.5 |
| Well 1 | -21N | 330 | -88 to -120 | 58 | 2000 | 5.0 |
| Guava | -21M | 239 | -52 to -62 | 38 | 3100 | 3.6 |
| Conf. Center | -20Q | 75 | -54 to -64 | 41 | 4400 | 1.6 |
| Collier | -21C | 40 | -22 to -27 | 48 | 4700 | 4 |
| Well 2 | -22E | 270 | -49 to -80 | 40 | 5600 | 1.5 |
| Smith | -22C | 141 | -5 to -25 | 21 | 7800 | 0.6 |
| Big Beef TH-2 | -22A | 50 | -133 to -187 | 38 | 8200 | 1.0 |

1 Screen elevation in feet below mean sea level.

2 Water level elevation in feet above mean sea level on June 1, 1994 prior to testing.

3 Feet of water level decline below the SWL.

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The drawdown interference likely encompassed the entire aquifer system. Any long-term, large volume withdrawal from Well 3, or any other production well, will affect all wells completed in the aquifer system. The production well PW-1 at the Big Beef Fisheries has been in production for over a decade but water level data has been sparse and production data is non-existent. There is evidence that suggests an overall decline in water level at Big Beef since the original testing in 1980. Figure 18 shows a hydrograph of all known water level measurements in TH-2 at Big Beef Creek. By comparing the original water level with the latest measurements, a decline of approximately 5.5 feet is evident. However, if the water level taken November 11, 1990 is compared to the November water levels of 1980, there is only a 2-foot decline. Is this decline caused by pumping at Big Beef and elsewhere, or is this decline a function of less than normal precipitation? To help answer these questions, the water recorder at TH-2 is going to remain active and monitor at least a full year of water levels. Arrangements must also be made to collect and record the production rates from the Big Beef production well.

**PROJECTED CAPACITY**

Based on the testing of Seabeck Well 3, any pumping is going to theoretically affect every well in the Seabeck Aquifer System to some degree. Pumping continuously at 584 gpm induced some drawdown interference at each well monitored. However, the amount of interference of this test, during the driest season in a drier than normal year, did not affect the ability of any of the wells to supply water. In addition, the recovery trend shows that the interference was a temporary condition and that the aquifer water levels returned to the expected non-stressed level.

One method of estimating the capacity of an aquifer is to calculate the natural ground water flow, or underflow, of the aquifer. The underflow is the amount of water that is flowing through a given area at a rate proportional to the hydraulic gradient. The rate is calculated by using the formula:

$$Q = Tiw,$$

where $Q$ is the flow rate, $T$ is the transmissivity, $i$ is the hydraulic gradient, and $w$ is the width of the area in question.

Caution was used in applying this underflow equation to the Seabeck Aquifer System by using only conservative values. Local transmissivity values were found to range from 73,000 to 86,000 gpd/ft at KPUD's Wells 1, 2, and 3. Based on the 60-day pumping test, the regional aquifer's transmissivity is approximately 50,000 gpd/ft (see Figure 16). The hydraulic gradient used herein is based on the potentiometric surface map drawn for the Seabeck Aquifer Protection study. The hydraulic gradient in the Seabeck Aquifer System ranges from 40 to 85 ft/mile. The width of the Seabeck Aquifer System is approximately 5 miles, with a 1 mile separation between Wells 3 and 2. The conservative values (T= 50,000 gpd, i= 40 ft/mile, w= 1 mile), when inserted into the above equation, results in a Q of 2,000,000 gpd or 1,389 gpm of underflow between Wells 2 and 3.

To judge whether this value is reasonable for the rate of recharge in the aquifer, an estimation of the amount of recharge area necessary to provide 1,389 gpm was made using the recharge rates given in the GWMP report. Table II-14 on page II- 73 of the GWMP report gives a direct recharge rate of 27 to 32 inches per year for the West Kitsap subarea. The rate of 1,389 gpm converts to 2240 acre feet per year. Using 27 inches per year, the estimated recharge area required to provide 2240 acre feet per year is 996 acres or 1.55 square miles. Since the minimum estimated recharge area directly upgradient from Wells 2 and 3 is approximately 4 square miles, a rate of 1,389 gpm appears to be reasonable.

The testing of Well 3 has shown that 584 gpm, in addition to other concurrent users, could be withdrawn from the Seabeck Aquifer System during the driest season of a dry year with no apparent residual effect. How the withdrawal of 1,389 gpm would affect the aquifer is not firmly known. By using the most conservative end of the range of parameters, the rate of 1,389 gpm should be considered a reasonable rate. For any long-range planning for the system, a rate of 1,000 gpm should be a safe starting point. Further increases in withdrawal could then be incrementally done subject to on-going monitoring.

To determine an upper limit to the production potential of the aquifer, the potential capacity of the aquifer system was also estimated based on the known parameters and less conservative values. The Seabeck Aquifer System has been found to be approximately 5 miles wide. Wells spaced to take advantage of the full width of the system might be drilled along a 4 mile wide line. Assuming the same transmissivity used in the conservative estimate, 50,000 gpd/ft, and a slightly higher gradient of 60 ft/mi (the "average" gradient of the aquifer), the estimated Q becomes 12,000,000 gpd or 8,333 gpm. The recharge area for the suggested well configuration would be approximately 10 square miles. This recharge area does not include the recharge contribution resulting from the runoff off Green Mountain where bedrock is at the surface. The precipitation on Green Mountain is as much as 80 inches per year. Therefore, a recharge rate incorporating direct recharge and additional recharge from Green Mountain runoff of 30 inches/yr over the indicated recharge area is reasonable. Using these less conservative values, the annual recharge to the Seabeck Aquifer System could be as much as 16,000 acre-ft/yr or 9,920 gpm.

The true underflow for the area is likely somewhere between the two estimates of 1,389 and 8,333 gpm. The true annual recharge rate is probably between the two estimates of 2,240 and 9,920 gpm. However, we recommend caution be used in the eventual utilization of the aquifer. Consequently, any further increases in production should be accomplished in increments starting at 1,000 gpm.

## WATER QUALITY

Two complete inorganic analyses were conducted on 1-day and 60-day samples from Well 3 (results attached). Overall, the results show excellent water quality. The iron and manganese values, two of the most common problems, were at levels below the detection limit of the laboratory. The hardness, total dissolved solids, chloride, and bicarbonate alkalinity levels are very low. The results also show that the individual parameters changed very little between sampling periods. Stiff diagrams, visual representation of major cation/anion distribution, were developed and attached. They show that the water is a calcium bicarbonate type with only minor other ions. The water is unusually low in total mineralization.

## SURFACE WATER

Based on the small magnitude of the drawdown interference in the monitoring wells near Big Beef and Seabeck Creeks, the pumping of Well 3 should have minimal affect on the flows in the creeks. At Big Beef Creek Fisheries TH-2, the creek is a "gaining" creek. The hydraulic head in the aquifers are higher than the creek surface, indicating that the aquifers are contributing base flow to the creek. A significant reduction in the head driving this exchange may reduce the inflow of ground water into the creek. However, the test indicated less than 1 foot of interference at TH-2, so a reduction in inflow should be minimal.

# RECOMMENDATIONS

*Plan to use 1,000 gpm from Wells 1, 2, and 3, calculated on average annual use.* This rate was estimated using the results of the 60-day testing of Well 3 and the on-going Seabeck Aquifer Protection Study. Further increases in withdrawal could then be incrementally accomplished, subject to on-going monitoring. The 1000 gpm rate can be exceeded instantaneously as long as the annual average is at or below this amount. For comparison purposes an annual rate of 1000 gpm equals:

1.44 million gallons per day
5.26 billion gallons per year
70.3 million cubic feet per year
703,000 KPUD's ERU's
1613 acre-feet per year

The monitoring of the Seabeck Aquifer System should include, in order of importance, the following:

*Monitor Wells 1, 2, and 3*: The data recording systems presently in place on Wells 1 and 2 should continue to be maintained. Long-term water level trends are important to the analysis of the capacity of the aquifer system.

*Monitor Big Beef TH-2*: Continue the water level recorder at TH-2 . This data should be analyzed after one year of record.

*Analyze creek flow, production and ground water levels at Big Beef Creek fishery*. Since the Big Beef facility is a major user of the aquifer, arrangements should be made to exchange data and information between KPUD and the fishery. Collection of production and long-term water level data at the fishery coupled with the USGS stream flow gage data is essential for the proper analysis of the Seabeck Aquifer System.

*Install a stream gage on Seabeck Creek*. The drainage basin of Seabeck Creek forms a large portion of the recharge area for the Seabeck Aquifer System. This fact makes the collection of long-term flow data on the creek an important part of the evaluation of the system.

*Drill and monitor an up-gradient monitoring well*: A lack of nearby monitoring points up-gradient of Well 3, would be corrected by drilling of a monitoring well in the southern half of Section 28 or the northern half of Sections 33 and 34. This well should target at least 100 feet below MSL.

# REFERENCES

Garling, M.E., Molenaar, D.E. and others, 1965, Water resources and geology of the Kitsap Peninsula and certain adjacent Islands: Washington State Division of Water Resources Water Supply Bulletin No. 18, 309p., 5 plates.

Deeter, J.D., 1979, Quaternary geology and stratigraphy of Kitsap County, Washington: MS thesis, Western Washington University, Bellingham, 175p., 2 plates.

Robinson and Noble, Inc., May, 1981, Ground water exploration at Big Beef Creek Fisheries Research Center, Seabeck, Washington. R&N File No. 80-17.

Robinson and Noble, Inc., April, 1991, Construction and testing of Seabeck Well 1 for Kitsap PUD #1. R&N File No. 5928D.

Robinson and Noble, Inc., August, 1991, Construction and testing of Seabeck Well 2 for Kitsap County Public Utility District #1. R&N File No. 5928D.

Purdy, J.W., June, 1993, Construction and testing of Seabeck Well 3 for Kitsap County PUD #1. R&N File No. 5928D2.

Kaminsky, J.F., June, 1994, Recommendations-in-progress report for the Seabeck Aquifer Protection Study. R&N File No. WHP 11.

# FIGURES

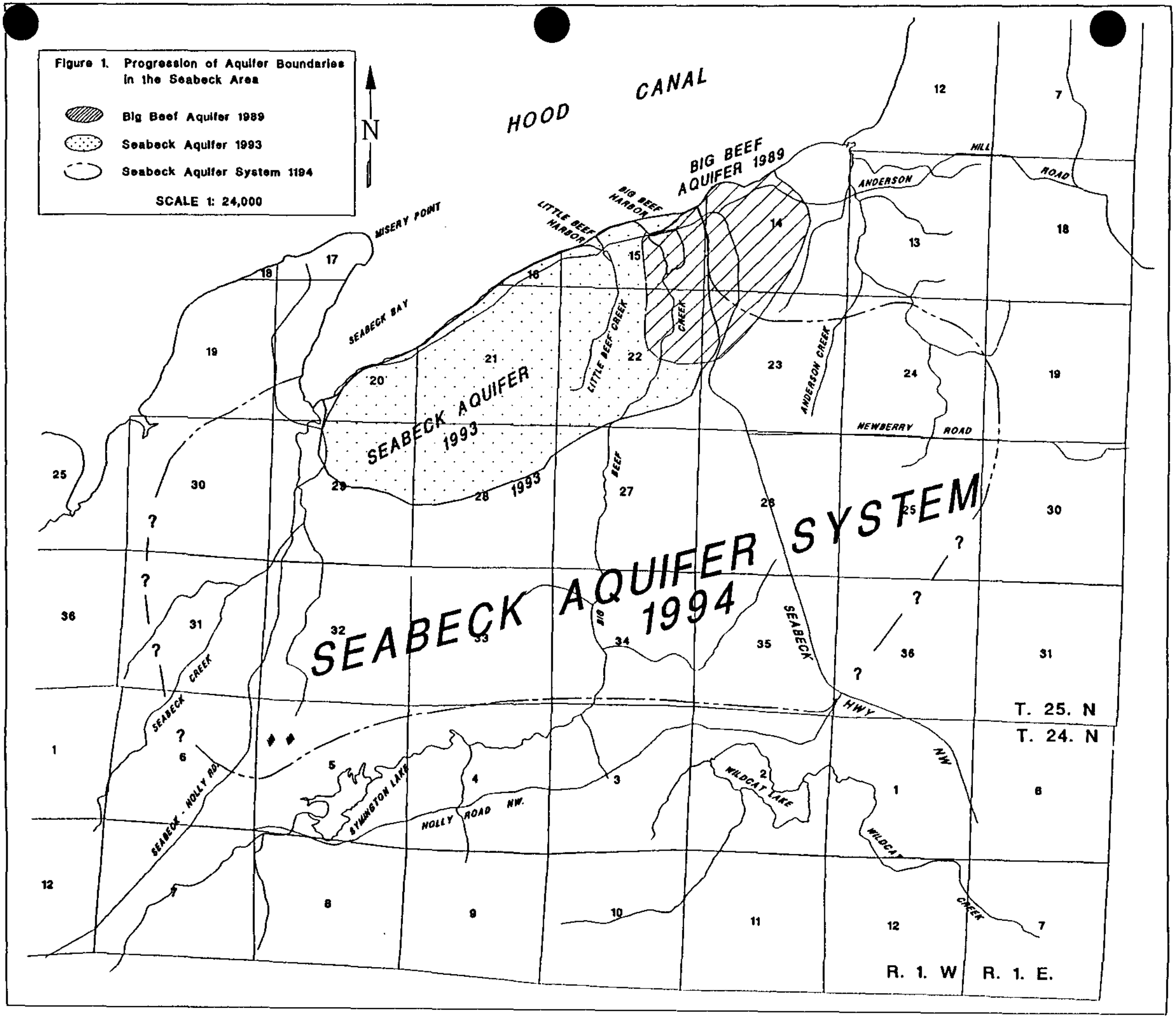



Figure 1. Progression of Aquifer Boundaries in the Seabeck Area

Figure 2. Seabeck Well 3 pre-test water levels.

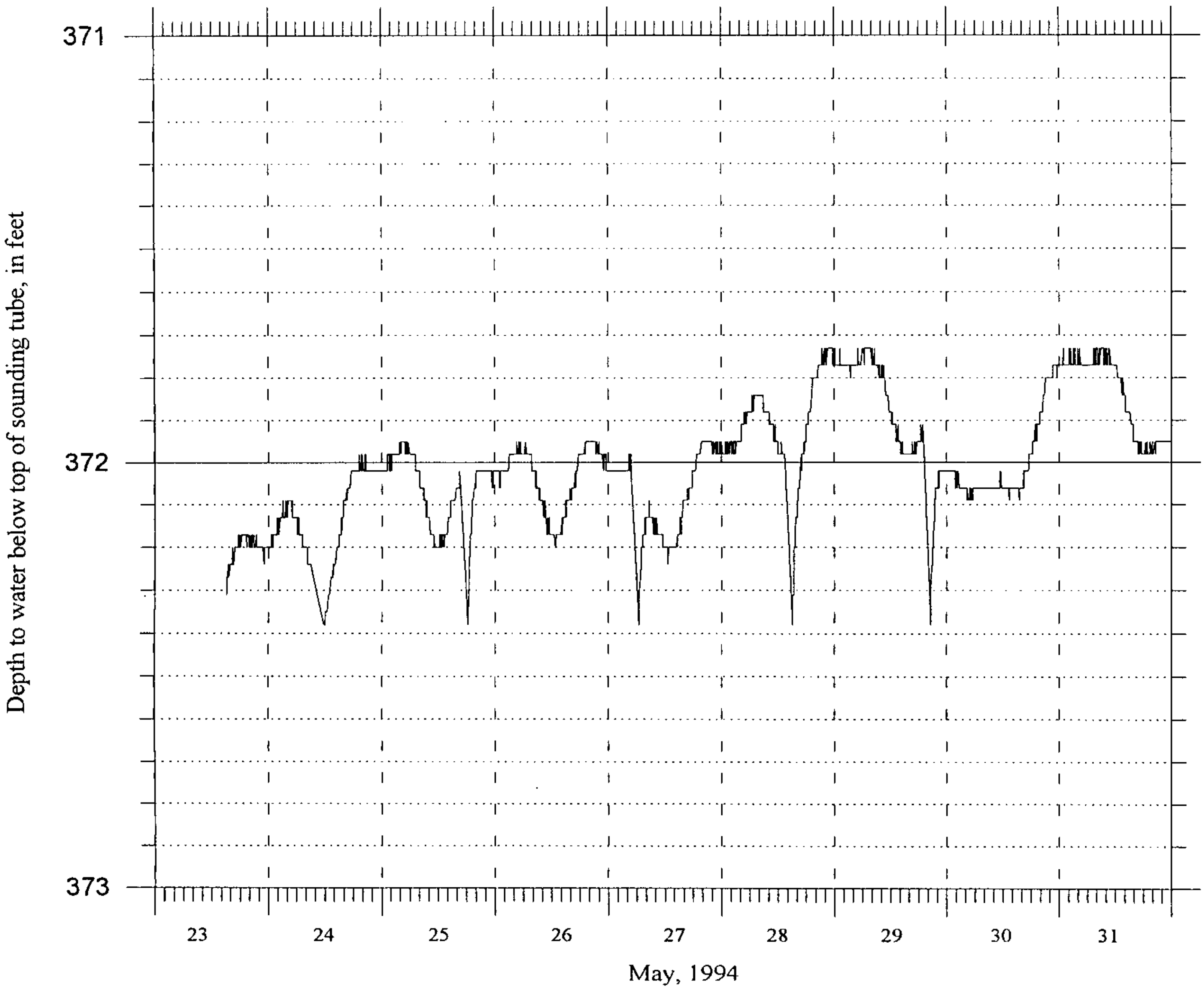


Figure 3. Kitsap PUD #1 Seabeck Well 3 drawdown. Average Q=584 gpm.
SWL=371.91 below top of sounding tube.

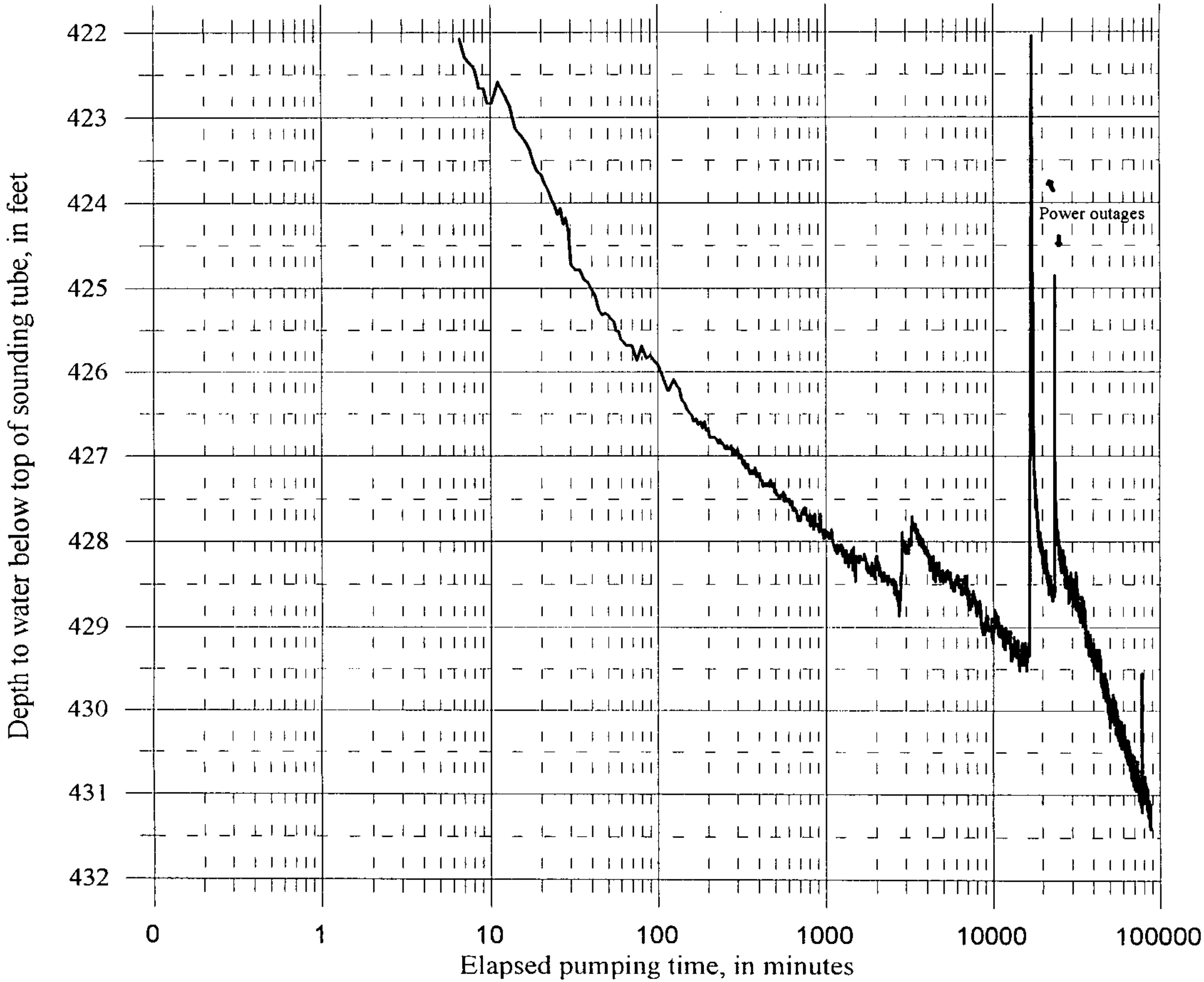


Figure 4. Location of monitoring Wells for the 60-day pumping test of KPUD'S Seabeck Well 3

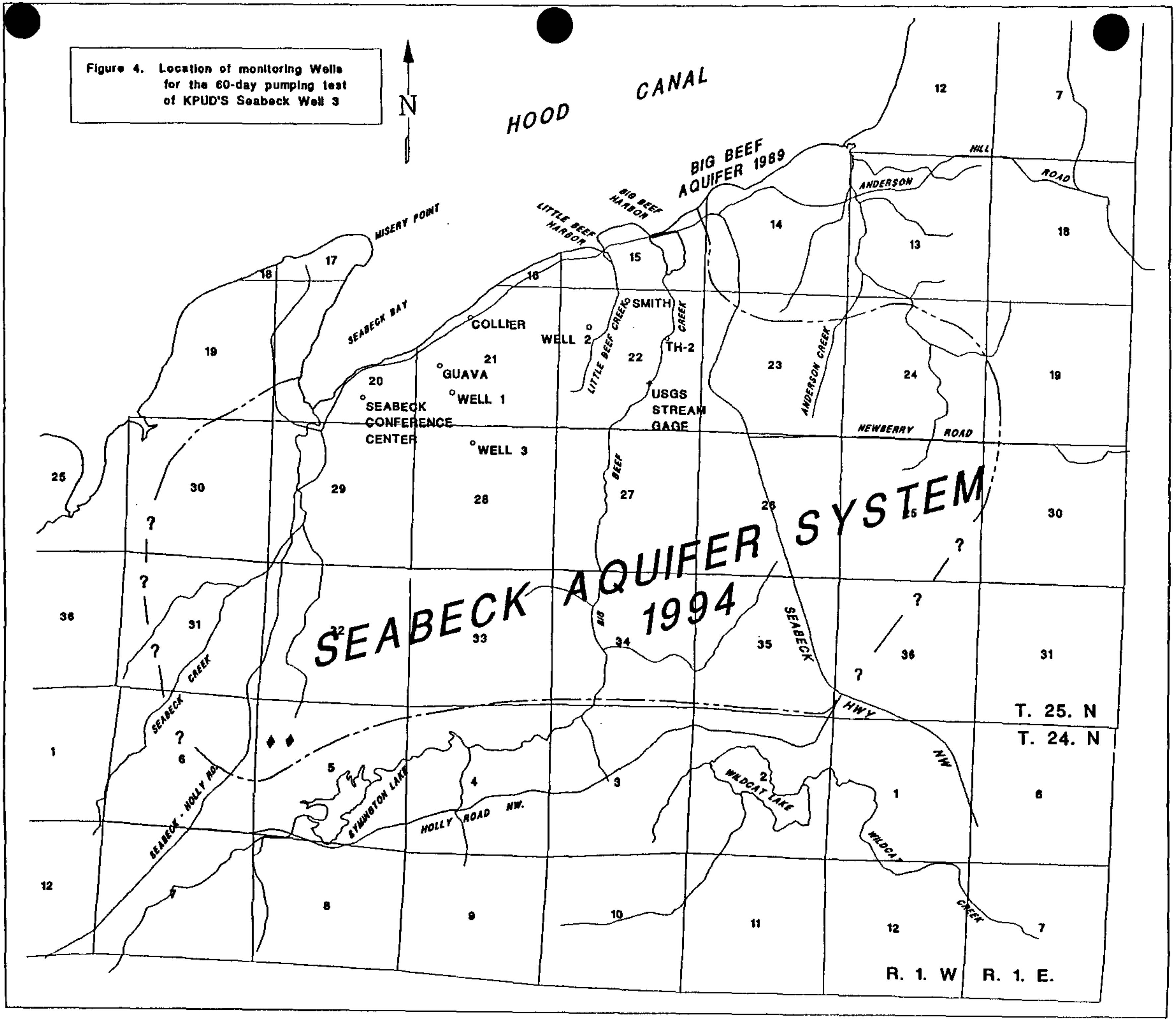


Figure 5. Kitsap PUD #1 Seabeck Well 1 (25N/1W-21P, AAA235, r= 2,000 ft).
Water levels from April 19 to September 16, 1994.

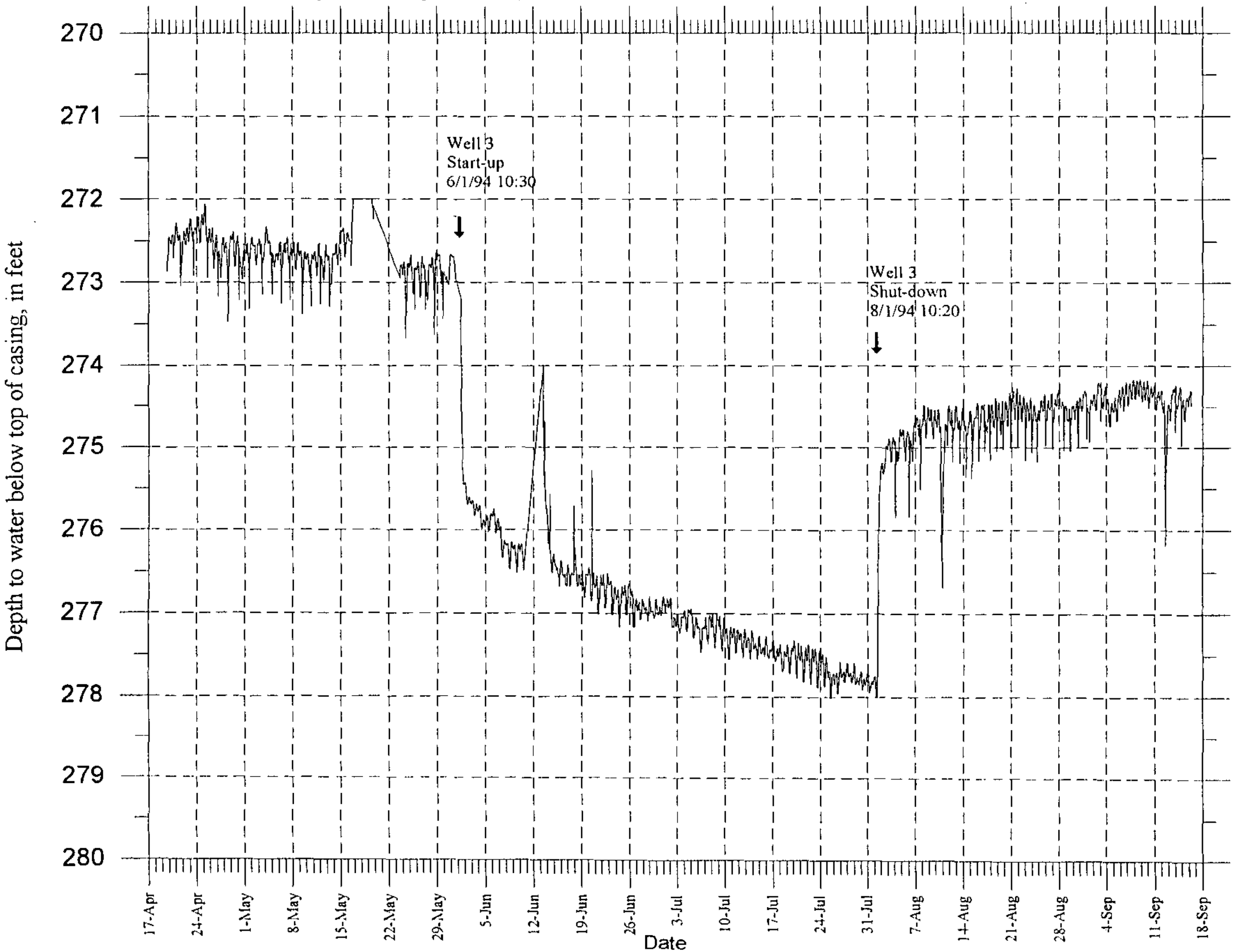


Figure 6. Guava Well (25N/1W-21M, AAA232, r=3,100 ft).
Water levels from May 9 to September 16, 1994.

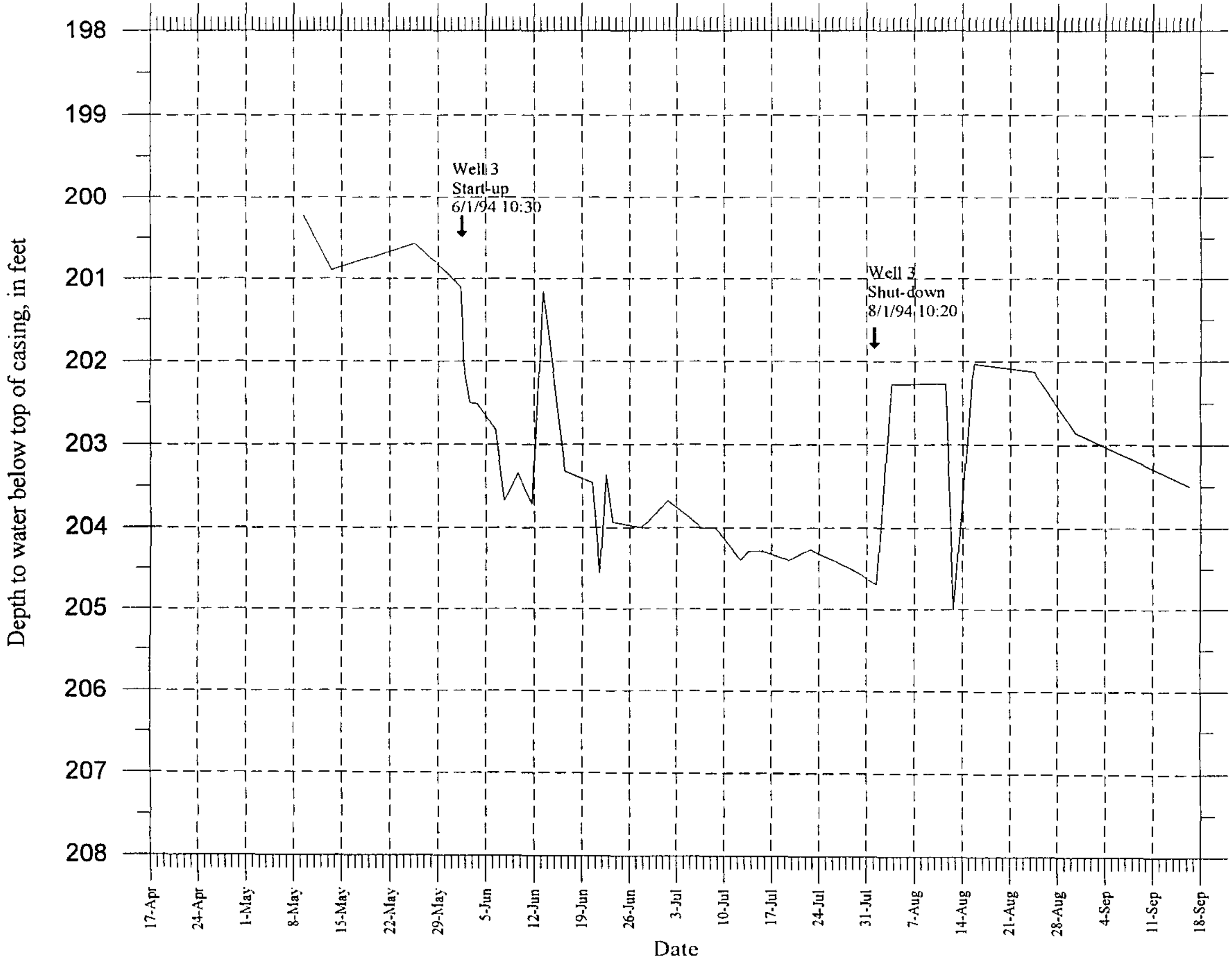


Figure 7. Seabeck Conference Center Well (25N/1W-20Q, AAC835, r = 4,400 ft).
Water levels from April 29 to September 16, 1994.

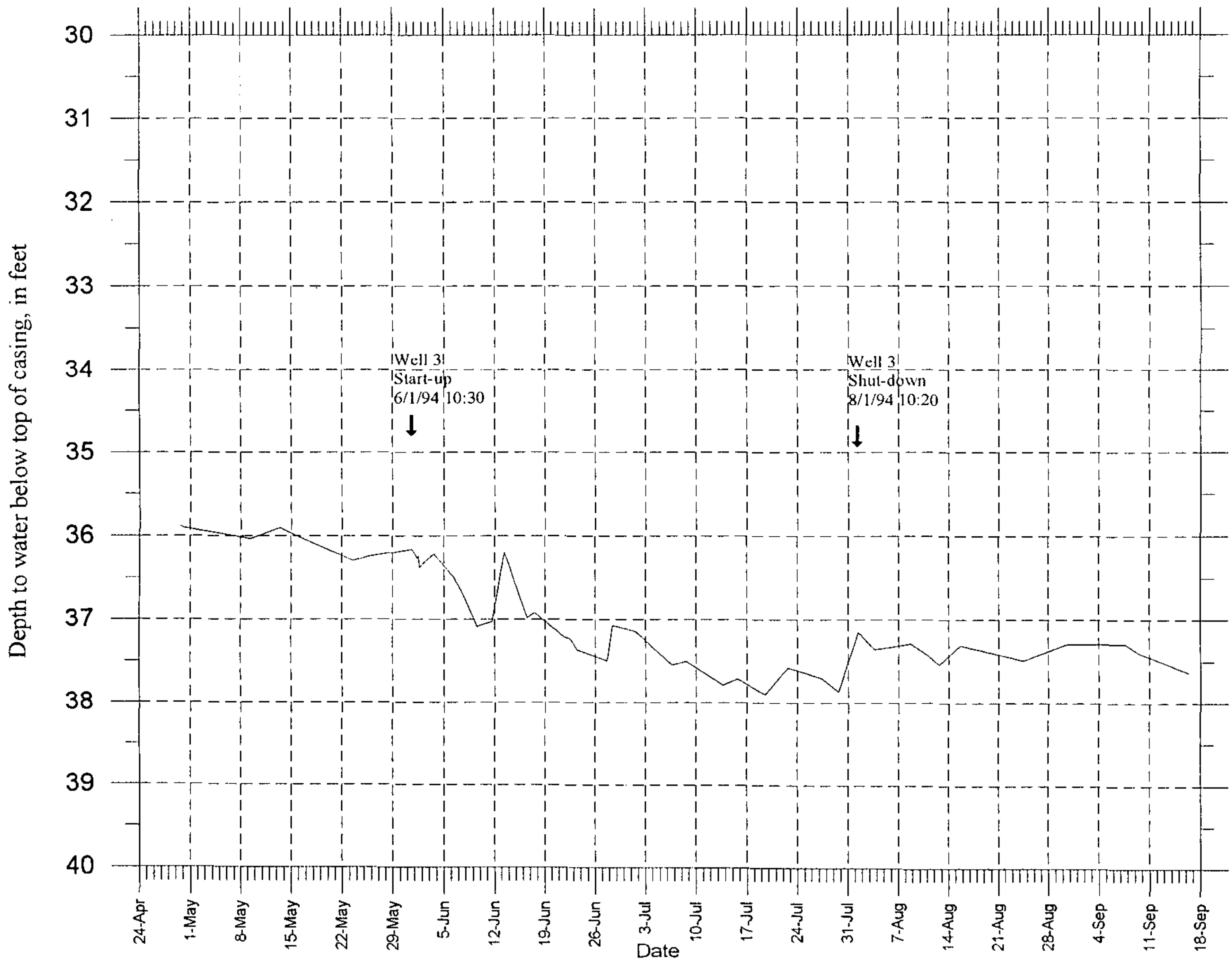


Figure 8. Collier Well (25N/1W-21C, AAC547, r = 4,700 ft)
Water levels from May 6 to September 16, 1994.

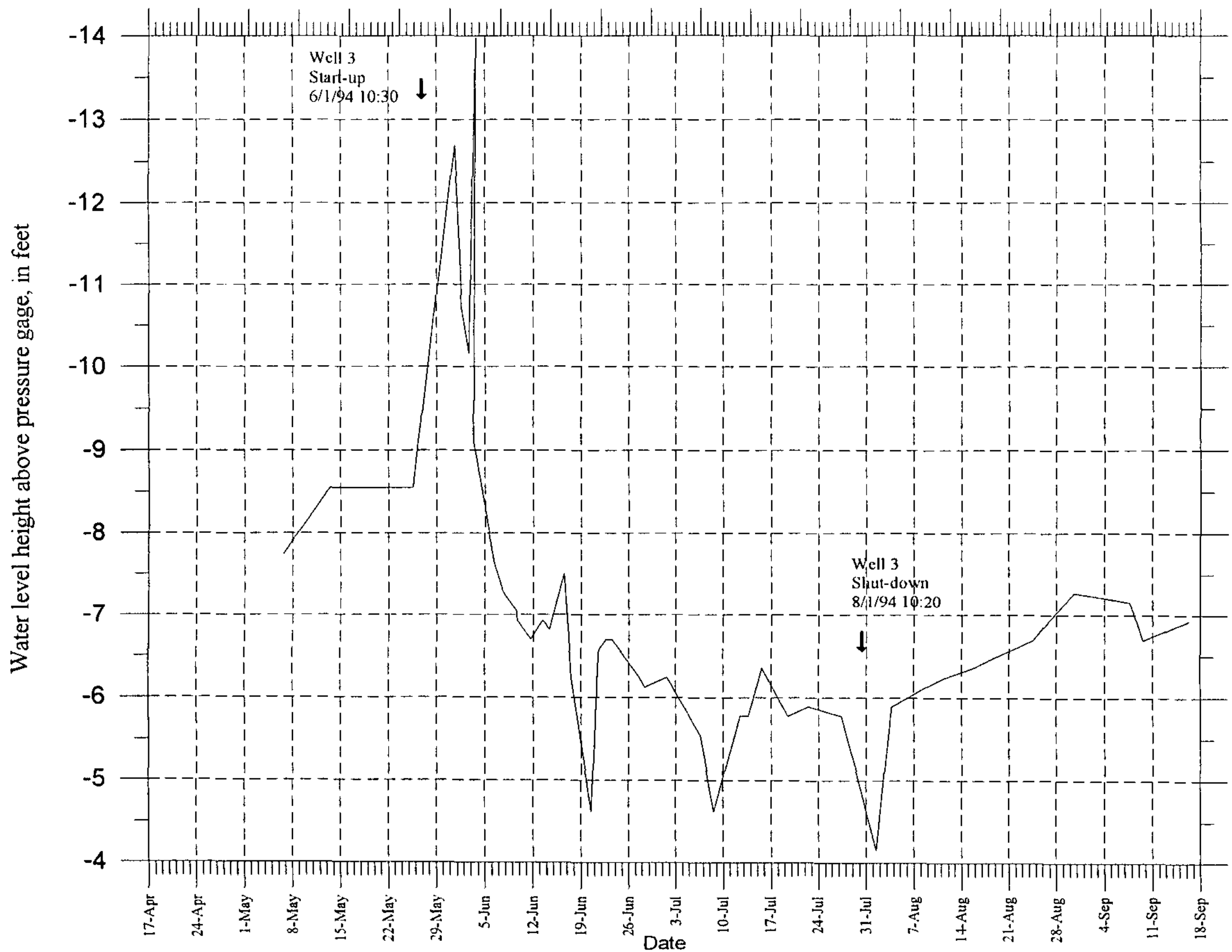


Figure 9. Kitsap PUD #1 Seabeck Well 2 (25N/1W-22E, AAC799, r=5,600)
Water levels from April 19 to September 16, 1994.

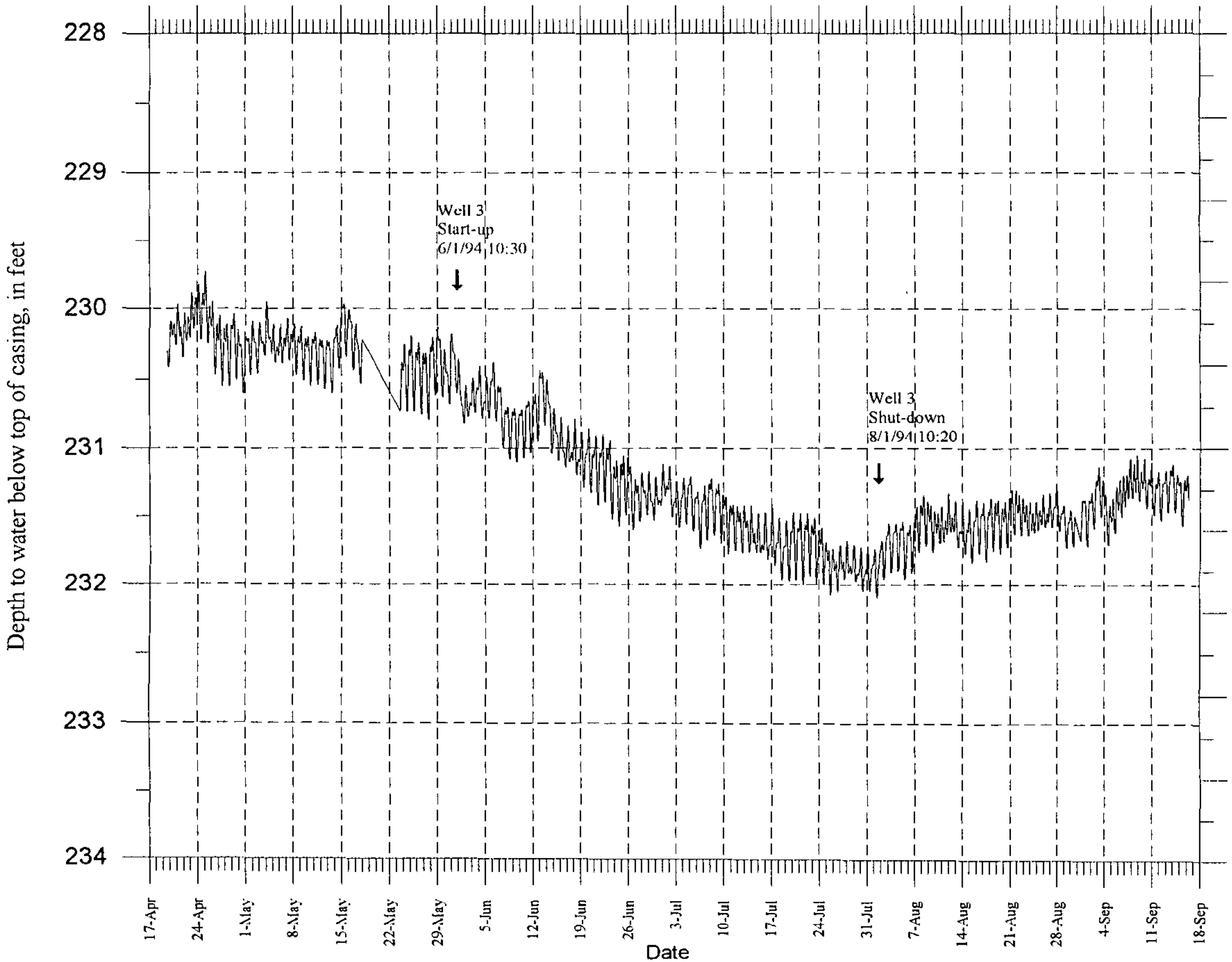


Figure 10. Smith Well (25N/1W-22C, AAC809, r= 7,800 ft).
Water levels from May 6 to September 16, 1994.

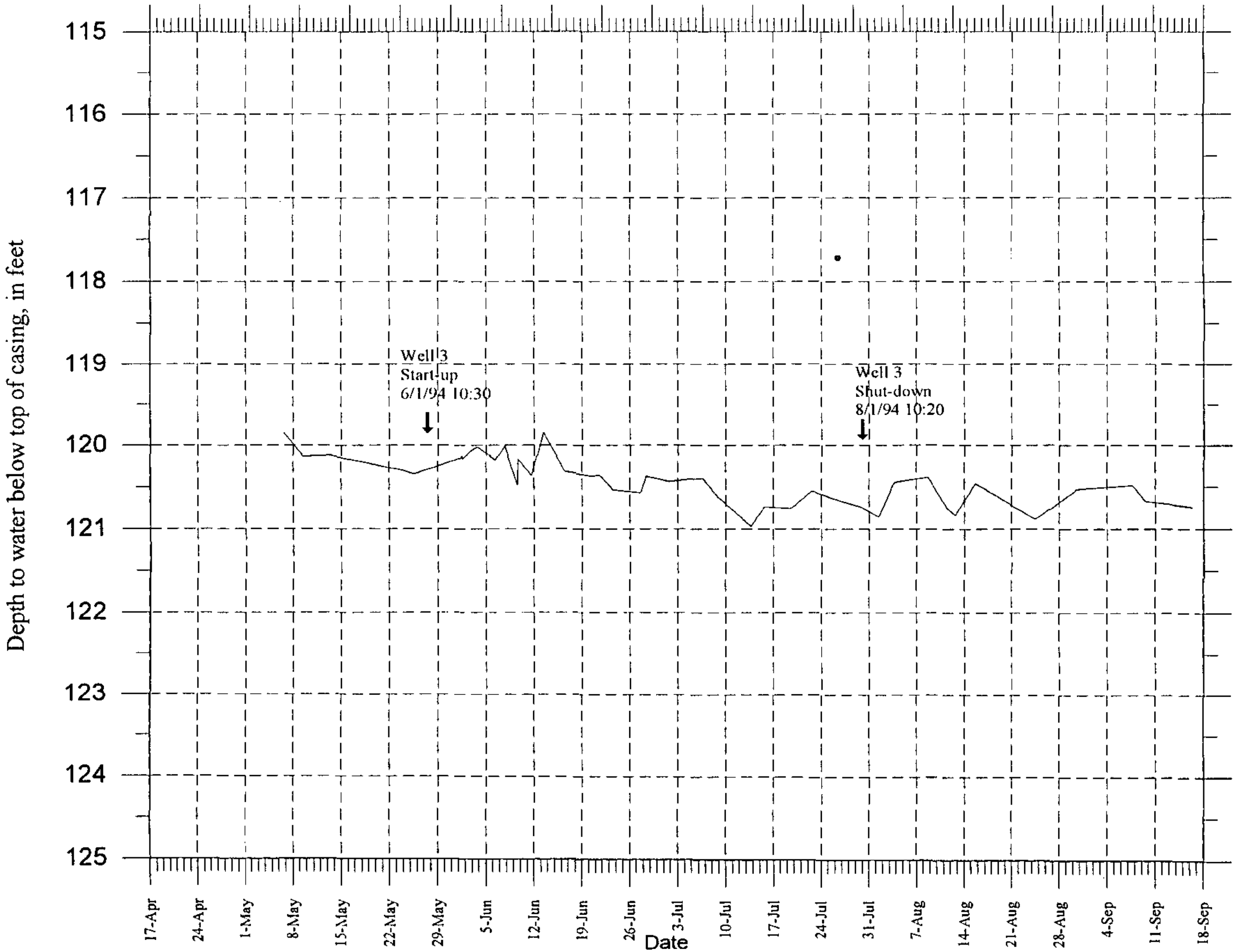


Figure 11. Big Beef Fisheries Test Hole 2 (25N/1W-22, r= 8,200 ft)
Water levels from April 25 to September 16, 1994.

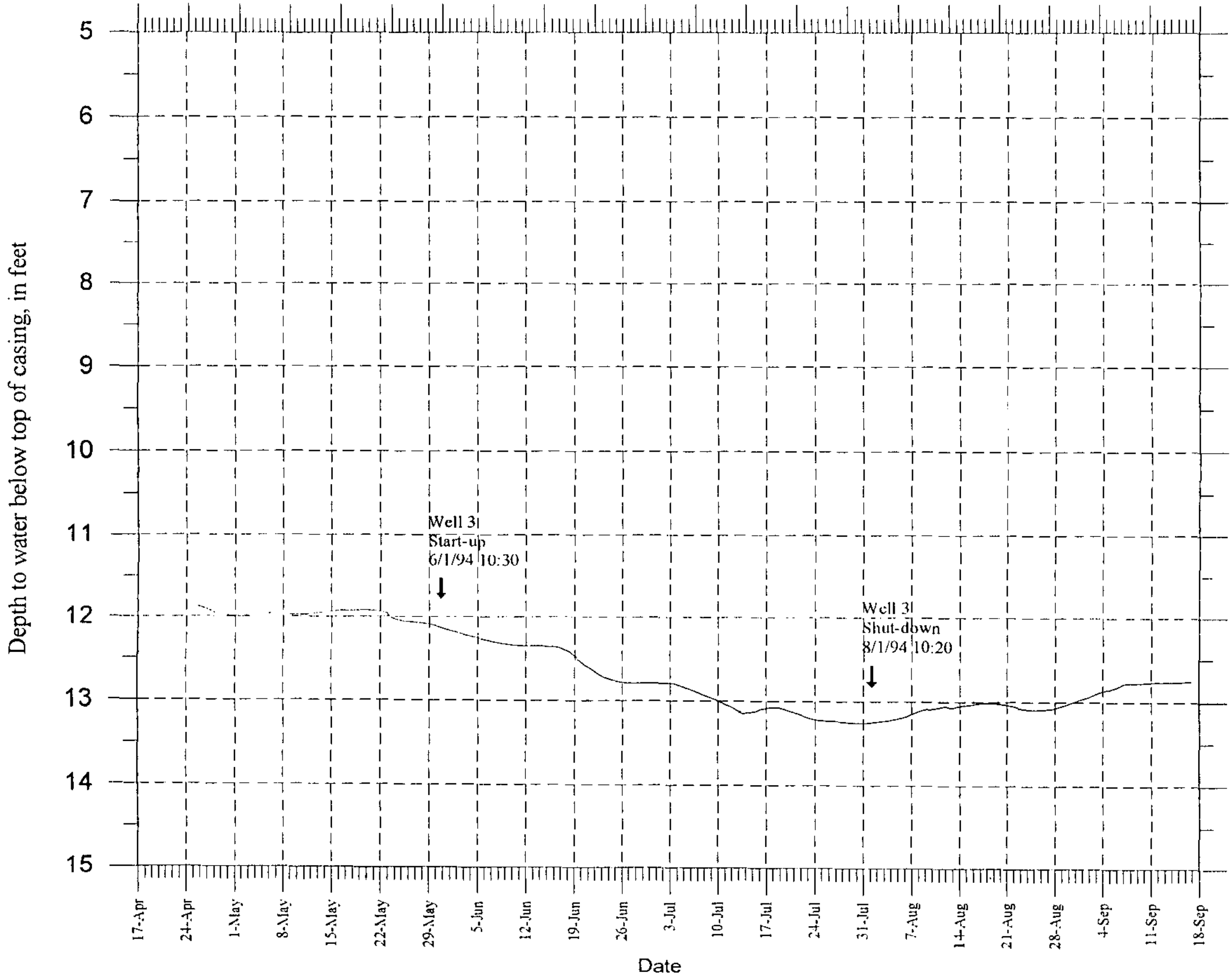


Figure 12. Kitsap PUD #1 Seabeck Well 3 pumping test.
Water levels in observation wells. From April 19 to September16, 1994.

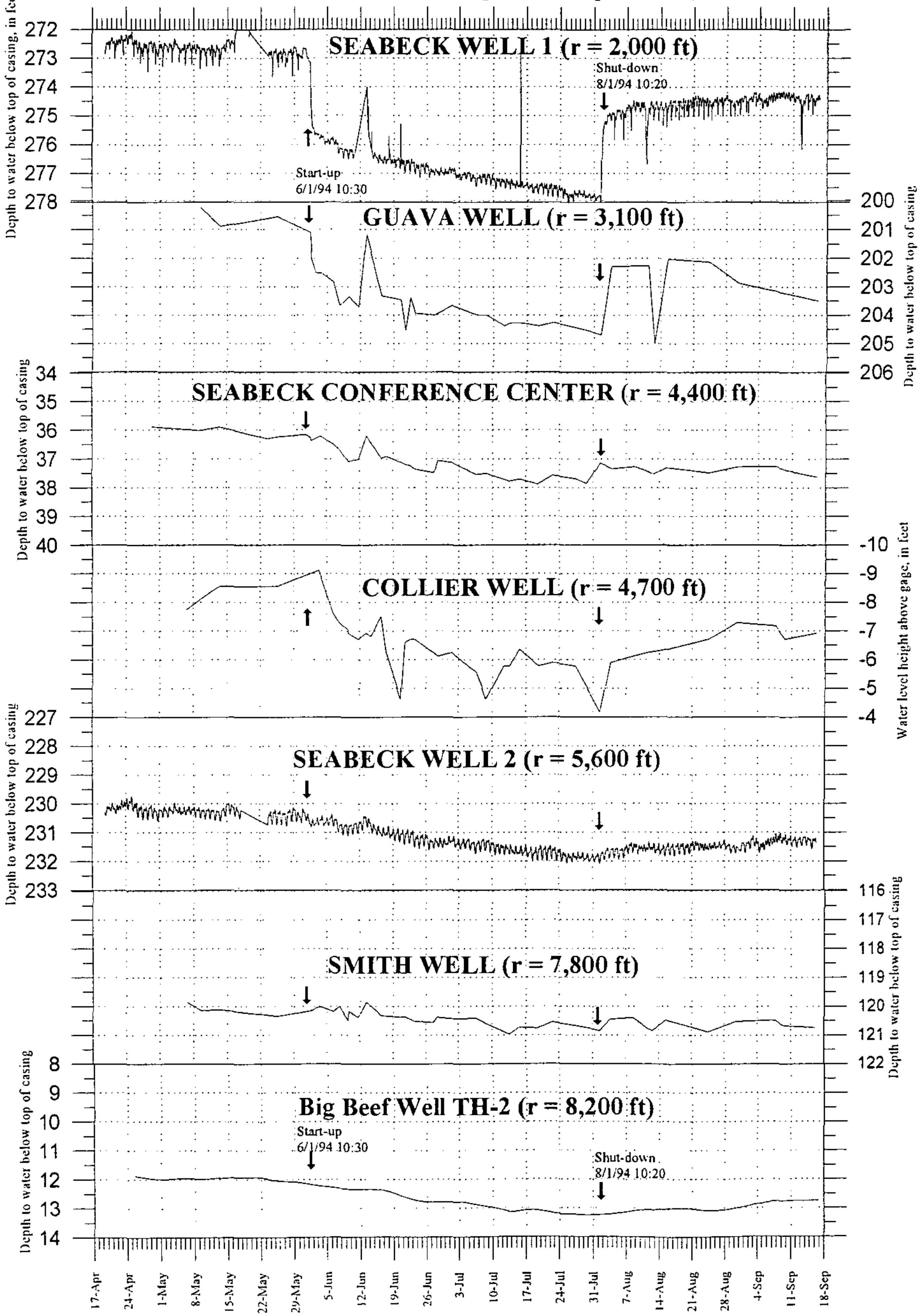


Figure 13. Big Beef Creek monthly mean flow of 5 cfs or less, from June 1969 to August 1994. Data from USGS station #12069550.

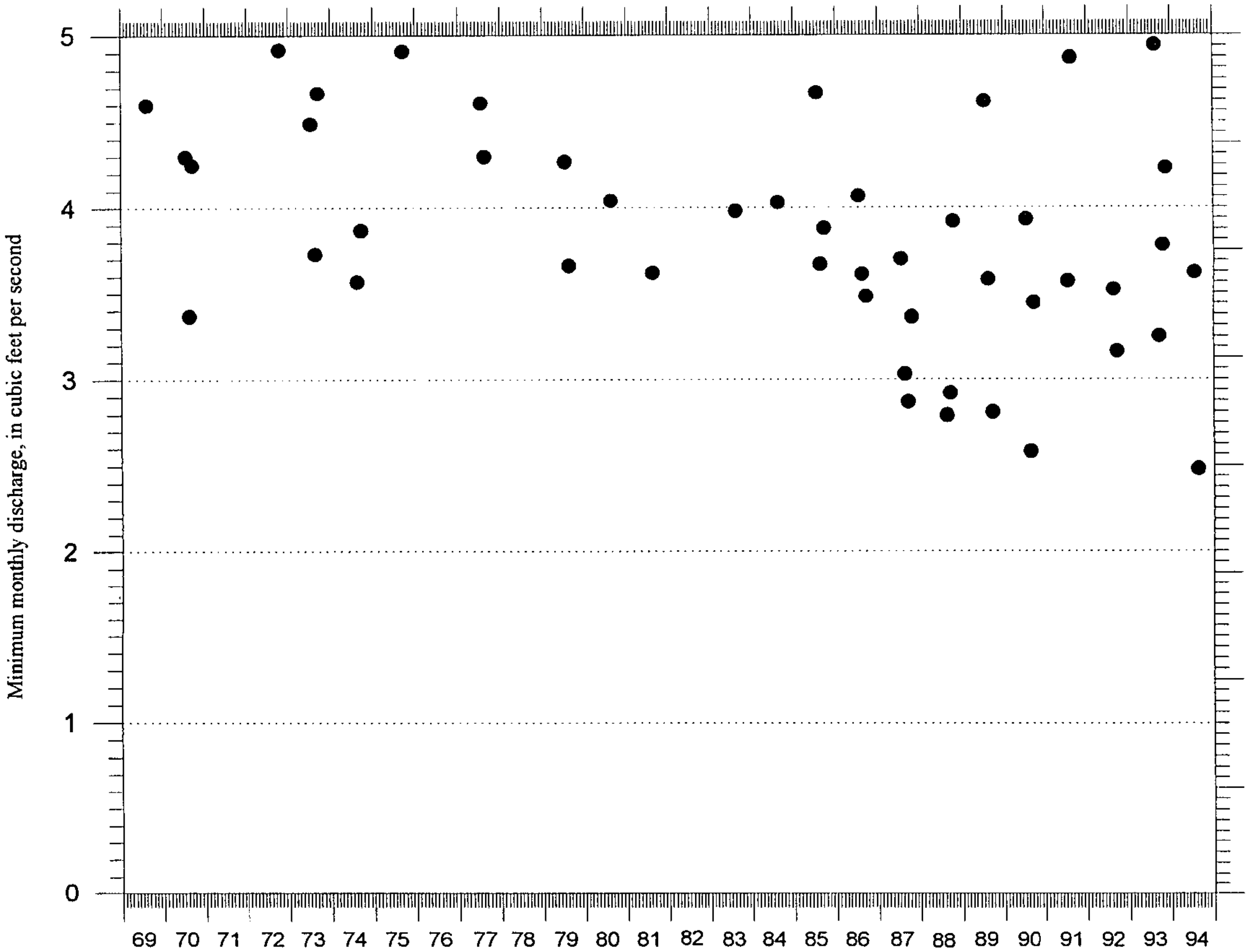


Figure 14. Big Beef Creek monthly minimum flow of 5 cfs or less, from June 1969 to August 1994. Data from USGS station #12069550.

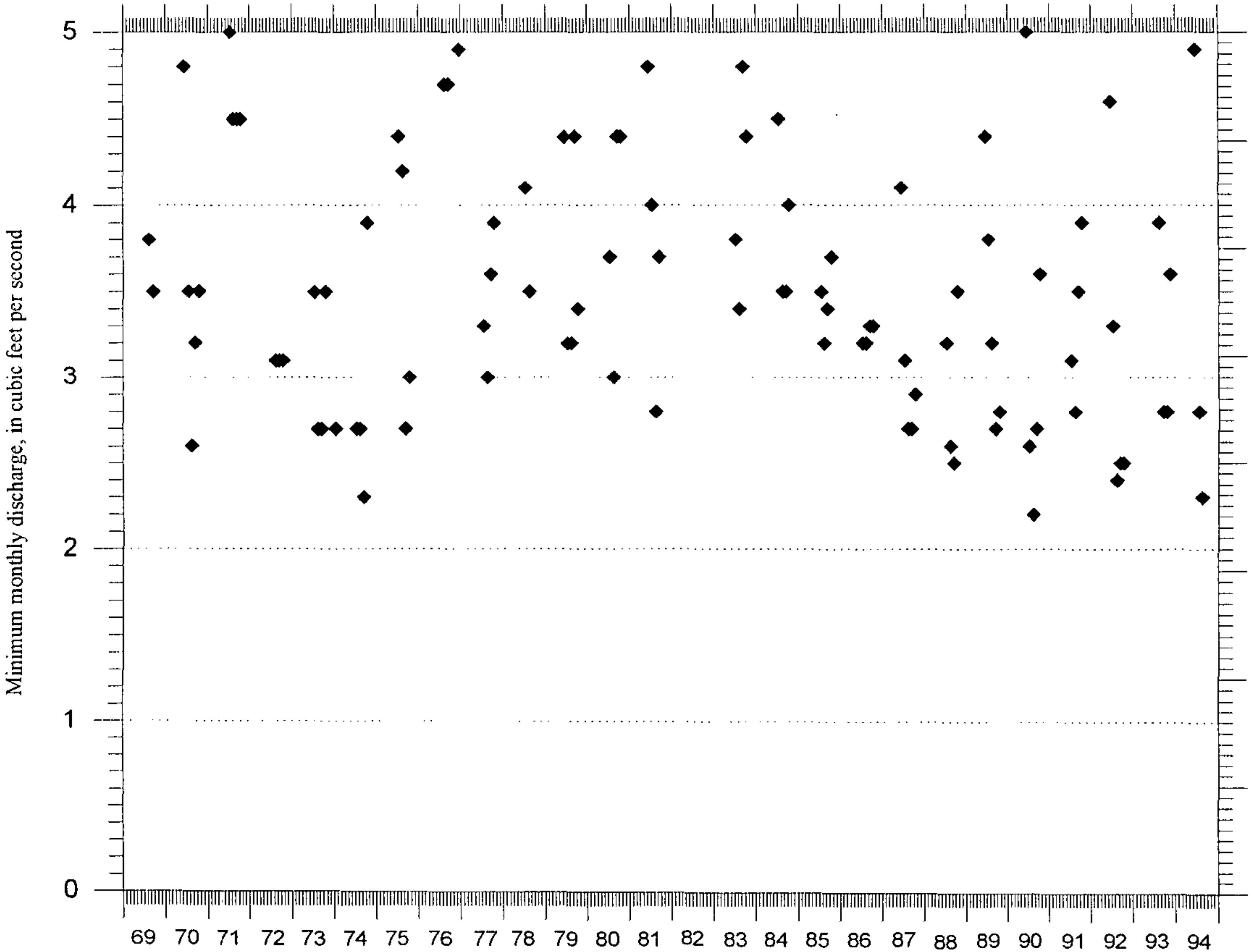


Figure 15. Cumulative departure from average yearly precipitation at Bremerton from 1969 to 1993.

Figure 16. Distance vs. drawdown after 60 days of pumping Well 3 at an average of 584 gpm.

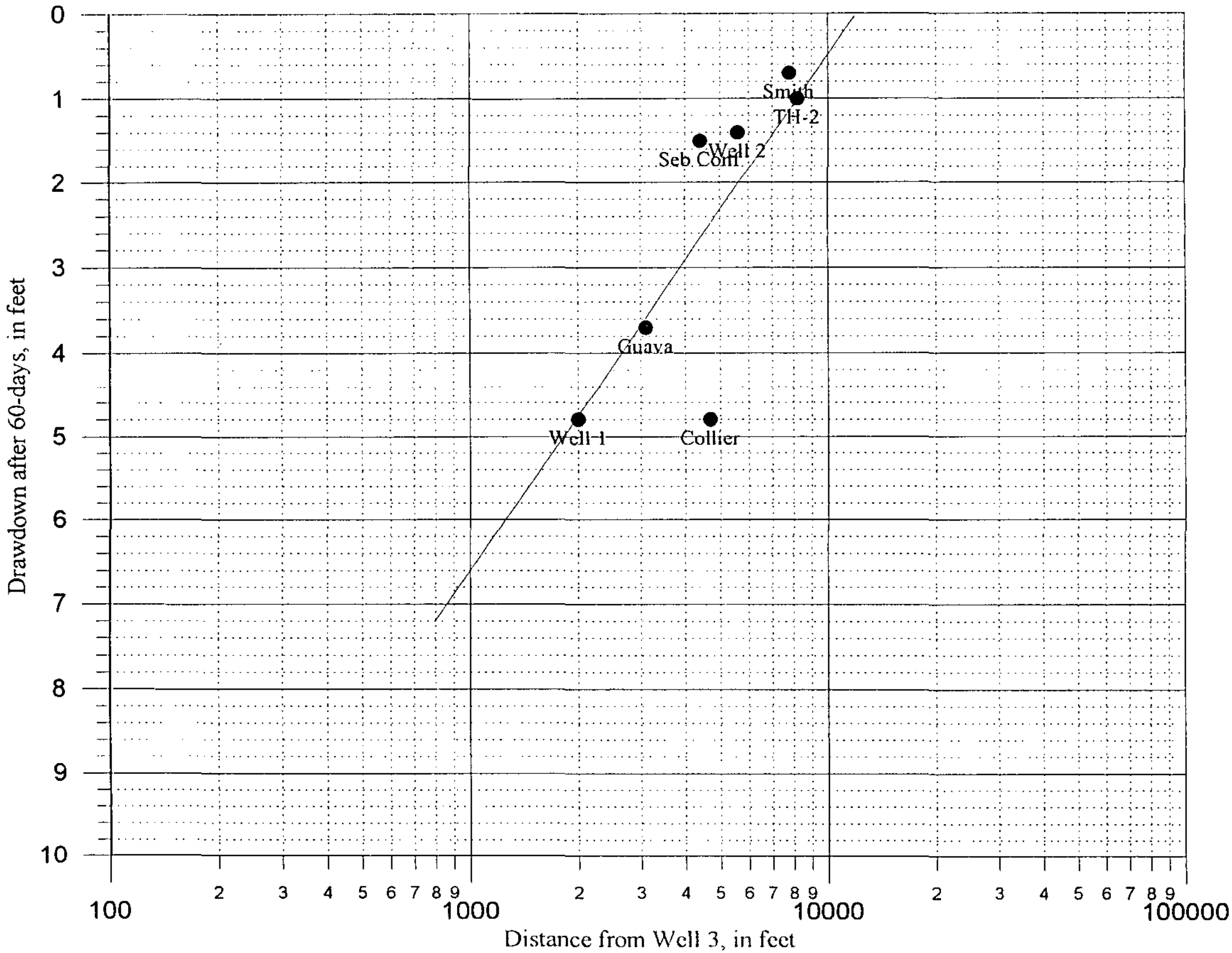


FIGURE 17

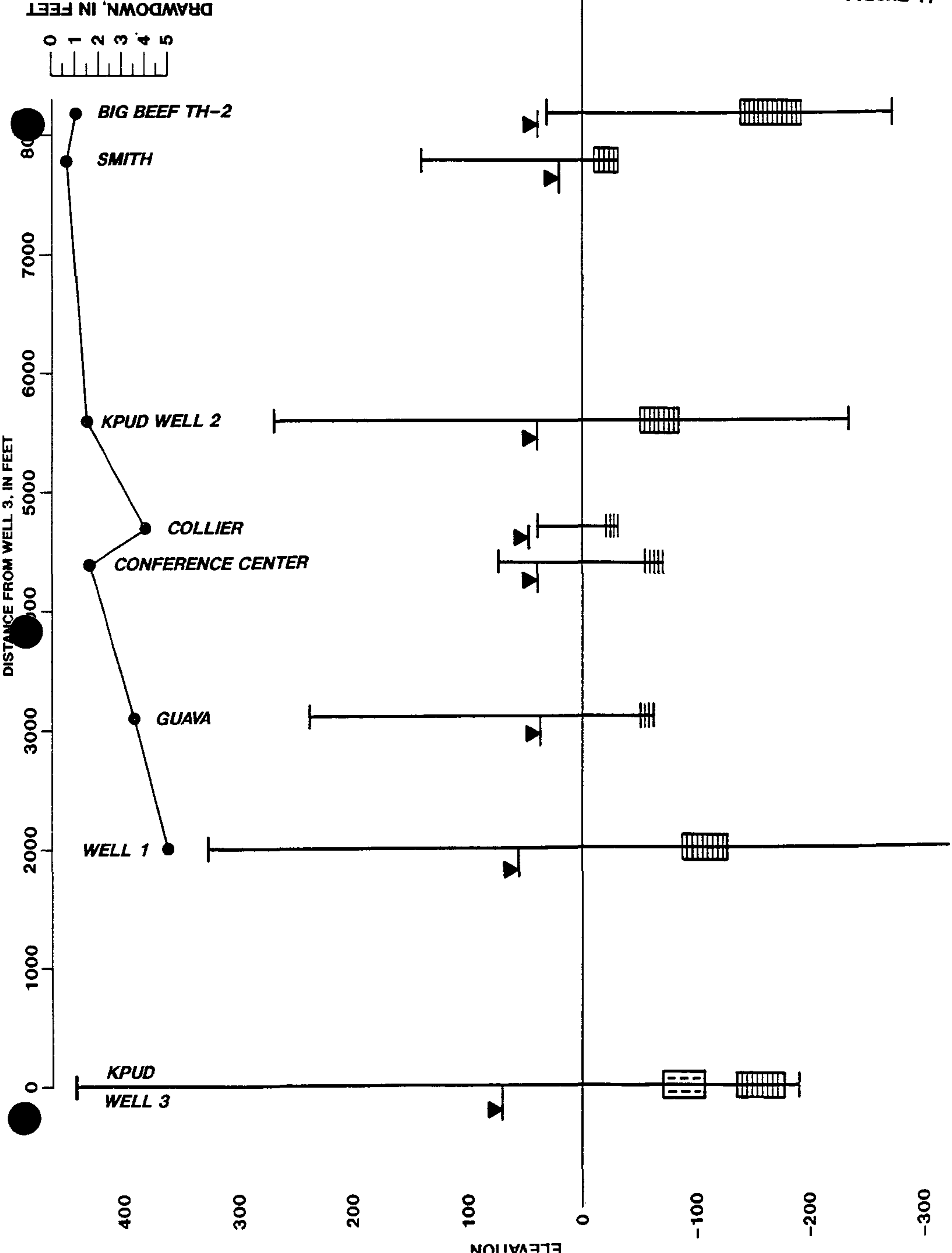
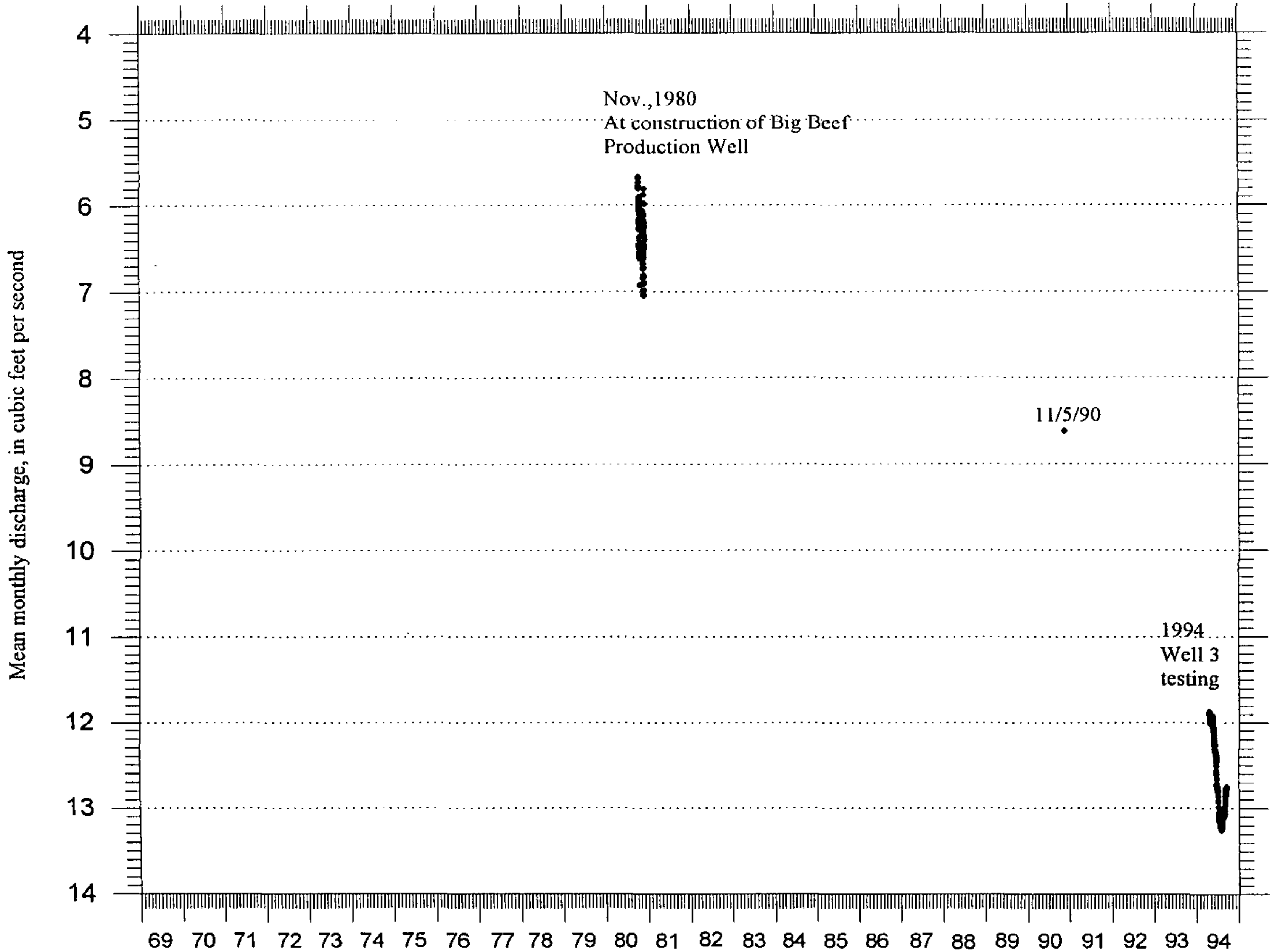

DRAWDOWN, IN FEET
0 1 2 3 4 5
DISTANCE FROM WELL 3, IN FEET
0
1000
2000
3000
5000
6000
7000
ELEVATION
400
300
200
100
0
-100
-200
-300
BIG BEEF TH-2
SMITH
KPUD WELL 2
COLLIER
CONFERENCE CENTER
GUAVA
WELL 1
KPUD
WELL 3

Figure 18. Historical water levels in Big Beef Test Hole 2 (Aquifer B).



# ATTACHMENTS

WATER MANAGEMENT LABORATORIES INC.

1515 80th St. E.
Tacoma, WA 98404
531-3121

August 31, 1994

Robinson and Noble
5915 Orchard Street West
Tacoma, WA 98467
Attn: Joel Purdy

**RE: Correction of report dated 06-13-94.**

Dear Sir:

Results of analysis of one groundwater engineering sample taken by yourself on 06-02-94 at 11:30 a.m. and received 06-02-94 at 1:30 p.m. are as follows:

**Sample Identification:** **Kitsap Co PUD #1 Seabeck Well #3**

| **TEST** | **RESULT** |
|---|---|
| Arsenic | less than 0.01 |
| Barium | less than 0.25 |
| Bicarbonate* | 55 |
| Cadmium | less than 0.002 |
| **Calcium** | **14** |
| Carbonate* | 0 |
| Chloride | 1 |
| Chromium | less than 0.01 |
| Color* | less than 5 |
| Copper | less than 0.02 |
| Fluoride | less than 0.2 |
| Iron | less than 0.03 |
| Lead | less than 0.002 |
| **Magnesium** | **3** |
| Manganese | less than 0.01 |
| Mercury | less than 0.001 |
| Nitrate Nitrogen | less than 0.2 |
| Potassium | 0.1 |
| Selenium | less than 0.005 |

| TEST | RESULT |
|---|---|
| Silica | 20 |
| Silver | less than 0.01 |
| Sodium | 4 |
| Specific Conductivity* | 96 |
| pH* | 7.9 |
| Sulfate | 2 |
| Total Dissolved Solids | 59 |
| Total Hardness* | 50 |
| Turbidity* | 0.4 |
| Zinc | less than 0.1 |

*All results are in milligrams per liter except color which is in color units, pH which is in pH units, specific conductivity which is in micro-mho per cm, and turbidity which is in nephelometric turbidity units. Bicarbonate, carbonate and total hardness are in milligrams per liter as calcium carbonate.

Lab Number: 89-17670

Sample was analyzed according to Standard Methods for the Examination of Water and Wastewater, 18th Edition.

Chain of Custody record is enclosed.

Sincerely,

George P. Schonhard

George Schonhard
Chemist

GS:cmh
enclosure

c:\comm\R&N8-2b

WATER MANAGEMENT LABORATORIES INC.
1515 80th St. E.
Tacoma, WA 98404
531-3121

August 19, 1994

Robinson and Noble
5915 Orchard Street West
Tacoma, WA 98467
Attn: Joel Purdy

Dear Sir:

Results of analysis of one groundwater engineering sample taken by yourself on 08-01-94 at 10:10 a.m. and received 08-01-94 at 12:35 p.m. are as follows:

**Sample Identification:** **Seabeck Well #3**
**Well #3**
**60 Day**

| TEST | RESULT |
|---|---|
| Arsenic | less than 0.01 |
| Barium | less than 0.25 |
| Bicarbonate* | 52 |
| Cadmium | less than 0.002 |
| Calcium | 15 |
| Carbonate* | 0 |
| Chloride | 1 |
| Chromium | less than 0.01 |
| Color* | less than 5 |
| Copper | less than 0.02 |
| Fluoride | less than 0.2 |
| Iron | less than 0.03 |
| Lead | less than 0.002 |
| Magnesium | 2 |
| Manganese | less than 0.01 |
| Mercury | less than 0.001 |
| Nitrate Nitrogen | less than 0.2 |
| Potassium | 0.2 |
| Selenium | less than 0.005 |

| TEST | RESULT |
|---|---|
| Silica | 15 |
| Silver | less than 0.01 |
| Sodium | 4 |
| Specific Conductivity* | 103 |
| pH* | 7.7 |
| Sulfate | 2 |
| Total Dissolved Solids | 64 |
| Total Hardness* | 48 |
| Turbidity* | 0.2 |
| Zinc | 0.4 |

*All results are in milligrams per liter except color which is in color units, pH which is in pH units, specific conductivity which is in micro-mho per cm, and turbidity which is in nephelometric turbidity units. Bicarbonate, carbonate and total hardness are in milligrams per liter as calcium carbonate.

Lab Number: 89-18189

Sample was analyzed according to Standard Methods for the Examination of Water and Wastewater, 18th Edition.

Chain of Custody Record is enclosed.

Sincerely,

Diane DuMond
Lab Coordinator

DD:jrc
enclosure

C:\COMM\R&N08-01

WATER MANAGEMENT LABORATORIES, INC.
1515 80TH STREET EAST, TACOMA, WA 98404
PHONE (206) 531-3121 FAX (206) 531-5287

***************
# CHAIN OF CUSTODY
***************

| LAB USE SAMPLE # | # OF CONTAINERS | TYPE OF SAMPLE: WATER | WASTE | OTHER | DATE TAKEN | TIME TAKEN | TAKEN BY (NAME) | SAMPLE IDENTIFICATION | TEST REQUESTED: R+N Special | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | ✓ | | | 8/1/94 | 10:10 | Joe Purdy | Seatech Well 3 | X | | | | | | |
| 2 | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | |

LAB USE
PRESERVED: YES NO (circled: NO)
CHAIN OF CUSTODY SEAL USED: YES NO (circled: NO)
SEAL INTACT: YES NO
DEPARTMENTS: BACT ___ INORG X ORG ___

TOTAL # OF CONTAINERS: 2

REPORT TO: Joe Purdy
Company Name: Robinson & Noble, Inc
Address: 5915 Orchard St. West
Tacoma, WA 98467
Phone: 206-475-7711 Fax: ( )

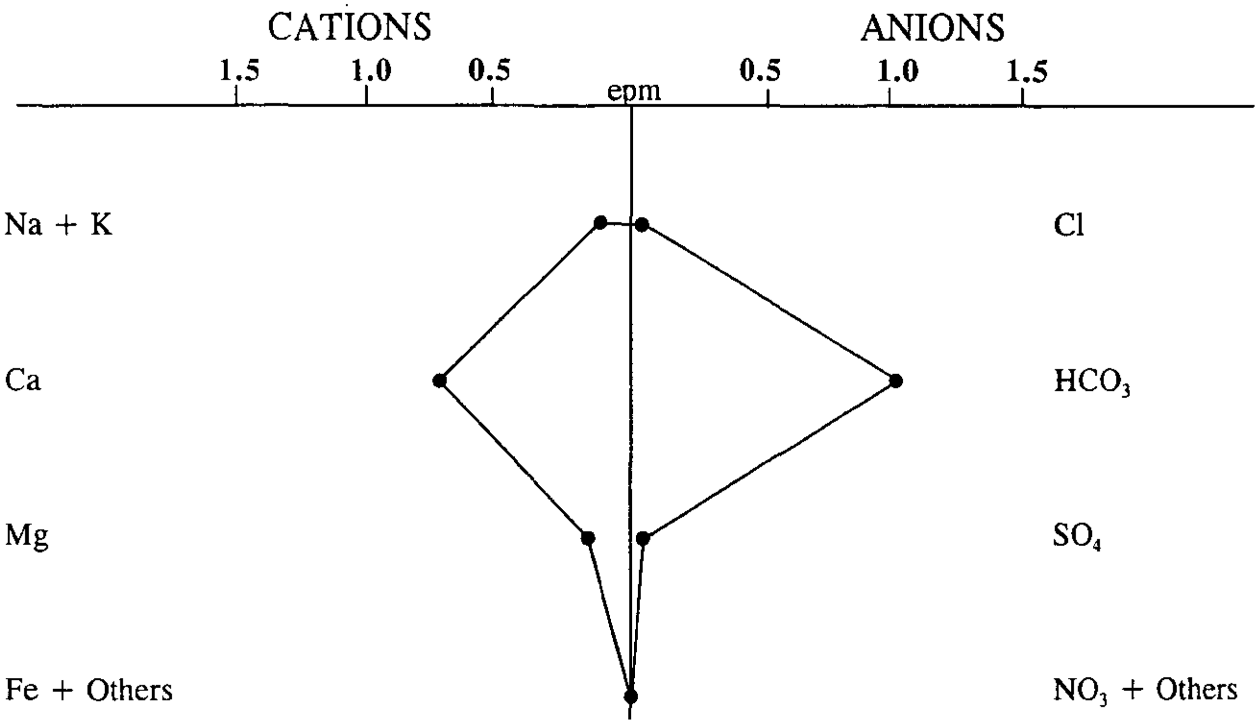
RELINQUISHED BY: [signature]
DATE: 8-1-94 TIME: 2:35
RECEIVED BY: [signature]
DATE: 08-01-94 TIME: 12:35pm

REMARKS:

REJECT REASON:

# Stiff Diagram

*Kitsap PUD #1*
*Seabeck Well 3 1-day sample*

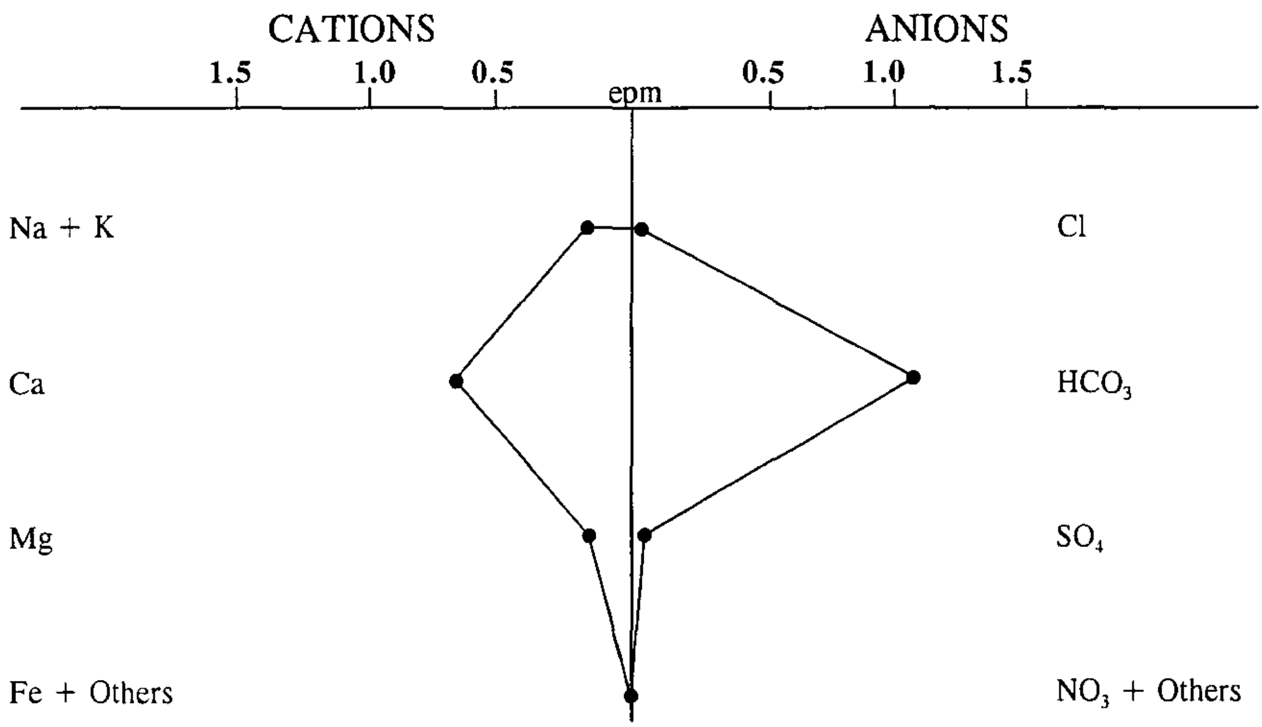



**Silica =** **20**
**Labratory TDS=** **59**
**Labratory Conductivity=** **96**

**Anion/Cation ratio=** **0.98**

# Stiff Diagram

*Kitsap PUD #1*
*Seabeck Well 3 60-day sample*




**Silica = 15**
**Labratory TDS= 64**
**Labratory Conductivity= 103**

**Anion/Cation ratio= 0.98**

File Original and First Copy with Department of Ecology
Second Copy—Owner's Copy
Third Copy—Driller's Copy

# WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. ______

Water Right Permit No. ______

(1) OWNER: Name KITSAP PUBLIC UTILITY DIS #1 Address PO BOX 1489 POULSBO 98370

(2) LOCATION OF WELL: County KITSAP SE 1/4 SW 1/4 Sec 21 T 25 N., R 1W W.M.

STREET ADDRESS OF WELL (or nearest address) AT THE NW CORNER OF 1/4 1/4 "P"

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☒ Municipal ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) ______
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐
Method: Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 12 inches.
Drilled 649 feet. Depth of completed well 470 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 12" Diam. from +2.5 ft. to 429 ft.
Welded ☒ ______" Diam. from ______ ft. to ______ ft.
Liner installed ☐
Threaded ☐ ______" Diam. from ______ ft. to ______ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name HOWARD SMITH
Type STAINLESS WIRE WOUND Model No. ______
Diam. 6 PS Slot size 30 from 418.5 ft. to 423.75 ft.
Diam. 6 PS Slot size 30 from 429.5 ft. to 450.25 ft.

Gravel packed: Yes ☒ No ☐ Size of gravel 8 X 12 Colorado
Gravel placed from 398 ft. to 470 ft.

Surface seal: Yes ☒ No ☐ To what depth? 19 ft.
Material used in seal CEMENT GROUT
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name N/A
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ~330 ft.
Static level 270.3 ft. below top of well Date 4/3/91
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? Charon/R+N
Yield: 325 gal./min. with 99.4 ft. drawdown after 24 hrs.
" " "
" " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

| Time | Water Level | Time | Water Level | Time | Water Level |
|---|---|---|---|---|---|
| 6 | 275.7 | 120 | 272.2 | | |
| 10 | 275.35 | 200 | 271.7 | | |
| 64 | 272.9 | 1325 | 270.3 | | |

Date of test 4/1-3/91

Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water ______ Was a chemical analysis made? Yes ☒ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

| MATERIAL | FROM | TO |
|---|---|---|
| BROWN M-C SAND, SILT + GRAVEL | 0 | 28 |
| PEAT LAYER | 28 | 30 |
| BROWN SILTBOUND SAND | 30 | 47 |
| GRAY SILTY GRAVEL + SAND | 47 | 54 |
| BROWN/GRAY SAND + GRAVEL W/ SILT LAYERS | 54 | 73 |
| BROWN SILT + CLAY LAYERS | 73 | 85 |
| BROWN SILTY SAND + GRAVEL, W/ BINDER | 85 | 108 |
| ORANGE/BROWN SILTBOUND SAND + GRAVEL | 108 | 285 |
| BROWN SAND + GRAVEL W.B. | 285 | 296 |
| BROWN SILTBOUND M-C SAND | 296 | 307 |
| BRN SILTBOUND M-C SAND + GRAVEL | 307 | 349 |
| BRN C. SAND + GVL W/ COBBLES W.B. | 349 | 356 |
| " SILTBOUND S+G W/ COBBLES | 356 | 360 |
| " M-C SAND + GRAVEL W.B. | 360 | 381 |
| " M-C SAND, SOME GRAVEL W.B. | 381 | 445 |
| " F-M SAND SILTY W.B. | 445 | 457 |
| RUST BROWN CLAY + SILTBOUND SAND | 457 | 464 |
| BRN SAND + GRAVEL W/ SILT BINDER | 464 | 469 |
| BROWN/ORANGE SILT/CLAYBOUND S+G | 469 | 493 |
| GRAY SILTBOUND GRAVEL + SAND | 493 | 509 |
| GRAY/BROWN SILTBOUND GRVL + SAND | 509 | 577 |
| DARK GRAY/BLACK SILTBOUND SAND + GVL | 577 | 587 |
| BRN/GRAY CLAYBOUND GVL + SAND | 587 | 600 |
| LAYER OF GRAY SAND + GRAVEL W.B. | 600 | 601 |
| GRAY/BROWN SILTBOUND GVL + SAND | 601 | 649 |

PREPARED BY JOEL W. PURDY
ROBINSON + NOBLE, INC.

ORIGINAL SIGNED BY DRILLER

Work started 10/23/90, 19 Completed 4/3, 1991

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME CHARON DRILLING INC. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address ______

(Signed) ______ (WELL DRILLER) License No. ______

Contractor's Registration No. ______ Date ______, 19__

(USE ADDITIONAL SHEETS IF NECESSARY)

ECY 050-1-20 (10/87) -1329-

File Original and First Copy with Department of Ecology
Second Copy—Owner's Copy
Third Copy—Driller's Copy

# WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. ______

Water Right Permit No. ______

(1) OWNER: Name Kitsap County PUD #1 Address ______

LOCATION OF WELL: County Kitsap SW ¼ NW ¼ Sec. 22 T. 25 N., R. 1W W.M.

(2a) STREET ADDDRESS OF WELL (or nearest address) @ the NW corner of SW¼ of NW¼

(3) PROPOSED USE: ☐ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☒ Municipal ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) Seabeck Well 2

Abandoned ☐ New well ☐ Deepened ☐ Reconditioned ☐ Method: Dug ☐ Cable ☐ Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 12 inches.
Drilled 500 feet. Depth of completed well 364 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 12 " Diam. from +2.0 ft. to 320 ft.
Welded ☒ 12 " Diam. from 468.5 ft. to 497.5 ft.
Liner installed ☐
Threaded ☐ ______ " Diam. from ______ ft. to ______ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ______
SIZE of perforations ______ in. by ______ in.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.
______ perforations from ______ ft. to ______ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Johnson
Type Stainless Wire Wound Model No. ______
Diam. 10 P Slot size 100 from 319.25 ft. to 350.0 ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel ______
Gravel placed from ______ ft. to ______ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal Cement grout
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name N/A
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level 245 (altimeter) ft.
Static level 226.5 ft. below top of well Date 7/24/91
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? Charon / RTN
Yield: 720 gal./min. with 21.3 ft. drawdown after 24 hrs.
" 910 " 25.8 " 9 hrs "
T = 73,000 to 86,000 gpd/ft

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

| Time | Water Level | Time | Water Level | Time | Water Level |
|---|---|---|---|---|---|
| 2m | 233.0 | 100m | 229.3 | | |
| 10m | 232.5 | 240m | 228.5 | | |
| 60m | 229.7 | 1330m | 226.0 | | |

Date of test 7/24-26/91

Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water 49 Was a chemical analysis made? Yes ☒ No ☐

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

| MATERIAL | FROM | TO |
|---|---|---|
| Brown hard till | 0 | 20 |
| " claybound gravel + sand | 20 | 70 |
| " gravel + sand w/ binder | 70 | 88 |
| " gravel silt, sand water bearing | 88 | 93 |
| " claybound gravel | 93 | 115 |
| " Layer of gravel + sand w.b. | 115 | 116 |
| " clay/siltbound gravel + sand | 116 | 208 |
| " sticky sandy clay | 208 | 216 |
| Tan/Brown siltbound sandy gravel | 216 | 298 |
| Brown m-c sand + gravel w.b. | 298 | 310 |
| Chocolate brown siltbound sand + gravel | 310 | 318 |
| Brown m-vc sand + gravel (30%) w.b. | 318 | 357 |
| " siltbound gravel + sand (cobbles) | 357 | 383 |
| " silty clay w/ layers of S+G | 383 | 412 |
| " silty sand some gravel | 412 | 421 |
| " siltbound sand some gravel | 421 | 430 |
| " silty sand | 430 | 464 |
| " sand + gravel, silty w.b. | 464 | 481 |
| Orange clayey silt w/ minor S+G | 481 | 487 |
| Brown/orange siltbound gravel+sd | 487 | 500 |

Original Signed by Driller

Work started 4/29, 19__ Completed 7/26, 1991

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Charon Drilling (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)

Address ______

(Signed) ______ (WELL DRILLER) License No. ______

Contractor's Registration No. ______ Date ______, 19__

(USE ADDITIONAL SHEETS IF NECESSARY)

File Original and First Copy with Department of Ecology
Second Copy- Owner's Copy
Third Copy- Driller's Copy

# WATER WELL REPORT
## STATE OF WASHINGTON

Start Card No. ______
Unique Well ID # AAA990
Water Right Permit No. G1-25894

(1) OWNER: Name Kitsap PUD #1 Address PO BOX 1989, Poulsbo WA 98370

(2) LOCATION OF WELL: County Kitsap - NE ¼ NW ¼ Sec 28 T. 25 N., R. 1 W W.M.
(2a) STREET ADDRESS OF WELL (or nearest address) ______

(3) PROPOSED USE: ☐ Domestic ☐ Industrial ☒ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐ DeWater

(4) TYPE OF WORK: Owner's number of well (if more than one) Seabeck Well 3
☐ Abandoned ☒ New well ☐ Deepened ☐ Reconditioned
Method: ☐ Dug ☐ Bored ☒ Cable ☐ Driven ☐ Rotary ☐ Jetted

(5) DIMENSIONS: Diameter of well 16 inches
Drilled 630 feet. Depth of completed well 622.1 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 16 " Diam. from +2.0 ft. to 577 ft.
☒ Welded 16 " Diam. from 617 ft. to 628 ft.
☐ Liner installed ______ " Diam. from ______ ft. to ______ ft.
☐ Threaded

Perforations: ☒ Yes ☐ No
Type of perforator used Mills knife
Size of perforations 1/2 in. by 2 in.
96 perforations from 510 ft. to 526 ft.
48 perforations from 534 ft. to 542 ft.
______ perforations from ______ ft. to ______ ft.

Screens: ☒ Yes ☐ No
Manufacturer's Name Johnson
Type stainless, wire Model No. ______
Diam. 10 PS Slot size 50 from 576 ft. to 617 ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.
Diam. ______ Slot size ______ from ______ ft. to ______ ft.

Gravel packed: ☒ Yes ☐ No Size of gravel 8 x 12 CSSI
Gravel placed from 545.5 ft. to 622.1 ft.

Surface Seal: ☒ Yes ☐ No To what depth? 55 ft.
Material used in seal Cement grout
Did any strata contain unusable water? ☐ Yes ☒ No
Type of water? ______ Depth of strata ______
Method of sealing strata off ______

(7) PUMP: Manufacturer's Name N/A
Type: ______ H.P. ______

(8) WATER LEVELS: Land-surface elevation above mean sea level ~~450~~ 440 altimeter ft.
Static level 368.6 ft. below top of well Date 6/9/93
Artesian pressure ______ lbs. per square inch Date ______
Artesian water is controlled by ______ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water is lowered below static level
Was a pump test made? ☒ Yes ☐ No If yes, by whom? Holt/R&N
Yield: 600 gal./min. with 73.5 ft. drawdown after 24 hrs.

Recovery data (time taken as zero when pump turned off)(water level measured from well top to water level)

| Time | Water Level | Time | Water Level | Time | Water Level |
|---|---|---|---|---|---|
| 3 | 374.7 | 100 | 371.1 | | |
| 10 | 373.2 | 200 | 370.8 | | |
| 40 | 371.8 | 1544 | 367.7 | | |

Date of test 6/9-11/93
Bailer test ______ gal./min. with ______ ft. drawdown after ______ hrs.
Airtest ______ gal./min. with stem set at ______ ft. for ______ hrs.
Artesian flow ______ g.p.m. Date ______
Temperature of water 49 Was a chemical analysis made? ☒ Yes ☐ No

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

| MATERIAL | FROM | TO |
|---|---|---|
| Brown silty sand and gravel | 0 | 4 |
| Brown silt and sand, large cobble at 9 ft | 4 | 18 |
| Brown silty sand and gravel | 18 | 76 |
| Gray clean sand and gravel | 76 | 88 |
| Gray silty sand and gravel | 88 | 154 |
| Brown loose sand | 154 | 155 |
| Peat and silt | 155 | 157 |
| Brown sandy silt | 157 | 160 |
| Rusty brown siltbound sand and gravel | 160 | 168 |
| Peat and silt layer | 155 | 157 |
| Brown sandy silt | 157 | 160 |
| Rusty brown siltbound sand and gravel | 160 | 168 |
| Grayish-brown siltbound sand and gravel, some cobbles | 168 | 204 |
| Brown silty sand, gravel and cobbles, weeps water at 210-215 ft | 204 | 255 |
| Brown silt | 255 | 263 |
| Rusty red and multicolored silt with gravel | 263 | 270 |
| Brown silt, sand and gravel | 270 | 280 |
| Rusty-red, sandy, silt with gravel | 280 | 344 |
| Green and greenish-gray silt and gravel | 344 | 413 |
| Mostly brown silty sand and gravel, with thin water-bearing zones | 413 | 507 |
| Brown sand, gravel and cobbles with siltbound layers | 507 | 525 |
| Brown siltbound sand and gravel | 525 | 561 |
| Brown/tan sandy silt | 561 | 574 |
| Brown medium to coarse sand and gravel | 574 | 605 |
| Brown medium to v. coarse sand and gravel | 605 | 613 |
| Orange/brown sand and gravel | 613 | 615 |
| Rusty brown hard siltbound sand and gravel with clay layers | 615 | 630 |

PREPARED BY JOEL W. PURDY ROBINSON & NOBLE, INC
ORIGINAL SIGNED BY DRILLER

Work started February 5 1993. Completed June 11 1993

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME HOLT TESTING, INC. (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 10621 Todd Rd E, Puyallup 98372
(Signed) ______ (WELL DRILLER) License No. ______
Contractor's Registration No. ______ Date ______, 19__

473817 1224938

25/01W-20D

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

# WATER WELL REPORT

STATE OF WASHINGTON

Application No. ________

AAC835 Permit No. ________

**(1) OWNER:** Name Seabeck Conference Center Address P.O. Box 117 Seabeck Wash 98

**(2) LOCATION OF WELL:** County Kitsap — SW ¼ SE ¼ Sec 20 T 25 N., R. 1W W.M.

Bearing and distance from section or subdivision corner

**(3) PROPOSED USE:** Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

**(4) TYPE OF WORK:** Owner's number of well (if more than one) ....

New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☒ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

**(5) DIMENSIONS:** Diameter of well 8 inches.
Drilled 139 ft. Depth of completed well 139 ft.

**(6) CONSTRUCTION DETAILS:**

Casing installed: ____" Diam. from ____ ft. to ____ ft.
Threaded ☐ ____" Diam. from ____ ft. to ____ ft.
Welded ☒ 8" Diam. from 0 ft. to 129 ft.

Perforations: Yes ☐ No ☒
Type of perforator used ________
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Johnson
Type Stainless Model No. ____
Diam. 8 Slot size 20 from 129 ft. to 134 ft.
Diam. 8 Slot size 18 from 134 ft. to 139 ft.

Gravel packed: Yes ☐ No ☒ Size of gravel: ____
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☒ No ☐ To what depth? 20 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ____ Depth of strata ____
Method of sealing strata off ____

**(7) PUMP:** Manufacturer's Name ____
Type: ____ H.P. ____

**(8) WATER LEVELS:** Land-surface elevation above mean sea level.... 50 75 ft. KPUD
Static level 34 ft. below top of well Date 3-17-87
Artesian pressure ____ lbs. per square inch Date ____
Artesian water is controlled by ____ (Cap, valve, etc.)

**(9) WELL TESTS:** Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☒ If yes, by whom? ____
Yield: ____ gal./min. with ____ ft. drawdown after ____ hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

| Time | Water Level | Time | Water Level | Time | Water Level |
|---|---|---|---|---|---|
| | | | | | |

Date of test ____
Bailer test 60 gal./min. with 62 ft. drawdown after 4 hrs.
Artesian flow ____ g.p.m. Date ____
Temperature of water ____ Was a chemical analysis made? Yes ☐ No ☒

**(10) WELL LOG:**

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

| MATERIAL | | FROM | TO |
|---|---|---|---|
| Top dirt — Rocky | Brown | 0 | 4 |
| Hardpan — Rocky | " | 4 | 30 |
| Hardpan | Gray | 30 | 60 |
| Hardpan — Hard | " | 60 | 100 |
| Sand & Gravel — Cemented | | 100 | 106 |
| " & " — Loose | | 106 | 108 |
| " & " — Cemented | | 108 | 110 |
| " & " — Loose | | 110 | 114 |
| " & " — Cemented | | 114 | 115 |
| Sand & Gravel — Loose — water | | 115 | 137 |
| " & " — Cemented | | 137 | — |

RECEIVED
APR 0? 1987
DEPT. OF ECOLOGY

Work started March 2 1987 Completed March 17 1987

**WELL DRILLER'S STATEMENT:**

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME CRABTREE DRILLING Co (Person, firm, or corporation) (Type or print)

Address 32249 EGLON RD NE KINGS

[Signed] Jerry Crabtree (Well Driller)

License No. 82 Date March 17 1987

(USE ADDITIONAL SHEETS IF NECESSARY)

Check Location? 25/1W-21M 25/01W-20 J

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

Guava well

# WATER WELL REPORT

AAH232

Application No.

STATE OF WASHINGTON

Permit No. G1-23061

(1) OWNER: Name Fryckoff Co. Address 1508 [illegible] Bank Bldg. Seattle, Wash. 98171

(2) LOCATION OF WELL: County Kitsap SE 1/4 of NE 1/4 SE 1/4 Sec 20 T 25 N., R 1W W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one) ....
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☒ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 8 inches.
Drilled 301 ft. Depth of completed well 301 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 8 " Diam. from 0 ft. to 291 ft.
Threaded ☐ ___" Diam. from ___ ft. to ___ ft.
Welded ☒ ___" Diam. from ___ ft. to ___ ft.

Perforations: Yes ☐ No ☒
Type of perforator used ___
SIZE of perforations ___ in. by ___ in.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.
___ perforations from ___ ft. to ___ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Johnson
Type Stainless Model No. ___
Diam. 8 Slot size 12 from 291 ft. to 301 ft.
Diam. ___ Slot size ___ from ___ ft. to ___ ft.

Gravel packed: Yes ☐ No ☒ Size of gravel: ___
Gravel placed from ___ ft. to ___ ft.

Surface seal: Yes ☒ No ☐ To what depth? 19 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? ___ Depth of strata ___
Method of sealing strata off ___

(7) PUMP: Manufacturer's Name Gould
Type: Sub. H.P. 5

(8) WATER LEVELS: Land-surface elevation above mean sea level.... 260
Static level 198 ft. below top of well Date 10/5/77
Artesian pressure ___ lbs. per square inch Date ___
Artesian water is controlled by ___ (Cap, valve, etc.)

252'

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☒ No ☐ If yes, by whom? Driller

| Yield: gal./min. | with ft. drawdown | after hrs. |
|---|---|---|
| 50 | 56 | 8 1/2 |
| | | |

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

| Time | Water Level | Time | Water Level | Time | Water Level |
|---|---|---|---|---|---|
| | | | | | |

Date of test ___
Bailer test 30 gal./min. with 30 ft. drawdown after 6 hrs.
Artesian flow ___ g.p.m. Date ___
Temperature of water ___ Was a chemical analysis made? Yes ☐ No ☒

(10) WELL LOG:

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.

| MATERIAL | FROM | TO |
|---|---|---|
| Hard pan orange | 0 | 23 |
| " " Hard Brown | 23 | 30 |
| " " Mild Orange | 30 | 52 |
| " " Hard Brown | 52 | 75 |
| " " Orange | 75 | 214 |
| Cemented gravel & cobbles | 214 | 287 |
| Water sand | 287 | 300 |
| Large cobbles | 300 | 301 |

Work started Aug. 31, 1977 Completed Oct. 5, 1977

## WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report true to the best of my knowledge and belief.

NAME CRABTREE DRILLING CO. (Person, firm, or corporation) (Type or print)

Address 23349 Elton Rd. N.E. Kingston

[Signed] Jerry Crabtree (Well Driller)

License No. 23-32 Date Oct. 7, 1977

USE ADDITIONAL SHEETS IF NECESSARY

25N/01W - 21C 25/1W/21C

The Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

# WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W32810
UNIQUE WELL I.D. # AAC547
Water Right Permit No.

(1) OWNER: Name June C. Collier Address 13160 Seabeck Hwy.N.W., Seabeck 98380

(2) LOCATION OF WELL: County Kitsap NE 1/4 NW 1/4 Sec 21 T. 25 N., R. 1W W.M.

(2a) STREET ADDRESS OF WELL (or nearest address) Lot 10 & 11 Seabeck Hwy N.W. (13160 Seabeck Hwy N.W.)

(3) PROPOSED USE: Domestic ☒ Irrigation ☐ DeWater ☐ Industrial ☐ Test Well ☐ Municipal ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (If more than one)
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐ Method: Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 67 feet. Depth of completed well 67 ft.

(6) CONSTRUCTION DETAILS:
Casing installed: 6" Diam. from 0 ft. to 67 ft.
Welded ☒ " Diam. from ft. to ft.
Liner installed ☐ " Diam. from ft. to ft.
Threaded ☐

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Johnson
Type stainless steel Model No.
Diam. 6 Slot size 10 from 62 ft. to 67 ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☒ Size of gravel
Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name Goulds
Type: submersible [illegible] H.P. [illegible]

(8) WATER LEVELS: Land-surface elevation above mean sea level 40 NVD ALT ft.
Static level 0" flowing ft. below top of well Date 10/10/93
Artesian pressure 5 lbs. per square inch Date 10/10/93
Artesian water is controlled by Cap (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom? Gresham
Yield: 20 gal./min. with 13.5 ft. drawdown after 1 hrs.

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)
Time Water Level Time Water Level Time Water Level
Full recov. in 2 min.

Date of test 10/[illegible]
Bailer test gal./min. with ft. drawdown after hrs.
Airtest gal./min. with stem set at ft. for hrs.
Artesian flow g.p.m. Date

(10) WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

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| MATERIAL | FROM | TO |
|---|---|---|
| Brown overburden | 0 | 2 |
| Brown gravelly hardpan | 2 | 42 |
| Brown sandy silt & gravel | 42 | 46 |
| Brown gravelly hardpan | 46 | 59 |
| Brown silty sand | 59 | 63 |
| Brown sand,gravel, H2O | 63 | 67 |

Work Started 10/05/93 19. Completed 10/07/93 19

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Gresham Well Drilling (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 3105 N.W. Lakeness Rd.,Poulsbo 98370
(Signed) [signature] (WELL DRILLER) License No. 0761
Contractor's Registration No. GRESHWD206NF Date 10/21/93 19

(USE ADDITIONAL SHEETS IF NECESSARY)

25/01W-22C

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

Jan Smith

# WATER WELL REPORT
## STATE OF WASHINGTON

Application No. ______
Permit No. ......

(1) OWNER: Name Jerry Christofferson Address P.O. Box 345 Seabeck, WA

(2) LOCATION OF WELL: County Kitsap — NE ¼ NW ¼ Sec. 22 T. 25 N., R. 1W W.M.

Bearing and distance from section or subdivision corner

(3) PROPOSED USE: Domestic ☒ Industrial ☐ Municipal ☐ Irrigation ☐ Test Well ☐ Other ☐

(4) TYPE OF WORK: Owner's number of well (if more than one)....
New well ☒ Method: Dug ☐ Bored ☐
Deepened ☐ Cable ☐ Driven ☐
Reconditioned ☐ Rotary ☐ Jetted ☐

(5) DIMENSIONS: Diameter of well 6 inches.
Drilled 166 ft. Depth of completed well 166 ft.

(6) CONSTRUCTION DETAILS:

Casing installed: 6 " Diam. from 0 ft. to 150 ft.
Threaded ☒ ____" Diam. from ____ ft. to ____ ft.
Welded ☐ ____" Diam. from ____ ft. to ____ ft.

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations ____ in. by ____ in.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.
____ perforations from ____ ft. to ____ ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Johnson
Type Stainless Steel Model No.
Diam. 6 Slot size .020 from 146 ft. to 166 ft.
Diam. ____ Slot size ____ from ____ ft. to ____ ft.

Gravel packed: Yes ☐ No ☐ Size of gravel:
Gravel placed from ____ ft. to ____ ft.

Surface seal: Yes ☒ No ☐ To what depth? 18 ft.
Material used in seal Bentonite
Did any strata contain unusable water? Yes ☐ No ☐
Type of water? ____ Depth of strata
Method of sealing strata off

(7) PUMP: Manufacturer's Name
Type: ____ H.P.

(8) WATER LEVELS: Land-surface elevation above mean sea level.... ft.
Static level 118 ft. below top of well Date 4-23-84
Artesian pressure ____ lbs. per square inch Date
Artesian water is controlled by ____ (Cap, valve, etc.)

(9) WELL TESTS: Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

| Time | Water Level | Time | Water Level | Time | Water Level |
|---|---|---|---|---|---|
| | | | | | |

Date of test
Bailer test 20 gal./min. with 2 ft. drawdown after 1 hrs.
Artesian flow ____ g.p.m. Date
Temperature of water ____ Was a chemical analysis made? Yes ☐ No ☐

(10) WELL LOG: 25-1W-22C

Formation: *Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of formation.*

| MATERIAL | FROM | TO |
|---|---|---|
| Brown sand gravel clay | 0 | 30 |
| Brown clay | 30 | 32 |
| Brown sandy clay | 32 | 40 |
| Brown sand gravel clay | 40 | 98 |
| Yellow brown clay some gravels | 98 | 105 |
| Brown sand gravel clay | 105 | 123 |
| Brown sand gravel clay seams brown sand gravel water | 123 | 166 |

Well total 166 ft. 1 1/8 in.
To top of packer 146 ft. 2 1/8 in.
#.020 plastic well screen
Screen overall 19 ft. 11 in.
Six in. casing 150th 5 1/8 in.
Static head 118 ft. 8 in.
10 G.P.M. 119 ft.
20 G.P.M. 120 ft.
18 ft. surface seal

RECEIVED
MAY 11 1984
DEPARTMENT OF ECOLOGY
NORTHWEST REGION

Work started 20 April 19 84. Completed 23 April 19 84

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Nicholson Well Drilling Co. (Person, firm, or corporation) (Type or print)

Address P.O. Box 123 Port Orchard, WA

[Signed] [signature] (Well Driller)

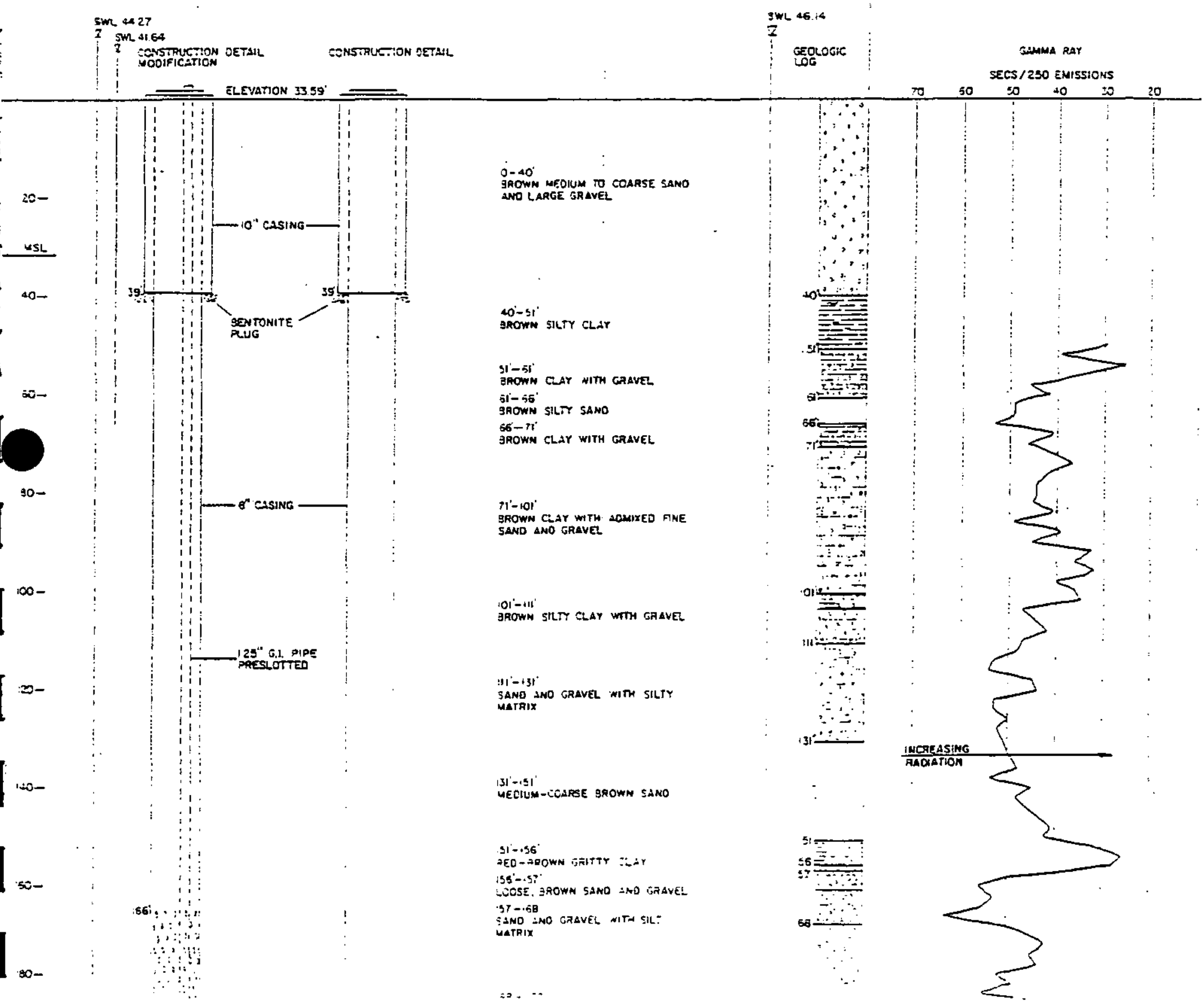
License No. 0519 Date 23 April 19 84

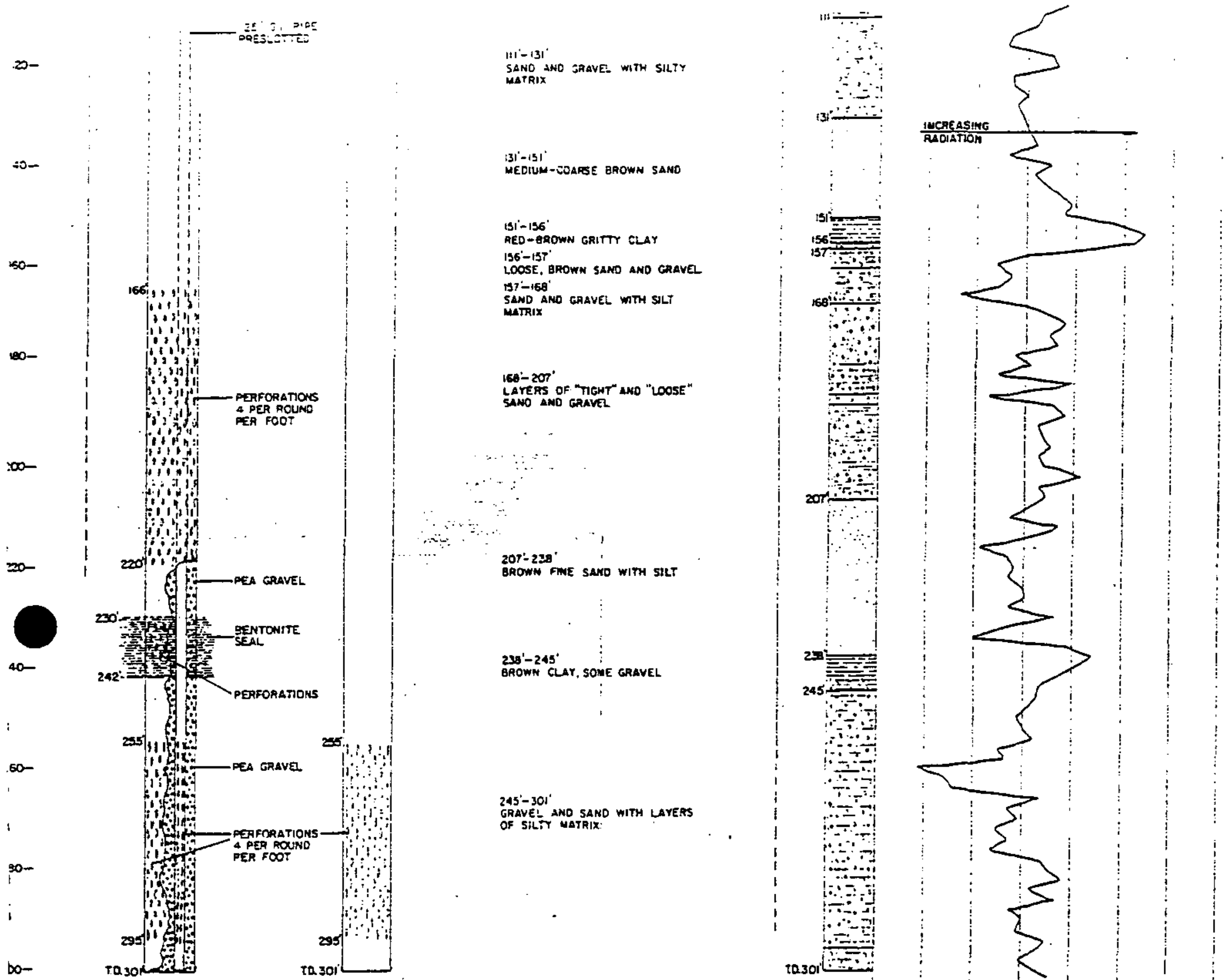
(USE ADDITIONAL SHEETS IF NECESSARY)

UNIVERSITY OF WASHINGTON
BIG BEEF CREEK FISH HATCHERY

TEST HOLE 2

PLATE 2






NOTE: 15' OF 8" CASING IS ABOVE GROUND

ROBINSON, NOBLE & CARR, INC

DRILLED BY RICHARDSON WELL DRILLING, TACOMA, WASH.

# APPENDIX C

**Data base used for potentiometric surface map**

**APPENDIX C** Well data base used for potentiometric surface map (Figure 14) of the Seabeck Aquifer System

| SITEID | LOCAL_NO | LATITUDE | LONGITUDE | WTRLVL | ELEV. | WLELV | LOCAL_NAME | DPTH_W | DPTH_H | Q/s |
|---|---|---|---|---|---|---|---|---|---|---|
| AAA469 | 24N/01W-03A03 | 473614. | 1224650. | 277.00 | 420.00 | 143 | PRIVATE CRAMER | 358.00 | 358.00 | 0.78 |
| AAA645 | 24N/01W-03A04 | 473611. | 1224646. | 263.55 | 409.00 | 146 | PRIVATE JOHNSON | 300.00 | 0.00 | |
| 473612122470301 | 24N/01W-03G01 | 473612.000 | 1224703.000 | 315.00 | 460.00 | 145 | DAHL | 498.00 | 502.00 | 0.47 |
| 473538122514401 | 24N/01W-06N01 | 473538.000 | 1225144.000 | 292.00 | 450.00 | 158 | | 326.00 | 326.00 | |
| AAB603 | 25N/01W-13D02 | 473955. | 1224506. | 36.00 | 76.00 | 40 | GROUP B BOCK, RARICK, SHERMAN | 164.00 | 164.00 | |
| AAA280 | 25N/01W-13F02 | 473941. | 1224445. | 182.50 | 261.00 | 79 | PUBLIC WELL CADY ANDERSON HILL W.S. | 215.00 | 215.00 | |
| 473934122443001 | 25N/01W-13G01 | 473929.000 | 1224435.000 | 261.00 | 340.00 | 79 | HARBOR GREENWOOD WATER SYSTEM | 310.00 | 310.00 | 0.77 |
| AAC723 | 25N/01W-13K04 | 473927.64 | 1224431.98 | 295.00 | 370.00 | 75 | GROUP B HARVCO WATER (TURNER) | 312.00 | 312.00 | 17 |
| AAB529 | 25N/01W-13K05 | 473923. | 1224436. | 298.00 | 361.00 | 63 | PRIVATE BONI | 357.00 | 357.00 | 15 |
| 473945122454001 | 25N/01W-14B01 | 473942.000 | 1224548.000 | 230.00 | 260.00 | 30 | LOC ON DEETERS OVERLAYS- STIRRETT | 501.00 | 501.00 | 0.05 |
| 473942122460201 | 25N/01W-14C01 | 473942.000 | 1224601.000 | 100.00 | 110.00 | 20 | BATTIN | 339.00 | 339.00 | 0.32 |
| AAB267 | 25N/01W-14C04 | 473940. | 1224610. | 40.00 | 65.00 | 25 | PRIVATE GREEN | 198.00 | 198.00 | 0.5 |
| 473938122462201 | 25N/01W-14E01 | 473938.000 | 1224622.000 | -7.00 | 15.00 | 22 | WELL 3 | 149.00 | 149.00 | 24.62 |
| 473932122462101 | 25N/01W-14E03 | 473932.000 | 1224621.000 | 36.00 | 40.00 | 24 | WILKOWSKI | 72.00 | | |
| 473934122462001 | 25N/01W-14E05 | 473934.000 | 1224620.000 | 0.00 | 20.00 | 20 | WADE | 200.00 | | |
| 473934122461701 | 25N/01W-14E06 | 473934.000 | 1224617.000 | 1.00 | 20.00 | 19 | | 90.00 | | |
| 473939122455301 | 25N/01W-14G01 | 473939.000 | 1224553.000 | 190.00 | 220.00 | 30 | HOLLINGSWORTH | 531.00 | 531.00 | 5 |
| AAA878 | 25N/01W-14L01 | 473924. | 1224557. | 212.00 | 254.00 | 42 | PRIVATE GASS | 538.00 | 538.00 | 0.23 |
| 473922122462801 | 25N/01W-14M01 | 473922.000 | 1224628.000 | 55.00 | 100.00 | 45 | HUBBELL | 70.00 | | 0.8 |
| 473919122462601 | 25N/01W-14M02 | 473919.000 | 1224626.000 | 50.00 | 95.00 | 45 | SANFORD | 94.00 | | 0.9 |
| 473926122463201 | 25N/01W-14M03 | 473926.000 | 1224632.000 | 39.00 | 80.00 | 41 | GREER | 69.00 | | |
| AAA591 | 25N/01W-14N03 | 473904. | 1224626. | 135.61 | 183.00 | 48 | PRIVATE REED | 0.00 | 0.00 | |
| AAA069 | 25N/01W-15H06 | 473930. | 1224637. | 13.00 | 20.00 | 7 | PRIVATE LAMBERT | 48.00 | 48.00 | 1.08 |
| 473925122464802 | 25N/01W-15J02 | 473925.000 | 1224648.000 | 2.00 | 10.00 | 8 | PROHASKA | 57.00 | | |
| 473916122470402 | 25N/01W-15K02 | 473916.000 | 1224704.000 | 42.00 | 50.00 | 8 | SALO | 87.00 | | 0.65 |
| 473920122472801 | 25N/01W-15L01 | 473920.000 | 1224728.000 | 0.00 | 10.00 | 10 | LIND | 119.00 | 119.00 | 0.26 |
| 473919122473101 | 25N/01W-15L02 | 473919.000 | 1224731.000 | 6.50 | 10.00 | 3.5 | SCHONING | 132.00 | 132.00 | 2.45 |
| AAA993 | 25N/01W-15L03 | 473923. | 1224712. | 21.76 | 40.00 | 18 | GROUP B HUTCHINS/SPALDING | 110.00 | 110.00 | 0.4 |
| 473927122464501 | 25N/01W-15M01 | 473927. | 1224645. | -0.23 | 10.00 | 10 | PRIVATE STUBER | 0.00 | 0.00 | 3.5 |
| 473903122465001 | 25N/01W-15R01 | 473903. | 1224650. | 6.40 | 20.00 | 13 | PRIVATE GEORGE | 81.00 | 81.00 | |
| 473906122464601 | 25N/01W-15R02 | 473906. | 1224646. | -6.90 | 15.00 | 22 | PRIVATE GEORGE | 98.00 | 98.00 | |
| AAA331 | 25N/01W-16R01 | 473905. | 1224810. | 48.63 | 93.00 | 44 | PRIVATE IRONS | 100.00 | 100.00 | 1 |
| AAA802 | 25N/01W-16R03 | 473908. | 1224748. | 124.00 | 160.00 | 36 | PRIVATE HOCKETT | 164.00 | 164.00 | 2.86 |
| 473906122500601 | 25N/01W-17N01 | 473906.000 | 1225006.000 | 1.00 | 10.00 | 9 | MIAMI BEACH RES. | 190.00 | | |
| 473902122495001 | 25N/01W-17P01 | 473902.000 | 1224950.000 | 35.00 | 40.00 | 5 | BERG | 72.00 | | |
| AAA805 | 25N/01W-17P03 | 473901. | 1225003. | 50.00 | 73.00 | 23 | PRIVATE KINNEY | 80.00 | 80.00 | 5 |
| 473901122503001 | 25N/01W-18R01 | 473902.000 | 1225031.000 | 26.00 | 40.00 | 14 | DUPAR CAMP SCENIC BEACH | 30.90 | 75.00 | |
| 473852122504601 | 25N/01W-19B02 | 473852.000 | 1225046.000 | 60.00 | 70.00 | 10 | STATE PARK | 216.00 | | 3.6 |
| AAC043 | 25N/01W-19J02 | 473824. | 1225041. | 223.00 | 266.00 | 43 | PRIVATE ROBBECKE | 263.00 | 263.00 | 3 |
| AAB562 | 25N/01W-19L01 | 473829.00 | 1225118.00 | 63.50 | 90.00 | 27 | PRIVATE LEWIS | 138.00 | 138.00 | |
| 473823122512201 | 25N/01W-19M01 | 473823.000 | 1225122.000 | 52.80 | 60.00 | 7 | CUNNINGHAM | 55.00 | | |
| 473816122512701 | 25N/01W-19N01 | 473816.000 | 1225127.000 | 32.00 | 40.00 | 8 | SWANSON | 33.00 | | |
| 473818122504001 | 25N/01W-19R01 | 473817.000 | 1225043.000 | 249.00 | 290.00 | 41 | MARTIN | 300.00 | 300.00 | 5 |
| 473854122495801 | 25N/01W-20C01 | 473854.000 | 1224958.000 | 49.00 | 60.00 | 11 | BASKETT | 89.00 | | 1.4 |
| 473858122500001 | 25N/01W-20C02 | 473858.000 | 1225000.000 | 74.00 | 80.00 | 6 | STUART WATER | 124.00 | 125.00 | 0.47 |
| 473842122501601 | 25N/01W-20E01 | 473842.000 | 1225016.000 | 61.00 | 80.00 | 19 | TOBACCO | 101.00 | | 3.33 |
| 473844122500001 | 25N/01W-20F01 | 473844.000 | 1225000.000 | 15.00 | 20.00 | 5 | HILFIKER | 78.00 | | 2.67 |
| 473830122501101 | 25N/01W-20M01 | 473830.000 | 1225011.000 | 7.00 | 40.00 | 33 | KEELER | 19.00 | | |
| AAA804 | 25N/01W-20M02 | 473822. | 1225017. | 13.00 | 37.00 | 24 | PRIVATE JETER | 82.00 | 82.00 | 0.44 |
| AAC852 | 25N/01W-20Q01 | 473858 | 1224716 | 34.00 | 75.00 | 41 | SEABECK CONFERENCE CENTER | 139 | 139 | 1 |
| AAC547 | 25N/01W-21C01 | 473847.09 | 1224840.29 | -8.00 | 40.00 | 48 | PRIVATE COLLIER | 67.00 | 67.00 | 0.7 |
| 473845122485001 | 25N/01W-21E01 | 473845.000 | 1224850.000 | 4.00 | 40.00 | 36 | BOYCE | 46.00 | | |
| 473841122485301 | 25N/01W-21E03 | 473841.000 | 1224853.000 | 2.50 | 40.00 | 37 | VAMVAS | 84.00 | 85.00 | 1.74 |
| 473844122484001 | 25N/01W-21F01 | 473844. | 1224840. | 24.15 | 70.00 | 46 | PRIVATE MUNGER | 57.00 | 0.00 | |
| 473835122490701 | 25N/01W-21M01 | 473835.000 | 1224907.000 | 1.00 | 40.00 | 39 | SNEDT | 53.00 | | |
| AAA232 | 25N/01W-21M02 | 473831. | 1224855. | 201.00 | 239.00 | 38 | PRIVATE PAC. SOUND RES. (WYCHOFF) | 301.00 | 301.00 | 1 |
| AAA235 | 25N/01W-21P01 | 473821.23 | 1224850.29 | 270.30 | 329.00 | 58 | KPUD SEABECK WELL 1 | 470.00 | 649.00 | 3.2 |
| 473818122475401 | 25N/01W-21R01 | 473818.000 | 1224754.000 | 250.00 | 300.00 | 50 | SCHLEHUBER | 279.00 | | 0.4 |
| AAA005 | 25N/01W-22A07 | 473850. | 1224650. | -5.00 | 33.00 | 38 | UW BIG BEEF TEST HOLE 2 UPPER | 220.00 | 301.00 | 15 |
| AAC809 | 25N/01W-22C02 | 473858.000 | 1224716.000 | 120 | 141 | 21 | SMITH monitoring well | 166 | 166 | 10 |
| AAC799 | 25N/01W-22E02 | 473847.53 | 1224736.88 | 226.50 | 269.00 | 40 | KPUD SEABECK TEST WELL 2 | 364.00 | 500.00 | 33.8 |
| AAC690 | 25N/01W-22F02 | 473842.09 | 1224719.81 | 205.00 | 255.00 | 50 | PRIVATE KASSON | 286.00 | 286.00 | |
| 473837122471101 | 25N/01W-22G01 | 473837.000 | 1224711.000 | 199.00 | 240.00 | 41 | ADAMS | 235.00 | 235.00 | |
| 473824122472801 | 25N/01W-22L02 | 473824.000 | 1224728.000 | 225.00 | 280.00 | 55 | BROWN | 339.00 | 339.00 | 2.77 |
| AAA287 | 25N/01W-23B02 | 473900. | 1224537.8 | 340.00 | 395.00 | 55 | PRIVATE SMITH | 492.00 | 492.00 | 6 |
| 473851122442301 | 25N/01W-24B01 | 473851.000 | 1224423.000 | 272.00 | 350.00 | 78 | | 294.00 | 294.00 | |
| 473851122443201 | 25N/01W-24B02 | 473851.000 | 1224432.000 | 274.00 | 350.00 | 76 | | 311.00 | 311.00 | |
| 473859122443201 | 25N/01W-24B03 | 473859.000 | 1224432.000 | 287.00 | 350.00 | 63 | TUDARO WS | 317.00 | 317.00 | 25 |
| | 25N/01W-25E01 | 473748.000 | 1224517.000 | 432.00 | 502.00 | 70 | KPUD NEW TEST WELL @ SCH | 631.00 | 631 | 6 |
| AAB541 | 25N/01W-27A03 | 473759.82 | 1224642.40 | 450.00 | 503.00 | 53 | PRIVATE SHANKLE CONSTRUCTION | 517.00 | 517.00 | 0.62 |
| AAC484 | 25N/01W-27A05 | 473801.30 | 1224648.59 | 434.00 | 495.00 | 61 | GROUP B BYE WATER SYSTEM | 474.00 | 474.00 | 20 |
| AAC709 | 25N/01W-28A01 | 473800.40 | 1224801.79 | 332.00 | 410.00 | 78 | GROUP B BLACK BEAR WATER SYSTEM | 383.00 | 383.00 | 2.7 |
| AAA990 | 25N/01W-28C01 | 473803. | 1224838. | 368.60 | 440.00 | 71 | KPUD SEABECK PRODUCTION WELL 3 | 622.10 | 630.00 | 10 |
| 473726122493801 | 25N/01W-29Q01 | 473726.000 | 1224938.000 | 227.00 | 310.00 | 83 | MORGENSON | 287.00 | 287.00 | 1.33 |
| 473742122504901 | 25N/01W-30G01 | 473742.000 | 1225049.000 | 314.00 | 380.00 | 66 | HAWKINS | 419.00 | 419.00 | 3 |
| AAA875 | 25N/01W-30H03 | 473758. | 1225033. | 263.00 | 308.00 | 45 | PRIVATE DLUGOSH | 330.00 | 330.00 | 0.48 |
| AAC518 | 25N/01W-30H04 | 473741.32 | 1225039.34 | 252.00 | 323.00 | 71 | PRIVATE ENLOE | 318.00 | 318.00 | 0.44 |
| 473741122505001 | 25N/01W-30K01 | 473741.000 | 1225050.000 | 310.00 | 370.00 | 60 | RAYBURN | 304.00 | 374.00 | 2.5 |
| AAA206 | 25N/01W-31H01 | 473652. | 1225036. | 280.00 | 384.00 | 104 | PRIVATE HEIM | 339.00 | 339.00 | 0.6 |
| AAB645 | 25N/01W-31H02 | 473654. | 1225035. | 274.70 | 366.00 | 91 | PRIVATE DOLL | 320.00 | 320.00 | 0.66 |
| 473639122502801 | 25N/01W-31J02 | 473639.000 | 1225028.000 | 275.00 | 390.00 | 115 | | 318.00 | 318.00 | |
| 473629122505301 | 25N/01W-31Q01 | 473629.000 | 1225053.000 | 320.00 | 450.00 | 130 | | 346.00 | 346.00 | |
| AAB607 | 25N/01W-32E01 | 473655. | 1225021. | 165.00 | 276.00 | 111 | PRIVATE SCOTT | 289.00 | 289.00 | 0.24 |
| AAC822 | 25N/01W-32E02 | 473701.19 | 1225023.30 | 171.00 | 277.00 | 106 | PRIVATE SCOTT | 314.00 | 314.00 | 0.15 |
| AAC707 | 25N/01W-34H04 | 473702.19 | 1224656.02 | 310.00 | 420.00 | 110 | PRIVATE DOLAN | 343.00 | 343.00 | 1.67 |

# APPENDIX D

**Water Rights in the Seabeck Study Area**

## APPENDIX D. SEABECK AREA HYDROGEOLOGIC CHARACTERIZATION OF THE SEABECK AQUIFER SYSTEM

### Active Water Rights from the Department of Ecology Records as of 1/24/95

**Table Key:**

**Control #** - DOE water right
**Status** - C= certified, P= permited, A= application, E = error in report
**Local #** - Township/range-section
**Date** - Priority date
**Name** - Owner name
**QI** - Instantaneous discharge (gpm)
**QA** - Annual discharge/diversion (acre-ft/yr)
**Use** - Water use

| | |
|---|---|
| MUNI - municipal | MINING |
| D MULT- Domestic multiple | POWER |
| COMM- Commercial | FIRE - Fire protection |
| FISH- Fish propogation (non-consumptive) | WILD- Wildlife propagation |
| IRR- Irrigation | STOCK- Stock watering |
| DOM - Domestic single | REC - Recreation and beautification |
| MULT - Multiple use | |

**Remarks** - well name, surface water source
**Use type** - C = consumptive use, N= non consumptive use

| Control # | Sta | Local # | Date | Name | QI | QA | Use | Remarks |
|---|---|---|---|---|---|---|---|---|
| G1-23115C | C | 24N/01W-03C | 05/19/78 | MILES, RICHARD A | 4.5 | 2 | D MULT | |
| G1-22823C | C | 24N/01W-03M | 03/28/77 | GABES WTR WKS INC | 20 | 8.1 | D MULT | |
| G1-23528C | C | 24N/01W-04J | 12/14/79 | ILIAD INC. | 35 | 14.5 | MUNI | GREEN MT ACRES |
| G1-25781A | A | 24N/01W-04M | 08/03/90 | C. KITSAP SCH DIST | 100 | | D MULT | GREEN MT ELEM |
| G1-24719P | P | 24N/01W-05F | 10/01/85 | WILDE & ERIKS | 120 | 28.8 | D MULT | |
| G1-22046C | C | 24N/01W-05G, P | 08/15/74 | SYMINGTON OF SEATTLE | 123 | 138 | D MULT | |
| G1-22045C | C | 24N/01W-05J | 08/14/74 | SYMINGTON OF SEATTLE | 130 | 146 | D MULT | |
| G1-24921C | C | 24N/01W-05N | 11/04/86 | BONNETT, CHARLES R. | 13 | 4 | D MULT | |
| G1-24713C | C | 24N/01W-05P | 09/27/85 | SYMINGTON OF SEATTLE | 41 | 66.1 | D MULT | SUPPLEMENTAL RIGHT |
| G1-22872C | C | 24N/01W-06R | 05/17/77 | LARA LEE, INC. | 60 | 19 | D MULT | |
| G1-23503C | C | 24N/01W-08C | 09/20/79 | LARA LEE, INC. | 30 | 8 | D MULT | |
| G1-25307PC | P | 24N/01W-18F | 8/5/88 | NORTHWEST WTR SYS | 31 | 4.5 | D MULT | |
| G1-25329C | C | 24N/02W-01P | 08/12/88 | SUNSET RIDGE WTR | 31 | 3.5 | D MULT | |
| G1-26611A | A | 24N/02W-12Q | 06/03/92 | PAPPAS GT & JA | 100 | 30 | D MULT | |
| G1-27271A | A | 25N/01E-19N | 8/24/93 | NASH, DON | 50 | | D MULT | |
| G1-26243A | A | 25N/01E-19N | 7/5/91 | GOLDENDALE ASSOC. | 60 | | D MULT | |
| G1-24913C | C | 25N/01E-19N | 10/31/86 | GERJETS, RICHARD | 40 | 4.5 | D MULT | |
| G1-25492P | P | 25N/01E-19P | 7/12/89 | SILVERDALE WD | 1000 | 62.1 | D MULT | WIXON RD WELL |
| G1-25018C | C | 25N/01E-30D | 6/3/87 | FAITH FELLOWSHIP | 13 | 1.8 | D MULT | |
| G1-25037C | C | 25N/01E-30D | 7/15/87 | HURST, JIM | 31 | 4 | D MULT | |
| G1-23507C | C | 25N/01E-30D | 11/15/79 | FAITH FELLOWSHIP | 13 | 1.8 | D MULT | |
| G1-22376C | C | 25N/01W-13C | 01/02/75 | MATHESON, G. D. & H..E. | 30 | 16 | D MULT | SUNSET FARMS |
| G1-20007C | C | 25N/01W-13D | 03/03/72 | BOLON, VICTOR R. | 35 | 14 | DOM, IRR | |
| G1-21896C | C | 25N/01W-13G | 06/26/74 | HARBOR WATER CO. | 30 | 23.4 | D MULT | |
| G1-24854C | C | 25N/01W-13R | 07/03/86 | SMITH, LES E. | 37 | 4.5 | D MULT | |
| G1-26075P | P | 25N/01W-14 | 01/30/91 | LONE ROCK WTR ASSOC. | 10 | 9 | D MULT | |
| G1-06768C | C | 25N/01W-14E | 06/24/63 | WADE, W.W. | 260 | 416 | DOM, FISH | |
| G1-25167C | C | 25N/01W-14F | 01/19/88 | LAKS TROUT FARM | 600 | 529 | FISH | |
| G1-06823C | E | 25N/01W-14F | 08/09/63 | GASS, M.A. | 20 | 8 | DOM, WILD | SUPPLEMENTAL |
| G1-25113C | C | 25N/01W-14G | 11/12/87 | BEARBOWER, RICHARD | 37 | 4.5 | D MULT | |
| G1-24778C | C | 25N/01W-14J | 12/31/85 | ANDERSON HILL HOME | 31 | 4.5 | D MULT | |
| G1-20684C | C | 25N/01W-14K | 06/04/73 | SICKS, D.W. & F.B. | 20 | 20 | DOM, IRR | |
| G1-24374C | C | 25N/01W-14N | 08/15/83 | BRONOW, ROBERT B. | 30 | 4 | D MULT | |
| G1-08786C | C | 25N/01W-15H | 06/09/67 | DUPAR, E.L. | 60 | 4.5 | D MULT, IRR | |
| G1-22382C | C | 25N/01W-15R | 01/14/75 | UNIVERSITY OF WA | 300 | 480 | FISH | BIG BEEF HATCHERY |
| G1-23284C | C | 25N/01W-15R | 01/03/79 | COLLEGE OF FISHERIES | 30 | 2 | DOM, COMM | BIG BEEF HATCHERY |
| G1-21934C | C | 25N/01W-17 | 06/28/74 | AARTS, HENNY MRS | 37.5 | 20 | D MULT | |
| G1-23069C | C | 25N/01W-17L | 03/15/78 | WYCOFF CO. | 50 | 4 | D MULT | |
| G1-23404C | C | 25N/01W-17P | 06/07/79 | WATER WATER INC | 50 | 10 | D MULT | |
| G1-10162C | C | 25N/01W-19 | 04/23/69 | WA ST PK&REC COMM | 25 | 5 | D MULT | SCENIC BEACH PARK |
| G1-20821C | C | 25N/01W-19H | 08/08/73 | WA ST PK&REC COMM | 40 | 15 | D MULT | SCENIC BEACH PARK |
| G1-04622C | C | 25N/01W-20D | 06/05/57 | PRIDDY, R. M. | 47 | 56 | D MULT | |
| G1-11353C | C | 25N/01W-20R | 10/19/70 | SCHLEHUBER, J.L. | 15 | 1 | DOM, FIRE | |
| G1-23061C | C | 25N/01W-21M | 02/23/78 | WYKOFF CO | 50 | 6 | D MULT | GUAVA WELL |
| G1-25893A | A | 25N/01W-21N | 09/14/90 | KITSAP CO PUD #1 | 1500 | | D MULT | SEABECK WELL 1 |
| G1-25892A | A | 25N/01W-22E | 09/14/90 | KITSAP CO PUD #1 | 1500 | | D MULT | SEABECK WELL 2 |
| G1-23559C | C | 25N/01W-22G | 02/14/80 | UNIVERSITY OF WA | 1200 | 1920 | FISH | BIG BEEF HATCHERY |
| G1-26760A | A | 25N/01W-23G | 10/20/92 | HARDSTROM, TRUDY | 31 | | D MULT | |
| G1-24856C | C | 25N/01W-23H | 07/07/86 | HUGHES, TERRY L. | 60 | 4 | D MULT | |
| G1-26758A | A | 25N/01W-23K | 10/20/92 | HUGHES, TERRY L. | 31 | | D MULT | |
| G1-24999C | C | 25N/01W-23K | 04/20/87 | HUGHES, TERRY L. | 5 | 4.5 | D MULT | BERT & ERNIE WS |
| G1-24076C | C | 25N/01W-23Q | 05/03/82 | MORRIS, WILLIAM | 30 | 6.5 | D MULT | |
| G1-23967C | C | 25N/01W-24H | 10/19/81 | JONES, DONALD D. | 12 | 3 | D MULT | |
| G1-24920C | C | 25N/01W-24J | 11/10/86 | HARBOR WATER CO. | 100 | 25 | D MULT | |
| G1-24928C | C | 25N/01W-25A | 11/17/86 | NEW HAVEN LN ASSOC | 21 | 4.5 | D MULT | |
| G1-25838A | A | 25N/01W-25E | 09/14/90 | KITSAP CO PUD #1 | 1500 | | D MULT | SEABECK WELL 4 |
| G1-26678A | A | 25N/01W-26Q | 08/04/92 | CENTRAL KITSAP SCH | 250 | | D MULT | |
| G1-26305A | A | 25N/01W-27A | 08/29/91 | BYE, EDWARD | 10 | | DOM | |
| G1-25387C | C | 25N/01W-27R | 05/10/90 | SCHUETT, FRED H. | 23 | 4.5 | D MULT | KLAHOWAY WATER CO |
| G1-25689P | P | 25N/01W-27R | 02/21/89 | SCHUETT, FRED H. | 33 | 4.5 | D MULT | |
| G1-25894A | A | 25N/01W-28C | 09/14/90 | KITSAP CO PUD #1 | 1500 | | D MULT | SEABECK WELL 3 |
| G1-23064C | C | 25N/01W-33M | 03/07/78 | CHATEL, AL | 55 | 75.6 | D MULT | |
| G1-27428A | A | 25N/01W-35N | 03/07/94 | LONG ENGINEER INC | 50 | | D MULT | |
| G1-27429A | A | 25N/01W-35N | 03/09/94 | LONG VERL | 20 | | D MULT | |
| G1-11121P | P | 25N/01W-35N | 08/04/70 | JEWELL, DAVE | 200 | 8.3 | D MULT | |
| G1-24942C | C | 25N/01W-35Q | 12/03/86 | HARBOR WATER CO. | 150 | 75 | D MULT | |

**Surface Water Rights in study area**

| Control # | Sta | Local # | Date | Name | QI | QA | Use | Remarks | Use Type |
|---|---|---|---|---|---|---|---|---|---|
| S1-23930C | C | 24N/01W-03E | 07/20/81 | HALADY, THEODORE J. | 0.01 | 1 | DOM | UNN STR to BIG BEEF CR | C |
| S1-23252C | C | 24N/01W-03E | 10/20/78 | KRACHE, JOHN C. | 0.01 | 1 | DOM | UNN STR to BIG BEEF CR | C |
| S1-00279C | C | 24N/01W-03M | 05/25/70 | RAY, KENNETH F. | 0.05 | 5 | DOM, IRR | UNN SPR | C |
| S1-17242C | C | 24N/01W-04J | 04/19/62 | LEWIS, W.O. | 0.034 | | D MULT | UNN STR to BIG BEEF CR | C |
| S1-16932C | C | 24N/01W-05J | 09/26/61 | SYMINGTON OF SEATTLE | 5 | | REC & BEAUT | BIG BEEF CREEK | N |
| R1-16933C | C | 24N/01W-05J | 09/26/61 | SYMINGTON OF SEATTLE | 0.2 | 670 | REC & BEAUT | BIG BEEF CREEK | N |
| S1-19968C | C | 24N/01W-08E | 11/07/66 | FISH, W.H. ET UX | 0.01 | 1 | DOM | UNN STR to BIG BEEF CREE | C |
| S1-23504C | C | 25N/01E-30D | 11/7/79 | FAITH FELLOWSHIP | 5.56 | | FIRE | UNN STR to ANDERSON CR | C |
| S1-09781C | C | 25N/01W-13C | 07/21/50 | PURVIS, R.E. | 0.15 | 30 | IRR | UNN STR | C |
| S1-17954C | C | 25N/01W-14 | 06/06/63 | GASS, M.A. | 0.01 | | DOM, FISH | UNN STR | C |
| S1-00628C | C | 25N/01W-14 | 11/16/70 | BROWN, AMOS W. | 0.01 | 1 | DOM, FISH, WILD | UNN SPR/UNN STR | C |
| S1-17953C | C | 25N/01W-14 | 06/06/63 | GASS, M.A. | 0.02 | | FISH | UNN CR | C |
| S1-03494C | C | 25N/01W-14 | 08/28/31 | WADE, W.W. | 0.25 | | FISH | JOHNSON CR | N |
| S1-14069C | C | 25N/01W-14 | 09/07/56 | POTTER, H. | 0.01 | | DOM | UNN SPRS | C |
| S1-12723CBL | C | 25N/01W-15 | 01/13/54 | WADE, W.W. | 0.5 | | FISH | SPR CR | N |
| S1-08956C | C | 25N/01W-16 | 08/03/49 | WALTON, A.E. / M.J. | 0.01 | | DOM | UNN SPR (changed point of us | C |
| S1-10445C | C | 25N/01W-20 | 06/27/51 | HUFF, E.P. / L.A. | 0.01 | | DOM, FISH | UNN STR | C |
| S1-09404C | C | 25N/01W-21C | 02/21/50 | PORTER, A. E. | 0.01 | | DOM | UNN SPR | C |
| S1-12723CAL | C | 25N/01W-22A | 01/13/54 | WADE, W.W. | 0.5 | | FISH | BIG BEEF CR | N |
| S1-00409C | C | 25N/01W-22K | 04/30/65 | WA ST UNIVERSITY | 1 | | FISH | UNN STR to BIG BEEF | C |
| S1-00408C | C | 25N/01W-22K | 04/19/65 | WA ST UNIVERSITY | 10 | | FISH | BIG BEEF CR | N |
| S1-06569C | C | 25N/01W-23N | 08/02/45 | SWOFFORD, L.F. | 0.06 | | DOM, POWER | UNN STR to BIG BEEF CR | C |
| S1-23104C | C | 25N/01W-25A | 05/10/78 | WILSON, BARTLEY ET AL. | 0.01 | 0.5 | STOCK | UNN SURFACE WATER | C |
| S1-12171C | C | 25N/01W-29C | 03/18/53 | SPROUT, H.M. | 0.02 | 4 | IRR | SEABECK CR | C |
| S1-10455C | C | 25N/01W-29C | 07/02/51 | SMITH, J.A. | 0.01 | | DOM | UNN SPR | C |
| S1-19153C | C | 25N/01W-29E | 07/19/65 | BRIGGS, O.W. | 0.01 | 1 | DOM | SEABECK CR | C |
| S1-12718C | C | 25N/01W-29M | 01/12/54 | LOWE, J.K. ET UX | 0.02 | | DOM, IRR | UNN SPRS | C |

5. HAZARD INVENTORY &
RISK ASSESSMENT

## Introduction

The purpose of this section is to describe the relative risks of contamination to the Seabeck Aquifer System posed by various types of human activity and the presence of suspected or known hazardous material. This description will be based on information concerning the current types of land use activities occurring in the area, the anticipated contamination potential from those activities, and known or suspected contaminated sites in the area. The relative risk of each site will be developed through a generalized approach based on an EPA-approved risk ranking methodology. Together, known or potential risks can be compared with existing risk reduction programs. Aquifer protection strategies were developed using this risk assessment information and analysis.

## Population/Land Use

### Population

The Seabeck subarea has one of the lowest population densities in Kitsap County. According to 1990 census data, the area has a total population of 3,653. This translates into a population density of about 135 persons/square mile. Through the year 2014, the population is expected to increase to 4,301, and the density is projected to increase to approximately 160 persons/square mile. The forecasted population increase of 648 people between 1990 and 2014 represents an average growth rate of 1.17%, one of the slowest growth rates in the County.

### Land Cover / Land Use

The Seabeck Aquifer System is located beneath one of the most rural and heavily forested areas in Kitsap County. Ninety-five percent of the area is forested or has natural cover. An evaluation of land use types classified by the County Assessor shows about the same percentage of the area in suburban, forested, or open space categories.

### Zoning

Zoning under the proposed County Comprehensive Plan (1994 and subsequent revisions) indicates the County desires to maintain the rural and forested character of the Seabeck subarea into the foreseeable future. Current land use policies require a minimum of 5 acres per residence. Assuming an average of two people per household, the projected growth would result in about 8% of the area being affected by parcel development (houses, outbuildings, roads, including open space). At one du/5 acres, the impact would be very low.

## Known and Potential Contaminant Source Inventory

### Methodology

Current and potential risks to the area had not previously been inventoried and evaluated. An inventory of known and potential contaminant sources for the Seabeck Subarea was completed utilizing existing Washington Department of Ecology databases and by conducting a "windshield" survey throughout the basin.

Ecology databases include both known and potential contaminant sources. Data sets pinpointed operational underground tanks, leaking underground tanks, hazardous waste generators, and confirmed or suspected contaminated sites. These data sets are described below:

- Washington State Department of Ecology, Toxics Cleanup Program, Leaking Underground Storage Tank (LUST) Site List. This list contains the name and address of sites located in the State of Washington where an underground storage tank has reportedly leaked. Also included on the list are the date of notification, the media affected by the leak, and the status of the site.

- Washington State Department of Ecology, Toxics Cleanup Program, Confirmed and Suspected Contaminated Sites Report. Ecology conducts an initial investigation within 90 days of learning of a potentially contaminated site. If the initial investigation shows that further action is needed, the site is included on the list. The list confirms whether or not hazardous substances are located at each site, the media affected by the contamination (ground water, soil, or surface water), site status, and the type of contaminant present.

- Washington State Department of Ecology, Toxics Cleanup Program, Independent Reports. Sites included on this list have previously been listed on the Site Register. The Site Register is issued bi-weekly to document cleanups taking place without Ecology oversight.

- Washington State Department of Ecology, Listing of Underground Storage Tanks. This listing includes the age, volume, status, and contents of underground storage tanks reported in Washington State. This list does not suggest that the tank contents are leaking, only that chemicals are being stored on-site.

- Washington State Department of Ecology, Superfund Amendments and Reauthorization Act of 1986 (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 annually submit a completed Tier I Emergency and Hazardous Chemical Inventory Form. Under certain conditions, the Tier Two form may be submitted in lieu of a Tier One form. 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, Toxic Release Inventory. This report is an annual summary of the toxic chemical report forms submitted by manufacturing facilities in Washington State. The report is prepared to enhance awareness about toxic chemicals within Washington communities (Community Right to Know). Authorized releases to air, water, land, off-site transfers, and transfers to wastewater treatment facilities are recorded by amount and type of chemical released. All releases are permitted and should not be interpreted as being contaminated sites.

- Washington State Department of Ecology, Solid Waste Facility Handbook, 1993. This document is a comprehensive list of solid waste handling facilities that require permitting under Chapter 173-304 WAC, *Minimum Functional Standards for Solid Waste Handling*. The report identified 459 regulated facilities statewide by classification and by primary type of waste received. An update was not completed in 1994.

An examination of all this data showed no known threats of contamination to the Seabeck subarea. The only potential threat is the operational underground tanks at a gas station in Camp Union, just southeast of William Symington Lake.

In addition to the database search, a windshield survey was conducted in April 1995. The objective of this effort was to field check the Seabeck subarea and locate the presence of:

- Hazardous material use or storage;

- Any commercial/industrial development which, through operation, might pose a risk of contamination to the aquifer;

- High density residential development; and

- Areas where stormwater runoff from residential or commercial activities might pose a contamination threat.

This survey verified the rural nature of the area. It also confirmed that there are few current threats to the subarea. There are no industrial sites located upgradient of the Seabeck Aquifer System. Upgradient commercial development is limited to the area around Camp Union. High density residential development is limited to the area around William Symington Lake.

Hazardous material usage is apparently minimal in the upgradient area, consisting of only the single existing gasoline outlet at Camp Union. Most transportation routes skirt the area. One does, however, cross the upgradient aquifer through Camp Union. Risks from a gasoline or petroleum product spill do exist, but are considered relatively minor.

Development along the Hood Canal shoreline are downgradient from the aquifer and do not represent a contamination threat to the main portion of the aquifer.

**Known Sources**

The database review and windshield survey confirmed the rural nature of the area. They also verified that there are few current contamination threats to the Seabeck Aquifer. The minor threats that were identified are discussed below.

Septic Systems: Septic systems are the only method utilized for sewage treatment and disposal upgradient of and overlying the Seabeck Aquifer System. Because of their existence, they pose a general, but minor, threat to aquifer water quality while, at the same time, serving as a source of recharge. However, the densities in the area are generally low to very low. Only the residential area of William Symington Lake reaches land use densities which might be of concern.

Septic systems are a general concern because they can cause ground water contamination with pathogenic organisms, toxic substances, and nitrogen compounds. Suspended solids in sewage, including pathogenic organisms such as coliform bacteria, are easily filtered by soil and should not be transported significant distances from septic drain fields. Ammonia and nitrate nitrogen, however, are highly soluble in water and can be expected in detectable quantities wherever portions of the aquifer are affected by septic system discharges. The greatest concern is for the improper and unlawful use of septic systems for the disposal of toxic substances.

Pesticide / Herbicide Application: Because of its rural nature, the Seabeck Subarea contains some small hobby farms. These units are not of "commercial" size and are not expected to rely heavily on pesticides and fertilizers. Nonetheless, some application can be assumed and, therefore, these farms should be considered as contributing a known chemical input to the system despite the magnitude of such applications being unknown.

The Washington State Department of Transportation (WSDOT) and the Kitsap County Public Works Department (KCPWD) maintain the roads and transportation corridors in the area. Seasonal application of herbicides and pesticides are standard practice in road maintenance. While use of these chemicals (WSDOT utilizes such products as 2,4-D, Roundup, Oust, Diuron, and Krenite; KCPWD's road crews rely on Oust, Diuron, Garlon, Escort, and Roundup) constitutes a known source of contaminant to the natural systems, licensed applicators direct the use of these materials so that their actual threats to the aquifer are minimized. (Typically, when applied by professionals, these chemicals are absorbed by the targeted roadside vegetation and by the first couple of inches of soil.)

Agricultural Practices: It is well documented that animal grazing, concentrated animal feeding, field cultivation, and general agricultural practices can affect surface and ground water systems. The level of this effect, and therefore its significance, is dependent on such factors as:

- An area's soils and surface geology;
- Topography and slope;
- Rainfall and surface hydrology; and
- Use of Best Management Practices (e.g., practices developed by the Department of Ecology in cooperation with the Department of Agriculture; 1978-95).

The combination of these factors on individual farm units in the Seabeck subarea was not assessed during this project. During the windshield survey, however, no observations of agricultural practices were observed which, from a visual standpoint, might constitute inappropriate land management practices and, thereby, pose a significant contamination threat to the aquifer.

**Potential Sources**

No industrial sites overlay or are upgradient of the Seabeck Aquifer area. Upgradient commercial development is limited to the area around Camp Union, and high density residential development is limited to the area around William Symington Lake. The few potential contamination sources noted are described below.

**Transportation of Hazardous Materials (Gasoline):** Most transportation routes skirt the area, though one crosses the upgradient aquifer area through Camp Union. Risks from a gasoline or petroleum product spill do exist, but are considered relatively minor.

**Operational Underground Tanks:** As noted above, one gasoline outlet exists upgradient of the aquifer in the community of Camp Union. This facility appears to have been constructed quite recently and, therefore, should have state-of-the-art spill detection and prevention devices installed.

Spill prevention/detention in the Seabeck subarea is a concern. The drainage from this small commercial area at Camp Union (which also includes a restaurant and a feed store) drains to what appears to be an infiltration/detention pond. This pond seems to be designed to allow infiltration and detention prior to overflow to Big Beef Creek. When the pond is full, the pond flows into Big Beef Creek and William Symington Lake. If a gasoline spill does occur, gasoline might reach the pond and potentially affect the quality of ground water in the Seabeck Aquifer System.

Home heating tanks are unregulated, except during building construction when they must satisfy the requirements of the Uniform Fire Code. These tanks can, to a limited degree, be a source of aquifer contamination and, therefore, are of some concern. Although these tanks are not regulated, the cost of clean-up has brought about and encouraged a variety of locally available heating oil company and financial institution service programs for testing and assuring tank integrity. The number of home heating tanks and the proportion of those which are located underground, however, remain unknown. Given the low number of instances of ground water contamination from these sources statewide, the risk from this source is considered small.

<u>Storage of Hazardous Materials:</u> Other than the gasoline tanks at Camp Union, there were no specific observations of hazardous material storage. On the other hand, the feed store adjacent to the gas station is likely to store some quantities of material which could be considered hazardous. In addition, some home businesses (e.g., a tractor/equipment repair facility) were seen, and these operations may utilize some hazardous materials considered essential to the conduct of the business.

<u>Disposal of Household Hazardous Materials</u>: Residential development in the Seabeck subarea, with the exception of the Hood Canal shoreline and the relatively high density area around William Symington Lake, is primarily rural in nature. With every household, there are numerous chemicals utilized in cleaning and maintenance. Some of these are hazardous materials. Disposal of these substances can represent a threat to ground water, especially when disposed of in a septic system or dumped on the ground.

Improper disposal of used motor oil is one practice commonly cited as a constant threat to water systems. In addition to the oil itself, used motor oil contains many metals. Sometimes this material is drained into ditches or poured onto driveways. Other household hazardous materials include cleaning solvents, paints, specialty cleaners, and so forth. Proper disposal of unused portions of these materials and their associated containers is important to eliminate the potential risks involved, assure ground water quality, and maintain the integrity of the aquifer.

Since household hazardous materials are in general use throughout the subarea, they must be considered a potential risk to the aquifer, although the magnitude of the risk is unknown.

<u>Silvaculture Practices</u>: Forest (silvaculture) practices may present a risk to surface and ground water quality. The impact of the practices themselves (such as clear-cutting) has been the subject of considerable debate over the last 20 years. On all levels, the debate continues without resolution.

Regardless, harvesting techniques, by their nature, involve heavy equipment and its frequent maintenance, and the storage of fuel. These practices present some risk.

In addition to the use of heavy machinery and its accompanying risk, both the private and public forestry sectors use herbicides and pesticides in their ongoing forest management routines. The use of these chemicals also presents risks. According to the Washington State Department of Natural Resources (WSDNR), current forest practices and rules prescribe Best Management Practices which regulate and severely restrict the application of chemicals, herbicides, and pesticides by WSDNR, as well as private timber companies, and thereby help limit the risk. In Kitsap County, for instance, the use of these toxic materials is limited to the application of Accord, Garlon, 2,4-D, and Arsenal. These chemicals are generally applied by applicators licensed by the Department of Agriculture. Such licenses must be renewed every five years and require the licensee to stay current with changes in product lines and application practices to control their toxicity and risk to the surrounding environment. The level and intensity of application of these materials in the Seabeck subarea is not known. Therefore, the risk level is unknown.

**Summary**

There are few potential and known contaminant sources in the Seabeck subarea. Of the known sources, many are downgradient of the primary public supply wells and, therefore, present little risk to the main public supply. For those upgradient or overlying the aquifer, the relative risk of contamination to the Seabeck Aquifer System is considered quite small.

## Risk Ranking of Known or Potential Contaminant Sources

Based upon the above hazardous material inventory and risk assessment, the threats of contamination to the Seabeck Aquifer System were categorized and ranked. The risk prioritization criteria, listed below, are part of the methodology recommended in the EPA Guidance document entitled, *Managing Ground Water Contamination Sources in Wellhead Protection Areas: A Priority Setting Approach.* This methodology, together with the level of confidence in available data and information, were used to rank known and potential contamination sites in priority sequence:

- Proximity of contaminated site to water source;
- Type of contamination per Department of Ecology database;
- Severity of contamination;
- Straight-line distance from the source to the site; and
- Contaminated media.

### Upgradient Proximity to Source

How close the contamination source is, on an upgradient line, was the first decision level for determining an overall prioritization of contaminant risks to the Seabeck Aquifer System. Obviously, the closer the source, the higher the prioritization.

### Type of Contamination

For the second decision level, contamination sites were prioritized according to whether they are known or potential risks to the source. Known contamination sites were defined as those located within the Seabeck subarea that have been identified in the Washington State Department of Ecology databases. Potential contamination sites are defined as those sites that are known to be used in ways that potentially pose a risk to the water quality of the Seabeck Aquifer System. The latter include both point and nonpoint sources. Known sites have a higher priority than potential sites.

### Severity of Risk

Based upon the USEPA Risk Prioritization Model (1991), the severity of risk can be prioritized by the likelihood of contamination and the relative seriousness of toxicity and attenuation involved. The likelihood of contamination criterion is based upon the *Likelihood of Release at the Source* (i.e., how likely is it that the contaminant will be released from the source into the soil underlying the source?), and the *Likelihood of the Contaminant Reaching the Source* (how likely is it to reach the recharge area?). The more likely the contaminant will be released and reach the recharge area, the higher the priority.

### Straight-line Distance from the Source

For those contamination sites having similar characteristics and qualifications under each of the prioritization ranking criteria set forth above, the straight-line distance from the contaminated site to the water source is used to further rank the sites. This criteria, how close the site is to ground water, differs from upgradient proximity criteria, which is how far upgradient the contamination is. Those sites closest to the water are given a higher priority.

### Contaminated Media

If contaminated sites existed within the Seabeck subarea and they possessed similar characteristics under each of the above prioritization ranking criteria, they would be further categorized and ranked based upon six different contamination media:

- Confirmed ground water contamination sites;
- Confirmed soil contamination sites;
- Confirmed surface water contamination sites;
- Suspected ground water contamination sites;
- Suspected soil contamination sites; or
- Suspected surface water contamination sites.

Since contaminated sites were not recorded in the Ecology database for the basin, and none were found in the field survey of the Seabeck subarea, this additional categorization of contaminated media was unnecessary to the present risk assessment effort.

By applying the risk prioritization criteria listed above to the risk inventory/assessment of known and potential contaminant sources in the recharge area, risks to the Seabeck Aquifer System are identified and ranked as follows:

1. Septic Tanks;
2. Operating Underground Storage Tanks; and
3. Forest/Agricultural Practices.

All of the potential risk categories listed above are considered minor and manageable.

## Strategies for Risk Reduction

### Kitsap County Ground Water Management Plan

Kitsap County has been developing a Ground Water Management Plan (GWMP) over the last several years. This effort has involved considerable citizen input and thousands of hours of effort, many of those voluntary. The objective of this project is to produce a plan that effectively assesses the County's ground water resource, identifies current and future risks to the resource, and provides measures to preclude, correct, or mitigate those risks.

The Plan is nearly complete. The effort which generated the Plan included development of many issue papers. Several issue papers focused on a particular risk area and proposed risk reduction measures. The papers describe a specific risk area, outline existing laws, practices, and procedures for achieving risk reduction, list gaps and problems, and give improvement recommendations (management strategies and corrective actions) for accomplishing further risk reduction.

**Strategies Useful to Specifically Protect the Seabeck Aquifer**

A review of GWMP strategies shows that nearly all would be beneficial to the goal of protecting the Seabeck Aquifer System. This finding is not surprising since the GWMP was intended to cover all of Kitsap County and all of its ground water resources. However, one of the remaining tasks needed to complement this GWMP effort is to prioritize the strategies for the Seabeck Aquifer Protection Plan. This effort will include an assessment of the viability of the recommended strategies and actions from various economic and social-political viewpoints. The result will be a much-refined list containing priority strategies, identification of responsible implementing agencies, and schedules for implementation of specific GWMP actions.

The content and timing of the Seabeck Aquifer Protection Plan precedes the completion of these Kitsap County GWMP tasks. Further, the focus of this effort requires the recommendation of specific strategies and actions based upon the risks identified above and most appropriate actions relative to the Seabeck subarea, not the County as a whole. This is consistent with the tenants of the GWMP process and the ultimate aim of ground water source protection programs.

6. MONITORING PROGRAM

The Seabeck Aquifer Protection Plan requires a network of monitor wells from which data can be systematically collected and analyzed to identify changes in water quality and quantity parameters. The current monitoring network consists of 18 wells which include private domestic and public/municipal wells distributed across the recharge area of the Seabeck Aquifer System. Figure 1 shows the aquifer boundaries and locations of the monitor wells.

Table 1 gives a summary of selected data for the set of monitor wells. Monitor wells may be added or deleted as dictated by the analysis of data, damage, or loss of access to a monitor well, or other factors that require a change in the network. The finalized monitoring network will be used in perpetuity to collect data discussed below.

## Water Quality Monitoring

The objectives of water quality monitoring are to provide the necessary data to evaluate changes in quality and associated risks to users of the Seabeck Aquifer System. The chosen frequency of measurement is designed to be affordable and practical. The results of the monitoring will determine if the frequency of measurement needs to be modified. Water quality monitoring will include chloride and specific conductivity (to identify seawater intrusion from overdrafting) and nitrate (an easily traceable contaminate from septic systems).

Water quality samples will be collected at all monitor wells that have pumping equipment. Pumpable wells will be tested for chloride and specific conductivity twice per year, once in October and once in April. Water samples will be collected directly from the well head or suitable sampling port where it can be assured that the sampled water is indicative of the aquifer water quality. The sampling frequency may be adjusted. Chloride and specific conductivity will be analyzed by KPUD with field equipment. Nitrate samples will be collected at least every three years and will be analyzed by a certified lab.

For those monitor wells lacking a basic inorganic analysis, or where the analysis is more than three years old, samples will be collected by KPUD and analyzed by a certified lab. The basic inorganic analysis will consist of those required for a new Group B public water supply, including but not limited to iron, manganese, chloride, nitrate, hardness, alkalinity, specific conductivity, field temperature, field pH, and turbidity. All available water quality data for each monitor well will be compiled in a database for easy review and tracking of the data.

| TABLE 6-1 - SUMMARY OF SELECTED DATA FOR THE MONITORING NETWORK WELLS. | | | | | |
|---|---|---|---|---|---|
| Well Name | Unique Well ID # | Local Number T/R-S | Site Elevation | Screen Elevation | Water level elevation, Date |
| **Public Wells** | | | | | |
| Blue Heron Water System (Dlugosh) | AAA875 | T25N/R01W-30H | 308 | -22 | 49.3, 7/17/95 |
| Guava | AAA232 | T25N/01W-21M | 239 | -52 to -62 | 38 |
| Miguelo Water | ABC665 | T25N/R01W-27G | 434 | -14 to -26 | 64, 12/22/93 |
| Seabeck Conference Center | AAC835 | T25N/R01W-20Q | 75 | -54 to -64 | 41 |
| Seabeck Well 3 | AAA990 | T25N/R01W-28C | 440 | -70 to -177 | 70 |
| Woodland Heights Water | AAB274 | T25N/R01W-26F | 535 | 294 to 278 | |
| Green Mountain Elementary | AAC804 | T24N/R01W-04M | 460.5 | 323 to 313 | 344.5, 3/27/96 |
| **Test/Observation Wells** | | | | | |
| Big Beef TH-2 | AAA005 | T25N/R01W-22A | 50 | -133 to -187 | 38 |
| Seabeck Well 1 | AAA235 | T25N/R01W-21N | 329 | -88 to -120 | 58 |
| Seabeck Well 2 | AAC799 | T25N/R01W-22E | 269 | -49- to -80 | 40 |
| Seabeck Well 4 | AAC377 | T25N/R01W-25E | 502 | -103 to -128 | 71.7, 12/10/94 |
| **Private Domestic Wells** | | | | | |
| Collier | AAC547 | T25N/R01W-21C | 40 | -22 to -27 | 48 |
| Dolan | AAC707 | T25N/R01W-34H | 420 | 82 to 77 | 110 |
| Miller | -- | T24N/R01W-03A | 400 | 124 | 200 |
| Rosander | -- | T25N/R01W-24Q | -- | -- | -- |
| Ellis (Scott) | AAB607 | T25N/R01W-32E | 276 | -8 to -13 | 118.7, 7/17/95 |
| Schold | AAC318 | T25N/R01W-15L | 20 | -65 to -70 | 13.2, 7/17/95 |
| Smith | AAC809 | T25N/R01W-22C | 137 | -9 to -29 | 21 |

## Water Level and Production Records Monitoring

The objectives of water level and production monitoring are to provide the necessary data to evaluate seasonal and annual water-level fluctuations and evaluate the amount of impact caused on aquifer levels by ground water withdrawals. Where data loggers can be utilized, water levels will be collected approximately once per hour. Other wells will be manually sounded at a frequency of approximately once per month. Where possible, manual soundings will be made with a permanently installed, calibrated electric sounding line, to increase the accuracy of the data and eliminate the potential for bacterial cross-contamination of wells. Water levels will be measured to a minimum accuracy of plus/minus 0.05 feet. Frequency of data collection may be more or less than above, and may be tailored to accommodate special circumstances such as pumping/aquifer testing. Production records will be collected from monitor wells or adjacent production wells to help evaluate water level trends.

# Seabeck Aquifer
# Proposed Network of Monitored Wells

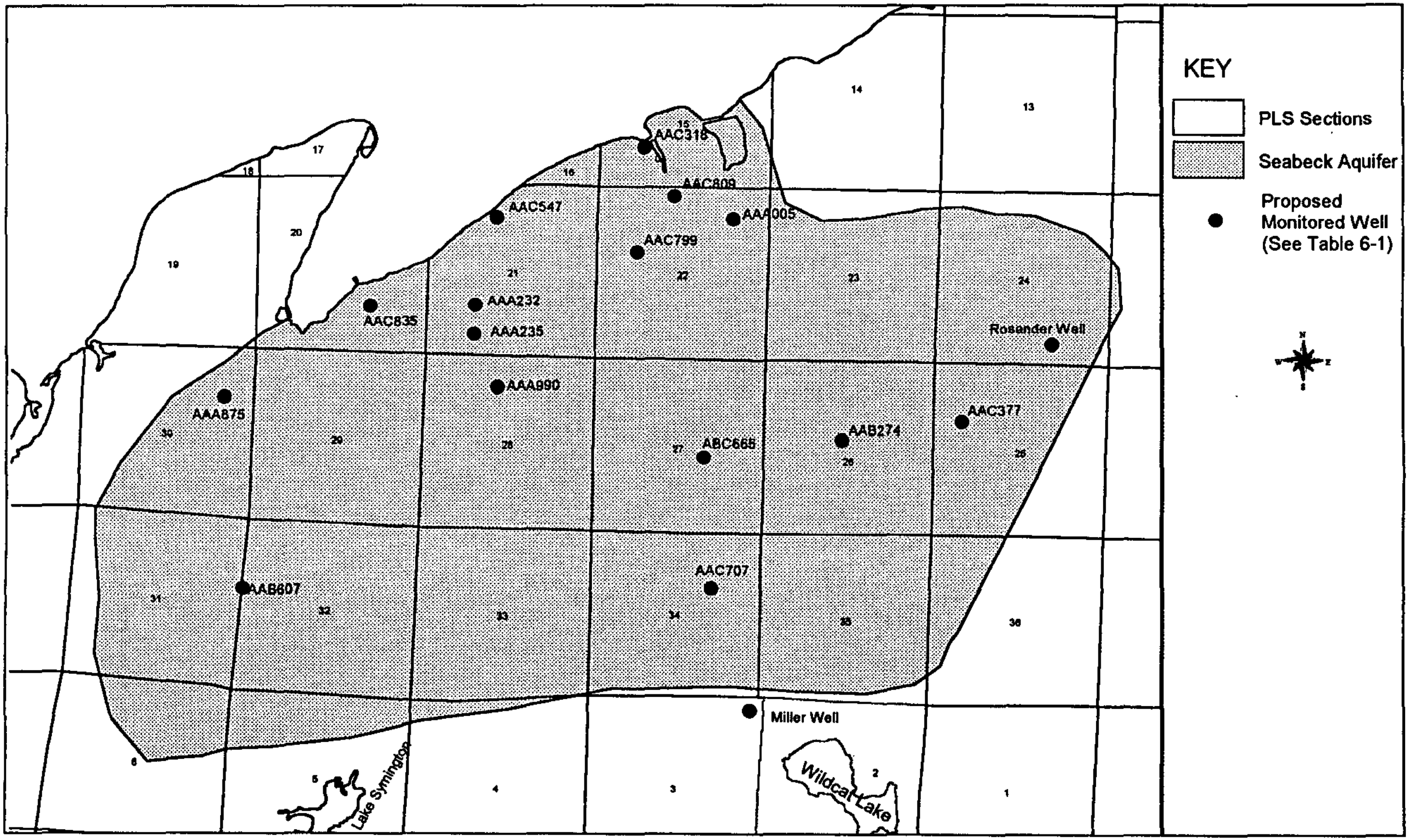



Figure 6-1