# CITY OF SEQUIM
# 2001 HYDROLOGIC MONITORING REPORT

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City Of Sequim 2001 Hydrologic Monitoring Report
Clallam County, Washington

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## 1 Introduction

The City of Sequim is located on the Sequim-Dungeness Peninsula, which extends off the Olympic Peninsula in Clallam County, Washington (**Figure 1**). The City obtains its drinking water from three groundwater sources located east of the Dungeness River, and has undertaken several large-scale water projects since the mid-1990's. These projects include:

- Development of a new wellfield at Port Williams Road;
- Installation of a Class "A" treatment system at the wastewater treatment plant;
- Construction of a pipeline to transmit the reclaimed water to points of use; and,
- Reuse of reclaimed water for irrigation and Bell Creek flow augmentation.

Based on its dedication to responsible water-resource management, environmental protection, and data sharing with interested parties, the City has established a monitoring program designed to document pumping withdrawals, groundwater level trends, precipitation trends, and water quality in both groundwater and Bell Creek. The monitoring program adds to the growing body of hydrologic data and supports evaluation of how observed hydrologic changes relate to changes in groundwater pumping and septic densities (i.e. population based changes) as well as changes in irrigation practices, and climatic variation. The monitoring is also designed to provide "early warnings" of hydrologic trends of potential concern to water-resource stakeholders. While some of the monitoring data have been discussed in prior reports (e.g. PGG, 1996 and PGG, 1998), this is the first report that provides all the data in one place as well as a more comprehensive interpretation. In addition, this report incorporates monitoring data collected on the Sequim-Dungeness Peninsula by other agencies and organizations.

In this report, groundwater level trends are interpreted in light of changes in pumping withdrawals (by the City and other water users), changes in recharge from irrigation, and variation in recharge from precipitation. Water quality analyses from the City's drinking water sources are evaluated relative to State Drinking Water Quality Standards, and water quality analyses from Bell Creek are evaluated relative to State Surface-Water Quality Standards. The analyses presented herein provide an overview of how the hydrologic system is responding to the City's water-resource management activities.

Pacific Groundwater Group (PGG) has assisted the City in developing its monitoring program since the mid-1990's. Our role in preparing this report was to: compile existing monitoring data from the City and other sources, present the data in readily understandable graphical formats, interpret the data with respect to water resource management and the "health" of the hydrologic system, and provide recommendations for future monitoring activities. City staff were instrumental in explaining system operations and compiling data available in hardcopy. PGG's work was performed, and this report prepared using generally accepted hydrogeologic practices used at this time and in this vicinity, for the exclusive use of the City of Sequim and for exclusive application to City's monitoring program. This is in lieu of other warranties, express or implied.

## 2 Findings and Recommendations

1. Three major aquifers are identified in the vicinity of Sequim and its water supply sources. They are commonly referred to as the Shallow, Middle, and Lower aquifers. The Dungeness River is the largest stream in the area. In the vicinity of Sequim (east of the river), smaller streams are typically fed by groundwater discharge and irrigation tailwater.
2. The City's three groundwater supply sources include: the Dungeness River Infiltration Gallery (Shallow Aquifer), the Silberhorn Wellfield (Shallow Aquifer), and the Port Williams Wellfield (Lower Aquifer). The City is actively shifting the bulk of its pumping withdrawals from the Infiltration Gallery and Silberhorn Wellfield to the Port Williams Wellfield.
3. Over the past 24 years (1978 to 2001), pumpage from the City's water supply sources has increased from about 0.4 million gallons per day (mgd) to about 0.8 mgd. Most of this increase occurred between 1982 and 1989, followed by a gentle increasing trend through present. Pumping from the City's two wellfields is estimated to have increased by about 0.38 mgd between 1990 and 2001 due to reduced withdrawals from the Infiltration Gallery. Because the City's service area is predominantly sewered, this pumping increase is predominantly associated with consumptive water use. However, a portion of the increased pumpage recharges the Shallow Aquifer as return flow from residential irrigation. The City estimates that it supplies about 30 percent of the water users on the Sequim-Dungeness Peninsula east of the Dungeness River.
4. Additional pumping from newly constructed domestic wells and other water supply systems contributes to the total change in groundwater withdrawals over time. Pumpage from domestic wells in the Sequim vicinity is estimated to have increased by at least 0.58 mgd between 1990 and 2001, of which about 0.32 mgd is estimated to be used consumptively. The remaining portion of the increased pumpage recharges the Shallow Aquifer via septic effluent and irrigation return flow. Based on population growth, significant pumping increases are similarly expected for public and private water systems; however, data were not readily available to support a quantitative estimate of this increase. The City currently reuses a portion of its reclaimed municipal wastewater for irrigation and flow augmentation in Bell Creek. Bell Creek flow augmentation is permitted by Washington State Departments of Ecology and Fish & Wildlife.
5. The City's hydrologic monitoring program includes: groundwater levels in monitoring wells located on the City's wellfields and in private wells surrounding the wellfields; climatic monitoring, water quality analyses from drinking water sources; water quality from reclaimed wastewater; water quality from Bell Creek. Monitoring data collected by Clallam County, Washington State Department of Ecology (Ecology); the U.S. Geological Survey (USGS), and the Jamestown S'Klallam Tribe have also been incorporated into this report.
6. Review of precipitation data reveals no long-term trends, however series of wet years and dry years do occur. Most recently, low rainfall in the Sequim vicinity is noted in the early

1990's, 2000 and 2001. Below average snowpack in the Olympic Mountains (which supply the Dungeness River) is noted between 1998 and 2001.

7. Annual agricultural diversions from the Dungeness River have reduced over the last two decades from about 115 cfs in 1979 to about 55 cfs in 2000. This reduction is largely due to: lining of ditches and laterals; improvement of on-farm irrigation efficiencies; replacement of pasture crops to crops with lower water demands; and reduced diversions for stock watering. Diversions were substantially reduced in 2001 due to insufficient flow in the Dungeness River caused by below average snowpack.

8. Groundwater levels in the vicinity of the City's Port Williams Wellfield have shown notable declining trends over the period of record (1996 thru present). Rates of decline are similar in all three aquifers (approximately 1-2 ft/year); however, seasonal variations are greatest in the Lower Aquifer where the City's production wells are completed. The data indicate that pumping from the Lower Aquifer affects groundwater levels in the Middle Aquifer, but that the Shallow Aquifer is somewhat insulated from seasonal water-level variations associated with Port Williams pumping. Water levels in all three aquifers are affected by a variety of factors, including: pumping by the City, smaller water systems and private wells; long-term changes in recharge from irrigation; and short-term changes in recharge from precipitation. In addition, trends observed in one aquifer may cause similar trends in an underlying or overlying aquifer due to hydraulic connection through intervening aquitards. Pumping from the Port Williams Wellfield likely contributes to the observed groundwater level declines; however, distinction between the City's pumping, other groundwater withdrawals, and changes in irrigation recharge is a complex task that requires analysis beyond the scope of this report.

9. Groundwater levels in the vicinity of the City's Silberhorn Wellfield have similarly shown declining trends over the monitoring period (1993 thru present) as well as since the wellfield was constructed in 1975. The most significant declines are reported to have occurred in the early 1990's. Since construction of the Port Williams Wellfield in 1996, the City has reduced pumping withdrawals from the Silberhorn Wellfield. However, groundwater levels have continued to decline. Local groundwater levels appear to be particularly responsive to irrigation recharge during the growing season. Irrigation managers report little change in summer diversions or ditch conveyance losses (e.g. tightlining) over the past several decades; however, winter stockwater diversions have declined. In addition, the number of wells in the Silberhorn vicinity increased by 140 percent over the last 20 years. Further evaluation of changes in irrigation recharge and increased pumping by other groundwater users would be required to better identify the cause of water-level declines observed near the Silberhorn Wellfield.

10. Where present, the observed groundwater level declines will have only minor effects on pumping yield for wells completed in the Lower Aquifer for most water users due to the relatively large pumping drawdowns available in Lower Aquifer wells. However, the observed rates of decline could have significant effects on pumping yield for some wells completed in the Shallow Aquifer, particularly shallow wells with little penetration below the

water table. In the Middle Aquifer, the degree to which observed water-level declines affect well yield will depend on the degree to which the available water column is used for drawdown, the efficiency of the well, and the permeability of the aquifer. If groundwater level declines continue at recently observed rates, pumping yield reductions will be exacerbated in selected wells.

11. Water quality from the City's sources of supply is excellent, with concentrations of drinking water constituents typically well below the State's drinking water standards.
12. Water quality in Bell Creek, both upstream and downstream of Carrie Blake Park, shows seasonal exceedence of the Class A standards for temperature and dissolved oxygen in the summer and early fall. Fewer exceedences are noted prior to the summer of 2001; however data are relatively sparse over the earlier period of record (1997 thru 2000). Phosphorus concentrations are elevated both upstream and downstream of the park, and may reflect contamination by livestock, other mammals, birds or failing septic systems. Class A standards for fecal coliform are regularly exceeded. Ammonia values show an increasing trend over time, but the laboratory results are inaccurate due to chemical interference with aqueous iron naturally occurring in the creek. The City will be revising its laboratory method to eliminate this source of analytical error.
13. The system for streamflow augmentation for Bell Creek was first tested in August 2001, and put into long-term operation in December 2001. The reclaimed water is introduced to the stream in Carrie Blake Park. The majority of sampling events reflect background water-quality conditions, with only two sampling rounds collected after augmentation began. In general, too few data are available to indicate water quality trends associated with the streamflow augmentation. Additional data collection from monitoring points upstream and downstream of the park will be required to evaluate possible effects. While ammonia data suggest an increase from upstream to downstream, but inaccuracies in the analytical method require improved sample analysis to establish whether such a difference actually occurs.
14. Recommendations for modifications to the City's monitoring program and further data analysis are presented in Section 11 of this report. The following items summarize PGG's recommendations:
    a) The frequency of water-level measurements in the City's wells should be modified to improve data resolution and make the best use of data automatically recorded by computer datalogger. Overall, these modifications will result in a slight reduction in effort required of the City's staff but will maintain the quality of the data. Operation of the existing datalogger should be maintained to continue collection of high quality data.
    b) Groundwater level monitoring in private wells, conducted by the City and other agencies, should be expanded to include more wells in the Middle and Lower Aquifers. Data sharing between agencies should continue, and coordination of monitoring activities should occur whenever possible. Private residents and water systems with relatively deep wells should be encouraged to provide access for water-level measurement or share data

they collect themselves. Monitoring of electrical conductance or chloride is recommend for wells completed in the Middle or Lower Aquifers along the coast.

c) The City should continue to enter digital data (currently stored on hard-copy) into spreadsheets provided by PGG on a regular basis.

d) The City's system of site identification for monitoring stations along Bell Creek should be integrated to avoid differing site ID's for the same stations. If ongoing Bell Creek sampling is expected to generate large quantities of data, the City should consider storing the data in a centralized database. Minor modifications to the parameters and procedures associated with the City's Bell Creek monitoring program are further suggested in Section 11.

## 3 Hydrologic Setting

### *3.1 Surface Water Hydrology*

The Dungeness River is the largest river on the Sequim-Dungeness Peninsula, and supplies water to a variety of irrigation districts through ditch diversions. The river emanates from the Olympic Mountains south of the peninsula, and has a drainage area of about 200 square miles. Streamflows are highest during late spring and early summer due to snowmelt in the upper watershed, and during winter months due to sporadic rainfall events. The lowest flows occur in September and October. Irrigation diversions occur year-round, but are highest during the growing season from mid-April to mid-September. Recent conservation efforts on the part of Dungeness River Agricultural Water Users have resulted in reduction of summer diversions from about 115 cfs in 1979 to 55 cfs in 2000 without significant loss of irrigated acreage (Jeldness, pers. com., 2002).

East of the Dungeness River, most of the streams are relatively small. Such streams as Bell Creek, Gierin Creek and Cassalery Creek have their headwaters on the Sequim-Dungeness Peninsula. In contrast, west of the Dungeness River, larger streams such as McDonald Creek and Siebert Creek have headwaters in the Olympic Mountains or their foothills. The smaller streams are predominantly supplied by groundwater discharge and irrigation tailwater, and have relatively constant flows throughout the year (Thomas et al., 1999). Flow regimes in the larger streams are dominated by snowmelt and rainfall runoff, with highest flows during winter and spring. Streams in near vicinity to the City of Sequim include Gierin Creek and Bell Creek.

The surface-water hydrology of the Sequim-Dungeness Peninsula is significantly affected by the many irrigation canals, laterals and tailwater ditches that convey water diverted from the Dungeness River (shown on **Figure 10**). Historically, these conveyances were also used to route stormwater away from areas of higher development density. Local changes in the management of this irrigation system are discussed below in Section 7.

### *3.2 Groundwater Hydrology*

The regional hydrogeology of the Sequim-Dungeness Peninsula was recently characterized by the U.S. Geological Survey (Thomas et al., 1999). Much of the discussion in this section is summarized from this USGS study. The study describes a stratified system of geographically extensive aquifers and aquitards consisting of a “Shallow Aquifer” underlain by a fine-grained “upper confining bed”, a confined “Middle Aquifer”, a “lower confining bed”, a “Lower Aquifer”, and deeper undifferentiated sediments. Over most of the peninsula, all or some of these six hydrostratigraphic units overlie Tertiary bedrock of sedimentary and volcanic origin. The total thickness of unconsolidated sediments beneath the peninsula ranges from zero feet in the south (where bedrock is exposed on the land surface) to as much as 2,500 feet in the northeast. Hydrogeologic cross-sections, presented on **Figures 2, 3** and **4** show the hydrostratigraphy of the area. The cross-sections, as well as portions of the hydrogeologic descriptions below, were excerpted from the USGS study (ibid.). Cross-section traces are presented on **Figure 1**.

The Shallow Aquifer is composed of a variety of geologic materials, including: stream alluvium, glaciomarine drift, glacial outwash, ice contact deposits, and glacial till. The alluvium was deposited by the current Dungeness River along its current floodplain and by the ancestral Dungeness River as a floodplain terrace predominantly east of the existing river channel. The glacial and glaciomarine sediments are associated with the most recent continental glaciation (Vashon stade of the Frasier glaciation), which ended approximately 13,000 years ago. Given the range of geologic materials present, the texture of the Shallow Aquifer can vary from fine-grained to coarse-grained, and can be highly heterogeneous (locally variable). The thickness of the Shallow Aquifer generally ranges from 50 to 200 feet, although larger and smaller thicknesses have been observed. The aquifer is generally unconfined but can exhibit some local confinement with the occurrence of shallow clay deposits. Groundwater flow directions are shown on **Figure 5** to be generally north-northeast.

The underlying "Upper Confining Bed" is typically 30 to 110 feet thick, and is mainly composed of pre-Vashon silts and clays with locally discontinuous lenses of water bearing sand and gravel. Beneath the upper confining bed, the "Middle Aquifer" is typically about 10 to 70 feet thick, and contains pre-Vashon glacial outwash deposits of sand and gravel and coarse-grained interglacial deposits. Although fewer wells are completed in the Middle Aquifer than the Shallow Aquifer, wells in the Middle Aquifer potentially offer higher and more reliable yields due to greater available drawdown in the deeper wells. Larger water systems tend to prefer wells completed in the Middle or Lower aquifer to wells completed in the Shallow Aquifer. Groundwater flow directions in the Middle Aquifer are shown on **Figure 6**. Flow directions "fan out" radially beneath the Sequim-Dungeness Peninsula, with northeast flow in the vicinity of Sequim. Groundwater in the Middle Aquifer occurs under confined conditions.

The Middle Aquifer is underlain by the "Lower Confining Bed", composed of till and interbedded clay, silt and fine-grained sand with possible discontinuous lenses of water-bearing sand. Because few wells penetrate this confining unit, the USGS define a broad range for its thickness (10 to 300 feet) with a "typical" thickness of 100 feet. A thickness of about 70 feet is observed at the Port Williams Wellfield. The underlying "Lower Aquifer" is composed of sand with thin lenses of sand and gravel, silt and clay. Associated information is limited due to few well completions. The aquifer is present in the northern and eastern portions of the peninsula, and absent in the southern and western portions where bedrock occurs closer to the land surface. It's thickness is believed to range from 10 to 180 feet, with a typical value of about 90 feet. While few wells are completed in this aquifer, it is capable of producing significant amounts of water and serves major water users, including the City of Sequim at its Port Williams Wellfield. Groundwater flow directions in the Lower Aquifer are believed to be similar to those documented in the Middle Aquifer. Groundwater in the Lower Aquifer occurs under confined conditions.

The Lower Aquifer is underlain by "undifferentiated deposits", which reach thicknesses as great as 1000 feet in the northern peninsula but pinch out against bedrock in southern and southwestern portions of the peninsula. While productive aquifers may exist in the undifferentiated deposits, few well completions occur in this unit. The underlying bedrock is composed of tertiary sedimentary and volcanic rocks, and is an unreliable source of groundwater because it yields small quantities of water to wells.

The groundwater flow system is recharged at the surface from precipitation, irrigation applications to fields, septic system effluent, and seepage losses from unlined irrigation ditches, the Dungeness River and other streams[1]. Additional recharge occurs via subsurface pathways near the foothills of the Olympic Mountains, where water-bearing zones in the bedrock discharge into the unconsolidated aquifers described above. Recharge incident upon the land surface flows downward into the various aquifers and aquitards; and eventual discharges into marine waters, the lower reaches of various streams, portions of the Dungeness River, and to wells. Groundwater flow patterns have both horizontal and vertical components. Typically, flow within aquifers is predominantly horizontal whereas flow between aquifers (through aquitards) is predominantly vertical. Downward flow generally occurs in recharge areas, whereas upward flow occurs along discharge areas (e.g. near the coast and lower stream reaches). Vertical flow rates are relatively slow due to the low permeability aquitards between aquifers. Water levels measured at the Port Williams Wellfield indicate downward flow between the Shallow, Middle and Lower Aquifers.

# 4 City Water Sources and Water Use

## *4.1 Water Supply Sources*

The City's water supply system consists of three sources: the Dungeness River Infiltration Gallery, the Silberhorn Wellfield, and the Port Williams Wellfield. Prior to construction of the Infiltration Gallery, the City diverted water directly out of the Dungeness River. In 1953 the City was authorized to withdraw water from the infiltration gallery, and in 1954 a second surface-water diversion was authorized to convey water from the river to the infiltration gallery. Groundwater withdrawals from the Silberhorn Wellfield were authorized in 1975, and pumping from the Port Williams wellfield was authorized in 1996.

The Infiltration Gallery is located east of the Dungeness River in the NE ¼ of the NW ¼, Section 12, Township 29N, Range 4W. It consists of a large-diameter collection well located east of the river, from which horizontal interception pipes extend to about 150 feet from the current stream channel. The interception pipes are buried and set in gravel pack. Until the mid 1980's, the City used to supplement Infiltration Gallery yield by diverting surface water from the Dungeness River into the gravel pack surrounding the laterals. Now that this practice is discontinued,

[1] In many cases recharge from septic tanks more accurately represents recirculation of groundwater, as water pumped aquifers of varying depths returns to the Shallow Aquifer as septic effluent..

discharge from the Infiltration Gallery flows via gravity to a treatment plant for chlorination. Gravity flows are taken on-demand at rates of about 200 gpm (0.45 cfs).

The Silberhorn wellfield is located in Doctor James Standard Memorial Park, 750 feet west of the intersection of Silberhorn and River Roads (NE ¼, NW ¼, Section 25, Township 30N, Range 4W). Three production wells were constructed between 1975 and 1985; however, Well #1 is no longer in production and is currently used for groundwater level monitoring. Well completions range from 132 to 220 feet below land surface (bls), and instantaneous pumping rates range from about 300 to 370 gallons per minute (gpm) on demand. Drilling information and pumping responses indicate that groundwater occurs under confined conditions at the wellfield. The three wells are tentatively identified as completed in a confined portion of the Shallow Aquifer (PGG, 1996). Occurrence of glacial till above the completion intervals and the confined nature of the aquifer conform to the USGS description of the Shallow Aquifer summarized above.

The Port Williams Wellfield is located just north of Port Williams Road, about 500 feet west of its intersection with Brown Road (SE ¼, NW ¼, Section 17, Township 30N, Range 3W). Two production wells were installed in 1995 and 1998, and are both completed in the Lower Aquifer. Well completions range from 284 to 411 feet bls. While maximum well yields range from 635 to 800 gpm, the wells are currently pumped on demand at instantaneous rates between 550 to 625 gpm. The Port Williams wellfield was constructed in order to shift a portion of the City's pumping withdrawals away from the Silberhorn Wellfield and the Dungeness River Infiltration Gallery towards a deeper groundwater source that has less hydraulic connection with the Dungeness River. Reduced withdrawals from the Infiltration Gallery are beneficial in that they leave more flow in the Dungeness River to benefit fish habitat, and were agreed upon between the City and Ecology in 1997 (Ecology, 1997). Reduced withdrawals at the Silberhorn Wellfield serve to reduce pumping stress on an aquifer with a history of local groundwater level decline (see Section 7.2), and may also benefit Dungeness River streamflow.

### *4.2 Water Use*

The City monitors water use from all three of its sources, with available records beginning in 1978. **Figure 7** shows that average annual water use has increased from about 0.4 million gallons per day (mgd) in the early 1980's to about 0.8 mgd in 2001. Most of the increase occurred between 1982 and 1989, with only minor increases noted after 1990 except for two peak years (1994 and 1995) when average water use reached about 0.9 mgd. While annual precipitation plotted on **Figure 7** shows that 1994 corresponds to a low precipitation year, relatively high pumping in 1995 cannot be similarly attributed to low rainfall.

Prior to 1992, water-use records only provide total pumping from the Infiltration Gallery and Silberhorn Wellfield *combined*. After 1992, the records show a reduced reliance on these two sources and an increased reliance on the Port Williams Wellfield. In the past four years (1998-2001), water use from the City's three sources was divided as follows:

| | |
|---|---|
| Infiltration Gallery | 27% of total water use |
| Silberhorn Wellfield | 23% of total water use |
| Port Williams Wellfield | 50% of total water use |

Seasonal patterns of water use are shown on **Figure 8**, a chart of monthly pumping from the City's three sources. Water use is relatively low between November and April, with values on the order of about 0.6 mgd. Beginning in April or May, water use begins to climb to maximum values of about 1.0 to 1.4 mgd in July and August. Water use remains relatively high in September and then declines back down to the relatively low winter rates observed in November through April. Relative to other areas on the Olympic Peninsula, water use near Sequim is higher due to low rainfall in the rain shadow of the Olympic Mountains.

The City currently reuses a portion of its treated municipal wastewater for irrigation purposes. In 1998 the City upgraded its wastewater treatment to meet Class "A" surface water standards for reclaimed water, with the goal of achieving 100% reuse. The wastewater treatment plant produces about 0.5 mgd of reclaimed water. Initially, the reclaimed water was used only for irrigation of ornamental roadside vegetation, the Highway 101 rest area, the yard at the City Shop, and for various City Shop operations. The City's Reuse Demonstration Site, located immediately north of Carrie-Blake Park, was constructed in 1999-2000 and has since been used to demonstrate reclaimed water irrigation of fields and gardens. It is one of the first sites of its kind, and includes data collection to evaluate hydrologic responses to the irrigation applications. Irrigation at the site began in the summer of 2000, and the City began augmenting streamflow in Bell Creek with 0.1 cfs (0.07 mgd) of reclaimed water in December 2001. The remaining reclaimed water is available for other certified uses, but is currently discharged to a new outfall in Sequim Bay a quarter mile northeast of Washington Harbor (at a water depth of 53 feet). Guidance for the City's program of water reuse was provided by the Water Reuse Task Force, a group composed of community members, tribal representatives, and agency staff from Washington Departments of Ecology, Health, and Fish & Wildlife (among others). Although the water savings associated with reuse of reclaimed water currently represents only a small portion of the area's overall water budget, the potential for water savings associated with developing new uses is significant.

Other pumping withdrawals in the vicinity of the City's two wellfields are taken by the PUD #1 of Clallam County, various other water systems, and individual private wells. East of the Dungeness River, the PUD operates the Loma Vista Wellfield (its largest source) and several small satellite systems. The Loma Vista wellfield is located about one mile east of the

Silberhorn Wellfield. Between 1995 and 2001, the Loma Vista Wellfield had an average withdrawal of 94,000 gallons per day (0.094 mgd), down from a prior average of 154,000 gallons per day (0.154 mgd) between 1992 and 1994. Some of the later pumping was shifted to the PUD's Holgerson Well on the same water system (Evergreen System), where average annual pumping ranged from 38,000 to 45,000 gallons per day (0.038 to 0.045 mgd) between 1999 and 2001. Other major water systems east of the Dungeness River include: Sunland Water District, Parkwood Mobile Home Community, and Dungeness Meadows Homeowner's Association. As a rough measure of the relative groundwater withdrawals, in 1996 these three systems had 630, 210, and 200 total connections, respectively (1,040 connections total). Several other water systems with between 50 and 100 total connections exist east of the river. In comparison, in 1996 the City had 1,086 total connections and the PUD's Evergreen System had 280 total connections.

Increases in the number of private domestic wells can be reasonably approximated by increases in the total number of wells for a given area. Based on a well database maintained by Clallam County Natural Resources Division (Soule, pers. comm., 2002), **Figure 9** presents charts of the annual numbers of total wells from 1950 onwards for three areas[2]:

1. The northern half of the Sequim-Dungeness Peninsula east of the Dungeness River;
2. Within approximately one mile of the Silberhorn Wellfield, and
3. Within approximately one mile of the Port Williams Wellfield.

In the overall Sequim vicinity (first area mentioned above), the number of wells has gone up by about 160 percent from 1980 to 2001 (from 944 to 2,462 wells) and by about 75 percent from 1990 to 2001 (from 1,409 to 2,462 wells). In the Silberhorn Wellfield vicinity, the growth rate for newly constructed wells was steepest in the 1970's and has continued at a gentler, steady rate from 1980 to 2001. Over this 21-year period, the number of wells went up by 140 percent from about 160 to 380 wells. In the Port Williams Wellfield vicinity, the rate of well growth was also steepest in the 1970's, slowed down in the 1980's, and steepened again in the 1990's. Between 1990 and 2001, the number of wells near the Port Williams Wellfield grew by about 83 percent from about 200 to 365.

The consumptive use of groundwater by residences associated with new well construction since 1990 is estimated on the table below. The estimate is sensitive to assumptions regarding irrigated acreage per residence, irrigation requirements for landscaping, indoor water use, and the degree to which areas are sewered. Although Ecology allows ½ acre of irrigation for the exempt water rights commonly associated with domestic wells, most residential lots in the area are not large enough to support ½ acre of irrigation. An irrigated area of ¼ acre was assumed for each

[2] The first (and largest) area includes all square-mile sections north of Township 29, west of Sequim Bay, south of the northern coast, and east of a north-south section line 1 mile west of Range 3W (approximate course of the Dungeness River). The areas within a mile of the two wellfields are based on quarter-quarter sections within a mile radius of the productions wells.

residence. A net irrigation requirement of 15.5 inches/year was assumed for lawns based on estimates of water requirements for pasture and turf (Montgomery Water Group, 1998). Because irrigation applications are typically inefficient, actual pumping for irrigation purposes is expected to exceed plant requirements. However, the extra water applied to lawns and gardens predominantly returns to the Shallow Aquifer as Irrigation return flow.

Indoor water use is estimated to be about 170 gpd based on systems with little residential landscaping (Montgomery Water Group, 1998, Appendix C). In non-sewered areas, only a portion of groundwater pumping for indoor use is estimated to be consumptive, with the remaining (non-consumptive) portion returning to the Shallow Aquifer as recharge from septic tank effluent. In sewered areas, a higher portion of the water use is consumptive because wastewater from indoor use is predominantly discharged to Sequim Bay rather than shallow groundwater. For the purpose of this analysis, a conservative assumption of 100 percent non-sewered areas was used (thus potentially under-estimating consumptive water use). Out of the total household indoor use, septic return to groundwater was estimated to be 87 percent, leaving 13 percent of the domestic pumpage attributed to consumptive use (Solly et. al., 1993).

**Estimated Water Use from Domestic Wells**

| | Overall Sequim Vicinity | Silberhorn | Port Williams |
|---|---|---|---|
| Wells in Dbase Completed in or Before 1990 | 1,409 | 237 | 199 |
| Wells in Dbase Completed in or Before 2001 | 2,462 | 381 | 365 |
| 1990-2001 Well Count Increase | 1,053 | 144 | 166 |
| Domestic Use Per Well (gpd) | 170 | 170 | 170 |
| Total Domestic Use (gpd) | 179,010 | 24,480 | 28,220 |
| Percent of Wells Assumed Sewered | 0% | 0% | 0% |
| Assumed Return from Septic Systems | 87% | 87% | 87% |
| Total Domestic Consumptive Use (gpd) | 23,271 | 3,182 | 3,669 |
| Irrigated Acres per Domestic Well | 0.25 | 0.25 | 0.25 |
| Crop Irrigation Requirement (in/yr) | 15.5 | 15.5 | 15.5 |
| Irrigation Consumption per Well (gpd) | 288 | 288 | 288 |
| Total Irrigation Consumption (gpd) | 303,540 | 41,510 | 47,851 |
| Total Water Consumption (gpd) | 326,811 | 44,692 | 51,520 |

It should be noted that the figures presented above represent best estimates of water use associated with domestic wells based on the assumptions listed above, but that actual data are largely lacking for single domestic wells in the Sequim vicinity. Estimated daily water use per equivalent residential unit (ERU) averages 458 gpd year-round, and is likely to range from about 170 gpd in the winter to about 1,300 gpd in the summer. A review of water use by various purveyors in the Sequim vicinity (6 “Group A” water systems) shows use per ERU widely ranging from 173 to 495 gpd (Montgomery Water Group, 1998, Appendix C). In comparison, Ecology allocates as much as 5,000 gpd to individual wells based on exempt water rights (½-acre maximum irrigated area). While the above water-use estimates are based on reasonable assumptions, data that quantify *actual* water use from single domestic wells can only be obtained with a monitoring program that includes metering of wells.

In the overall Sequim vicinity, the increase in *consumptive use* by domestic wells between 1990 and 2001 is estimated to be approximately 0.32 mgd, and is predominantly associated with irrigation for landscaping. Over the same period, the total increase in *total pumping* from domestic wells (including the non-consumptive portion of use) is likely to be at least 0.58 mgd[3]. The sub-area immediately surrounding the Silberhorn Wellfield accounts for about 14 percent of this increase, and the sub-area immediately surrounding the Port Williams Wellfield accounts for about 16 percent of the increase. Increased total pumping from the City's two wellfields is estimated to be approximately 0.38 mgd over the same 11-year period and 0.48 mgd since the late 1970's[4]. A portion of the City's pumpage increase is non-consumptive and is returned to shallow groundwater via residential irrigation applications and (limited) portions of the City's service area without sewer coverage. Thus, increases in *consumptive* groundwater use estimated for domestic wells and the City's two wellfields are of similar magnitude between 1990 and 2001. It should be noted that the City's withdrawals are localized to its wellfield locations, whereas domestic withdrawals are spread out over larger areas.

## 5 Monitoring Activities Performed by the City

The City is committed to long-term hydrologic monitoring in order to responsibly manage its share of water resources on the Sequim-Dungeness Peninsula. For the purpose of water-resource management, the City's monitoring program includes collection of the following information:

- Pumping volumes at the City's three water sources (discussed above);
- Groundwater levels in monitoring wells located on the City's wellfields and in private wells surrounding the wellfields;
- Climatic measurements taken at the sewage treatment plant;
- Water quality analyses from drinking water sources;
- Water quality analyses from Class A reclaimed wastewater; and
- Water quality analyses from Bell Creek.

**Figures 10** and **11** show the locations of monitoring points, and **Table 1** summarizes their measurement frequencies, periods of record, and other pertinent information. Daily pumping

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[3] Based on the assumption that residential irrigation efficiency (plant requirement divided by irrigation application) is about 75 percent. If actual efficiencies are lower, total estimated pumping would be higher.

[4] While data are generally lacking for the distribution of pumping between the Infiltration Gallery and the Silberhorn Wellfield prior to 1992, discussions with the City indicate that withdrawals were approximately divided as 30% from the Silberhorn Wellfield and 70% from the Infiltration Gallery. Assuming this to be the case, analysis based on Figure 7 yields the above numbers.

volumes are recorded manually from flow meter readings at all three of the City's sources. In addition, pumping rates are recorded continuously on charts at the Silberhorn and Port Williams wellfields and summarized on a computer datalogger at the Port Williams Wellfield. In addition to pumping data, the Port Williams datalogger also records groundwater levels in production wells and onsite monitoring wells. Digital data are automatically collected every minute, and statistics (maximum, minimum, average) are recorded on an hourly and daily basis. Manual groundwater level monitoring performed by the City includes:

- Twice weekly measurements in Port Williams production wells PW-1 and PW-2, and Silberhorn Well #1 (former production well converted into a monitoring well);
- Monthly measurements in private domestic wells surrounding the City's two wellfields (by agreement with the well owners) and in Silberhorn production wells #2 and #3.

The City records precipitation and other climatic measurements from a monitoring station installed at the Treatment Plant, and shares the data with the National Weather Service. As required by Washington Department of Health (WDOH), the City samples its water supply sources for inorganic compounds, organic compounds, and radionuclides; and provides the data to the State. Water from the City's sources are analyzed every three years for these parameters, except for nitrate (analyzed on an annual basis) and pesticides, herbicides and insecticides (analyzed twice per three years). Coliform sampling is performed at a minimum frequency of five times per month, with samples typically collected within the distribution system rather than at the City's water supply sources.

The remainder of the City's monitoring program is related to reclaimed water reuse for Bell Creek flow augmentation. In order to assess potential effects on water quality associated with the streamflow augmentation, water quality is monitored in Bell Creek and directly from the reclaimed water. Bell Creek monitoring stations are located both upstream and downstream of the point where reclaimed water enters the creek. To date, the majority of data available represent background conditions to be used for comparison to water quality data collected during augmentation. While all other monitoring is long-term, monitoring associated with the streamflow augmentation program will likely be discontinued after the program is operational for several years as long as no significant water quality degradation is identified.

One final component of the City's monitoring, not discussed in this report, is measurement of changes in soil moisture with depth in irrigation and non-irrigated areas of the Demonstration Site and sampling of shallow groundwater on either side of Bell Creek. During portions of the last two growing seasons (2000 and 2001), reclaimed water has been used to irrigate fields and ornamental gardens on the site[5]. Monitoring devices record soil moisture over depth profiles to support evaluation of whether irrigation applications exceed plant requirements, resulting in recharge to the underlying Shallow Aquifer. The monitoring allows the City to adjust its

[5] Fields have been irrigated for only about two months during years 2000 and 2001. Irrigation of ornamental gardens has been more ongoing throughout the growing season.

irrigation application rates to demonstrate agronomic plant requirements, minimize over-watering, and maximize the amount of reclaimed water available for other permitted uses. Given the relatively short period of irrigation and data collection, the City is still adjusting its application rates to minimize over-watering at the site. Data from the shallow groundwater monitoring along Bell Creek are still preliminary, with only two rounds collected after testing of the augmentation system began. Additional data, once collected, will be summarized in a separate report or memorandum.

In addition to monitoring performed by the City, a number of other agencies and organizations collect hydrologic data on the Sequim-Dungeness Peninsula. Ecology, the USGS and Clallam County Natural Resources Division have collected groundwater level and water quality data from wells, both individually and through cooperative agreements. Ecology conducts long-term ambient monitoring of groundwater levels in the Sequim area; 8 to 10 wells are measured each quarter by Ecology and/or the County. The USGS has historically measured water levels in wells on the Peninsula during distinct data collection periods, and have recently completed a study on the relationship between the river and Shallow Aquifer in which water-level data were collected from shallow monitoring wells near the river. The USGS maintains a streamgage on the Dungeness River in the foothills of the Olympic Mountains; Ecology now maintains a streamgage at Schoolhouse Bridge. Agricultural diversions from the Dungeness River to irrigation ditches are monitored by the irrigation districts and companies. Water-quality and streamflow data from Bell Creek are collected periodically by the Jamestown S'Klallam Tribe and Clallam County Streamkeepers. Some of these various data are referenced in this report. A number of short-term (or multiple "snapshot") data collection efforts have occurred to meet specific objectives, including: evaluation of seepage losses from ditches and streams, salinity in coastal wells, and nitrate concentrations in groundwater. These data have been described in various hydrologic reports, but are not presented alongside the City's data in this report.

## 6 Precipitation Trends

Climatic data have been recorded in the Sequim vicinity since 1927. In 1980, the original climatic monitoring station (located in downtown Sequim) was moved to a nearby location at the City's Treatment Plant. The following description of precipitation on the Sequim-Dungeness Peninsula is adapted from Thomas et al. (1999):

> *The Sequim-Dungeness area has a temperate marine climate with cool, wet winters and warm, dry summers. The area lies in the rain shadow of the Olympic Mountains to the south and west. Sequim receives only an average of 16 in. of annual rainfall. Annual rainfall ranges from 15 inches in the north to about 35 in. in the hills to the southwest. The annual precipitation at Sequim has been moderately variable since 1923. There were no significant increasing or decreasing trends in annual precipitation over the 1923-1996 record or from 1979 to 1996. The distribution of precipitation varies throughout a typical year, and 38% of the annual precipitation is during the winter, December through February. Summers are typically dry, with only 14% of the annual precipitation in June through August.*

**Figure 7** presents values of annual precipitation over the period for which Sequim's other hydrologic data are available (1978 to 2001). Relatively high precipitation is observed in the early 1980's and from 1995 to 1999. Relatively low precipitation occurred in the mid 1980's, the early 1990's (with a drought year in 1994), 2000 and 2001. Although the most recent measurements of low annual precipitation near the City of Sequim are limited to 2000 and 2001, irritators dependent on flows in the Dungeness River report lower streamflows due to below-average snowpack in the Olympic Mountains over the 4-year period from 1998-2001 (Gather, pers. comm., 2002).

## 7 Irrigation Trends

Annual agricultural diversions from the Dungeness River have reduced over the last two decades from about 115 cfs in 1979 to about 55 cfs in 2000 (**Figure 12**). According to Mike Jeldness of the Sequim-Dungeness Valley Agricultural Water Users Association (pers. comm., 2002), this reduction is largely due to:

- Lining of ditches and laterals;
- Improvement of on-farm irrigation efficiencies; and,
- Replacement of pasture crops to crops with lower water demands (e.g. lavender and seed crops).

In addition, both within and outside the irrigation season, diversion for stockwater has diminished from an estimated 25-30 cfs to approximately 15-20 cfs due to a general reduction in livestock raised and a recent regulation limiting diversion for stockwater for only those situations where no other nearby source (such as wells) are available (ibid). Finally, below-average snowpack has caused minor reductions in irrigation diversions from the Dungeness River between 1998 and 2000, and substantial reductions in 2001 (ibid).

The overall reduction in irrigation diversions is associated with specific changes in irrigation practices in the vicinity of the City's wellfields. The following subsections present a general overview of these changes, based on discussions with Mike Jeldness, Greg Stone of the Sequim-Prairie Tri Irrigation Association (pers. comm., 2002), and Steve Gather of the Highland Irrigation District (pers. comm., 2002).

### *7.1 Irrigation Trends in the Port Williams Wellfield Vicinity*

- The old Sequim-Prairie Company ditch along Old Olympic Highway was tightlined in 1996 between Evans Road and Sequim-Dungeness Way; however, a 700-foot stretch remains unlined immediately east of Sequim-Dungeness Way. An unlined tailwater conveyance, approximately 1500 feet long, delivers about 0.1 to 0.5 cfs inflow to Gierin Creek during the irrigation season. A lateral off this ditch, running through the Stone property (due west of the Port Williams Wellfield) was also tightlined in 2001.

- The Sequim-Prairie Tri Irrigation Company ditch along Evans Road had notably high seepage losses until it was tightlined. The portion of the ditch south of Old Olympic Highway, previously managed by the Eureka Company, was tightlined in the mid 1980's. The portion of the ditch north of Old Olympic Highway has been lined incrementally from the mid 1980's to present as residential development has expanded along Evans Road.
- In 2001, the City of Sequim lined much of the Sequim-Prairie Tri Irrigation Company ditch that runs east-west, about one mile south of the Port Williams Wellfield. The ditch was lined between 5th Avenue and the siphon at Sequim-Dungeness Way, which conveys the water to about 500 feet west of Brown Road. The ditch is still open between Brown Road and the woods to the east, but was partially lined in the woods during the 1990's.
- Changes in stormwater control practices since 1998, and the concurrent construction of the SR101 bypass, have resulted in less water conveyed by ditches that pass through residential areas. In the past, stormwater ran off into ditches and conveyances (e.g. Bell Creek) and was allowed to flow down laterals, ultimately flooding fields and seeping into surface soils. Spillways have now been constructed that conduct storm runoff into streams and wetlands.

### *7.2 Irrigation Trends in the Silberhorn Wellfield Vicinity*

- Laterals of the Sequim-Prairie Tri Irrigation Company and Highland Irrigation District occur in the vicinity of the Silberhorn Wellfield. The ditches run over very rocky substrate and exhibit high leakage losses, especially when the ditch bottom is disturbed. The ditches are predominantly unlined, except for a short lateral near Riverside Road (approximately ½ mile west of River Road in Section 25 of T30N, R4W).
- The ditches run at high flow during the summer irrigation season, between April 15 and September 15. Overall, little changes in ditch lining or operation are noted during the summer months. During the winter months the ditches convey water for stock use, and associated diversions are turned down to lower flow rates. The lower winter flow rates cause some laterals to go dry in more distant reaches. Due to reductions in stock raising and new stock watering rules (discussed above), winter stock diversions are smaller than historic rates.

## 8 Groundwater Level Trends

The City's program of groundwater level monitoring is designed to observe water-level trends in the vicinity of their wellfields and in surrounding outlying areas. Groundwater levels are monitored in the City's own monitoring and production wells, as well as private wells in the wellfield vicinities. Monitored wells are completed in the Shallow, Middle and Lower aquifers.

Water-level trends and variations are observed in all three aquifers. Groundwater levels are affected both seasonally and from year to year by changes in both aquifer recharge and discharge. Aquifer recharge originates from infiltration of incident precipitation and by seepage losses from irrigation ditches and field applications. While recharge from rainfall occurs largely during the fall and winter months, recharge from irrigation is more substantial during the summer months.

However, in the Middle and Lower aquifers seasonal patterns in groundwater recharge are typically more muted. Short-term variations in recharge may occur from several contiguous years of high or low rainfall; however, a longer-term trend exists in the form of agricultural water use conservation. The lining of ditches, increased on-farm irrigation efficiencies, use of lower water-demand crops, and reduction of winter stockwater diversions occurring over the last 15-20 years have resulted in reduced agricultural recharge to the Shallow Aquifer. Consequently, some degree of recharge reduction is expected for the Middle and Lower aquifers.

Changes in aquifer discharge originate predominantly from changes in pumping withdrawals. In the area of interest, population growth has resulted in increased water use by the City of Sequim, domestic wells, and is similarly inferred for other public and private water systems. Since construction of the Port Williams Wellfield in 1996, the City has actively shifted its pumpage away from the Infiltration Gallery and Silberhorn Wellfield towards production wells in the Lower Aquifer at Port Williams. Reduced Infiltration Gallery withdrawals leave more flow in the stream to benefit fish habitat. Reduced pumping from the Silberhorn Wellfield is beneficial for two reasons: 1) the production wells are completed in the Shallow Aquifer and therefore may influence baseflows in the nearby Dungeness River; and 2) the Shallow Aquifer was showing declining water-level trends in the early 1990's and corresponding yields in both the Silberhorn production wells and surrounding domestic wells were also declining. As discussed below, groundwater levels in the wellfield vicinities have responded to changes in pumping withdrawals as well as other factors.

### *8.1 Groundwater Level Trends in the Port Williams Wellfield Vicinity*

The City's monitoring program in the Port Williams Wellfield vicinity includes water-level measurements in both Port Williams production wells, two City monitoring wells at the wellfield, and (originally) 6 private wells with distances from the wellfield ranging from 600 feet to 1.5 miles. The private wells (PD-7 through PD-12) are listed on **Table 1** and shown on **Figure 10**. They are completed in all three major aquifers as well as the underlying undifferentiated deposits. In the past four years, access to wells PD-9, PD-11 and PD-12 has been denied by the well owners. In the Shallow Aquifer, wells monitored in the Port Williams Vicinity include the City's MW-1 and private wells PD-7 and PD-8. In the Middle Aquifer, wells monitored in the Port Williams vicinity include the City's MW-3 and private wells PD-9 and PD-10. In the Lower Aquifer, monitored wells include the City's production wells (PW-1 and PW-2) as well as private well PD-11. Well PD-12, completed in the undifferentiated deposits, is now monitored by the well owner; however, data were not provided for analysis at the time of writing this report.

For the purpose of analyzing water-level trends in the three major aquifers, charts were constructed to allow comparison of groundwater levels to annual pumping, monthly pumping, and annual precipitation. **Figure 13** presents groundwater level trends in the Lower Aquifer, from which the City withdraws groundwater at the Port Williams Wellfield. The water levels presented from PW-1 represent "daily high" values collected by the datalogger during non-pumping periods, and are likely influenced by recovery from daytime pumping withdrawals. The groundwater levels presented from PD-11 are hand measured during daytime hours, and may reflect interference drawdowns when the wellfield is in operation (PD-11 is located 600 feet from PW-1). Despite possible pumping influences, trends in measured high groundwater levels are indicative of aquifer conditions[6]. The groundwater levels shown on **Figure 13** clearly respond to periods of heavy pumping, with seasonal declines noted in the summers of 1996, 1998, 1999, 2000, and 2001. The magnitude of seasonal decline generally corresponds to the intensity of summer pumping. On an annual basis, greater depths to groundwater correspond to higher average annual pumping rates. An overall increasing trend in Port Williams pumping between 1996 and 2001 corresponds to an overall decreasing trend in seasonal groundwater level highs.

The response of the Lower Aquifer to Port Williams pumping is consistent with basic hydrogeologic principals. In an undeveloped state, an aquifer will be in hydraulic equilibrium with the rest of the hydrologic system. When new pumping or changes in recharge affect the aquifer, water levels will adjust until a new equilibrium is reached. Pumping will cause groundwater levels to decline, whereas additional recharge will cause them to rise. Water-level declines associated with pumping will cause increased hydraulic gradients toward the pumped aquifer and increased inflow to the pumped aquifer from adjacent aquifers. When the increased inflow equals the rate of pumping withdrawal, water levels in the pumped aquifer will stabilize. Annual pumping in the Port Williams Wellfield has varied from year-to-year and shows an overall increasing trend (**Figure 13**). Groundwater level changes in the Lower Aquifer associated with Port Williams pumping will stabilize once the City's annual withdrawals become relative constant from year to year.

Observed groundwater level trends in the Lower Aquifer show about 10 feet of decline over the past six years, with smaller values expected with increasing distance from the wellfield. To put this magnitude of decline into perspective, it should be noted that Lower Aquifer wells in the Port Williams vicinity generally have water columns of over 200 feet. Reductions in available drawdown on the order of 10 or 20 feet are unlikely to have significant impacts on well yields at the pumping rates common for private wells and smaller water systems.

While local water-level trends in the Lower Aquifer are clearly affected by the City's withdrawals, other factors also affect observed aquifer responses. For example, in 1997 the wellfield was not pumped for 7 months between March and September, during which time groundwater levels exhibited a gradual decline. If Port Williams pumping were the only factor affecting groundwater levels, a rising trend would be expected due to aquifer recovery. The minimum 1997 water level occurred in August during the height of seasonal water demand, and therefore appears to be caused by the pumping of other water users. In addition, groundwater levels in the Middle Aquifer may affect those in the Lower Aquifer, and those in the Shallow Aquifer may affect the Middle Aquifer. Similarities and differences in trends observed between

[6] Because local pumping rates are relatively high and vary both daily (between day and night) and seasonally, true *static* conditions are not expected near the wellfield. However, trends in minimum depth-to-water are generally representative of aquifer trends with the immediate effects of pumping drawdowns removed.

adjacent aquifers, as well as the multiple causes potentially affecting groundwater levels, are further discussed in the following paragraphs.

Groundwater trends in the Middle Aquifer near Port Williams Wellfield are shown on **Figure 14**. Wells monitored by the City include MW-3 (located on the wellfield), PD-9 (located about 0.8 miles east), and PD-10 (located about 0.9 miles west). In addition, **Figure 14** presents hydrographs from two wells monitored by Ecology. The wells are included to allow comparison with trends on other parts of the Peninsula. Well EW-1 is located 2 miles southeast of the Port Williams Wellfield, and Well EW-8 is located 5 miles from the wellfield on the west side of the Peninsula (**Figure 10**). Similar water-level trends are observed in wells MW-3, PD-9 and PD-10. These Middle Aquifer trends are also comparable to those observed in the Lower Aquifer with similar timing of seasonal water-level variations, similar water-level declines over the 6-year record, but smaller ranges of seasonal water-level variation. **Figure 15** presents a direct comparison of average rates of water-level decline in wells from all three aquifers located in the vicinity of the Port Williams Wellfield. In onsite wells, PW-1 (Lower Aquifer) shows a period-of-record decline of 1.7 ft/yr compared to 2.2 ft/yr in MW-3 (Middle Aquifer). Farther from the pumping center, Middle Aquifer Well PD-9 shows an average decline rate of 1.1 ft/yr. It should be noted that the decline rate estimated for Production Well PW-1 may be affected by “noise” in the water-level data due to recovery from periods of pumping.

Farther from the wellfield, Ecology Well EW-1 also shows a similar trend to MW-3, PD-9 and PD-10, although its recent dataset is relatively sparse. However, more distant Well EW-8 shows little similarity, with relatively modest water-level decline and data too sparse to compare seasonal variations. Given the well’s distance from the Port Williams area, differing trends are not surprising.

The similar trends observed in the Port Williams vicinity for the Middle and Lower aquifers demonstrate a hydraulic connection between the two units. If Port Williams pumping is the dominant cause of water-level decline, both seasonal variations and long-term declines would be greatest in the wellfield vicinity and in the Lower Aquifer. The observed smaller range of seasonal variations in the Middle Aquifer is consistent with this understanding; however, estimated average rates of decline are steeper in the Middle Aquifer than the Lower Aquifer (possibly a result of noise in the data from Production Well PW-1). The rate of decline within the Middle Aquifer decreases by 50 percent from trends observed at the wellfield to those observed 0.8 miles to the east. Overall, the data suggest that Port Williams pumping plays a significant role in causing local drawdowns in both the Lower and Middle aquifers. However, the overall trend of declining water levels may well be affected by pumping from both aquifers, as well as pumping and changes in recharge to the Shallow Aquifer. As noted in Section 4.2, significant increases have occurred in groundwater withdrawals by domestic wells and are similarly expected for other (e.g. smaller) water systems.

Groundwater trends in the Shallow Aquifer near the Port Williams Wellfield are shown on **Figure 16**. Wells monitored by the City include MW-1 (located on the wellfield), PD-7 and PD-8 (both located about 0.4 miles west). In addition, **Figure 16** presents hydrographs from 6 wells monitored by Ecology in widely varying locations on the Peninsula (see **Figure 10**). Similar water-level trends are observed in wells MW-1, PD-7 and PD-8[7]. The three wells show very little seasonal water-level variation and show estimated declines ranging from 1.3 ft/yr in MW-1 to 1.7 ft/yr in PD-7 (see **Figure 15**). Most of the Ecology monitoring wells show much gentler rates of decline (e.g. 0.2 ft/yr), with wells located along the Dungeness River (EW-5 and EW-7) showing negligible declines. Water levels in these wells are likely supported by the stage of the river, whereas other wells are more influenced by changes in pumping and recharge. None of the wells show exacerbated declines associated with low rainfall in years 2000 and 2001.

Although water-level trends in the Shallow Aquifer show similar declines over the 6-year period of record to those observed in the Middle and Lower aquifers, they do not indicate similar influence from Port Williams pumping. Aquitards between the aquifers tend to dampen the influence of one aquifer on an adjacent aquifer, especially on the timescale of seasonal variations. However, steady declines in a single aquifer can propagate to an adjacent aquifer because the longer timescale allows gradual adjustment of the neighboring aquifer. Available data from the Shallow Aquifer show varying rates of water-level decline at different locations on the Peninsula. The highest recorded rate occurs 0.4 miles west of Port Williams Wellfield, with a slightly gentler rate observed at the wellfield. While declines may be affected by Port Williams pumping, the varying geographic distribution suggests that other factors are also influencing declines in the Shallow Aquifer.

The USGS analyzed water-level trends in the Shallow and Middle aquifers between the late 1970's and the mid 1990's (prior to Port Williams pumping), and found a southwest-northeast trending zone of water-level decline between Gierin Creek and Cassalery Creek with values ranging from –3 to –10 feet (**Figure 17**) (Thomas et al, 1999). USGS monitoring wells did not exist at the Port Williams wellfield, but the closest wells show declines on the order of –3 feet. While the USGS do not cite causes for the measured declines, reductions in recharge associated with changing irrigation practices and increased pumping associated with local population growth are likely candidates. Rainfall trends are not a likely candidate due to their relatively short-term nature. Although the USGS incorporated few monitoring wells from the Middle Aquifer in their analysis, these wells showed very similar long-term declines to those observed in nearby Shallow Aquifer wells.

While the magnitude of groundwater level declines is unlikely to significantly affect water availability in wells completed in the Lower Aquifer, wells completed in the Shallow Aquifer may be impacted. If drilled with little water column "reserve" above the well intake or maximum

[7] A hydrograph for Well PD-8 is not shown on Figure 15 because it almost exactly matches the hydrograph for Well PD-7. Although Well PD-8 was drilled to a depth of 247 feet, it is completed in the Shallow Aquifer at a depth of between 40 and 52 feet below land surface.

pump setting, 10 feet of groundwater level decline could limit pumping yield from shallow domestic wells. The regulatory issues associated with potential impacts to shallow wells in the Shallow Aquifer are complex and beyond the scope of this monitoring report. Similar water-level declines in Middle Aquifer wells could reduce yields in wells where most of the water column is already used during pumping drawdown. While domestic users are unlikely to drawdown the entire water column during pumping, multi-household water systems may make use of most (or all) of their available drawdown. The degree of yield reduction associated with the observed water-level decline depends on many factors, including pre-existing available drawdown and aquifer properties (which vary by location) and well efficiency (which varies by well). If groundwater level declines continue at the rates shown on **Figure 15**, maximum production capacities from wells would be further reduced.

Determination of the relative roles of the factors causing groundwater declines in the three major aquifers requires complex analysis, and is beyond the scope of this monitoring review. Previous groundwater flow modeling has shown that changes in recharge from irrigation ditches can have substantial impacts on groundwater levels in the Shallow Aquifer and in underlying aquifers (Drost, 1983 and Montgomery Water Group, 1998)[8]. The interrelationship between water-level declines caused by Port Williams pumping, pumping by other public and private water systems, pumping by domestic wells, and changes in groundwater recharge are best evaluated by refining existing groundwater flow models for the Sequim-Dungeness Peninsula and simulating reasonable estimates of the associated changes to the groundwater budget.

### *8.2 Groundwater Level Trends in the Silberhorn Wellfield Vicinity*

Groundwater level declines in the vicinity of the Silberhorn Wellfield were identified as problematic in the early 1990's. In 1996, PGG evaluated pumping and water-level data in the Silberhorn vicinity and reached the following conclusions:

- *From the time of well installation to 1996, depth to water dropped about 17 feet over 21 years in Well 1, 13 feet over 11 years in Well 2, and 10 feet over 11 years in Well 3.*
- *Groundwater levels remained relatively stable between 1993-1996, although seasonal variations are noted. Deepening of private wells was prevalent between 1991-1993, but slowed down significantly between 1994-1996.*

In 1996, the City expanded their water-level monitoring at the wellfield from onsite Wells 1, 2, and 3 to include 6 neighboring private wells (PD-1 through PD-6 on **Table 1** and **Figure 10**). In addition, the City reduced their pumping rates from the Silberhorn Wellfield. Pumping records prior to 1992 do not distinguish between Silberhorn and Infiltration Gallery withdrawals, but do

[8] Both studies compared irrigation-caused groundwater level declines in the Shallow and Middle Aquifers, and estimated declines in the Middle Aquifer to be smaller than those in the Shallow Aquifer. Newly available hydrogeologic data (Thomas et al, 1999) will allow refinement of the models for improved evaluation of water-level impacts.

indicate increasing combined withdrawals over the period of record. Pumping from the Silberhorn Wellfield likely reached maximum withdrawals between 1992 and 1995.

**Figure 18** presents a comparison of groundwater level trends to pumping at the Silberhorn Wellfield and Sequim precipitation. All private wells monitored by the City are located east of the Dungeness River within 0.5 miles of the wellfield and are completed in the Shallow Aquifer. Also shown on the figure is a hydrograph of Ecology Well EW-10, located across the river about 0.7 miles west of the wellfield and completed in the Shallow Aquifer[9]. Groundwater trends in wells monitored by the City are generally similar, with some exceptions noted in the magnitude of seasonal water-level variation. Well 1 on the Silberhorn Wellfield shows a fairly stable trend between 1993-1997, followed by an accelerating rate of decline from 1998-2001 with a significant seasonal high in the summer of 2001. The 2001 seasonal high corresponds with the irrigation season, and is likely associated with recharge from irrigation practices. Prior years also show seasonal highs during the irrigation season (July, August) or toward the season's end (September, October). Some years also show high water levels in the middle of winter (January-March), which are likely associated with precipitation recharge. The other wells monitored east of the Dungeness River show similar seasonal patterns, with even more prominent seasonal highs during the irrigation season (typically reaching maxima in September). These responses indicate that irrigation provides significant recharge to the Shallow Aquifer east of the Dungeness River.

West of the Dungeness River, Well EW-10 shows a more gradual rate of water-level decline than observed to the east and does not show a similar magnitude of seasonal variations. The scarcity of data from this well prevents comprehensive evaluation of seasonal trends, however less variation can be discerned. The Dungeness River may form a partial "hydraulic boundary" that separates
Shallow Aquifer responses to either side; however, insufficient information were unavailable to discern the hydraulic connection between the aquifer and the river at this location[10]. While rainfall is likely the same on both sides of the river, irrigation practices and ditch seepage losses may vary significantly.

The declining water-level trend near the Silberhorn Wellfield over the past five years does not appear to be related to Silberhorn pumping. In general, withdrawals from the wellfield have reduced from 1995 through 2001, yet groundwater levels also declined. Local groundwater level trends do not appear to be particularly sensitivity to low pumping years (1996, 1999, 2001) or high pumping years (1997, 2000). Other likely causes for the observed trends include changes in precipitation, irrigation recharge, and construction of new domestic wells. While consecutive

[9] Well EW-10 has a similar groundwater elevation to Well 1 on the Silberhorn Wellfield. Its depth-to water is significantly greater because the land surface elevation is 60 feet higher at EW-10.

[10] While the groundwater elevation in Silberhorn Well 1 averages about 250 feet msl, the Dungeness River is mapped at an elevation of 260-270 feet msl. However, groundwater levels in the Shallow Aquifer may be higher immediately below the river due to: 1) recharge from streambed seepage and 2) downward gradients from the water table to the deeper zone in which Well 1 is completed.

low-rainfall years in 2000 and 2001 may have affected the tail end of the observed decline, variations in precipitation cannot explain the declining trend noted over the last 10 to 15 years. Depth to water in Well 1 was 39 feet when installed in 1975, and has recently fallen to below 65 feet. The groundwater level decline that caused local residents to deepen their wells in the early 1990's has continued despite significant reductions in Silberhorn pumping. More detailed analysis of local changes in irrigation recharge, other pumping withdrawals, and local hydrogeologic constraints would be required to better understand the cause(s) of the observed declines.

## 9 Water Quality from Water Supply Sources

Groundwater from the City's sources of supply is of excellent quality. PGG compiled water-quality data from WDOH records (1997 and later) and the City's files (pre-1997). A large variety of water-quality parameters have been analyzed in samples from the City's sources. These parameters are grouped into five categories: inorganic chemicals (IOCs), radionuclides (RADs), soluble organic compounds (SOCs), volatile organic compounds (VOCs), and total coliform. IOCs (except nitrate), SOCs, VOCs, and RADs are sampled every three years. Nitrate is sampled annually. A subset of the SOC's and VOC's (pesticides, herbicides, and insecticides) is sampled twice per three years. Total coliform is sampled a minimum of five times per month in the distribution system, but has been sampled only once from one of the sources. Total coliform data collected from the distribution system were not examined in this report.

**Table 2** and the following paragraphs provide a summary of maximum values for water-quality parameters that have been detected in City of Sequim's water-supply wells. State drinking water standards for some of these compounds are defined in WAC 246-290-310. The standards are called Maximum Contaminant Levels (MCLs). Some IOCs have primary MCLs, which the Department of Health (DOH) must enforce as its first priority. Other parameters have secondary MCLs, for which DOH has a lower enforcement priority because they do not pose health concerns. RADs and total coliform have primary standards, only. MCLs for SOCs and VOCs are equal to those defined in Federal standards of 40 CFR 141.61(a).

No MCLs have been established by the State Board of Health for copper, lead, and sodium. However, the Ground Water Quality Standards (WAC 173-200- 040) define standards for enforcement limits for lead and copper. Furthermore, EPA has established "action levels" for copper and lead in drinking water that are related to corrosion control in the distribution system, and these action levels are referenced in **Table 2**. Finally, EPA also has recommended a sodium limit of 20 mg/l for people on sodium restricted diets.

*Inorganic Chemicals (IOCs)*

This group contains common metals, such as sodium, trace metals, such as lead, specific (electrical) conductivity, nitrate, and turbidity. It also contains hardness, which is a rough measure of the production of insoluble soap scum during household washing. Concentrations for most of the IOC parameters were very low. None of the IOC results exceeded the MCLs, and many of the values were detectable but too low to quantity accurately (noted as "LTPQL" in **Table 2**).

Nitrate is a constituent of concern in the Sequim-Dungeness vicinity. The USGS found that elevated concentrations of nitrate occur in a large area east of the Dungeness River and north of Bell Creek (Thomas et al., 1999). Also, they found that nitrate concentrations were higher in the Shallow Aquifer than the Middle Aquifer, because shallow groundwater is closer to sources of nitrogen (e.g. septic tanks and agricultural sources). Natural concentrations of nitrate (concentrations unaffected by human activity) are typically are below 1 mg/l-N, and the State drinking water standard is 10 mg/l-N. **Figure 19** presents nitrate concentrations over time at the City's drinking water sources. Nitrate concentrations are generally less than or equal to 1 mg/l-N, well below the MCL; however, concentrations at the Silberhorn Wellfield increased to 2.1 mg/l-N between 1994 and 1997, and then slowly returned to 1 mg/l-N. The slow (5-year) decay of nitrate concentration suggests that a nitrogen "plume" may have passed through the Shallow Aquifer, and perhaps, experienced natural attenuation.

*Radioisotopes (RADs)*

Available radioisotope data from the City's sources include 1 sampling for both the Infiltration Gallery and the Silberhorn Wellfield, and 2 samplings at Port Williams Well PW-1. In all but one case, no radioactivity was detected. Gross alpha radiation was detected in Port Williams Well PW-1, but was below the quantifiable limit of 5 picocuries per liter (pci/l) and the MCL of 15 pci/l.

*Soluble Organic Compounds (SOCs)*

Organic compounds are carbon-based molecules. Soluble organic compounds of interest are the soluble herbicides and pesticides. Available data from the City's sources include 1 sampling at the Port Williams Wellfield and 3 samplings at the Silberhorn Wellfield and the Infiltration Gallery. SOC's were not detected in any of these samplings.

*Volatile Organic Compounds (VOCs)*

Volatile organic compounds include certain herbicides and pesticides, petroleum products, and cleaning product, such as those used for dry cleaning. Available data from the City's sources include 1 sampling at the Port Williams Wellfield and 3 samplings at the Silberhorn Wellfield and the Infiltration Gallery. VOC's were not detected in any of these samplings.

*Total Coliform*

Total coliform usually is typically measured in water samples from the City's distribution system, but is not often measured directly from the City's sources. Available data indicate only one source sample, taken at the Infiltration Gallery during July 1994. This single analysis showed 15 colonies per 100 ml, and exceeded the drinking water standard of 1 colony per 100 ml. Occasional detections of total coliform bacteria, followed by no detection during repeat sampling, are not uncommon. Overall, the City's coliform sampling program within its water distribution system meets or exceeds the WDOH drinking water standards.

## 10 Water Quality in Bell Creek

This section presents a summary of water quality data collected from Bell Creek, both to review current water quality in the creek and to provide a basis for evaluation of potential water-quality changes associated with the City's streamflow augmentation program. While short-term testing of the streamflow augmentation system occurred between the months of August and November (2001), the system gained State approval and was put into long-term operation in December, 2001. The data evaluated in this section were predominantly collected prior to streamflow augmentation, and therefore generally represent background conditions. Samples collected after streamflow augmentation was initiated are compared to background conditions.

Samples from Bell Creek have been collected and analyzed by City of Sequim, Clallam County Streamkeepers, and the Jamestown S'Klallam Tribe. The City also samples reclaimed water at the Treatment Plant and at a discharge pond located on the Demonstration Site. PGG compiled data spreadsheets and maps of sampling locations from all three organizations. The sampling locations referenced in this report are shown on **Figure 11** and summarized on **Table 1** (other sampling locations exist but were not referenced, typically because few data were collected from these sites). In addition, a detailed map of the Demonstration Site is presented on **Figure 20**. The water-quality data were evaluated with respect to applicable State surface water quality standards (WAC 173-201A)[11]. The standards classify streams according to their background quality, from AA (extraordinary), through A (excellent) and B (good) to C (fair). Bell Creek is a Class AA stream (Beckett, pers. com., 2002).

The various samples have been analyzed for one or more of the following parameters:

- Alkalinity
- Biological Oxygen Demand
- Coliform bacteria – total and fecal
- Dissolved oxygen (DO)
- Water temperature
- Nitrogen compounds: ammonia, nitrate, nitrite, and total Kjeldahl
- PH
- Specific conductivity (electrical)
- Total dissolved solids (TDS)
- Total Suspended solids
- Turbidity
- Phosphorous compounds: orthophosphate and total phosphorous

Few of the samples were analyzed for all parameters. Most were analyzed only for temperature and dissolved oxygen. The City's sampling program on Bell Creek includes two components: field measurement of temperature, dissolved oxygen, and pH several times per month at the

[11] Analysis of effluent quality relative to conditions of the City's NPDES permit for streamflow augmentation is performed regularly by the City as a requirement of their permit. NPDES data analyses are not addressed in this report.

Demonstration Site (Sampling Sites 4 and 5[12]), and near-monthly field and laboratory analyses of samples obtained upstream and downstream of the Demonstration Site (Sites 22 and 24[13]). The City performed additional coliform analysis at up to 6 stream sites during the summer of 2001. Samples collected by the Jamestown S'Klallam Tribe (from sampling sites identified with the letter "T") were analyzed for temperature and fecal coliform bacteria. The Tribe also measured streamflow at sampling Site T2 during many of sampling events. Samples collected by Clallam County Streamkeepers (from sampling sites identified with the prefix "SK") were analyzed for dissolved oxygen, fecal coliform, nitrate, pH, specific conductivity, temperature, and turbidity. Streamkeepers also measured creek discharge during most of the sampling events. Note that sampling locations on

Samples collected by City were analyzed at their Treatment Plant laboratory, which is certified for BOD, TSS, pH, turbidity, and ammonia. However, laboratory operators report that many of the ammonia measurements are inaccurate due to analytical interference with iron present in the water samples. Samples analyzed by Lauchs Laboratories (Seattle, WA) for ammonia typically showed lower concentrations than those analyzed at the City's lab. Analyses for nitrate and total phosphorus were conducted on a Hach spectrophotometer and should be considered approximate until further instrument calibration is performed. Analytical procedures associated with the water quality data reported by Streamkeepers and the S'Klallam Tribe are unknown.

While all of the monitoring data is valuable for a variety of reasons, some parameters are more diagnostic than others for detecting the influence of streamflow augmentation with reclaimed water, particularly if a particular constituent is known to occur in the reclaimed water. Based on comparison of background water quality in Bell Creek and reclaimed water, nitrate, dissolved oxygen, total phosphorus, and temperature are most likely to show trends related to the streamflow augmentation (ammonia is not included in this list due to laboratory inaccuracies). In addition, while fecal coliform is not detectable in the effluent, it is good indicator of the quality of aquatic habitat. Results for fecal analyses are also discussed herein. **Figures 21** through **24** present time-series plots for these parameters, distinguished by station and station location (upstream vs. downstream of the streamflow augmentation point). Visual inspection of these plots was used to evaluate trends over time and between upstream and downstream locations

*Dissolved Oxygen and Temperature*

WAC 173-201A contains surface water quality standards for both DO and temperature. The standards vary by stream quality classification. Standards for Class AA streams are temperature not exceeding 16$^{o}$C. and DO not less than 9.5 mg/l.

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[12] The field sampling program includes 9 sites, of which stream stage is measured at sites 1 through 6, and reclaimed water temperature and DO is measured at Sites 7 through 9.
[13] Laboratory analysis is also performed on treated water at the reclamation facility.

Dissolved oxygen concentration (DO) in water is inversely related to temperature because the solubility of oxygen is higher in colder waters. Based on this relationship, analytical results for these two parameters are presented for comparison on **Figures 21 and 22**. Annual cycles of water temperature and dissolved oxygen fluctuations are apparent in both figures, but are more obvious on the expanded time scale used for **Figure 21**.

Temperature sampling data are sparse prior to the fall of 2000 (**Figure 21**). The available data suggest that Class AA standards were rarely exceeded during that time period. However, more extensive sampling during late 2000 and 2001 show that temperatures exceeded Class A standards during the summer months (2001). A closer look at the latter data (**Figure 22)** reveals that temperatures downstream of the augmentation site tended to exceed those upstream during spring and summer but not during fall and winter. This observation applies both before and after testing of the augmentation system began in August 2001. Because the samples are collected during daylight hours, the data may reflect a warming effect in the ponds between the upstream and downstream stations. That is, the warm seasons' sun and warmer air will heat the water throughout the creek, but more so in the ponds at Carrie Blake Park where more surface area will proportionately gain more heat. This may partly explain why downstream temperatures tend to be higher.

DO measurements tended to fall below the Class AA surface-water standard of 9.5 mg/l during summer and autumn months, both before and after streamflow augmentation began (**Figures 21** and **22**). Similar to temperature data, DO data are relatively sparse prior to the fall of 2000. During 1998, when data are particularly sparse, DO concentrations downstream of Carrie Blake Park tended to exceed upstream concentrations. From early 1999 through winter 2002, this relationship generally reversed, with upstream concentrations exceeding those downstream. Because the latter relationship developed before testing of the streamflow augmentation system began, it is difficult to pick out any effect of the augmentation. Due to the sparsity of data, more sampling will be required to resolve the influences upstream and downstream of the augmentation.

*Ammonia*

The ammonia standards under WAC 173-201A are for chronic and acute toxicity, with the latter being higher. The standards are not fixed and must be calculated for each sample from pH, temperature, and the ammonia concentration. PGG reviewed ammonia data collected by the City from late 1997 to present, and evaluated the laboratory measurements by Laucks Labs and those made by the City (without apparent interference from iron) relative to standards for acute toxicity. About 25 admissible ammonia measurements showed a range from "non-detect" to 0.03 mg/l; of which only one sample exceeded acute toxicity standard. The remaining 26 measurements were inadmissible due to iron interference, and showed erroneous ammonia values as much as ten times larger than the admissible measurements. Because admissible measurements are available only before streamflow augmentation began, comparison of upstream vs. downstream concentrations cannot be performed. The City is currently modifying its analytical methods to correct the iron interference problem. Evaluation of future data will be required to assess whether water-quality impacts from streamflow augmentation occur.

*Nitrate*

Nitrate has no surface water quality standard in WAC 173-201A. However, it can be an indicator of contamination. The available nitrate measurements performed by the City's lab should be considered approximate due to the method of analysis (discussed above). All the values shown in **Figure 23** are very low and do not indicate contamination. No increase over time or downstream increases are consistently indicated. Although nitrate concentrations in the reclaimed water are typically less than 2 mg/l and rarely exceed the 10 mg/l, they are about 10-times higher than background concentrations in Bell Creek. Only two nitrate measurements are available since testing of the augmentation system began. These two measurements show no significant difference between upstream and downstream sampling locations; however, the data are too sparse to support definitive conclusions.

*Phosphorus*

Phosphorus also has no surface water quality standard in WAC 173-201A. However, values exceeding a few tenths mg/l probably indicate some form of contamination. Common sources include manure from livestock, other mammals and native birds. Cows in upper Bell Creek were reported on one of the S'Klallam Tribe's sampling notes, and the occurrence of cattle near the creek may not be uncommon. Failing septic systems could be another possible source of phosphorous if septic effluent flows directly into the steam without filtering through the soil. Phosphorous may be a useful indicator of effects from the augmentation water, because the reclaimed water has significantly higher concentrations than background water quality in Bell Creek.

The available phosphorus measurements performed by the City's lab should be considered approximate due to the method of analysis (discussed above). However, the graph of phosphorus over time **(Figure 23)** shows a minor increasing trend at both upstream and downstream stations increase, with no significant difference between upstream and downstream since augmentation began. Only two sampling events occurred since testing of the augmentation system began. The limited data do not indicate any water quality degradation from the City's augmentation program, and are too sparse and approximate for more definitive analysis.

*Fecal Coliform*

Fecal coliform standards vary according to stream classification, as with DO and temperature. As a Class A stream, Bell Creek has a standard of 100 colonies per 100 ml with some allowance for occasional exceedences. As shown in **Figure 24**, the standard frequently is exceeded both upstream and downstream. The reclaimed augmentation water contains no fecal coliform, and therefore cannot be a source to Bell Creek.

## 11 Recommendations for Future Monitoring

The City's monitoring system is currently collecting a variety of data valuable for management of its water supply sources and reclaimed water. After reviewing the available date, the following recommendations are offered:

1. Water levels in Silberhorn monitoring well "Well 1" and Port Williams production wells PW-1 and PW-2 are currently measured manually on a twice-weekly basis. This measurement frequency could be reasonably reduced to weekly. Notes should be made as to whether other wells in the wellfield are pumping at the time of measurement.
2. As long as the datalogger at Port Williams is operational, the majority of manual measurements in PW-1 and PW-2 should be static (non-pumping) water levels, although occasional pumping water levels are warranted. During pumping, the thickness of the water column maintained above the pump can be ascertained by the readout in the control room.
3. At the Port Williams wellfield, monitoring wells MW-1 and MW-3 are currently only monitored by the datalogger. Manual measurements should be obtained from these wells on a monthly basis in case of datalogger failure and/or to calibrate the pressure transducers in the wells. Measurements during non-pumping periods are preferable.
4. At the Silberhorn Wellfield, production wells "Well 2" and Well 3" are currently measured on a monthly basis. Since Well 1 is used as a monitoring well, the main purpose of measuring water levels in Wells 2 and 3 is to ensure that pumping drawdowns do not approach the top of the pump. Monthly water level measurements in Wells 2 and 3 are sufficient, and should be taken when the wells are pumping. Continued weekly measurements at Well 1 should emphasize static conditions, when possible.
5. The City's current monitoring network has diminished slightly due to private well owners denying access to their wells. Monitoring wells are unavailable in the Lower Aquifer and relatively sparse in the Middle Aquifer. Groundwater level monitoring regularly performed by Clallam County and/or Ecology also emphasizes the Shallow Aquifer, with few wells in the Middle Aquifer and no wells in the Lower Aquifer. While the USGS has measured water levels in many wells, detailed monitoring is sporadic and also emphasizes the Shallow Aquifer. One private well owner monitors water levels in the undifferentiated deposits that underlie the Lower Aquifer; however, the data were unavailable at the time of this writing. The current practice of data sharing between agencies (and with the public) should continue. In addition, cooperative efforts should be made by all agencies interested in water resource management on the Sequim-Dungeness Peninsula to include more wells in the Middle and Lower Aquifers. Monthly or quarterly static water level monitoring is highly valuable in documenting aquifer responses to pumping and changes in recharge, as well as calibrating models potentially used to make water management decisions. Private residents and water systems with relatively deep wells should be encouraged to provide access for water-level measurement or share data they collect themselves.

6. The Middle and Lower Aquifers are potentially most susceptible to saltwater intrusion in coastal areas. Agencies involved in water resource monitoring on the Sequim-Dungeness Peninsula attempt to incorporate coastal wells in these aquifers into their monitoring networks. Periodic sampling for measurement of electrical conductance or chloride concentration is advisable for such wells.
7. PGG has prepared various spreadsheets for entry of data that are predominantly recorded by the City in hard-copy format. Data forms maintained by City field staff have been recently submitted to the Public Works office for data entry into these spreadsheets. Hand entered data included: monthly pumping volumes, all manual groundwater level measurements, and daily rainfall. This data entry should continue on a regular basis over the long term. The data can be "stored up" on paper and periodically entered in the spreadsheets. Although rainfall data are eventually published by NOAA, the time delay makes the data unusable for management of irrigation applications on the Demonstration Site. The rainfall spreadsheet should be updated on a twice-monthly basis.
8. The City's sampling program on Bell Creek currently includes two components: 1) laboratory analysis of samples obtained upstream and downstream of the Demonstration Site on an approximately monthly basis, and 2) field analysis of temperature, dissolved oxygen and pH performed several times a month at the Demonstration Site[14]. In addition, detailed coliform analysis was performed at up to 6 sites during the summer of 2001. All of these sampling programs use different station ID's, even though sampling locations are sometimes shared between programs. Based on recent recommendations provided to the City's lab, the station nomenclature for the City's Bell Creek sampling should be unified.
9. PGG has provided the City with a spreadsheet for more efficient record keeping for the field analyses discussed above, however, this is not an ideal solution compared to using a database. If significant quantities of data will continue to be generated from Bell Creek monitoring, the City should consider switching their data storage from spreadsheets to a true database, such as Microsoft Access. Associated advantages include: 1) storage of all data in a single file, 2) easy export to other applications, and 3) easy generation of standard reports and graphs. PGG has created a customized database for water quality data that we used in many projects and could assist the City with setting the desired data entry forms and reports in short order.
10. The challenge of detecting potential water quality changes due to the streamflow augmentation requires that some changes be made to the monitoring program:
    a. Water-quality sampling parameters from Bell Creek can be reduced to the following subset: temperature, DO, specific conductivity, pH, turbidity, TDS, BOD, coliform (total and fecal), nitrate, ammonia, total Kjeldahl nitrogen, total phosphorous, and orthophosphates. Measurement of nitrite, total suspended solids, and alkalinity can

[14] Stream stages in culverts are also measured during these site visits.

be eliminated from Bell Creek samples. Measurement of chloride should be added to the list of parameters.

b. Bell Creek discharge is currently unmeasured, but is relatively indicated by stage measurements taken at culverts upstream and downstream of Carrie Blake Park. Because the stream is split into two culverts at road crossings near the park entrance and exit, measurement of stream stage at a single (and stable) point in the natural channel is preferred. If desired, stream stage can be related to flow by performing 3 or 4 wading discharge measurements per year. Alternatively, it might be possible to install a weir at one of the pond overflows to obtain accurate discharge measurements.

c. Correction of the method of analysis for ammonia is already underway. Further calibration of the Hach spectrophotometer used for measuring nitrate and phosphorus should be performed to develop a better understanding of the instrument accuracy. Calibration can be performed by maintaining standards and/or sending duplicate methods to a certified laboratory.

d. The upstream and downstream stations should always be monitored on the same day and as close to the same time as possible.

e. In order to better understand potential changes in water quality associated with the ponds on Carrie Blake Park, short-term sampling over several events is recommended. Whereas the stream is already sampled below the lower pond, additional sampling immediately upstream of this pond (for the same water quality parameters) is advised. Similar analysis on the upper pond is not recommended, as it may be obscured by inflow of the reclaimed water.

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* Reports citing the "Stone Wellfield" pertain to the Port Williams Wellfield.

**TABLE 1 - REFERENCED MONITORING STATIONS**

| Station ID | Station Type | Monitoring Activity | Monitoring Agency | Period of Record | Manual Monitoring Frequency | Automated Montiroring Frequency | Notes |
|---|---|---|---|---|---|---|---|
| Infiltration Gallery | Sequim Water Source | Pumping Withdrawals* | City of Sequim | 1978-present | Daily | N/A | |
| Silberhorn Wellfield | Sequim Water Source | Pumping Withdrawals* | City of Sequim | 1978-present | Daily | N/A | |
| Port Williams Wellfield | Sequim Water Source | Pumping Withdrawals* | City of Sequim | 1996-present | Daily | Hourly | |
| PW-1 | Sequim Production Well | GW Levels | City of Sequim | 1996-present | Twice Weekly | Hourly | Completed in Lower Aquifer at Port Williams Wellfield |
| PW-2 | Sequim Production Well | GW Levels | City of Sequim | 1996-present | Twice Weekly | Hourly | Completed in Lower Aquifer at Port Williams Wellfield |
| Well #2 | Sequim Production Well | GW Levels | City of Sequim | 1993-present | Monthly | N/A | Completed in Shallow Aquifer at Silberhown Wellfield |
| Well #3 | Sequim Production Well | GW Levels | City of Sequim | 1993-present | Monthly | N/A | Completed in Shallow Aquifer at Silberhown Wellfield |
| Well #1 | Sequim Monitoring Well | GW Levels | City of Sequim | 1993-present | Twice Weekly | N/A | Completed in Shallow Aquifer at Silberhown Wellfield |
| MW-1 | Sequim Monitoring Well | GW Levels | City of Sequim | 1996-present | N/A | Hourly | Completed in Shallow Aquifer at Port Williams Wellfield |
| MW-3 | Sequim Monitoring Well | GW Levels | City of Sequim | 1996-present | N/A | Hourly | Completed in Middle Aquifer at Port Williams Wellfield |
| PD-1 | Private Domestic Well | GW Levels | City of Sequim | 1996-present | Monthly | N/A | Completed in Shallow Aquifer near Silberhown Wellfield |
| PD-2 | Private Domestic Well | GW Levels | City of Sequim | 1996-present | Monthly | N/A | Completed in Shallow Aquifer near Silberhown Wellfield |
| PD-3 | Private Domestic Well | GW Levels | City of Sequim | 1996-1998 | Monthly | N/A | Completed in Shallow Aquifer near Silberhown Wellfield. Abandoned in 1998. |
| PD-4 | Private Domestic Well | GW Levels | City of Sequim | 1996-present | Monthly | N/A | Completed in Shallow Aquifer near Silberhown Wellfield |
| PD-5 | Private Domestic Well | GW Levels | City of Sequim | 1996-1998 | Monthly | N/A | Completed in Shallow Aquifer near Silberhown Wellfield. Abandoned in 1998. |
| PD-6 | Private Domestic Well | GW Levels | City of Sequim | 1996-present | Monthly | N/A | Completed in Shallow Aquifer near Silberhown Wellfield |
| PD-7 | Private Domestic Well | GW Levels | City of Sequim | 1996-present | Monthly | N/A | Completed in Shallow Aquifer near Port Williams Wellfield |
| PD-8 | Private Domestic Well | GW Levels | City of Sequim | 1996-present | Monthly | N/A | Completed in Shallow Aquifer near Port Williams Wellfield |
| PD-9 | Private Domestic Well | GW Levels | City of Sequim | 1996-present | Monthly | N/A | Completed in Middle Aquifer near Port Williams Wellfield |
| PD-10 | Private Domestic Well | GW Levels | City of Sequim | 1996-99 | Monthly | N/A | Completed in Middle Aquifer near Port Williams Wellfield; Property owner denied access in 1999. |
| PD-11 | Private Domestic Well | GW Levels | City of Sequim | 1996-99 | Monthly | N/A | Completed in Lower Aquifer near Port Williams Wellfield; Property owner denied access in 1999. |
| PD-12 | Private Irrigation Well | GW Levels | City of Sequim | 1996-98 | Monthly | N/A | Completed below Lower Aquifer; Now monitored by property owner; data unavailable. |
| EW-1 | Private Domestic Well | GW Levels | Ecology / Clallam Co. | 1990-present | Variable | N/A | Completed in Middle Aquifer |
| EW-2 | Private Domestic Well | GW Levels | Ecology / Clallam Co. | 1990-present | Variable | N/A | Completed in Shallow Aquifer |
| EW-4 | Private Domestic Well | GW Levels | Ecology / Clallam Co. | 1990-present | Variable | N/A | Completed in Shallow Aquifer |
| EW-5 | Private Domestic Well | GW Levels | Ecology / Clallam Co. | 1990-present | Variable | N/A | Completed in Shallow Aquifer |
| EW-6 | Private Domestic Well | GW Levels | Ecology / Clallam Co. | 1990-present | Variable | N/A | Completed in Shallow Aquifer |
| EW-7 | Private Domestic Well | GW Levels | Ecology / Clallam Co. | 1990-present | Variable | N/A | Completed in Shallow Aquifer |
| EW-8 | Private Domestic Well | GW Levels | Ecology / Clallam Co. | 1990-present | Variable | N/A | Completed in Middle Aquifer |
| EW-9 | Private Domestic Well | GW Levels | Ecology / Clallam Co. | 1990-present | Variable | N/A | Completed in Shallow Aquifer |
| EW-10 | Private Domestic Well | GW Levels | Ecology / Clallam Co. | 1993-present | Variable | N/A | Completed in Shallow Aquifer |
| USGS Streamgage | Streamgage | Streamflow | USGS | 1923-present | Unknown | Continuous | #12048000 - "Dungeness River Near Sequim, Washington" |
| Precip. Gage | Climatic Monitoring | Precip, Temp, Humidity | City of Sequim | 1980-present | Daily | N/A | "Sequim 2 E" (#457544) - continues 1931-80 record from "Sequim" (#457538) |

**TABLE 1 - REFERENCED MONITORING STATIONS**

| Station ID | Station Type | Monitoring Activity | Monitoring Agency | Period of Record | Manual Monitoring Frequency | Automated Montiroring Frequency | Notes |
|---|---|---|---|---|---|---|---|
| Site 4 | Bell Creek Sampling | Temp., DO | City of Sequim | 10/00-present | Weekly-Monthly | N/A | Carrie Blake Park entry (culvert downstream exit) |
| Site 5 | Bell Creek Sampling | Temp., DO | City of Sequim | 10/00-present | Weekly-Monthly | N/A | Rhodefer Rd. (upstream culvert entrance) |
| Site 22 | Bell Creek Sampling | SW Qual. Params. | City of Sequim | 12/97-present | Approx Monthly | N/A | Bell Creek at City Shop, Equivalent to Coliform Site "D" |
| Site 24 | Bell Creek Sampling | SW Qual. Params. | City of Sequim | 12/97-present | Approx Monthly | N/A | Bell Creek East Side of Carrie Blake Park, Equivalent to Coliform Site "F" |
| T-1 | Bell Creek Sampling | Coliform | Jamestown S'Klallam Tribe | 4/98 - 7/01 | Variable | N/A | Mouth of Bell Creek |
| T-2 | Bell Creek Sampling | Coliform, Q, Temp. | Jamestown S'Klallam Tribe | 4/98 - 7/01 | Variable | N/A | Schmuck Rd.- also used by Stream Keepers (SK - 1) and referred to as Reach 1 |
| T-3 | Bell Creek Sampling | Coliform | Jamestown S'Klallam Tribe | 4/98 - 7/01 | Variable | N/A | DOT, Sample taken on the downstream end of DOT site just before Smith's farm |
| T-4 | Bell Creek Sampling | Coliform | Jamestown S'Klallam Tribe | 4/98 - 7/01 | Variable | N/A | Carrie Blake Park - Sample taken at the small bridge on the east end of the park before Rhodefer Rd. |
| T-5 | Bell Creek Sampling | Coliform | Jamestown S'Klallam Tribe | 4/98 - 7/01 | Variable | N/A | Blake Rd.- sample taken upstream of the entrance to Carrie Blake Park |
| T-6 | Bell Creek Sampling | Coliform | Jamestown S'Klallam Tribe | 4/98 - 7/01 | Variable | N/A | Les Schwab - Sample taken on the North side of the Washington Street culvert/ Moved a little further downstream at the old Earnst store next to walking bridge |
| T-7 | Bell Creek Sampling | Coliform | Jamestown S'Klallam Tribe | 4/98 - 7/01 | Variable | N/A | Bell Creek Apartments (Sunny Side Apartments?) - sample taken at the first group of big alders |
| T-8 | Bell Creek Sampling | Coliform | Jamestown S'Klallam Tribe | 4/98 - 7/01 | Variable | N/A | City of Sequim Shop - Sample taken just downstream from the culvert on the east side of the big brush pile |
| SK-1 | Bell Creek Sampling | SW Qual. Params., Q | Streamkeepers | 7/97 - 7/98 | Variable | N/A | At stream mile 0.1 |
| " " | Bell Creek Sampling | Coliform | Streamkeepers | 9/99 - 10/1 | Variable | N/A | " " " |
| SK-2 | Bell Creek Sampling | SW Qual. Params., Q | Streamkeepers | 1/97 - 4/98 | Variable | N/A | At stream mile 1.8 |
| DS-MW-1 | Sequim Monitoring Well | GW Quality, Water Level | City of Sequim | 7/00-present | Variable | N/A | Located on Demonstration Site near Bell Creek |
| DS-MW-2 | Sequim Monitoring Well | GW Quality, Water Level | City of Sequim | 7/00-present | Variable | N/A | Located on Demonstration Site near Bell Creek |
| DS-MW-3 | Sequim Monitoring Well | GW Quality, Water Level | City of Sequim | 7/00-present | Variable | N/A | Located on Demonstration Site near Bell Creek |
| DS-MW-4 | Sequim Monitoring Well | GW Quality, Water Level | City of Sequim | 7/00-present | Variable | N/A | Located on Demonstration Site near Bell Creek |

NOTES:
* All City of Sequim water sources are sampled for State drinking water parameters (water quality) at the State specified schedule.
Only those Bell Creek monitoring points used in our analysis are shown on this table.  The City, Tribe and Streamkeepers all have additional sampling sites.
GW = Groundwater; SW = Surface Water; SW Qual. Parameters = Surface Water Quality Parameters; Q = Streamflow

## TABLE 2 - CITY OF SEQUIM DRINKING WATER ANALYSES, INORGANIC CONSTITUENTS

| Parameter Name | Number of Samples | Reporting Unit | Maximum Value | Maximum Value Date | Analysis Note | Maximum Contaminant Level (MCL) | Action Level (AL) | Exceed MCL or AL? |
|---|---|---|---|---|---|---|---|---|
| *Dungeness River Infiltration Gallery* | | | | | | | | |
| ANTIMONY | 4 | mg/l | 0.005 | 06/09/97 | LTPQL[1] | 0.006 | | N |
| ARSENIC | 4 | mg/l | 0.01 | 06/09/97 | LTPQL | 0.05 | | N |
| BARIUM | 4 | mg/l | 0.1 | 07/07/99 | LTPQL | 2 | | N |
| BERYLLIUM | 4 | mg/l | 0.003 | 07/07/99 | LTPQL | 0.004 | | N |
| CADMIUM | 4 | mg/l | 0.003 | 08/11/00 | LTPQL | 0.005 | | N |
| CALCIUM | 1 | mg/l | 24 | 08/09/00 | | None | | N |
| CHLORIDE | 4 | mg/l | 20 | 06/09/97 | LTPQL | 250 | | N |
| CHROMIUM | 4 | mg/l | 0.01 | 07/07/99 | LTPQL | 0.1 | | N |
| COLOR | 4 | color units | 5 | 08/09/00 | | 15 | | N |
| CONDUCTIVITY | 4 | micro-mhos/cm | 120 | 07/09/98 | | 700 | | N |
| COPPER | 4 | mg/l | 0.74 | 07/21/92 | LTPQL | None | 1.3 | N |
| CYANIDE | 4 | mg/l | 0.1 | 06/09/97 | LTPQL | 0.2 | | N |
| FLUORIDE | 4 | mg/l | 0.5 | 06/09/97 | LTPQL | 4 | | N |
| HARDNESS | 4 | mg/l | 74 | 08/09/00 | | None | | N |
| IRON | 4 | mg/l | 0.1 | 07/07/99 | LTPQL | 0.3 | | N |
| LEAD | 4 | mg/l | 0.003 | 07/21/92 | LTPQL | None | 0.015 | N |
| MAGNESIUM | 1 | mg/l | 3.4 | 08/09/00 | | None | | N |
| MANGANESE | 4 | mg/l | 0.01 | 07/07/99 | LTPQL | 0.05 | | N |
| MERCURY | 4 | mg/l | 0.0005 | 07/07/99 | LTPQL | 0.002 | | N |
| NICKEL | 4 | mg/l | 0.04 | 06/09/97 | LTPQL | 0.1 | | N |
| NITRATE-N | 6 | mg/l | 1 | 06/27/01 | LTPQL | 10 | | N |
| SELENIUM | 4 | mg/l | 0.005 | 06/09/97 | LTPQL | 0.05 | | N |
| SILVER | 4 | mg/l | 0.01 | 07/07/99 | LTPQL | 0.05 | | N |
| SODIUM | 4 | mg/l | 3 | 07/08/99 | | None | | N |
| SULFATE | 3 | mg/l | 10 | 06/09/97 | LTPQL | 250 | | N |
| THALLIUM | 4 | mg/l | 0.001 | 07/07/99 | LTPQL | 0.002 | | N |
| TURBIDITY | 4 | ntu | 0.6 | 07/07/99 | | 1 | | N |
| ZINC | 4 | mg/l | 0.2 | 07/07/99 | LTPQL | 5 | | N |
| *Silberhorn Wellfield* | | | | | | | | |
| ANTIMONY | 3 | mg/l | 0.005 | 06/09/97 | LTPQL[1] | 0.006 | | N |
| ARSENIC | 3 | mg/l | 0.01 | 06/09/97 | LTPQL | 0.05 | | N |
| BARIUM | 3 | mg/l | 0.1 | 07/07/99 | LTPQL | 2 | | N |
| BERYLLIUM | 3 | mg/l | 0.003 | 07/07/99 | LTPQL | 0.004 | | N |
| CADMIUM | 3 | mg/l | 0.002 | 06/09/97 | LTPQL | 0.005 | | N |
| CHLORIDE | 3 | mg/l | 20 | 06/09/97 | LTPQL | 250 | | N |
| CHROMIUM | 3 | mg/l | 0.01 | 07/07/99 | LTPQL | 0.1 | | N |
| COLOR | 3 | color units | 5 | 07/07/99 | LTPQL | 15 | | N |
| CONDUCTIVITY | 3 | micro-mhos/cm | 260 | 07/09/98 | | 700 | | N |
| COPPER | 2 | mg/l | 0.02 | 06/09/97 | LTPQL | None | 1.3 | N |
| CYANIDE | 3 | mg/l | 0.1 | 06/09/97 | LTPQL | 0.2 | | N |
| FLUORIDE | 3 | mg/l | 0.5 | 06/09/97 | LTPQL | 4 | | N |
| HARDNESS | 3 | mg/l | 130 | 07/09/98 | | None | | N |
| IRON | 3 | mg/l | 0.1 | 07/07/99 | LTPQL | 0.3 | | N |
| LEAD | 3 | mg/l | 0.002 | 07/07/99 | LTPQL | None | 0.015 | N |
| MANGANESE | 3 | mg/l | 0.01 | 07/07/99 | LTPQL | 0.05 | | N |
| MERCURY | 3 | mg/l | 0.0005 | 07/07/99 | LTPQL | 0.002 | | N |
| NICKEL | 3 | mg/l | 0.04 | 06/09/97 | LTPQL | 0.1 | | N |

TABLE 2 - CITY OF SEQUIM DRINKING WATER ANALYSES, INORGANIC CONSTITUENTS

| Parameter Name | Number of Samples | Reporting Unit | Maximum Value | Maximum Value Date | Analysis Note | Maximum Contaminant Level (MCL) | Action Level (AL) | Exceed MCL or AL? |
|---|---|---|---|---|---|---|---|---|
| NITRATE-N | 6 | mg/l | 2.05 | 02/05/97 | | 10 | | N |
| NITRATE+NITRITE | 3 | mg/l | 1.9 | 06/09/97 | | None | | N |
| SELENIUM | 3 | mg/l | 0.005 | 07/07/99 | LTPQL | 0.05 | | N |
| SILVER | 3 | mg/l | 0.01 | 07/07/99 | LTPQL | 0.05 | | N |
| SODIUM | 3 | mg/l | 5 | 07/07/99 | LTPQL | None | | N |
| SULFATE | 2 | mg/l | 10 | 06/09/97 | LTPQL | 250 | | N |
| THALLIUM | 3 | mg/l | 0.001 | 07/07/99 | LTPQL | 0.002 | | N |
| TURBIDITY | 3 | ntu | 0.11 | 07/09/98 | LTPQL | 1 | | N |
| ZINC | 3 | mg/l | 0.2 | 07/07/99 | LTPQL | 5 | | N |
| | | | | | | | | |
| *Port Williams Well 1* | | | | | | | | |
| ANTIMONY | 3 | mg/l | 0.005 | 06/09/97 | LTPQL[1] | 0.006 | | N |
| ARSENIC | 3 | mg/l | 0.01 | 06/09/97 | LTPQL | 0.05 | | N |
| BARIUM | 3 | mg/l | 0.1 | 07/07/99 | LTPQL | 2 | | N |
| BERYLLIUM | 3 | mg/l | 0.003 | 07/07/99 | LTPQL | 0.004 | | N |
| CADMIUM | 3 | mg/l | 0.002 | 06/09/97 | LTPQL | 0.005 | | N |
| CHLORIDE | 3 | mg/l | 20 | 06/09/97 | LTPQL | 250 | | N |
| CHROMIUM | 3 | mg/l | 0.01 | 06/09/97 | LTPQL | 0.1 | | N |
| COLOR | 3 | color units | 5 | 07/07/99 | LTPQL | 15 | | N |
| CONDUCTIVITY | 3 | micro-mhos/cm | 340 | 12/31/98 | | 700 | | N |
| COPPER | 3 | mg/l | 0.2 | 07/07/99 | LTPQL | None | 1.3 | N |
| CYANIDE | 3 | mg/l | 0.1 | 06/09/97 | LTPQL | 0.2 | | N |
| FLUORIDE | 3 | mg/l | 0.5 | 06/09/97 | LTPQL | 4 | | N |
| HARDNESS | 3 | mg/l | 140 | 06/09/97 | | None | | N |
| IRON | 3 | mg/l | 0.2 | 12/31/98 | LTPQL | 0.3 | | N |
| LEAD | 3 | mg/l | 0.002 | 07/07/99 | LTPQL | None | 0.015 | N |
| MANGANESE | 3 | mg/l | 0.01 | 07/07/99 | LTPQL | 0.05 | | N |
| MERCURY | 3 | mg/l | 0.0005 | 07/07/99 | LTPQL | 0.002 | | N |
| NICKEL | 3 | mg/l | 0.04 | 06/09/97 | LTPQL | 0.1 | | N |
| NITRATE-N | 4 | mg/l | 1.25 | 02/05/97 | | 10 | | N |
| NITRATE+NITRITE | 3 | mg/l | 0.5 | 07/07/99 | | None | | N |
| SELENIUM | 3 | mg/l | 0.005 | 07/07/99 | LTPQL | 0.05 | | N |
| SILVER | 3 | mg/l | 0.01 | 07/07/99 | LTPQL | 0.05 | | N |
| SODIUM | 3 | mg/l | 10 | 07/07/99 | | None | | N |
| SULFATE | 2 | mg/l | 10 | 06/09/97 | LTPQL | 250 | | N |
| THALLIUM | 3 | mg/l | 0.001 | 07/07/99 | LTPQL | 0.002 | | N |
| TURBIDITY | 3 | ntu | 0.7 | 12/31/98 | | 1 | | N |
| ZINC | 3 | mg/l | 0.2 | 07/07/99 | LTPQL | 5 | | N |
| | | | | | | | | |
| *Port Williams Well 2* | | | | | | | | |
| CALCIUM | 1 | mg/l | 39 | 12/30/98 | | None | | N |
| COLOR | 1 | color units | 5 | 12/30/98 | | 15 | | N |
| CONDUCTIVITY | 1 | micro-mhos/cm | 340 | 12/30/98 | | 700 | | N |
| HARDNESS | 1 | mg/l | 140 | 12/30/98 | | None | | N |
| IRON | 1 | mg/l | 0.2 | 12/30/98 | | 0.3 | | N |
| MAGNESIUM | 1 | mg/l | 10 | 12/30/98 | | None | | N |
| NITRATE-N | 1 | mg/l | 0.6 | 12/30/98 | | 10 | | N |
| NITRATE+NITRITE | 1 | mg/l | 0.6 | 12/30/98 | | None | | N |

**TABLE 2 - CITY OF SEQUIM DRINKING WATER ANALYSES, INORGANIC CONSTITUENTS**

| Parameter Name | Number of Samples | Reporting Unit | Maximum Value | Maximum Value Date | Analysis Note | Maximum Contaminant Level (MCL) | Action Level (AL) | Exceed MCL or AL? |
|---|---|---|---|---|---|---|---|---|
| SODIUM | 1 | mg/l | 10 | 12/30/98 | | None | | N |
| TURBIDITY | 1 | ntu | 0.7 | 12/30/98 | | 1 | | N |

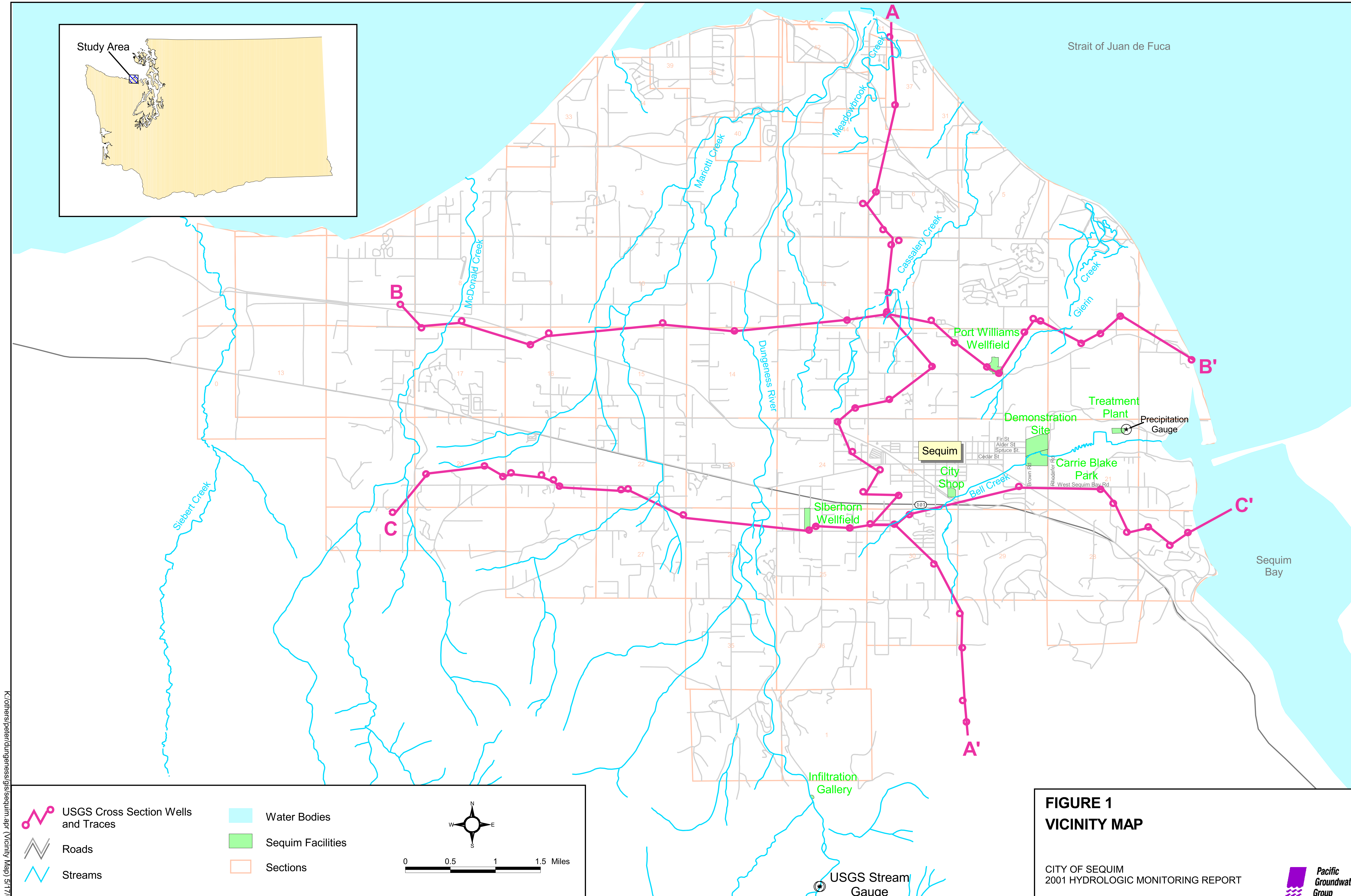



**FIGURE 1**
**VICINITY MAP**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

K:/others/peter/dungeness/gis/sequim.apr (Vicinity Map) 5/17/02

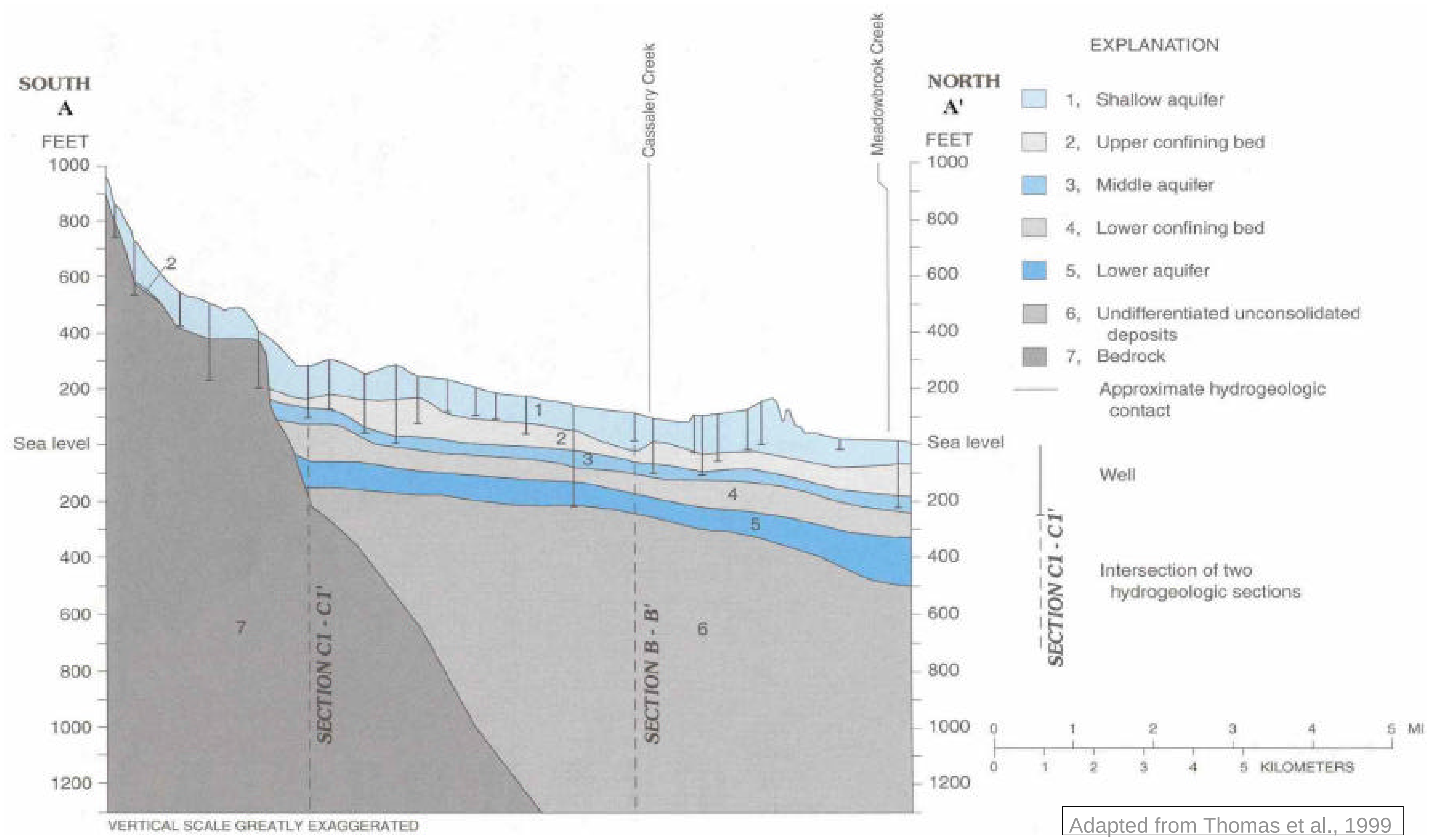
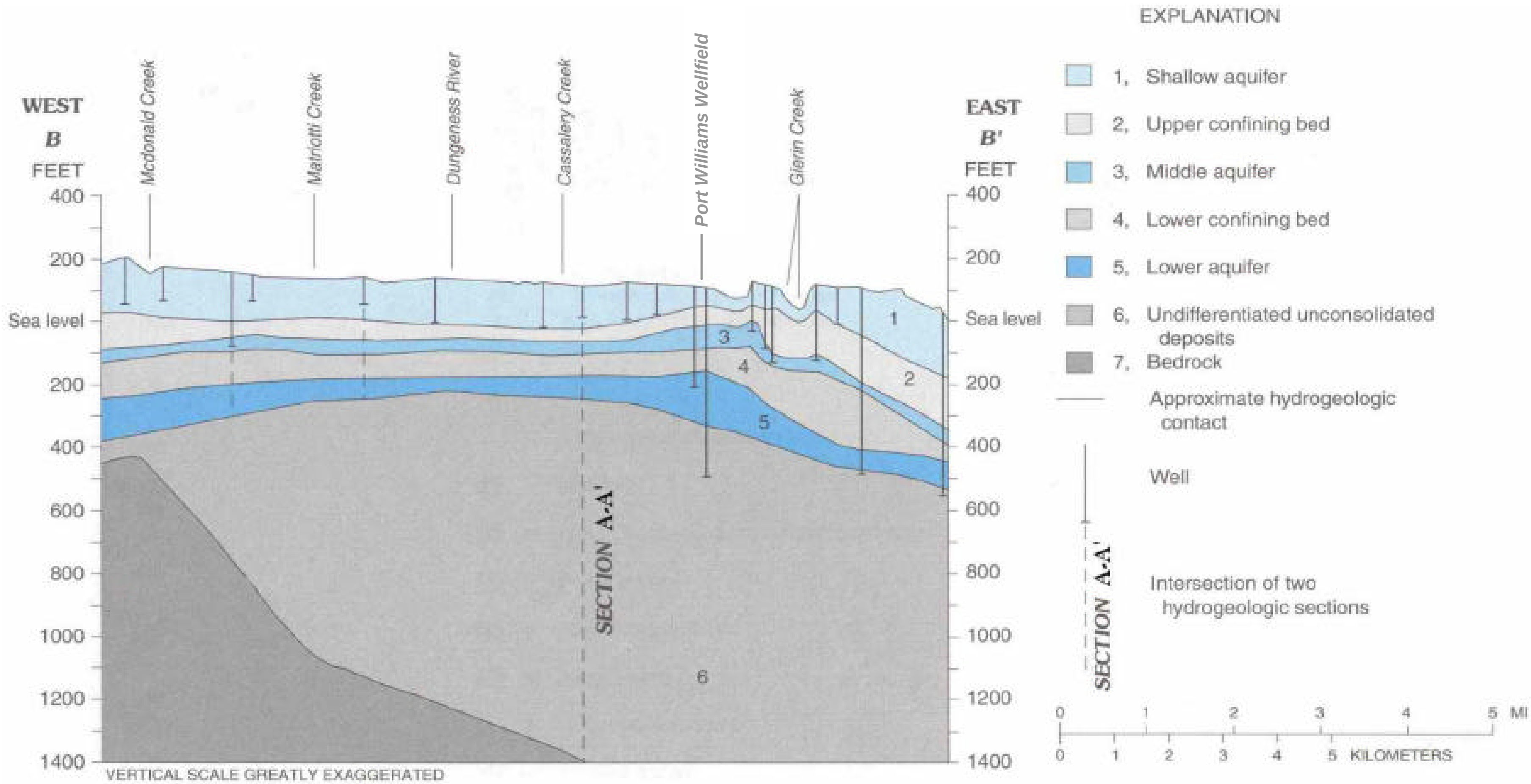



**FIGURE 2**
**HYDROGEOLOGIC CROSS SECTION A-A'**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

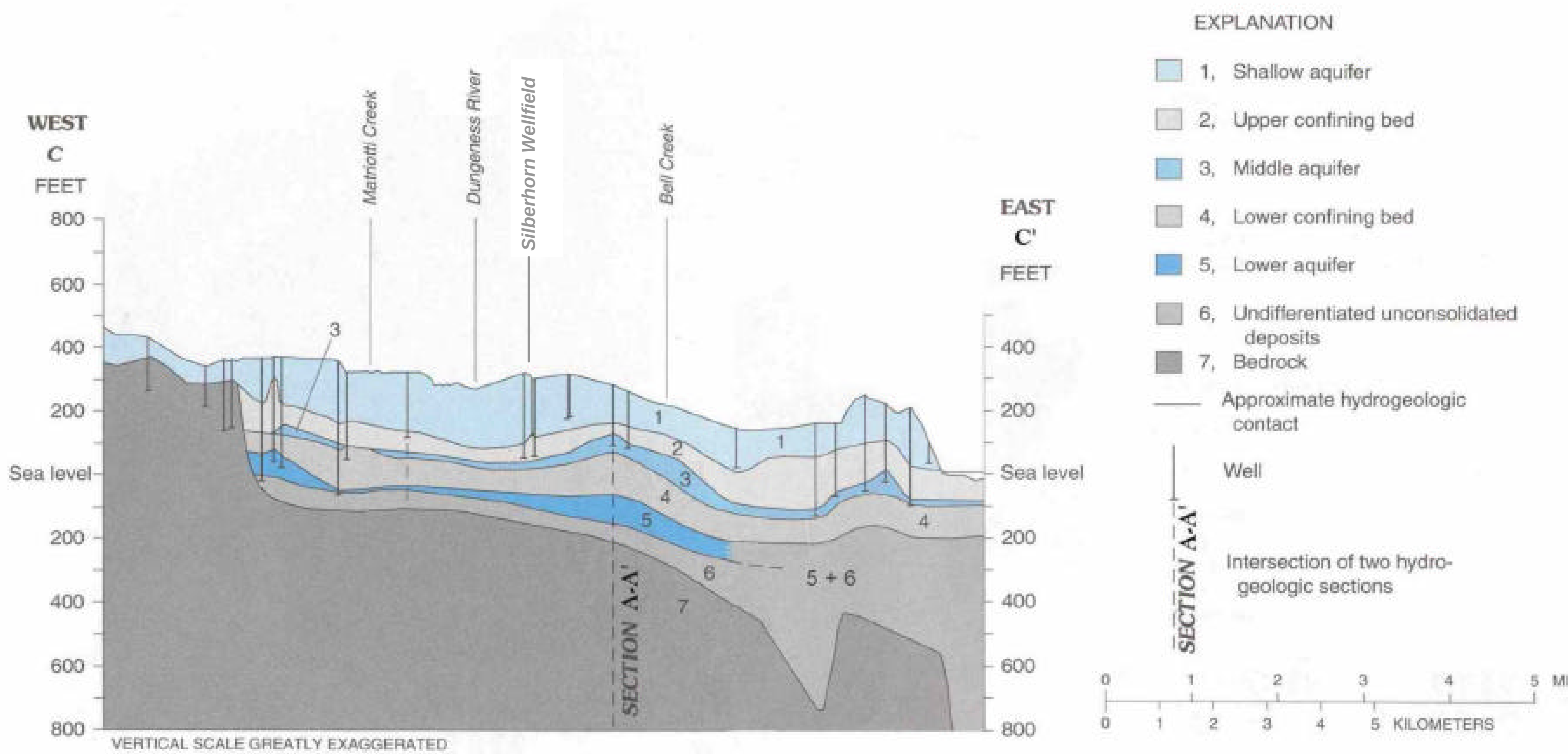



Adapted from Thomas et al., 1999

**FIGURE 3**
**HYDROGEOLOGIC CROSS SECTION B-B'**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group




Adapted from Thomas et al., 1999

**FIGURE 4**
**HYDROGEOLOGIC CROSS SECTION C-C'**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

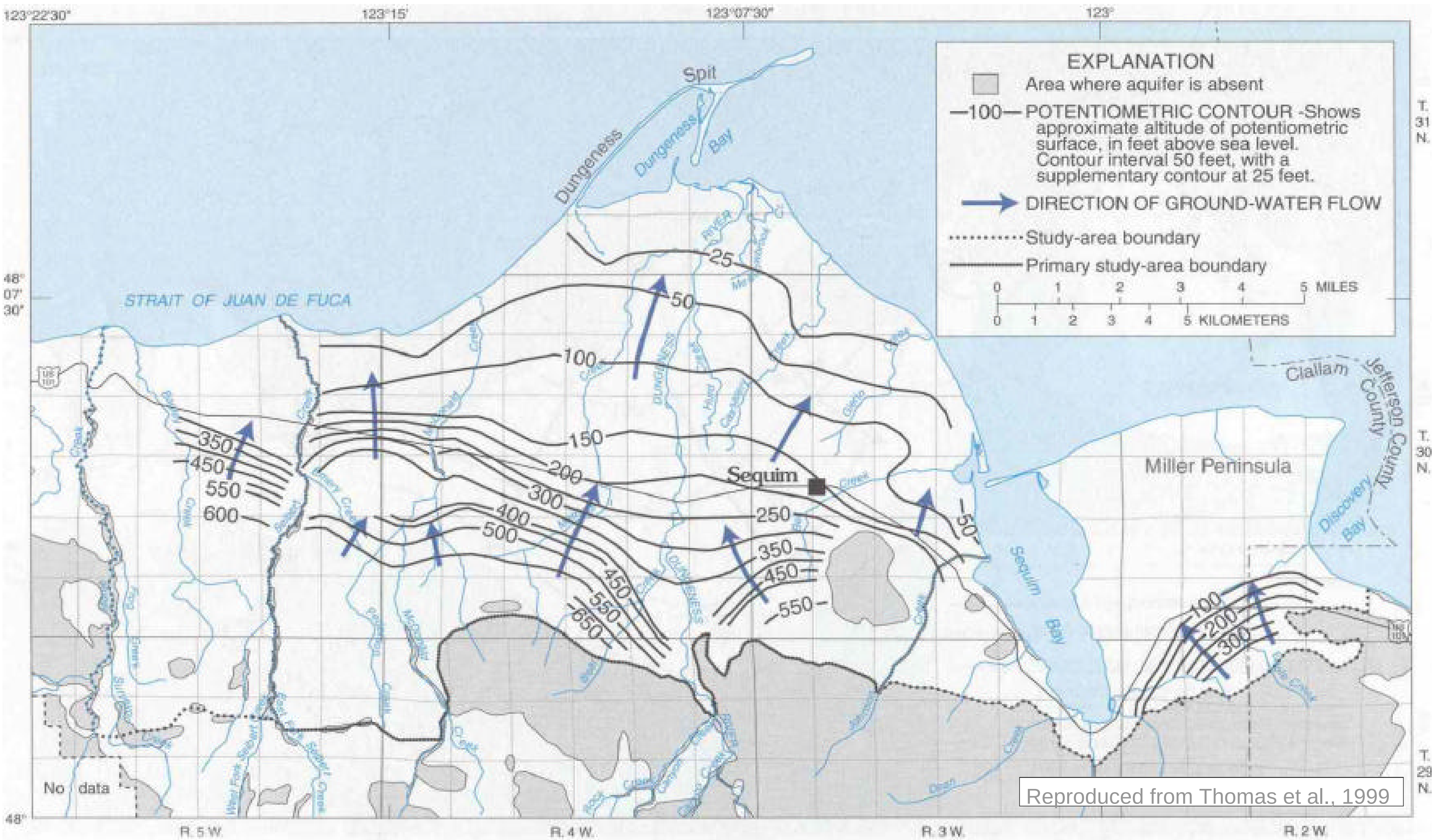
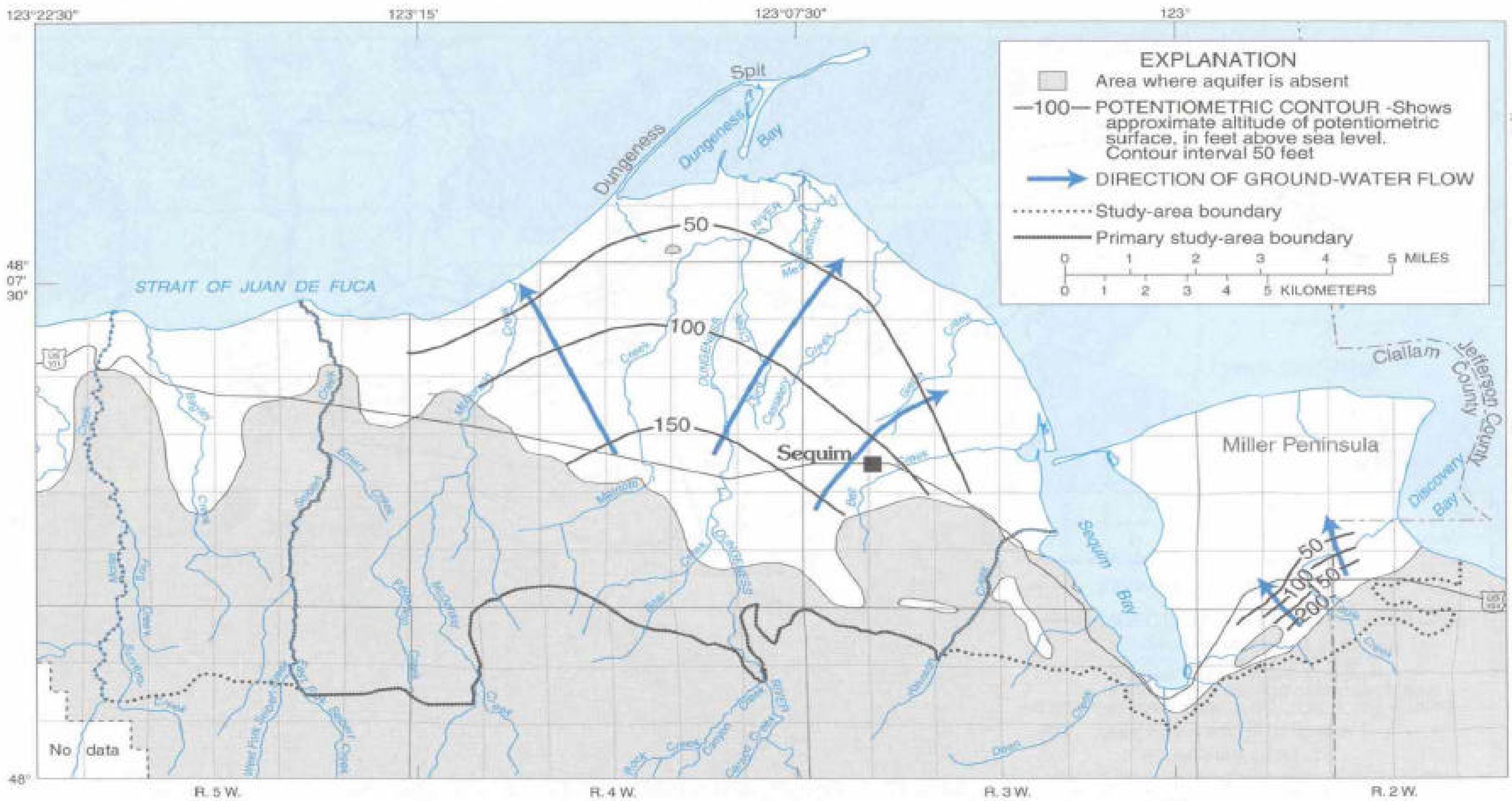



**FIGURE 5**
**GROUNDWATER FLOW DIRECTIONS IN THE SHALLOW AQUIFER**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group




Reproduced from Thomas et al., 1999

**FIGURE 6**
**GROUNDWATER FLOW DIRECTIONS IN THE MIDDLE AQUIFER**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

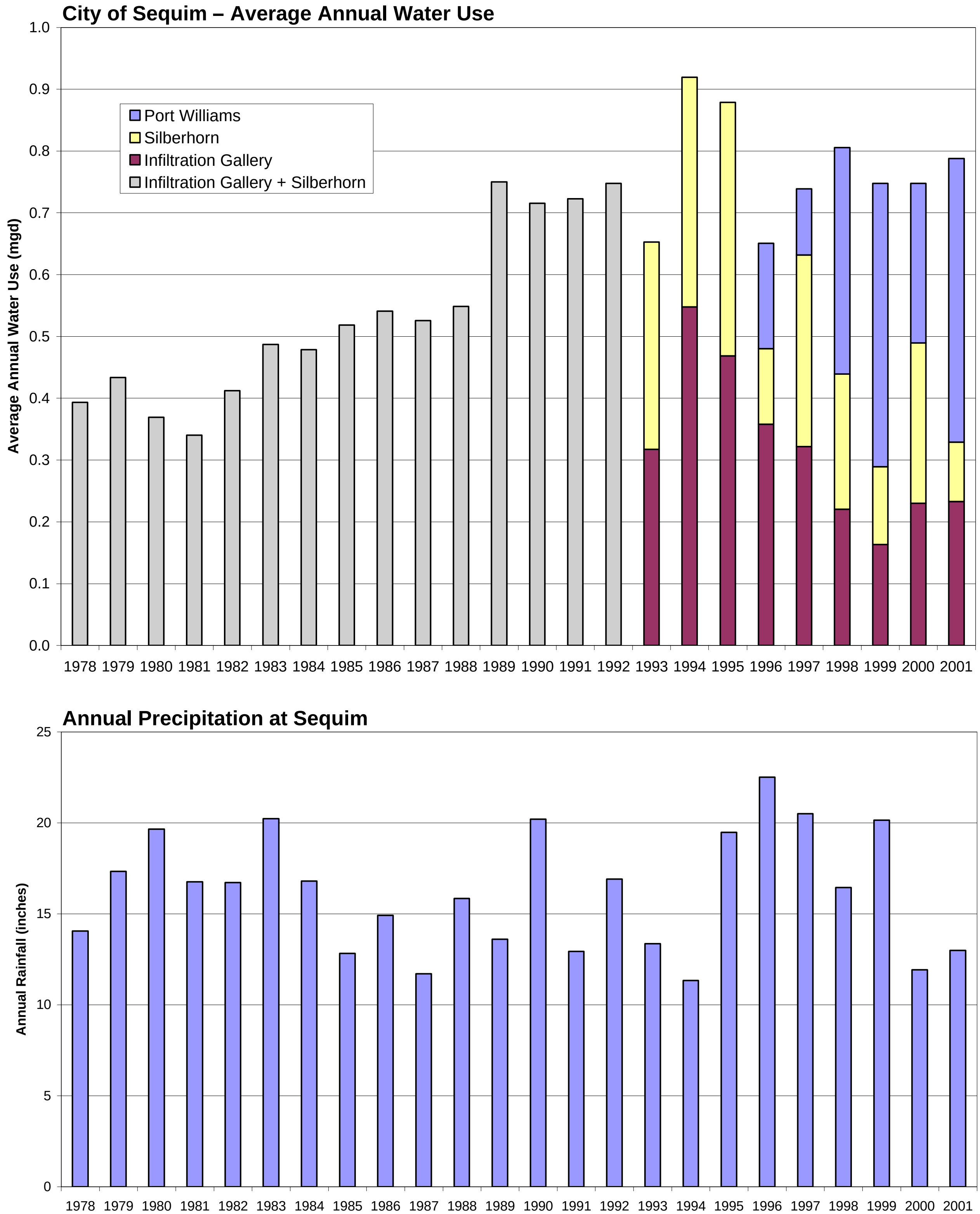



**FIGURE 7**
**TRENDS IN ANNUAL WATER USE AND PRECIPITATION**



Pacific Groundwater Group

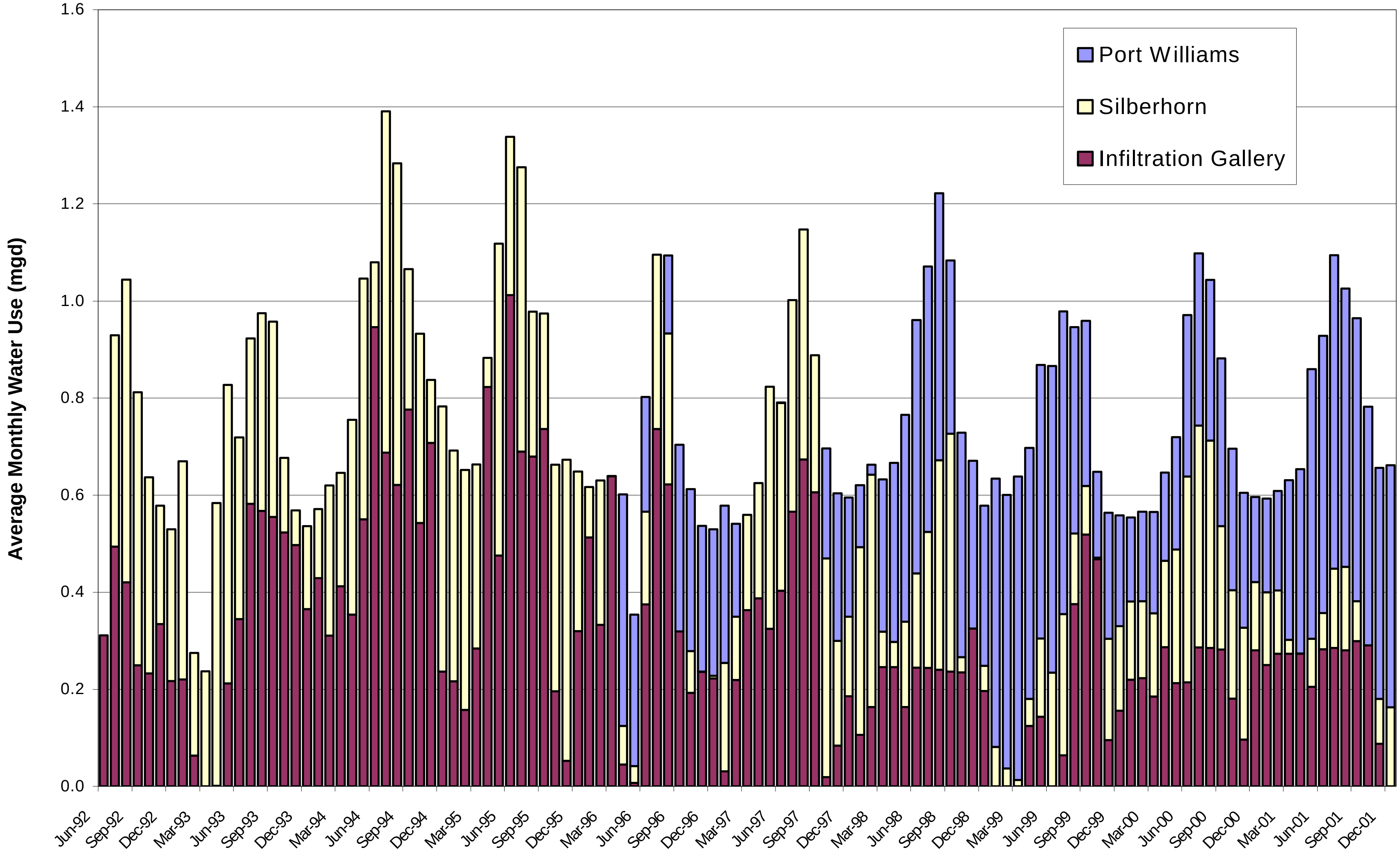



**FIGURE 8**
**MONTHLY WATER USE BY THE CITY OF SEQUIM**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

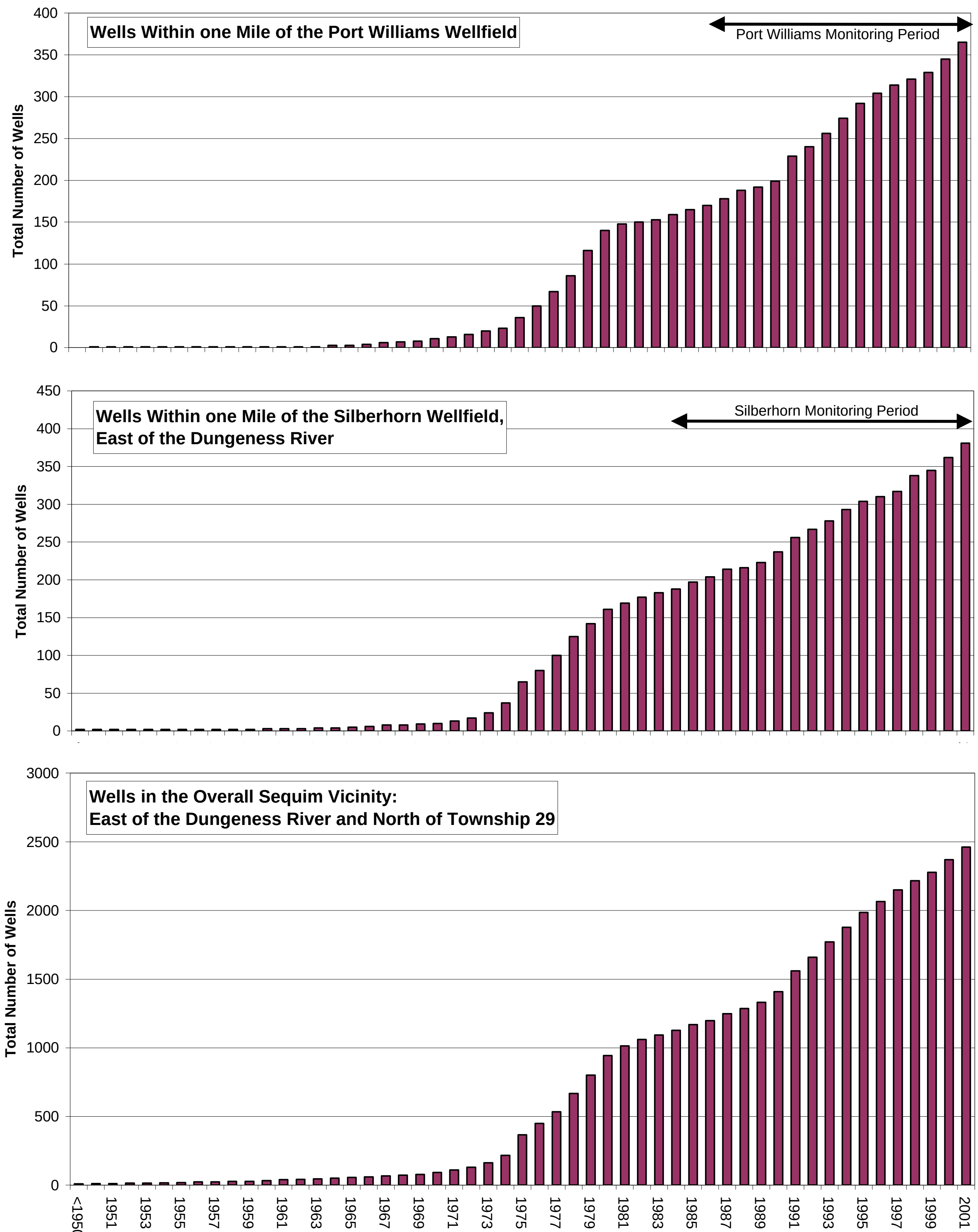



**FIGURE 9**
**GROWTH IN NUMBER OF WELLS DRILLED**
**IN THE SEQUIM VICINITY**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

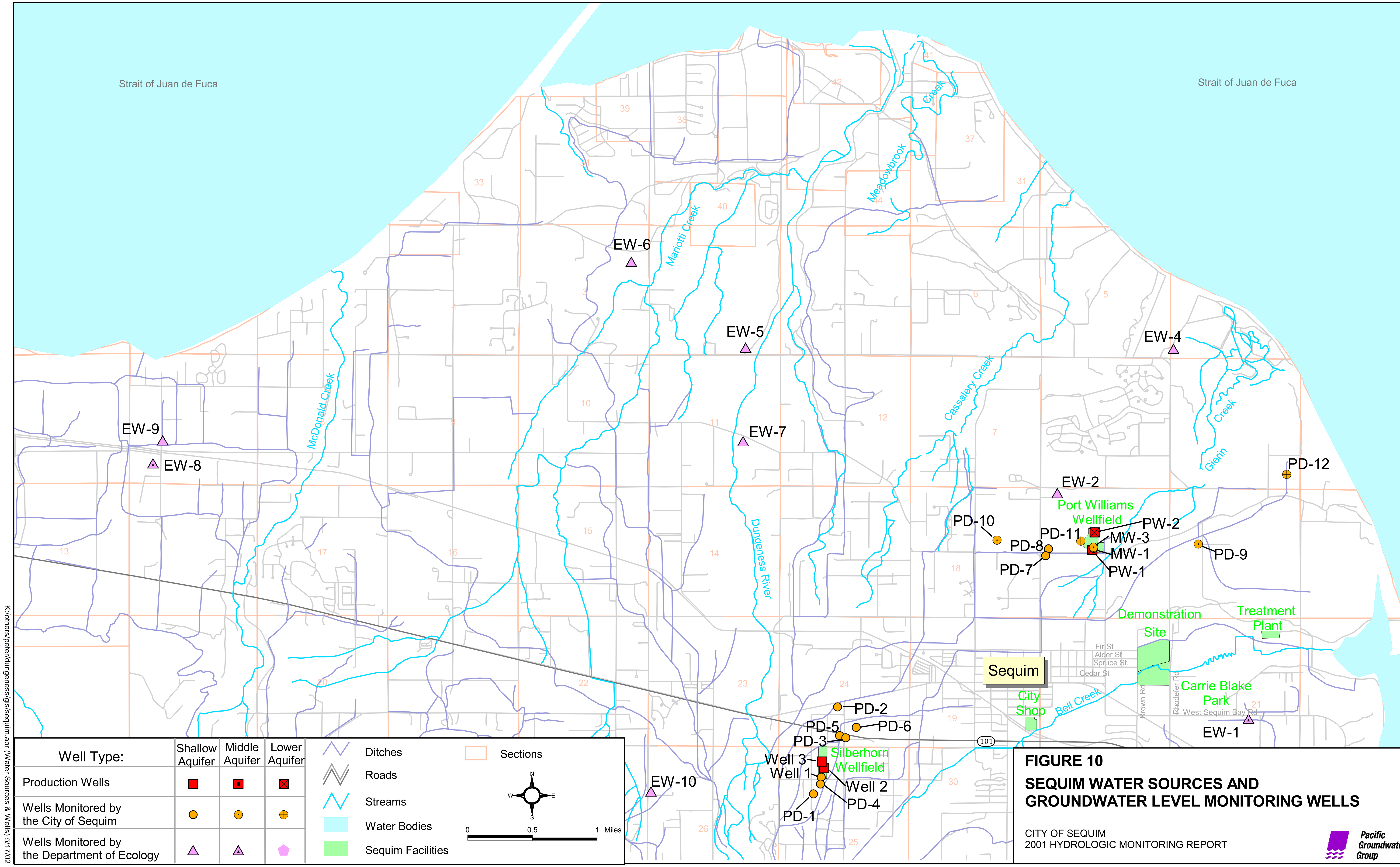
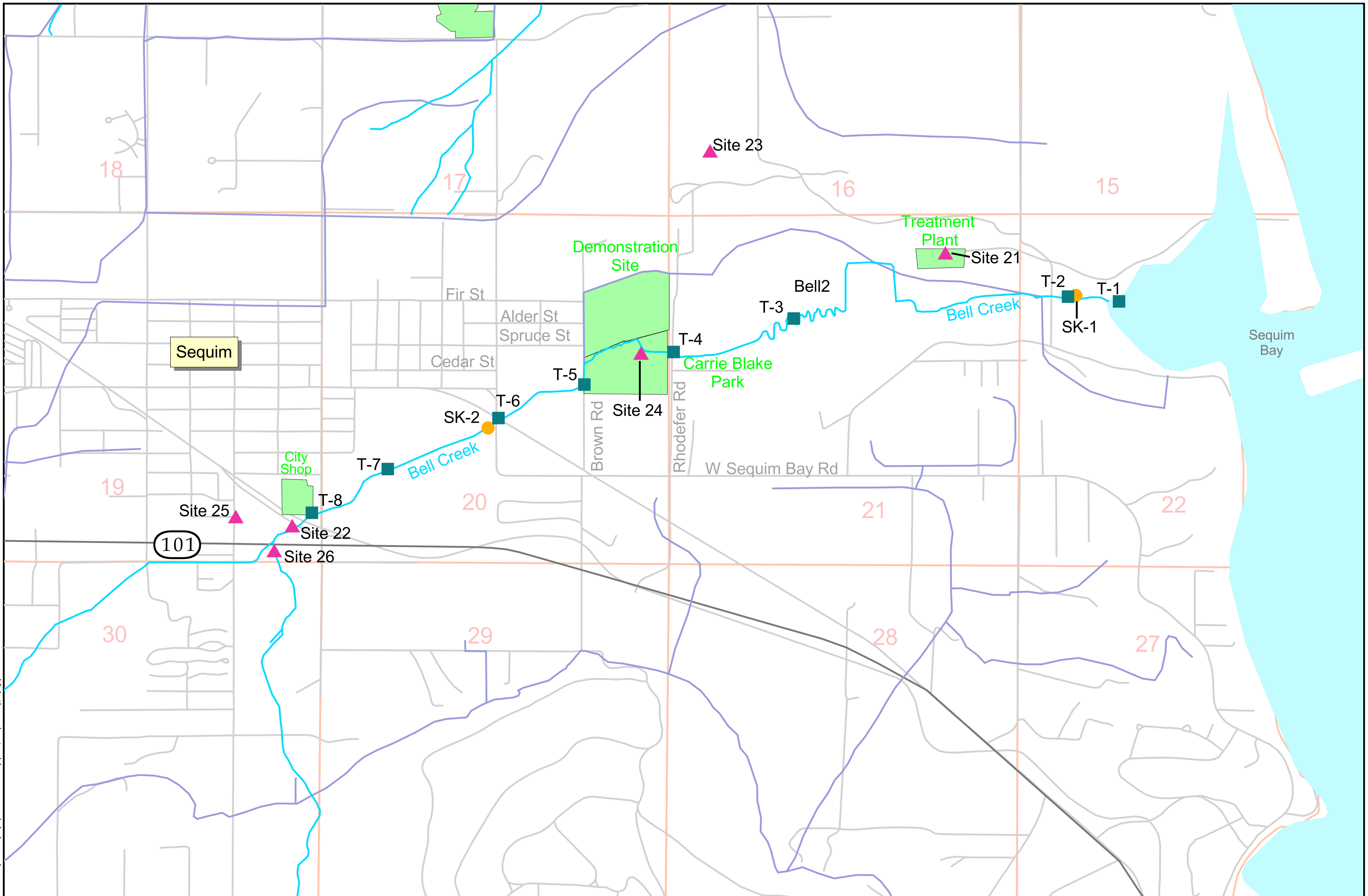



**FIGURE 10**

**SEQUIM WATER SOURCES AND GROUNDWATER LEVEL MONITORING WELLS**




Jamestown S'Klallam Tribe Monitoring Sites

StreamKeepers Monitoring Sites

City of Sequim Monitoring Sites

Sections

Ditches

Roads

Streams

Water Bodies

Sequim Facilities

N W E S

0 0.25 0.5 Miles

Note: See Figure _ for Sequim Monitoring Locations at the Demonstration Site

# FIGURE 11
# BELL CREEK MONITORING STATIONS

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

K:/others/peter/dungeness/gis/sequim.apr (Bell Creek Monitoring) 5/17/02

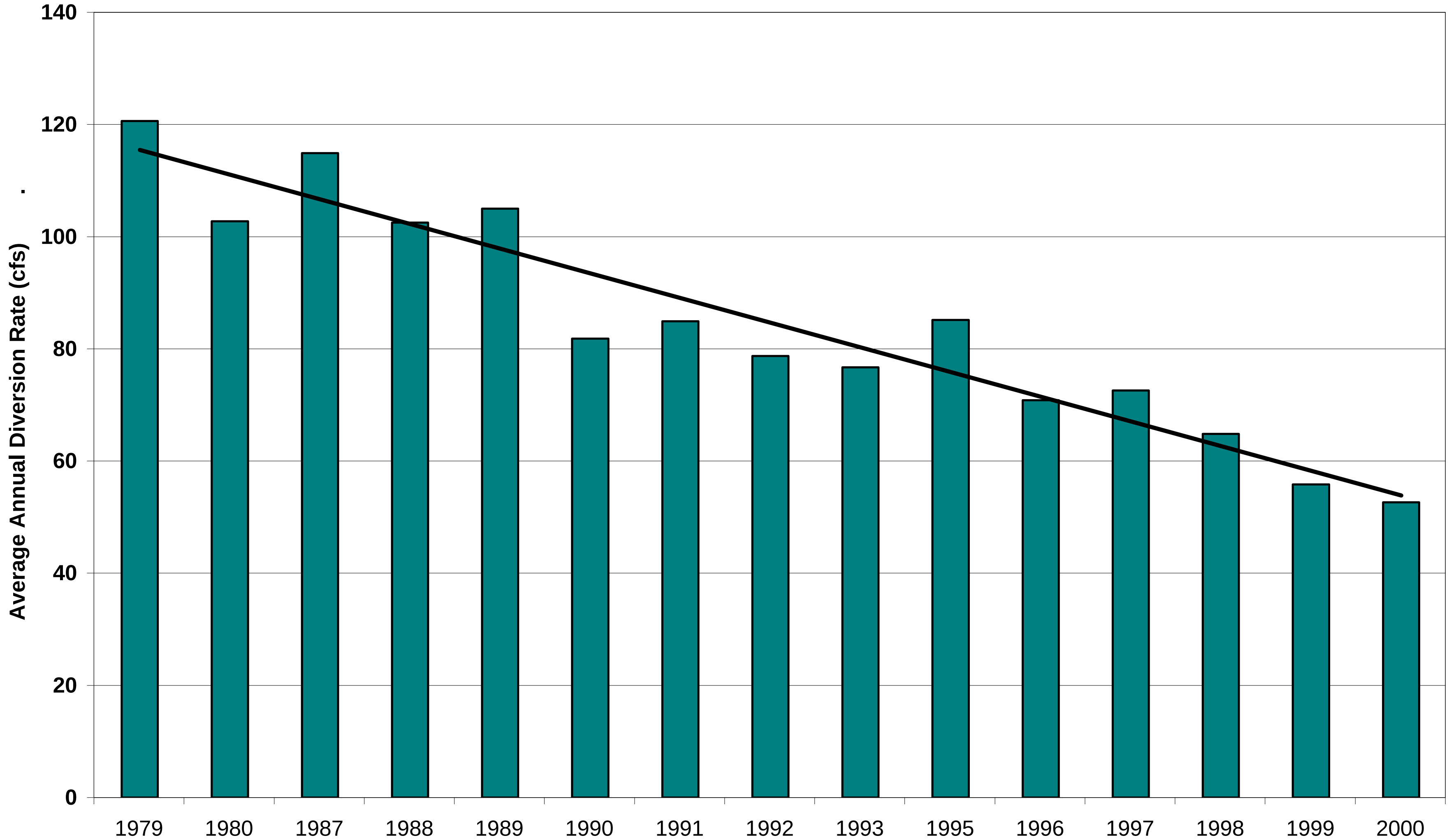



**FIGURE 12**
**AVERAGE ANNUAL STREAMFLOW DIVERSIONS BY DUNGENESS IRRIGATORS**
**(Source: Mike Jeldness, Pers. Comm., 2002)**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

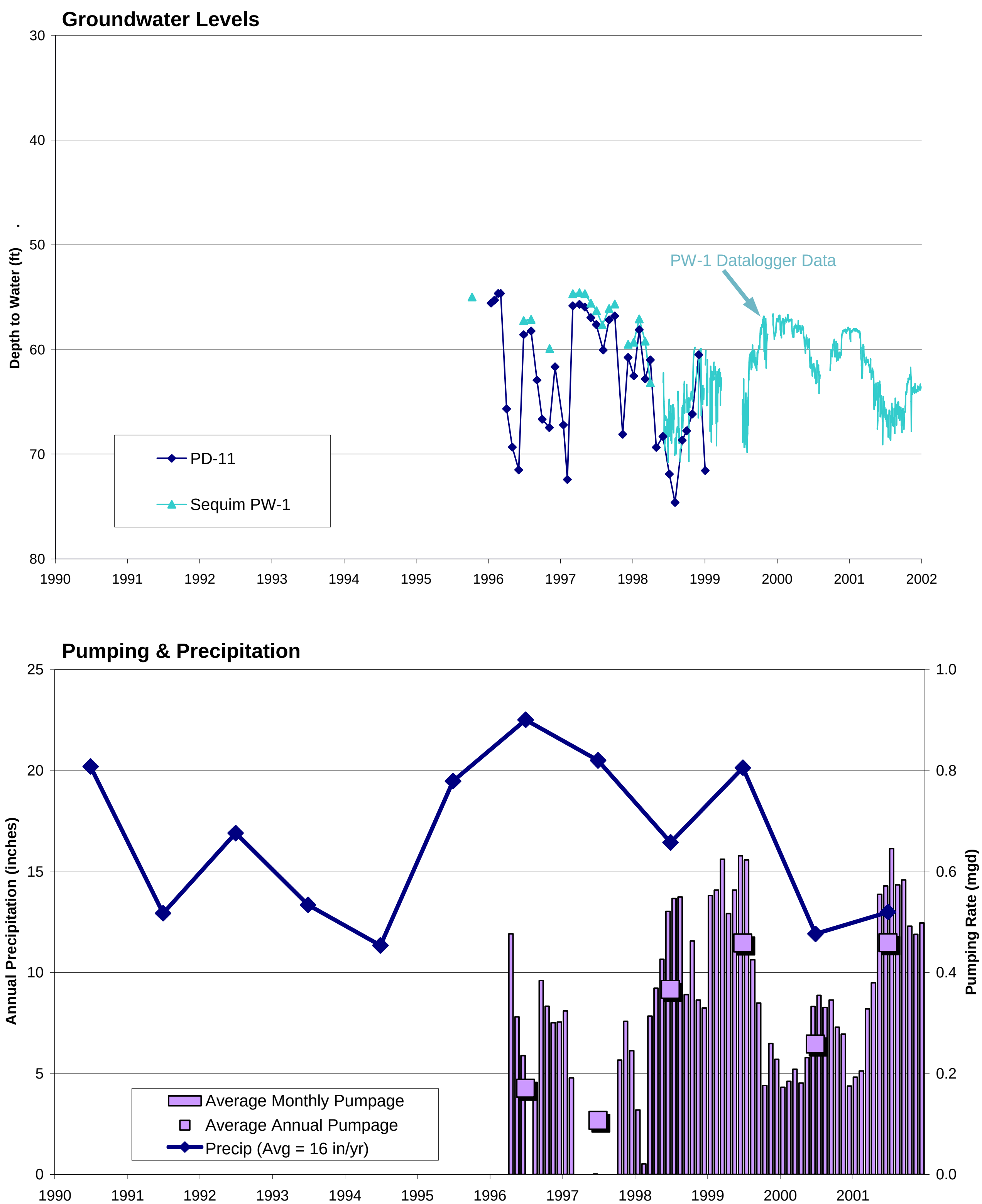
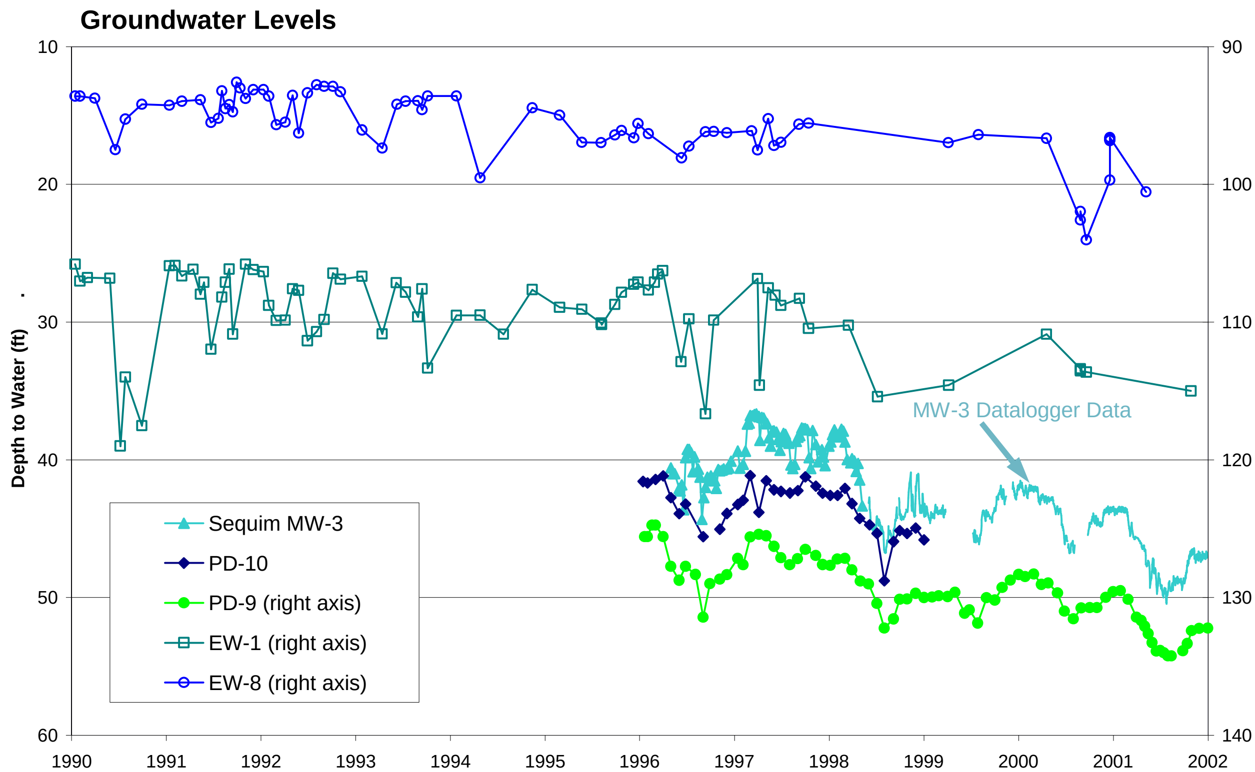



**FIGURE 13**
**GROUNDWATER LEVEL TRENDS IN THE PORT WILLIAMS WELLFIELD VICINITY – LOWER AQUIFER**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group



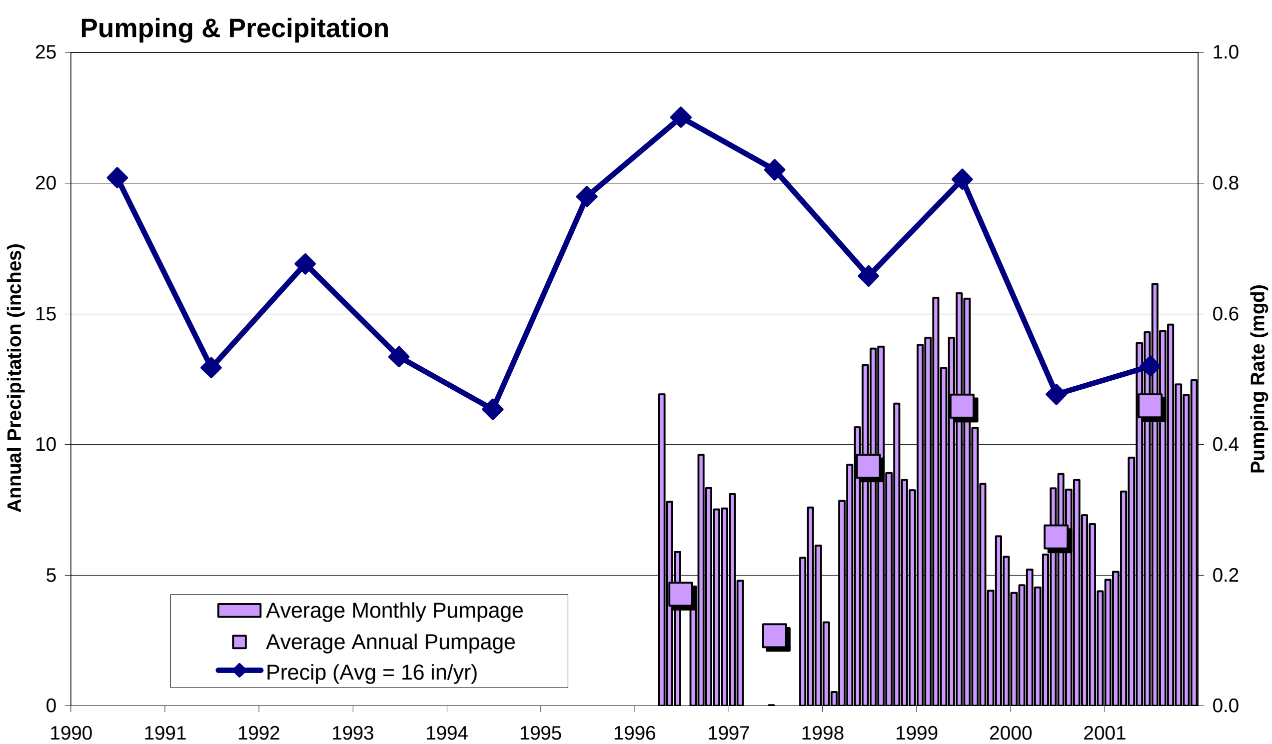




**FIGURE 14**
**GROUNDWATER LEVEL TRENDS IN THE PORT WILLIAMS WELLFIELD VICINITY – MIDDLE AQUIFER**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

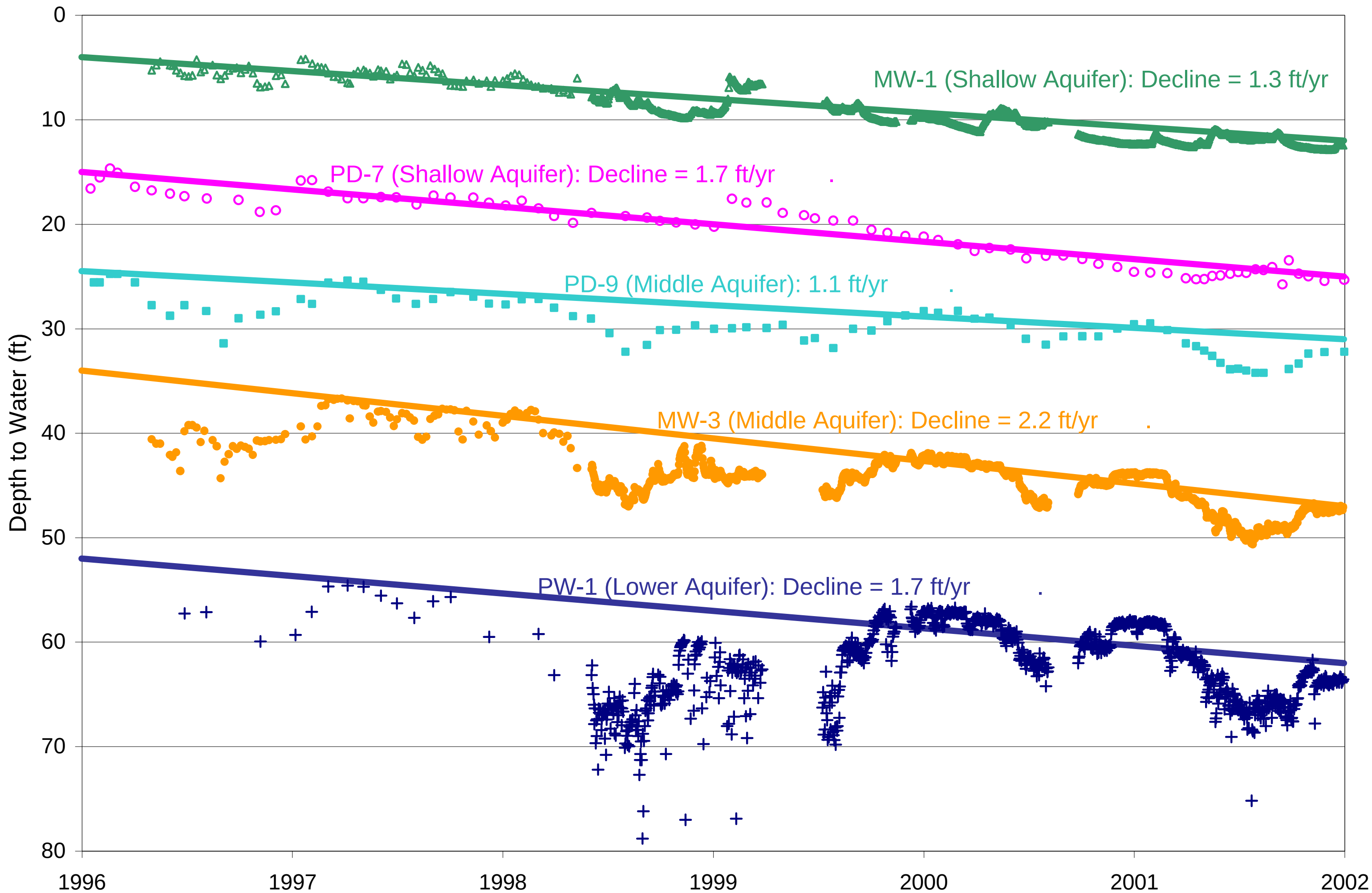



**FIGURE 15**
**COMPARISON OF GROUNDWATER LEVEL TRENDS NEAR THE PORT WILLIAMS WELLFIELD FROM WELLS COMPLETED IN THREE MAJOR AQUIFERS**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

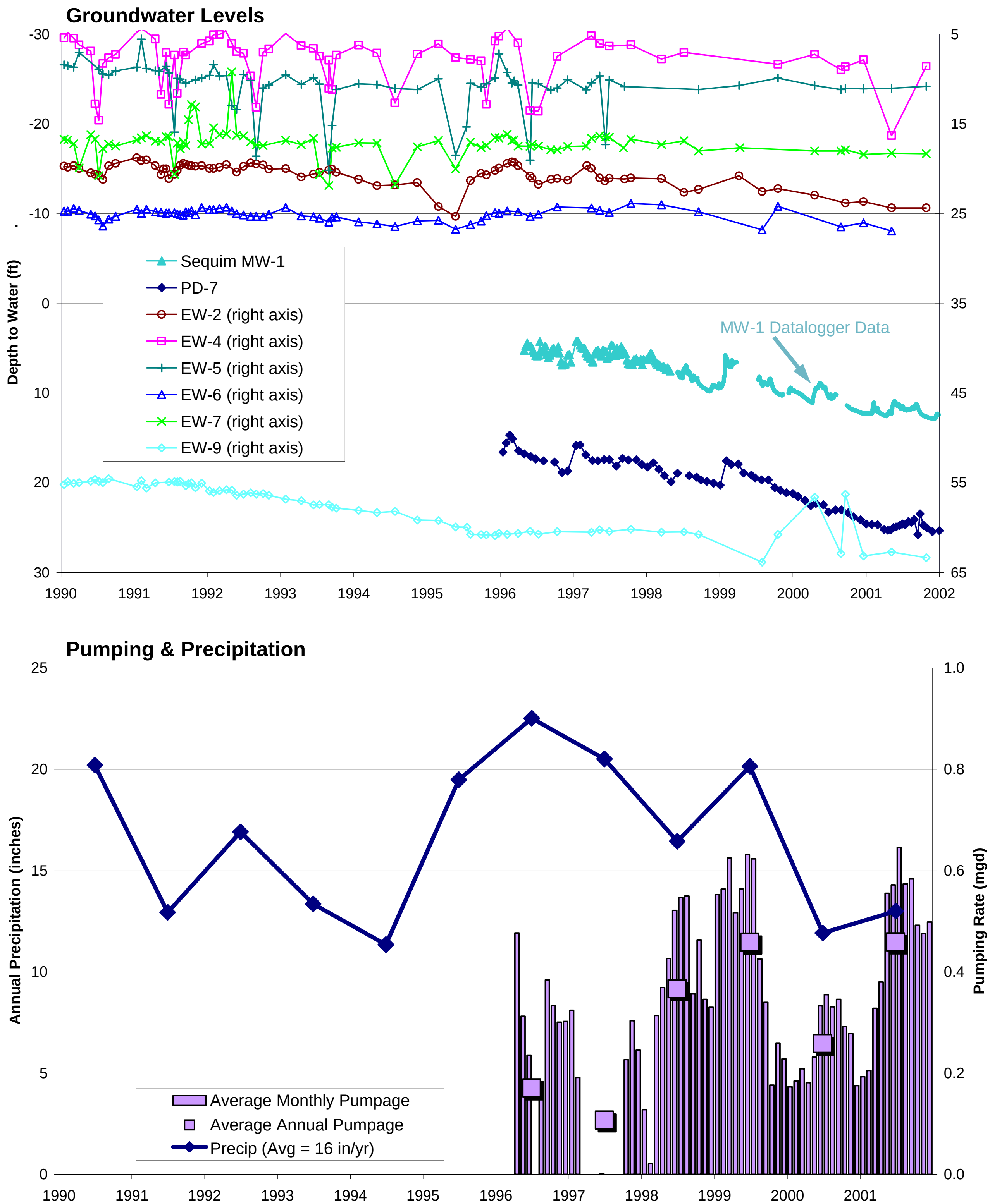



**FIGURE 16**
**GROUNDWATER LEVEL TRENDS IN THE PORT WILLIAMS WELLFIELD VICINITY – SHALLOW AQUIFER**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

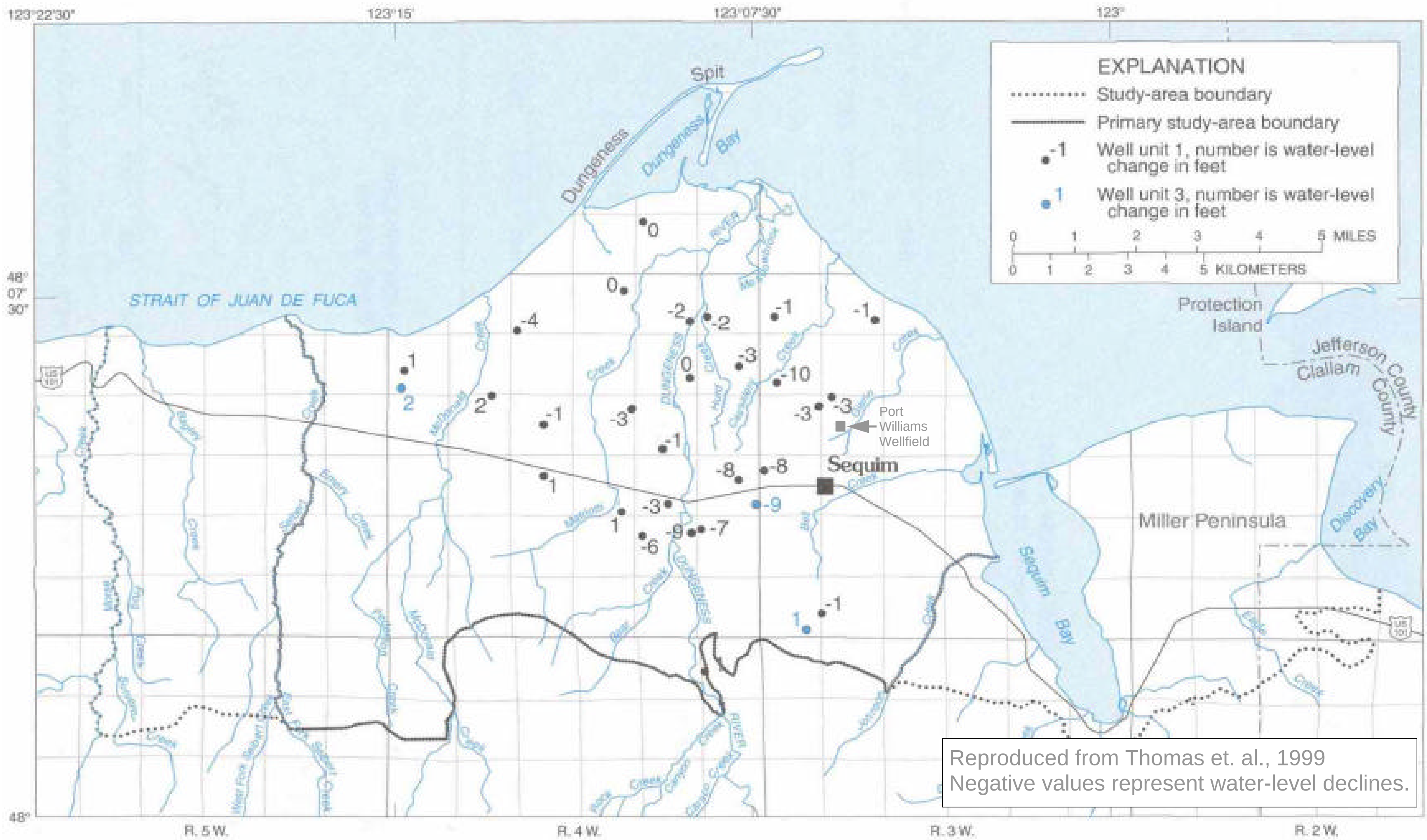
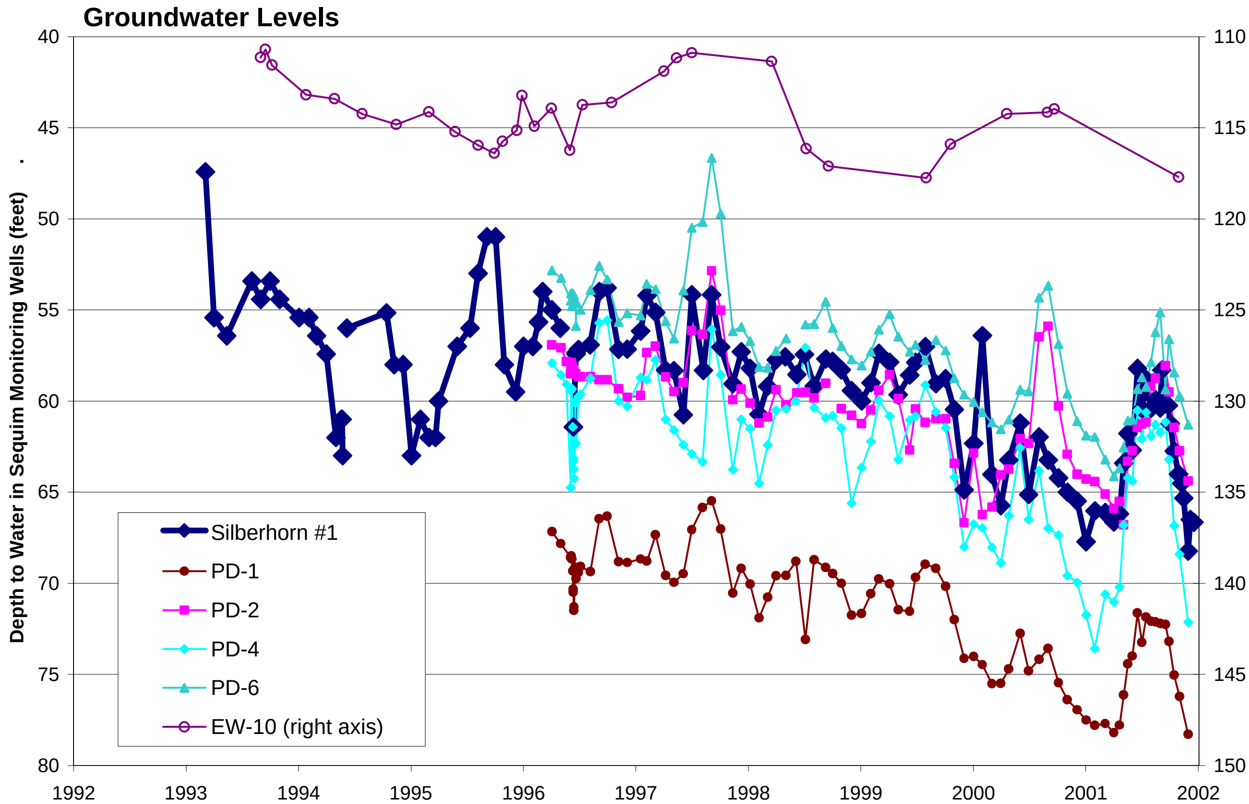



**FIGURE 17**
**GROUNDWATER LEVEL TRENDS IN USGS OBSERVATION WELLS BETWEEN THE LATE 1970'S (1978-1980) AND THE MID 1990'S (1993-1997)**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group



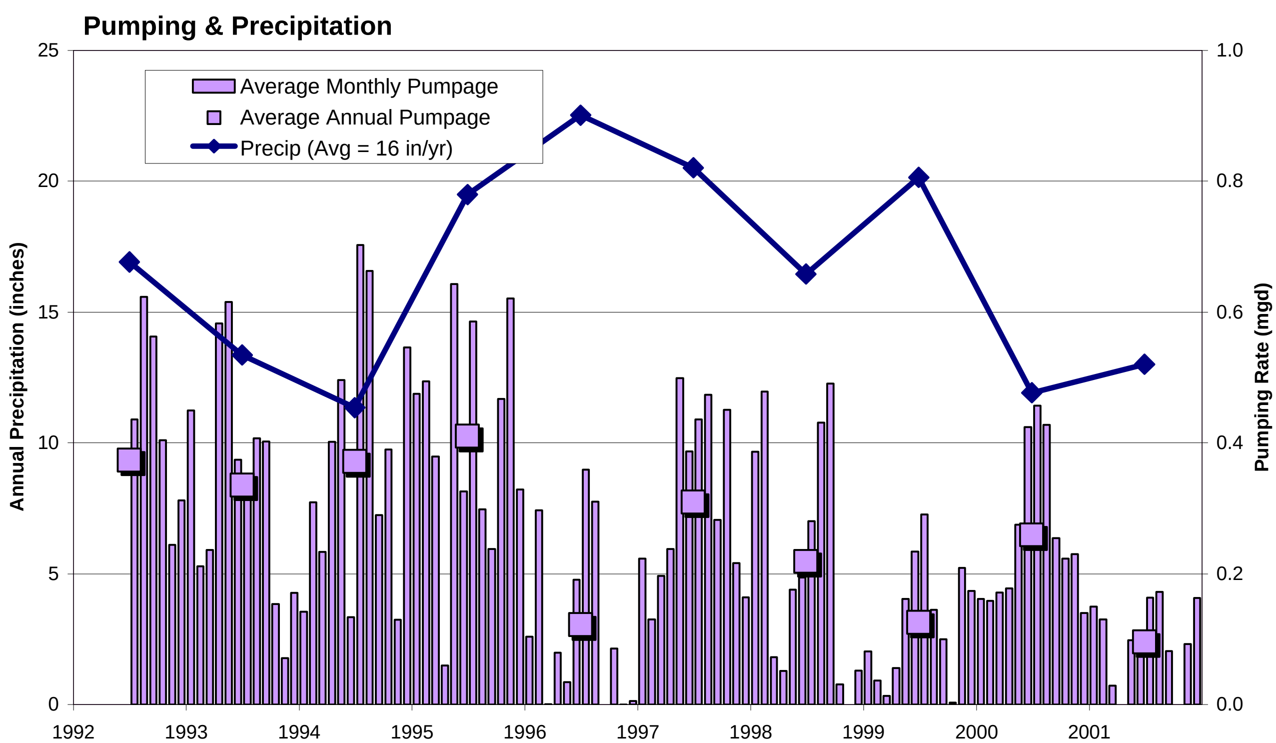




**FIGURE 18**
**GROUNDWATER LEVEL TRENDS IN THE SILBERHORN WELLFIELD VICINITY – SHALLOW AQUIFER**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

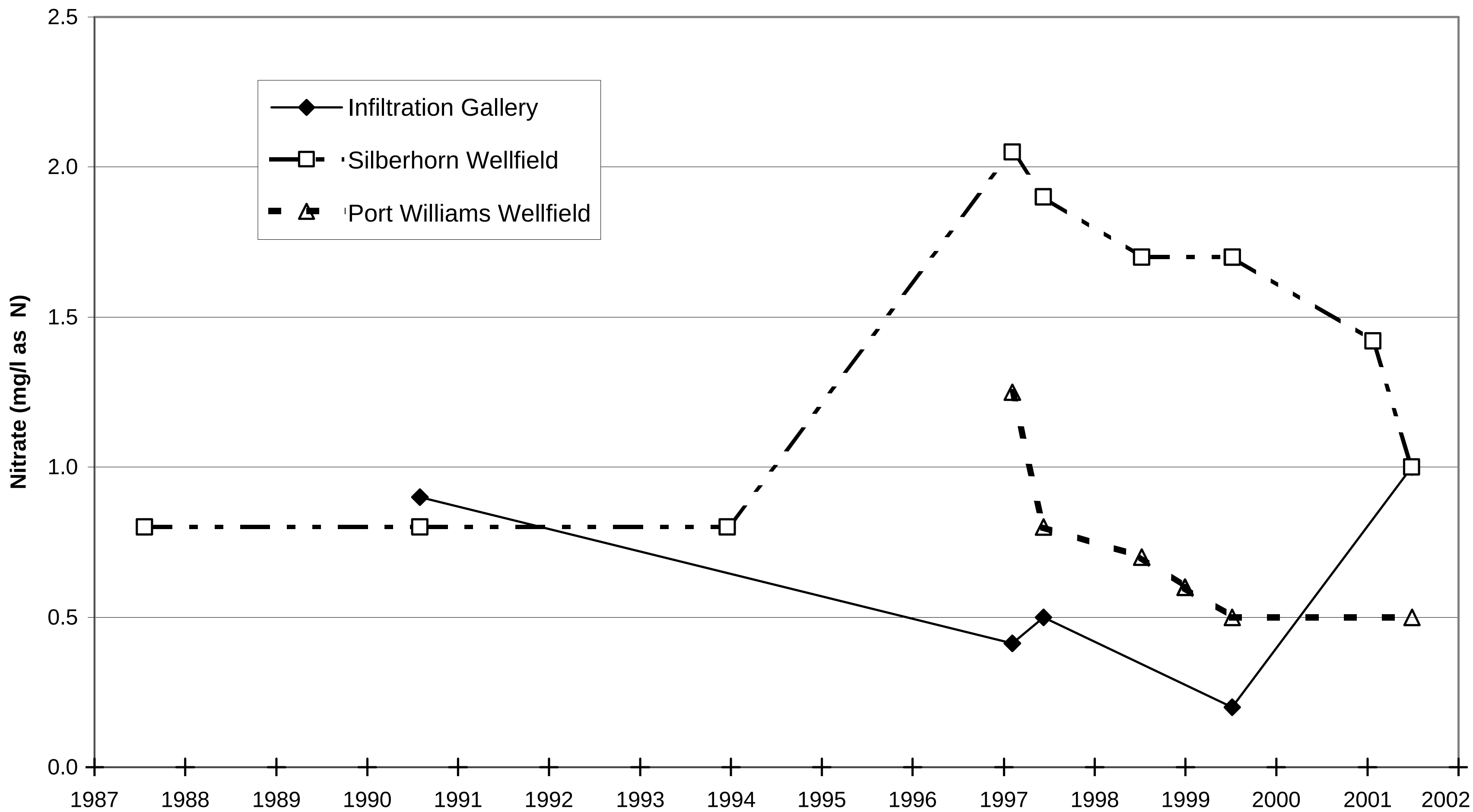
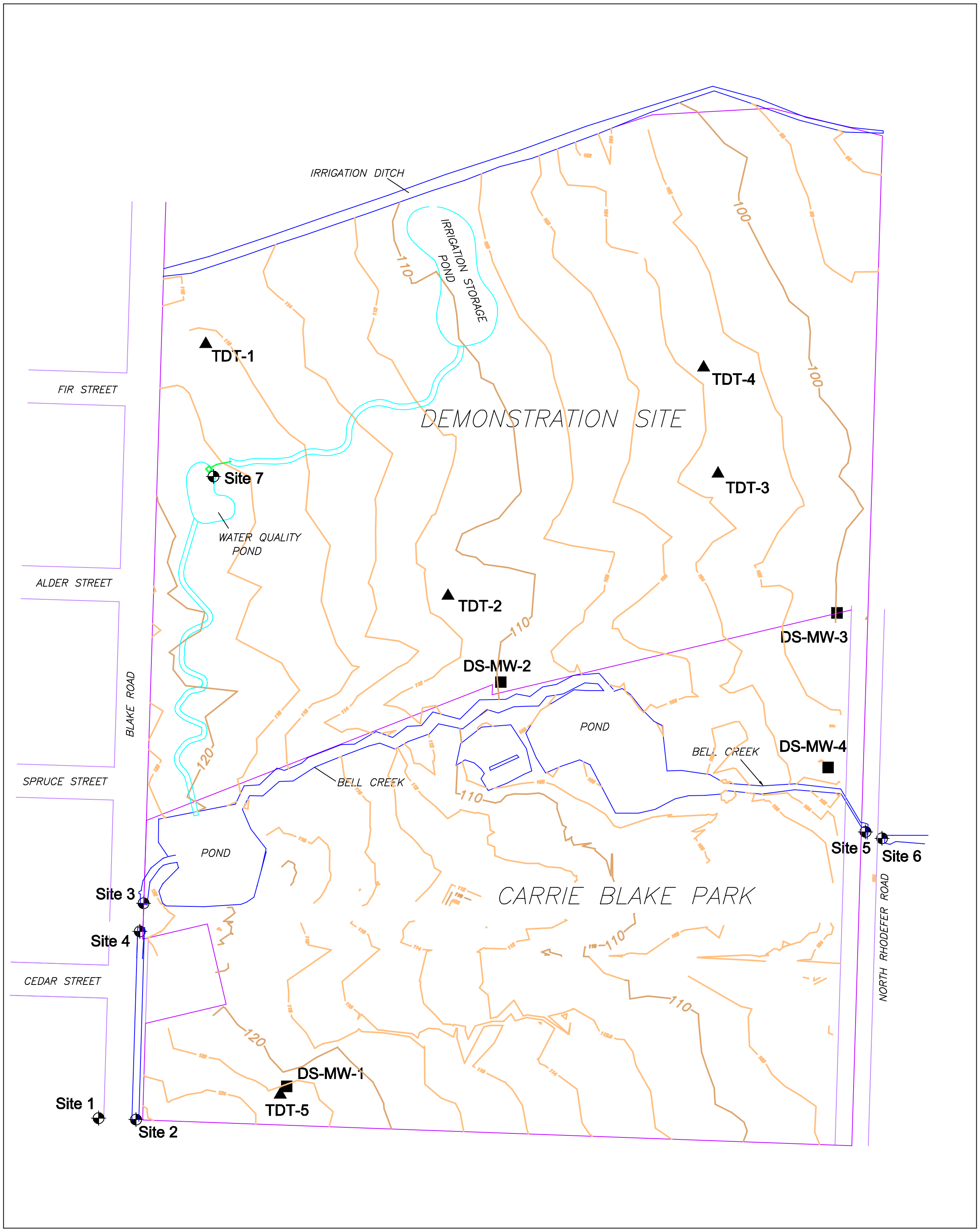



**FIGURE 19**
**NITRATE MEASUREMENTS FROM SEQUIM WATER SUPPLY SOURCES**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group




## Legend

Site 2 — **Bell Creek Sampling Location**

▲ TDT-1 — **TDT Soil Moisture Monitoring Installation**

■ MW-1 — **Monitoring Well**

**No Scale**

**Topographic contour interval = 2 feet**

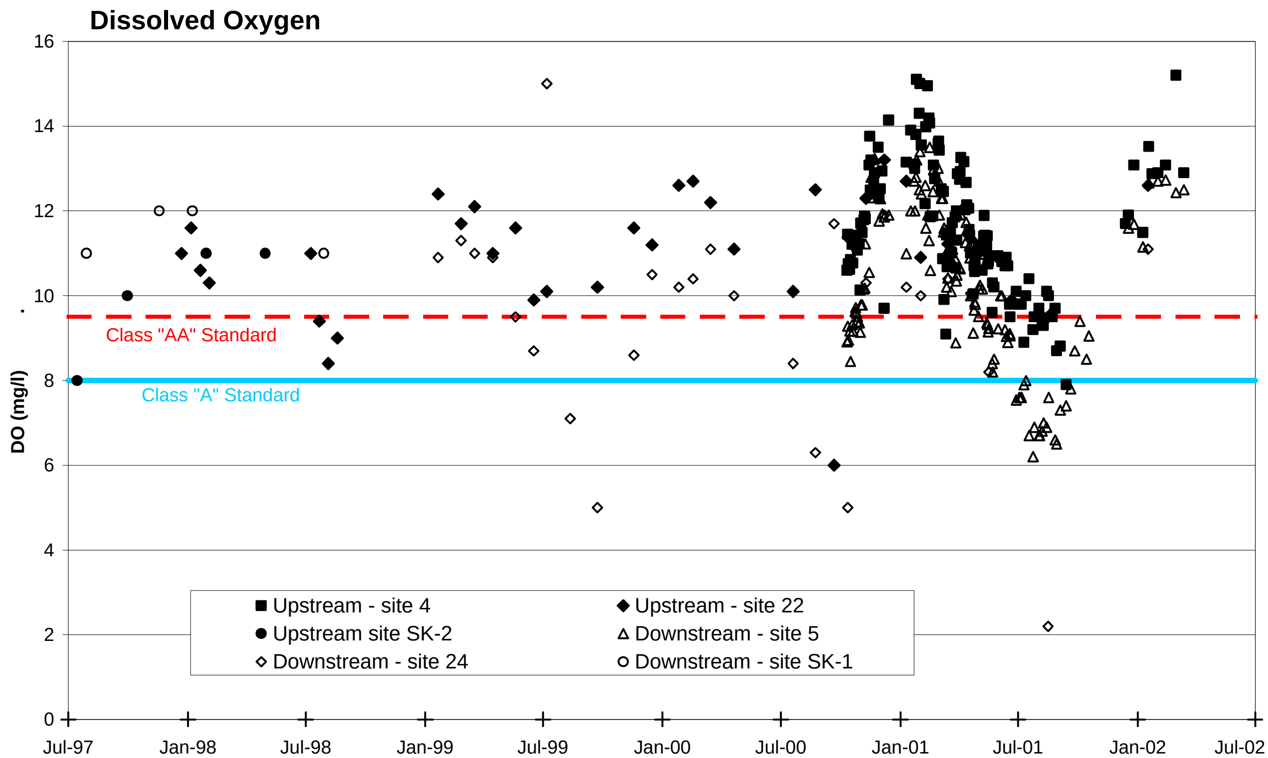
**Map from Gray & Osborne, Inc.**

# FIGURE 20
# DETAILED MAP OF THE DEMONSTRATION SITE

**CITY OF SEQUIM**
**2001 HYDROLOGIC MONITORING REPORT**

**JZ0107, DEMOSITE.DWG, 05/02**

Pacific Groundwater Group



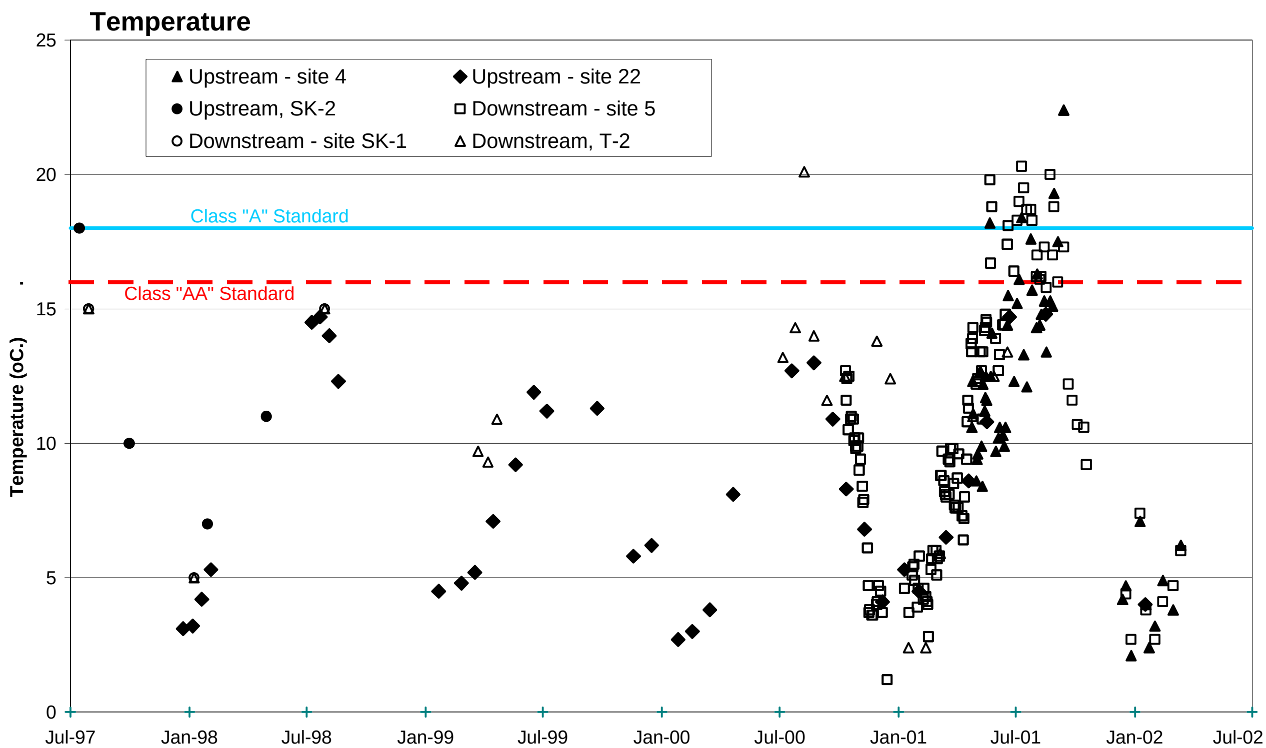
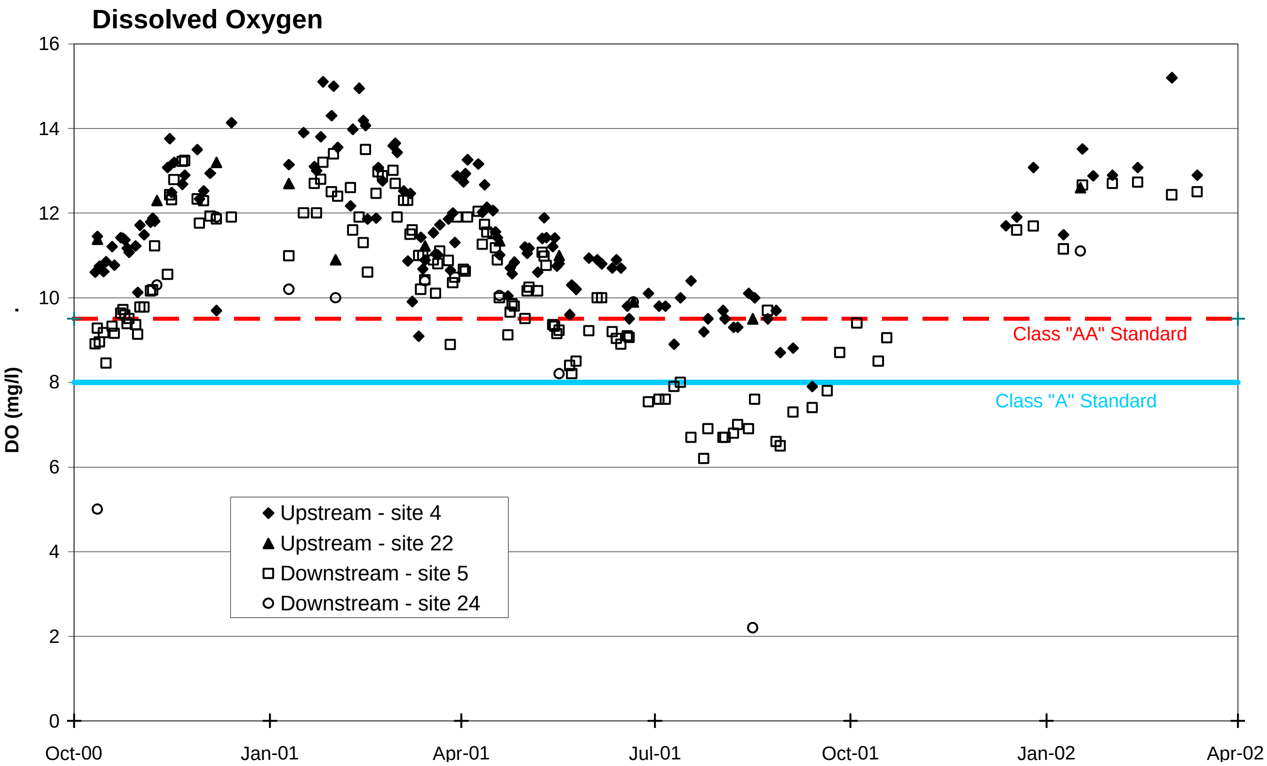




**FIGURE 21**
**DISSOLVED OXYGEN AND TEMPERATURE MEASUREMENTS FROM BELL CREEK MONITORING SITES (FULL RECORD)**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group



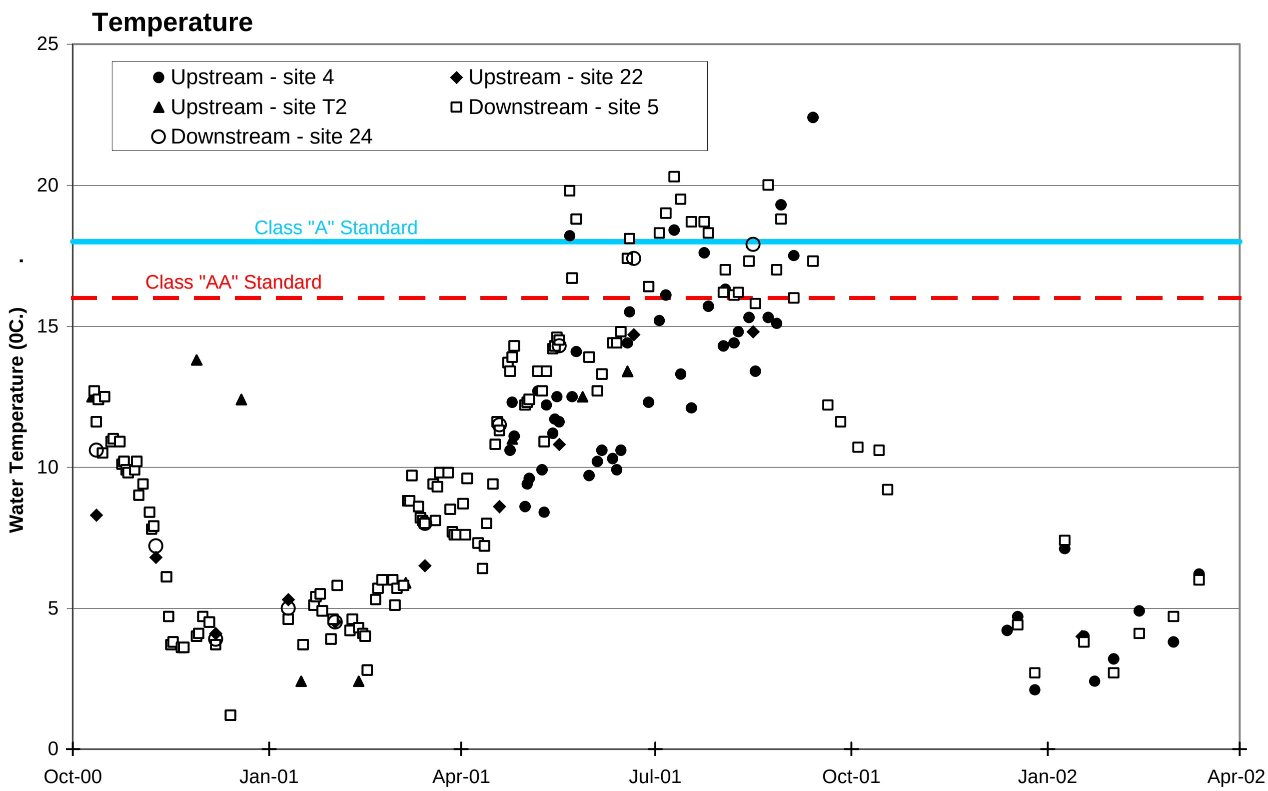
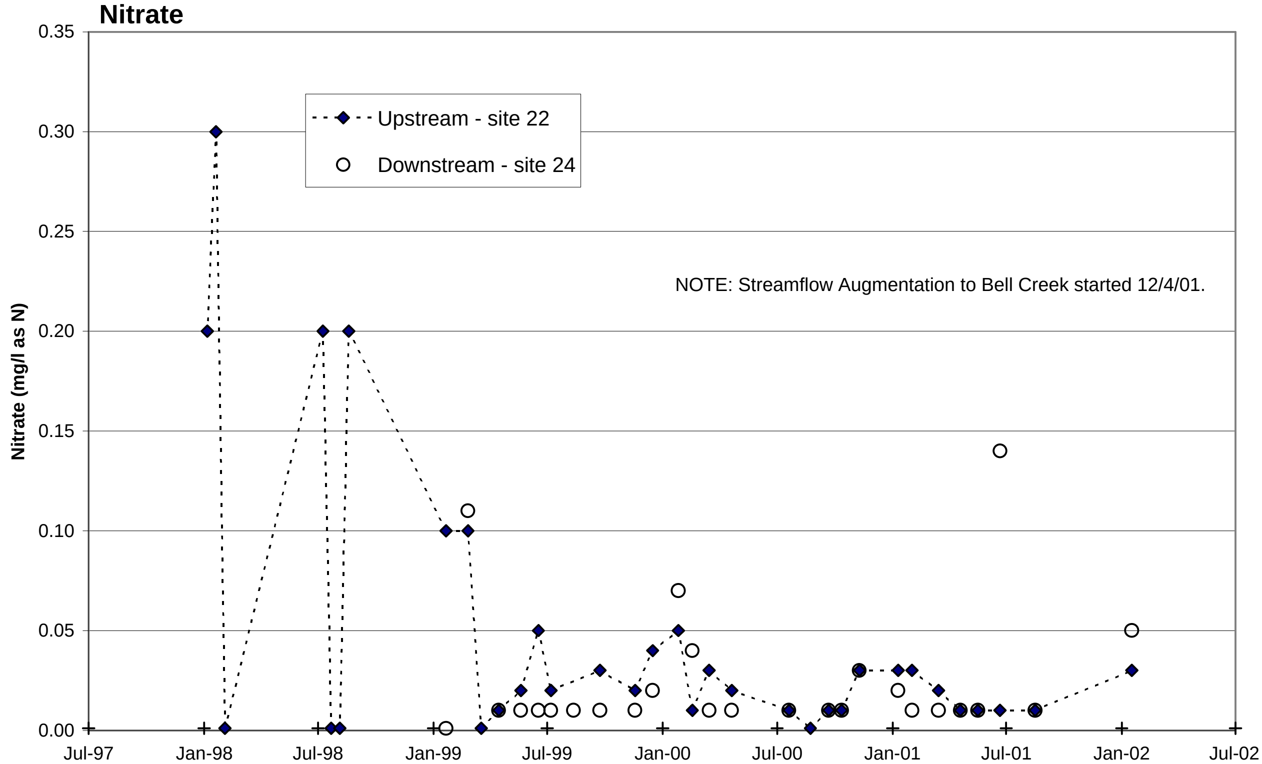




**FIGURE 22**
**DISSOLVED OXYGEN AND TEMPERATURE MEASUREMENTS FROM BELL CREEK MONITORING SITES (WY 2001-2002)**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group



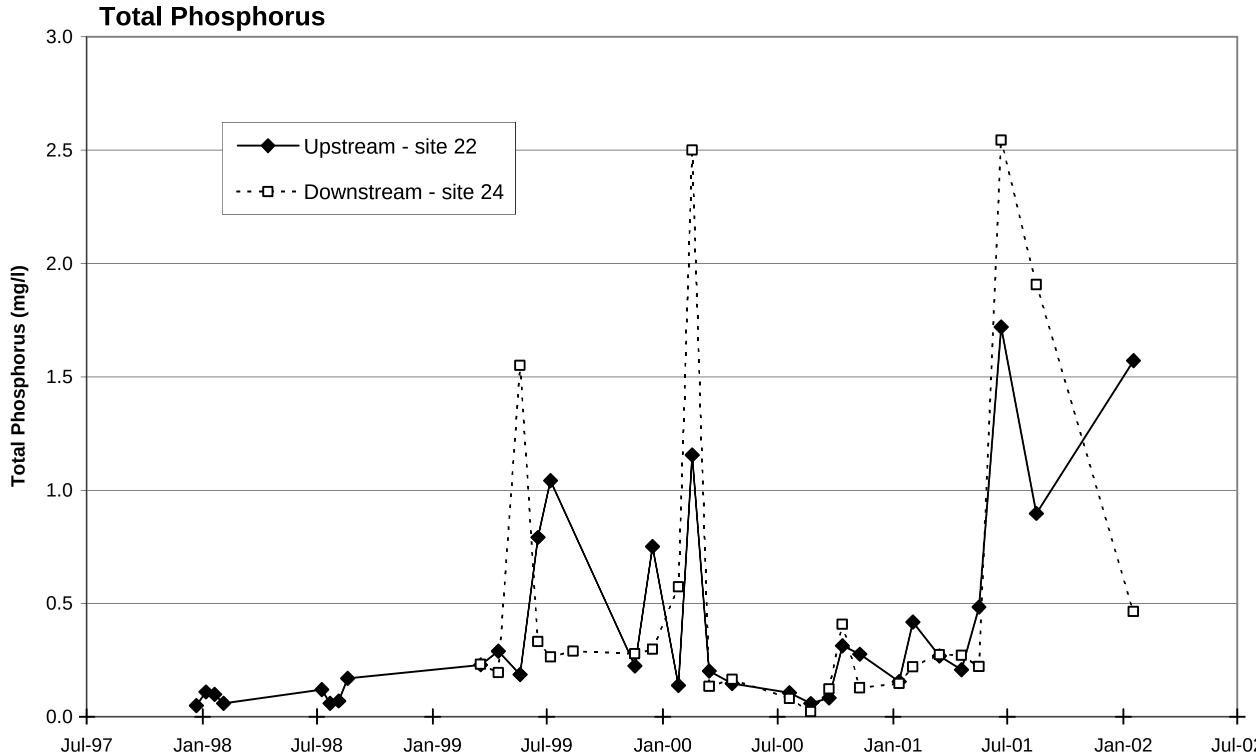




**FIGURE 23**
**NITRATE AND TOTAL PHOSPHORUS MEASUREMENTS FROM BELL CREEK MONITORING SITES**

CITY OF SEQUIM
2001 HYDROLOGIC MONITORING REPORT

Pacific Groundwater Group

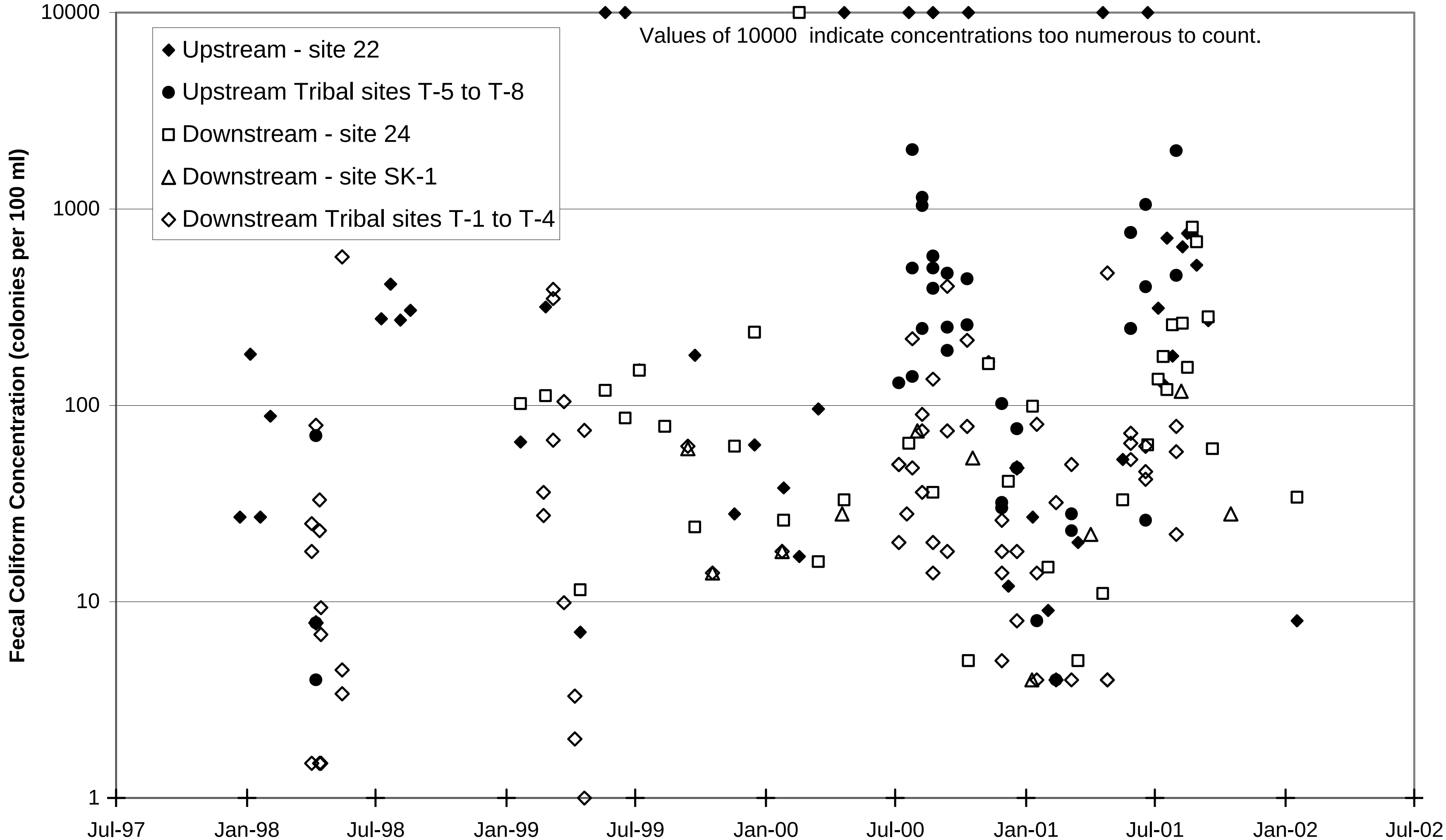



**FIGURE 24**
**FECAL COLIFORM MEASUREMENTS FROM BELL CREEK MONITORING SITES**